He Pou a Rangi
Climate Change Commission

Full assessment

2026 National Climate Change Risk Assessment for Aotearoa New Zealand

April 2026

This assessment is required under sections 5ZP and 5ZQ of the Climate Change Response Act 2002.

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Disclosure statement: As anticipated by the appointment criteria, the Climate Change Commissioners come from varying fields such as adaptation, agriculture, economics, te ao Māori and the Māori–Crown relationship. While a number of board members continue to hold roles within these fields, our advice is independent and evidence based. The Commission operates under its Interests Policy, which is derived from the Crown Entities Act 2004. You can read more about our board members on the Climate Change Commission website. The Commission regularly updates and publishes on its website a register of relevant board interests.

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List of abbreviations

AEP	annual exceedance probability
AR6	Sixth Assessment Report of the Intergovernmental Panel on Climate Change
CMIP	Coupled Model Intercomparison Project
CO_2	carbon dioxide
DOC	Department of Conservation
DPMC	Department of the Prime Minister and Cabinet
EEZ	Exclusive Economic Zone
ESL	extreme sea level
ESNZ	Earth Sciences New Zealand
GDP	gross domestic product
GCM	global climate model
GWL	global warming level, e.g. GWL 2 / GWL 3–3.5
IPCC	Intergovernmental Panel on Climate Change
ITP	Tourism Industry Transformation Plan
IVL	International Visitor Conservation and Tourism Levy
LFG	landfill gas
MBIE	Ministry of Business, Innovation and Employment
MfE	Ministry for the Environment
MPI	Ministry for Primary Industries
NAF	National Adaptation Framework
NIWA	National Institute of Water and Atmospheric Research (now ESNZ)
NPS-FM	National Policy Statement for Freshwater Management
NPS-NH	National Policy Statement for Natural Hazards
NZ ETS	New Zealand Emissions Trading Scheme
NZTA	NZ Transport Agency Waka Kotahi
PED	potential evapotranspiration deficit
RCPs	Representative Concentration Pathways
RPMPs	Regional Pest Management Plans
SLR	sea-level rise
SSPs	Shared Socioeconomic Pathways

PART A

Chapter 1: Introduction

He Pou a Rangi Climate Change Commission (the Commission) has conducted the second national climate change risk assessment. The purpose of the assessment is to assess the risks to Aotearoa New Zealand's economy, society, environment and ecology from current and future effects of climate change, and to advise Government on the most significant risks requiring attention in the second national adaptation plan.

Purpose of this report

Four reports make up the Commission's assessment:

- The Priorities for action report is focused on the most significant risks requiring immediate action to reduce serious consequences for people, places and ways of life. This report also provides a summary of recent projections for climate change.
- This Full assessment report covers all 37 risks assessed and provides an overview across seven interconnected systems or 'domains' of risk. It includes a more detailed presentation of current information about climate change in Aotearoa New Zealand.
- A companion report, Ngā mea hirahira o te ao Māori, provides a kaupapa Māori assessment of seven national climate-related risks that specifically affect iwi/Māori (these form part of the 37 risks).
- Our approach to assessment is described in a separate Summary of method report.

Other supporting material can be found on our website.

The analysis for Ngā mea hirahira o te ao Māori (things of importance in the Māori world) was completed by independent researchers from Manaaki Whenua Landcare Research (now part of the Bioeconomy Science Institute) and Ngā Pae o te Māramatanga Māori Centre of Research Excellence, contracted by the Commission. Their full analysis is published alongside this assessment (available on our website). It can be read as a standalone Māori climate risk assessment, as the complete analysis and risk-scoring rationale is provided. The Commission accepts its findings and has integrated them into the overall risk assessment, with summaries of the seven risks of Ngā mea hirahira o te ao Māori presented in *Chapter 3: Findings*.

The Summary of method for the 2026 National Climate Change Risk Assessment for Aotearoa New Zealand (the Summary of method report) provides greater details on the method and process followed to assess risks, including the identification and analysis of risks, assessment and scoring, and external review of the process.

Structure of this report

This report is structured in two parts.

Part A provides a summary of the scientific evidence of current and expected climate changes in Aotearoa New Zealand, along with a summary of the method and process the Commission applied in this risk assessment.

Part B sets out the summary of analysis for each of the risks identified. Risks have been organised by seven domains (**Table 1.1**). For full risk descriptions see the individual risk analysis, or the Summary of method report*, Appendix 1.*

Table 1.1: Domains and elements at risk

Domain	Elements at risk
Natural environment	The Natural environment domain considers all aspects of the natural environment that support Aotearoa New Zealand's indigenous species, and the ecosystems they form in terrestrial, freshwater, coastal and marine environments. **Elements at risk:** • Coastal ecosystems • Freshwater ecosystems • Marine ecosystems • Terrestrial ecosystems • Indigenous biodiversity (from invasive species and pathogens).
Built environment	The Built environment domain considers buildings, urban spaces and infrastructure. This includes transport, energy, water and waste management infrastructure. **Elements at risk:** • Water infrastructure • Buildings • Waste management infrastructure • Ports and airports • Road and rail networks • Electricity and communications infrastructure • Electricity supply.
People, health and communities	The People, health and communities domain encompasses people's identity, health, sense of community and social norms, and cultural values and traditions.

	Elements at risk: • Social cohesion and wellbeing (from displacement) • Physical health • Mental health • Ability of the emergency management system to respond • Social infrastructure and community services.
Ngā mea hirahira o te ao Māori (things of importance in the Māori world)	Ngā mea hirahira o te ao Māori considers matters of importance to iwi/Māori, including Māori interests and investments, health and wellbeing, culture and practices. **Elements at risk:** • Loss of access to taonga species • Damage to iwi/Māori infrastructure • Economic losses for iwi/Māori in primary industries • Disruption to tikanga and hapū/iwi identity • Loss of mātauranga Māori • Legal exclusion and governance failures for iwi/Māori • Increased Māori health vulnerabilities.
Economy and finance	The Economy and finance domain considers production, distribution, trade and consumption of goods and services, economic costs, and finance and insurance markets – essentially, what happens to and within the economy that affects people and their livelihoods. **Elements at risk:** • Central and local government funding • Stability of the financial system • Insurability of assets • Businesses and public organisations (from supply and distribution disruptions).
Sectors relying on the natural environment	The Sectors relying on the natural environment domain focuses on sectors whose economic productivity is directly linked to the natural environment. This includes the primary industries and tourism. **Elements at risk:** • Pastoral agriculture • Horticulture • Forestry • Tourism • Fisheries.

Governance	The Governance domain encompasses the decision-making institutions and processes that govern all aspects of how the country responds to climate change. These governance arrangements extend from the partnership between iwi/Māori and the Crown under Te Tiriti o Waitangi/The Treaty of Waitangi to the relationship between local government and communities. **Elements at risk:** • Enduring adaptation governance • Effective adaptation implementation • Legitimacy of democratic institutions (from contested climate decision-making) • Ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation.

Understanding 'climate-related risk'

The three main components of climate-related risk are hazard, exposure and vulnerability. The combination of these three factors create the potential for adverse consequences. See **Box 1.1** for an explanation of these and other key concepts.

Box 1.1: Key concepts underlying this climate change risk assessment

The nature of climate-related risks

Figure 1.1: Factors in climate change risks

Source: Commission analysis derived from IPCC

Understanding 'climate change risk'

In a climate change risk assessment, risk has a specific meaning. It is formally defined by the Intergovernmental Panel on Climate Change (IPCC) as "the potential for adverse consequences to human and ecological systems".[1]

The risk comes from a combination of three factors: *hazard*, *exposure* and *vulnerability*.

- **Hazard** refers to physical events or trends that result from climate change and that create problems for people or the environment. Climate-related hazards can be ongoing and progressive, like sea-level rise and changing weather patterns, or rapid onset, like extreme weather events and associated floods, landslides or fires.

- **Exposure** considers who or what can be affected by climate-related hazards. The elements exposed can include communities, ecosystems, economic sectors, cultural assets and infrastructure.
- **Vulnerability** focuses on the factors that determine how great the effect of a hazard might be on the exposed 'elements'. It covers what makes people, places or things more or less likely to be harmed (sometimes referred to as 'sensitivity') and whether they will be able to adapt (sometimes referred to as 'adaptive capacity').

The hazards that underlie the assessed risks

Different types of hazards drive risks. These include extreme events, progressive and ongoing hazards, and changes to variability.

- *Extreme events* include extreme rainfall, marine heatwaves, wildfire
- *Progressive and ongoing hazards* like sea-level rise
- *Changes to variability* such as trends in temperature or rainfall averages.

These hazards are discussed in more detail in *Chapter 2: Climate change in Aotearoa New Zealand*, and in relation to the assessed risks in *Chapter 3: Findings*.

Time horizons and global warming levels

Climate risk assessments look at how risks change over time, and how the consequences for people, places and ways of life would change depending on the rate of global warming.

In this assessment we have considered the severity of each risk for the present day, for the middle of the century (around 2050) and for the end of the century (around 2090).

While we assessed risks using two climate impact scenarios (based on different levels of global warming), risks were scored only once for 2050. This was because the difference in projected impacts between a low and high climate impact scenario by then is unlikely to be large enough to produce different scores.

Our scores for 2050 assume global warming of 1.5–2.0°C by the middle of the century – consistent with the 1.4°C of warming the world has already experienced from pre-industrial levels.[2]

When scoring the severity of risks in 2090, we considered two scenarios for different levels of global warming (as compared to pre-industrial levels) based on the latest international climate science:

- low climate impact scenario based on global warming of 2.0°C by 2090
- high climate impact scenario based on global warming of 3.0–3.5°C by 2090.

Indirect, compounding and cascading risks

While each of the 37 risks in the assessment has been analysed separately, in reality climate-related risks often interact.

An ‘indirect risk’ can emerge as a secondary consequence of a climate hazard, for example when extreme weather damages power lines, causing a power cut.

Sometimes multiple hazards can occur at once or in quick succession, creating a ‘compounding’ risk, for example when crews are unable to repair power lines damaged during a storm, because there is also a landslide blocking access.

Sometimes, risks run in ‘cascading’ chains of cause and effect, for example when households lose income because people are unable to work due to an extended power outage after extreme weather and landslides.

This assessment has incorporated these interactions between risks. This includes introducing ratings for indirect and cascading risks as part of the domains the Commission has analysed – see **Table 1.5**.

Residual risk

Residual risk describes the part of the risk that remains after efforts have been made to reduce it. In this context, it describes the level of risk that remains after adaptation and other efforts to address a climate-related risk. The Commission considered residual risk within the ‘policy readiness’ assessment of how prepared the country is to respond to climate-related risks – see **Table 1.4**).

Understanding adaptation

Adaptation reduces exposure and vulnerability

When we talk about adapting to the effects of climate change, the focus is on avoiding or reducing the harm or damage from climate hazards.

Adaptation reduces the climate-related risk overall, but it is not reducing a *hazard* – it cannot slow sea-level rise or prevent extreme weather events. What it can do is reduce *exposure* (for example, by moving key infrastructure out of a flood zone) and *vulnerability* (for example, by ensuring new buildings are designed to withstand higher temperatures).

Maladaptation can increase risk or transfer impacts

Not all action to adapt to climate change is effective at reducing the risk. Sometimes an action can make a risk worse or it can move the negative impacts elsewhere.

This ‘maladaptation’ is usually an accidental consequence of well-intentioned action. It can increase the residual risk. For example, building up a roadway to reduce the likelihood of road closures from flooding could end up damming floodwaters and causing deeper floods on nearby properties.

Lead time and lock in

'Lead time' reflects the period between the recognition of an issue and effective management of that issue. This can be because of delays in response and because the response decided on takes time to set up – for instance, to train a workforce to new requirements.

'Lock in' describes a situation where future outcomes are determined by events or decisions in the past. It recognises that decisions and ways of thinking from an earlier period can sometimes limit options in the future – for instance present-day building rules can 'lock in' performance standards that do not account for higher future temperatures.

Thresholds and tipping points

There are points when change can reach a level where a species, for instance, or a community or part of a human system, cannot absorb further change, and is no longer resilient.

- **Thresholds** are limits beyond which certain systems are no longer able to function.
- **Tipping points** refer to abrupt re-organisation of a system, such as dynamic feedbacks.

Where that tipping point or threshold lies is not always clear and can often only be confirmed in hindsight. Managing to stay away from thresholds and prevent tipping points being reached involves leaving a buffer to avoid permanent loss.

For more information, see the Priorities for action report, and the *Technical glossary*.

Working through uncertainty

Adaptation is a complex process of adjusting to climate change and its effects. It is an area where uncertainty is a constant. This uncertainty is part of what motivates a risk assessment. It is important that uncertainty does not prevent action or obscure the urgency of acting. Enough is already known about the changes Aotearoa New Zealand will face over the coming decades to put the country in a good position to prepare for those impacts.

Some of the ongoing shifts brought on by climate change can be foreseen, such as the continued rise in sea levels. While the exact amount of sea-level rise will vary from place to place, it can in general be anticipated.

There is much more uncertainty when it comes to extreme weather events. While it is clear those events will become more frequent and severe, it is not at all certain when and where they will happen, or quite what impact they will have in combination with other hazards. Scientific understanding is growing about many of the hazards the country faces, and can over time guide effective adaptation, but there will always be uncertainty.

Risk assessments are not predictions – they help New Zealanders look ahead to understand potential impacts and act early to prevent them. These reports discuss climate change projections, and variability between models. We don't assume the average is what will happen (and didn't rely on that for our assessment). This is why we look at different scenarios and rely on a range of published evidence to explore how serious the potential outcomes could be so that the country can take action to reduce them.

How the risks have been assessed

Requirements of the Climate Change Response Act 2002

Table 1.2 sets out the factors the Commission must consider when preparing a national risk assessment, and other matters it is required to consider in its advice.

The Commission may also take into account any opportunities that arise for the country as a result of the effects of climate change, and any other relevant or appropriate factor.

Table 1.2: Requirements of the Climate Change Response Act 2002

Factors the Commission must consider in a climate risk assessment	Key matters the Commission must consider in all its advice
• The economic, social, health, environmental, ecological and cultural effects of climate change. • The distribution of the effects of climate change across society, taking particular account of vulnerable groups or sections. • Aotearoa New Zealand's relevant obligations under international agreements. • How the assessment aligns or links with any other relevant national risk assessments produced by central government entities. • Current effects and likely future effects of climate change. • Scientific and technical advice.	• Current available scientific knowledge. • Existing technology and anticipated technological developments, including the costs and benefits of early adoption of these in Aotearoa New Zealand. • The likely economic effects. • Social, cultural, environmental and ecological circumstances, including differences between sectors and regions. • The distribution of benefits, costs and risks between generations. • The Crown–Māori relationship, te ao Māori (as defined in section 5H(2)) and specific effects on iwi and Māori. • Responses to climate change taken or planned by parties to the Paris Agreement or the United Nations Framework Convention on Climate Change.

Key steps in the process

Each risk was assessed across three factors – how severe risks are (risk severity), how ready the country is to address risks (policy readiness) and how connected risks are to other risks (cascading factors). This assessment was at a national scale.

Assessment of risk severity

This was assessed on a four-point scale (minor, moderate, major, extreme) across three time periods – present day, 2050 and 2090. 2090 was assessed under two scenarios – under both 2°C and 3–3.5°C of global warming by the end of the century.

While 2050 may seem far away, the infrastructure that is built today will likely still be in use mid-century, and often beyond.

The scores are based on expert judgement from the Commission and others, drawing from a wide range of evidence and with specific considerations for each domain. For more, see the separate Summary of method report.

Table 1.3 shows the high-level risk descriptors for the different levels of risk severity.[i]

Table 1.3: Risk severity assessment criteria

Minor	Moderate	Major	Extreme
• Minor and infrequent losses and damages. • No significant disturbance of system functionality. • Temporary and/or very slow onset impacts. • Unlikely to pose systemic risk.	• Moderate and/or recurring losses and damages. • Moderate disturbance of system functionality. • Medium-term and/or slow onset impacts. • Some potential to pose systemic risk.	• Large and/or frequent losses and damages. • Major and/or long-term disturbance of system functionality. • Long-term and/or rapid onset impacts. • Potential for impact thresholds or local tipping points to be reached, posing systemic risk.	• Very large and/or very frequent losses and damages. • Total and/or irreversible loss of system functionality. • Permanent and/or very rapid onset impacts. • High potential for impact thresholds or local tipping points to be reached, very likely to pose systemic risk.

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[i] Domain-specific guidance was also developed to help assess risk severity. This is set out in *Appendix 3* of the Summary of method report.

Assessment of policy readiness

Policy readiness refers to the extent that existing and planned adaptation actions will contribute to addressing the risk. Overall policy readiness was assessed on a four-point scale (no significant gaps, moderate gaps, significant gaps, insufficient). **Table 1.4** summarises the assessment criteria.

The ratings are based on expert judgement from the Commission and others, drawing from a wide range of evidence. For more, see the separate Summary of method report.

Our analysis had a cut-off date of 31 October 2025 for considering new information, including policy announcements, in the formal assessment and scoring. Important subsequent developments (up to late February 2026) have been noted in our descriptions but have not influenced scoring of risks.

Table 1.4: Policy readiness assessment criteria

No significant gaps	Moderate gaps	Significant gaps	Insufficient
• Policies respond well to this risk. • Mandate, funding and lead agencies are clear and active. • Risk largely mitigated by full implementation of current policy.	• Policies and actions only partially respond to this risk. • Some delivery under way, but there are gaps in mandate or uneven support. • Some risk would remain despite full implementation of current policy.	• Policy has not responded well to some important aspects of this risk. • Fragmented responsibility, unclear mandate or missing delivery structures. • Policies, plans and actions would leave major parts of the risk unaddressed, even if implemented as intended.	• Policy is either absent or has not responded to this risk. • Cannot be delivered under current conditions. No mandate, funding or mechanism for delivery. • Implementation would not reduce the risk meaningfully.

Assessment of indirect and cascading risks and impacts

The 2026 risk assessment has introduced ratings for indirect and cascading risks in the domains the Commission has analysed.[ii]

This allowed us to consider the relationships between risks, and to identify options that would address more than one risk at the same time. This is a relatively new concept for risk assessment and has been included to help ensure adaptation actions are targeted to effect.

The cascading risk scores range from 'low' to 'very high' (**Table 1.5**). We tested the relationships between risks and then ranked them in order of their potential: where addressing one risk would help to address others. The scores are relative.

Risks with high or very high cascading scores are those that, if addressed, would have the greatest potential to address other climate-related risks. Some risks with a low cascading score may still be important for enabling action on other risks. For instance, access to central or local government funding will be important to enable action on many risks, but funding alone will not be sufficient.

Table 1.5: Cascading risk assessment scores explained

Low	**Medium**	**High**	**Very high**
• These risks had lower-than-average potential to help address others. • They were in the bottom half of the ranked list.	• These risks had higher-than-average potential to help address others. • They were in the middle of the ranked list (between 51% and 75%).	• These risks were among those with the highest potential to help address others. • They were near the top of the ranked list (between 76% and 90%).	• These risks had the very highest potential to help address others. • They were in the top 10% of the ranked list.

[ii] Risks in Ngā mea hirahira o te ao Māori were not scored in this way, although the researchers assessing the risks in that domain did take potential cascading impacts into account – see Summary of method report.

Significant risks

As part of the risk assessment, the Commission must advise the Government on the most significant risks requiring attention in the second national adaptation plan.

Identifying the most significant risks

All these ratings – for severity, policy readiness, and indirect and cascading risks – were considered in our identification of the most significant risks.

The identification of the 'most significant risks' was the last stage in our assessment. We worked through three steps to identify what was most significant.

Step 1: We screened the risks using three principles

- *Principle 1:* Risks that present high potential for adverse consequences now with little in place to address them warrant immediate focus and can be considered significant.

  For this we screened for risks with a present-day severity rating of at least 'major' and a policy readiness rating of at least 'significant gaps'.

- *Principle 2*: Risks that will present high potential for adverse consequences by mid-century and have a very low base of current readiness will require significant lead time and can be considered significant.

  For this we screened for risks with a 2050 severity rating of at least 'major' and with a policy readiness rating of 'insufficient'.

- *Principle 3:* Risks that will present high potential for adverse consequences by mid-century and where acting now provides an opportunity to address several risks at once can be considered significant.

  For this we screened for risks with a 2050 severity rating of at least 'major' and with a cascading risk score indicating that actions to address them have 'high' or 'very high' potential to address other risks.

Step 2: We identified other potentially significant risks, taking into account:

- considerations such as equity or intergenerational impacts
- strategic decision points in the next six years (i.e. between now and when the next risk assessment is produced)
- where a risk was closely aligned with other risks already identified as significant.

Step 3: We looked for opportunities to combine risks, where:

- they were similar in scope
- they could be addressed by similar actions
- combining them would support explanation and action.

Our approach to identifying the most significant risks also included a scan for risks that might not score as highly as others, but that need immediate focus for other reasons.

The risks to central and local government funding are expected to combine with and intensify other risks from climate change, with potential consequences across generations to come. It is likely that other sources of finance will also fund adaptation actions; however, public funding ultimately underpins policy planning and infrastructure investment in Aotearoa New Zealand. Without adequate central and government funding for adaptation planning and action, the demand to fund intensifying climate impacts may make it difficult to fund other basic services such as health and education over the long term. For this reason, it was identified as one of the most significant.

The Summary of method report details the process applied to identify the most significant risks.

The Priorities for action report focuses on the part of our assessment that directly informs the Government’s work on a second national adaptation plan: the most significant risks. **Table 1.6** sets out the 10 risk areas we identified as the most significant, based on their nature, severity and the need for coordinated action to address them.

Table 1.6: The most significant risks

Most significant risks in 2026 national climate change risk assessment
Key infrastructure
Risks to water infrastructure This is about the infrastructure that provides people with drinking water, carries stormwater away from towns and manages sewage. Climate change threatens every part of this system, which is already under intense strain.
Risks to buildings This is about how buildings across Aotearoa New Zealand are exposed to a range of climate-related hazards that threaten both their structural integrity and performance.
Risks to road and rail networks This is about how climate hazards are putting increasing pressure on the country's road and rail networks, causing both short-term disruption and long-lasting damage.
Communities and safety
Risks to social and community wellbeing This is about growing impacts on people's wellbeing from the effects of climate change – particularly risks to individuals' mental health and to the ways society holds together. It combines two risks: Risks to mental health; and to social cohesion and wellbeing (from displacement).
Risks to emergency management This is about how the country's emergency management system is under acute pressure and may struggle to respond to the increasing frequency, severity and extent of disasters that can result from climate hazards.
Ngā mea hirahira o te ao Māori – risks in the Māori world This is about how climate hazards interact with longstanding structural factors to create a set of interconnected risks that specifically affect Māori. For iwi/Māori, climate change is not only a physical or economic problem. It reaches into identity, language, knowledge, governance and intergenerational wellbeing. It combines seven risks: Risks from loss of access to taonga species; damage to iwi/Māori infrastructure; economic losses for iwi/Māori in primary industries; disruption

to tikanga and hapū/iwi identity; loss of indigenous knowledge systems; legal exclusion and governance failures for iwi/Māori; and increased Māori health vulnerabilities.

Nature and the bioeconomy

Risks to ecosystems and biodiversity

This is about how climate change intensifies existing pressures and exacerbates threats to the country's ecosystems – threats like land degradation, invasive species, resource extraction and pollution.

It combines five risks: Risks to coastal ecosystems; freshwater ecosystems; marine ecosystems; terrestrial ecosystems; and indigenous biodiversity (from invasive species and pathogens).

Risks to forestry

This is about how climate change will affect the country's managed and production forests, and how the sector can better prepare for these impacts, including extreme weather, drought and wildfire, and new pests and diseases.

Decisions and funding

Risks to central and local government funding

This is about the growing pressure that climate change places on both central and local government finances. As climate impacts intensify, governments face higher costs for disaster response, infrastructure repair, welfare and health services, and long-term adaptation.

Risks to decision-making and delivery

This is about how climate-related demands are placing Aotearoa New Zealand's ability to plan, decide and act together under increasing pressure. The effects of climate change are going to keep hitting harder, and decision-makers may be increasingly caught up in urgent responses that take time and resources away from planning for the future and reducing harm.

It combines four risks: Risks to enduring adaptation governance; effective adaptation implementation; legitimacy of democratic institutions; and ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation.

Chapter 2: Climate change in Aotearoa New Zealand

This chapter provides an overview of current and future climate change impacts for the country.

It highlights the impacts of climate change that are already happening and then provides an overview of climate change projections for Aotearoa New Zealand as well as the country's exposure to climate hazards.

Projections are scenarios that provide information about how different future climates might unfold. They can be used to help assess the potential future impacts of climate change and to inform risk assessments and adaptation decision-making; they are not predictions. In the context of this risk assessment, projections are important tools to aid analysis of risk severity, as the risks are sensitive to the amount of climate change that occurs.

Climate change is happening here, now

Internationally, increasing quantities of greenhouse gases in the atmosphere from human activities are causing the climate to change. These changes have been observed in both global and regional climates.[3] The warming of the atmosphere, oceans and land is causing sea-level rise (SLR) and changes in rainfall and temperature patterns, as well as extreme events such as heatwaves, heavy rainfall events and droughts.[3] Reducing greenhouse gas emissions can slow this trend, but historical emissions and the delayed effects of these long-lived gases on atmospheric (and subsequently ocean) warming mean that further climate change cannot be prevented entirely.

Aotearoa New Zealand is already experiencing the impacts of climate change and, as a result of past greenhouse gas emissions, these impacts will continue far into the future. Global surface temperatures have warmed on average by nearly 1.4 degrees Celsius (°C) since the late 19th century.[2] In Aotearoa New Zealand, warming of 1.1°C over the period 1909–2019 has been observed.[4] The warmest year on record in Aotearoa New Zealand was 2022, followed by 2023 and then 2021. Four of the country's five warmest years since records began have occurred in the last five years.[5] Shifts in average and extreme temperatures have been recorded across the country, and will continue to do so with further warming, with the impacts greatest in the east and northern half of the North Island.[6]

Sea levels around Aotearoa New Zealand are rising faster than before

Although regional climate trends and gravitational effects mean that sea level does not rise uniformly around the globe, the sea level rose 0.21 m on average across Aotearoa New Zealand between 1901 and 2020. Splitting the record into approximately two equal periods of 60 years shows that the rate of SLR around the Aotearoa New Zealand coastline has doubled since 1960.[7]

Higher sea levels mean more frequent coastal inundation and flooding and greater risk of erosion. A 2015 study for the Parliamentary Commissioner for the Environment estimated that a SLR of 0.3 m – projected to occur by the second half of this century – would mean that high water levels, currently only experienced once in 100 years, would happen around once every four years in Auckland, and every year in Wellington and Christchurch. For 0.7 m of rise, current 1-in-100 year levels would occur daily in some locations.[8]

Rainfall patterns and extreme weather are shifting

Rainfall patterns are changing, with southern regions becoming wetter, and northern and eastern regions becoming drier. Droughts are becoming more frequent, and extreme weather events causing flooding and slips are becoming more frequent and severe.[9] Climate change is also affecting weather patterns and increasing the frequency and intensity of extreme events around Aotearoa New Zealand, often exacerbating existing patterns. It has been estimated that human-caused (anthropogenic) warming increased the total rainfall of 2023's Cyclone Gabrielle by about 10%, and its peak hourly rainfall by 20%, compared to if the same storm had occurred with no warming.[10]

Climate-related damages are already substantial and growing

The 2023 North Island Severe Weather Events collectively became the most severe and destructive weather events in Aotearoa New Zealand's recent history. Fifteen people lost their lives and between NZ$9 and NZ$14.5 billion of physical damage was caused to households, businesses and infrastructure. The likelihood of similar concurrent, compounding and cascading extreme events taking place is expected to increase as the climate changes.[11]

It is clear that climate change is causing damages. Quantifying the exact overall social, economic and environmental impacts of these severe events is challenging, as the impact of any one event will depend on its location and extent, whether it co-occurs with other events, and how well-prepared a community is to deal with the event and its aftermath. However, attribution of climate impacts is an expanding field and some estimates do exist. For example, between 2007 and 2017, flood and drought costs attributable to human-driven climate change were estimated at NZ$120 million for insured damages from floods, and NZ$720 million for losses from drought – with the total costs almost certainly higher.[12]

Climate projections for Aotearoa New Zealand

Projecting how the climate may change

The international climate modelling community has developed scenarios and pathways that explore a range of futures, based on possible scenarios for future greenhouse gas concentrations in the atmosphere that originate from a range of socio-economic drivers. The Intergovernmental Panel on Climate Change (IPCC) has published extensive climate model simulations that provide insight on future changes across a range of climate variables for each of these emissions scenarios globally.[13] *Appendix 1* sets out the details of the different scenarios used in the risk assessment and how they relate to each other, including those that were used for the downscaled projections used in this chapter.

Earth Sciences New Zealand (ESNZ, formerly NIWA) has refined these global projections with a higher spatial resolution for Aotearoa New Zealand, based on the IPCC Sixth Assessment Report (AR6).[14]

Downscaling global climate projections for this country

Understanding how national climate projections are developed

The climate change projections for Aotearoa New Zealand used in this report were developed by ESNZ by downscaling coarse resolution global climate models (GCMs) released in the IPCC's Sixth Assessment Report. The ESNZ downscaling provides a consistent methodology that enables localised risk assessments to be undertaken, as well as assessment of the relative risks between locations, and as such is a valuable input into the national risk assessment.

GCMs should not be used directly for local and regional applications, as they do not adequately represent certain features of atmospheric circulation, particularly in regions that have complex terrain, which is important for determining regional climates.[14,15] Dynamical downscaling, used to produce the ESNZ projections, is a valuable tool to better capture finer scale processes that impact local and regional climates while increasing the spatial resolution of projections.[14] This can help decision-makers and researchers better understand projected future changes in Aotearoa New Zealand's climate.

Data from the downscaled models is available on the Ministry for the Environment's (MfE) website.[16] SLR projections for Aotearoa New Zealand are available on the NZ SeaRise platform and in MfE's *Coastal hazards and climate change guidance*.[7,17]

Selecting global climate models for downscaling

The first step of dynamical downscaling is to choose which GCMs to downscale from the Coupled Model Intercomparison Project 6 (CMIP6)[iii] ensemble. ESNZ selected six GCMs based on consideration of data availability, historical model evaluation, model independence and future warming rate.[14] Developing climate projections from a range of GCMs is important for capturing model uncertainty in the downscaling, but it is not practical to downscale all GCMs (there are more than 60 GCMs in the CMIP6 ensemble) and certain GCMs have relatively poor performance for key indicators over the Aotearoa New Zealand region.[14]

The average of each scenario provides useful information

The projections used in this chapter are based on an average of six different climate models (a 'multi-model mean' – see **Figure 2.1**). Individual model results vary because each model is built differently and relies on distinct assumptions.

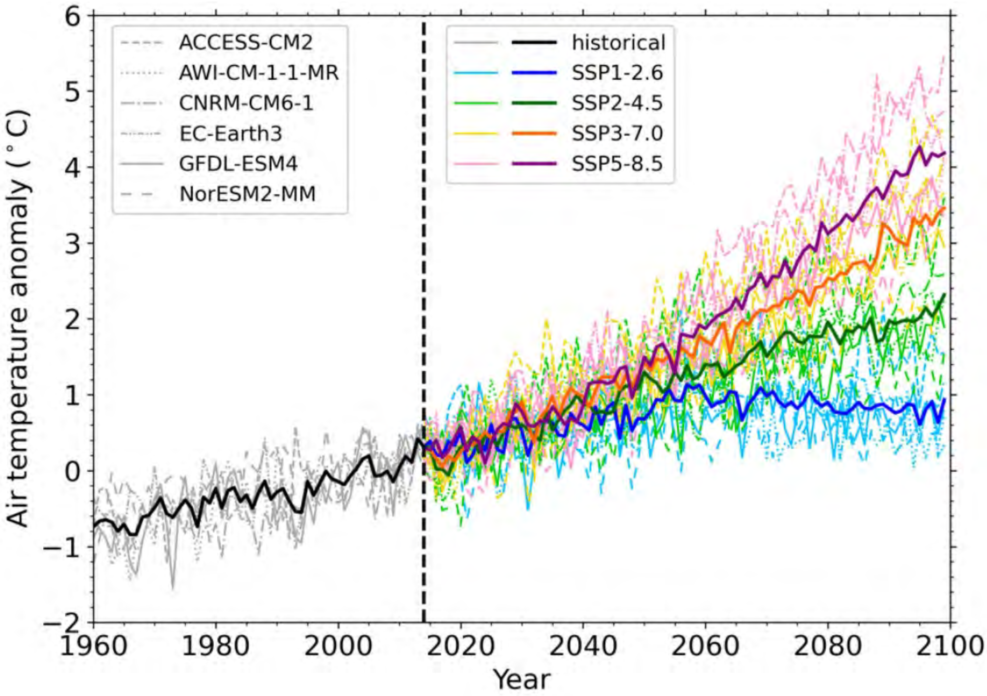
Averaging across models provides a central picture that highlights overall directions and patterns of change. However, this central picture masks the wider range of outcomes shown by individual models. The key takeaway is that a multi-model mean should not be the sole basis for adaptation planning. Effective adaptation requires ensuring that systems are robust across a range of plausible future conditions, including more extreme scenarios.

The range in projections across models provides practical and useful information about possible futures, with variation between the models explained by differences in modelling approaches and inherent variability.[iv, 18,19]

[iii] The Coupled Model Intercomparison Project (CMIP) is a framework for climate model experiments, allowing scientists to analyse, validate and improve GCMs in a systematic way. There have been several generations of CMIP, and each iteration becomes more sophisticated. A new generation is released every 5–6 years, and updates are coordinated around the schedule of IPCC assessment reports, with a new set of model results released in the lead-up to each one.

[iv] Variability between models stems from the inherent uncertainty in any projection of future climate change due to limitations in the representation of climate processes in climate models; natural climate variability; future social and economic changes; and uncertainties inherent in the process of downscaling to more detailed spatial and temporal scales.

Figure 2.1: Evolution of national (land-based) annual air temperature anomalies projected by the downscaled models to 2100 under various SSPs, relative to the 1995–2014 base period[20]



Source: Earth Sciences New Zealand | NIWA

Consistency in time periods and scenarios

The climate projections for 2041–2060 are described as mid-century, or 2050 for brevity, representing the average for that 20-year period. The climate projections for 2081–2100 are described as the end of the century, or 2090, representing the average for that 20-year period. Unless otherwise specified, all projections in this chapter refer to a baseline time period of 1995–2014 and represent projections under two scenarios: SSP1–2.6, subsequently referred to as the low climate impact scenario, and SSP3–7.0, subsequently referred to as the high climate impact scenario. See *Appendix 1* for full descriptions of the scenarios and the Summary of method report for a full description of how they are used for this risk assessment.

A picture of future climate change impacts

While projections of future climate are by their nature based on the effects of global emissions, when downscaled from the global scale to the local and regional scale, they can be used to provide a picture of the climate change impacts that Aotearoa New Zealand may face. The downscaled projections indicate Aotearoa New Zealand is likely to experience increasing effects of climate change this century (**Table 2.2**). These include:

- higher temperatures, with an increase of about 1.4°C by 2050 and about 3.0°C by 2090 under a high climate impact scenario, in relation to the 1995–2014 baseline. Slight gradients from north to south and from east to west are projected, and the North Island is projected to experience slightly greater warming than the South Island

- an increase in the number of hot days and decrease in the number of frost days
- an overall pattern of reduced annual rainfall in the north and east of the South Island and across the North Island; and increased annual rainfall in the west and south of the South Island. Changes in seasonal rainfall are more pronounced than for annual rainfall
- an increase in extreme rainfall almost everywhere, particularly in the west and south of the South Island
- an increase in drought exposure for the already drought-prone northern and eastern coasts of the North and South Islands
- a decrease in strong winds across the north of the North Island and an increase across most of the South Island.

Over the past 10,000 years, Aotearoa New Zealand's climate has largely been stable. Although natural variations have and always will occur, climate change is expected to shift the range and pattern of this variability and, indeed, is already doing so. Aotearoa New Zealand is experiencing increasing average temperatures, changing rainfall patterns and rising sea levels, as well as more frequent and severe extreme weather events such as heatwaves, droughts, storms and coastal flooding.[9] These changes in the climate pose significant risks to safety, wellbeing, homes and communities, natural environment, livelihoods and the economy.

Table 2.2: Multi-model means (and range across the six CMIP6 models, where applicable) of climate change projections for New Zealand in 2050 and 2090 under low climate impact and high climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050*		Change in 2090**	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Temperature				
Daily mean temperature (°C)	+0.8 (+0.4 to +1.3)	+1.4 (+0.9 to +1.9)	+0.8 (+0.6 to +1.5)	+3.0 (+2.0 to +3.8)
Daily minimum temperature (°C)	+0.8 (+0.3 to +1.2)	+1.3 (+0.8 to +1.8)	+0.8 (+0.6 to +1.4)	+2.8 (+1.8 to +3.6)
Daily maximum temperature (°C)	+0.9 (+0.5 to +1.4)	+1.4 (+1.0 to +2.0)	+0.9 (+0.6 to +1.6)	+3.1 (+2.2 to +4.0)
Number of cold nights (<0°C)	-9 (-4 to -11)	-14 (-9 to -18)	-9 (-7 to -14)	-28 (-20 to -32)
Number of hot days (>25°C)	+9 (+5 to +16)	+16 (+9 to +24)	+8 (+5 to +16)	+39 (+24 to + 54)
Rainfall				
Average rainfall (%)	+0.2 (-3.1 to +5.3)	-0.2 (-10.4 to +5.8)	+1.4 (-1.3 to +5.1)	-1.1 (-6.1 to +10.4)
Number of dry days (<1 mm)	+1 (-0.3 to +3)	+0.1 (-2 to +4)	-0.7 (-1.5 to +1)	+5 (+3 to +7)
Extreme rainfall (99th percentile) (%)	+4.5 (+1.2 to +10.4)	+5.2 (-0.3 to +12.1)	+4.4 (+1.9 to +9.2)	+10.4 (+4.2 to +24.8)

Potential evapotranspiration deficit (mm)	+25.2 (+12.0 to +39.5)	+32.7 (+4.8 to +72.4)	+19.8 (+7.5 to +32.7)	+61.2 (+28.0 to +83.5)
Other variables				
Average daily wind speed (%)	-0.2 (-1.4 to +1.0)	-0.6 (-3.0 to +1.1)	+0.8 (-1.3 to +2.0)	-1.9 (-4.5 to +0.1)
Strong winds (99th percentile) (%)	+0.2 (-0.8 to +2.0)	-0.3 (-1.2 to +1.5)	0 (-0.4 to +0.8)	-0.4 (-1.7 to + 1.0)
Incoming solar radiation ($W\ m^{-2}$)	+0.6 (-1.1 to +2.1)	+0.7 (-1.7 to +2.9)	+0.1 (-1.8 to +2.3)	+1.1 (-0.4 to +2.6)
Average relative humidity (%)	-0.3 (-0.1 to -0.5)	-0.4 (-0.1 to -1.0)	-0.3 (-0.2 to -0.4)	-0.6 (-0.3 to -0.9)
Sea-level rise (m)	+0.2	Approx +0.23[v]	+0.4	+0.6

* Values represent the average of the six downscaled GCMs (that is, multi-model mean). The range in brackets represents the range across the six models. See *Projecting how the climate may change* for discussion of the multi-model mean. The SLR projections are from the Ministry for the Environment's *Coastal hazards and climate change guidance*.[7]

** Under the low climate impact scenario it is assumed the world takes sufficient action to reduce emissions and therefore we start to see a reduction in some of the climate variables from what is expected in 2050. For example, there are fewer hot days listed in the table in 2090 under a low climate impact scenario than in 2050.

Updated projections show some changes between 2018 and 2024

The information below highlights some of the changes in the latest 2024 projections, compared to the 2018 projections. These are summarised in **Box 2.1**.

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[v] 0.2 m is reached in 2045 under this scenario.

Box 2.1: Changes between 2018 projections and 2024 projections

Climate projections are updated over time in light of improvements in scientific understanding and methodology. For example, the development of the Shared Socioeconomic Pathways (SSPs) for the IPCC Sixth Assessment Report allows for the incorporation of key drivers of emissions that were not included in the scenarios used in the earlier Fifth Assessment Report. The information below highlights some of the changes between the downscaled projections that were published in 2016 (updated 2018), and the latest ones released in 2024. These are summarised below.

Average temperature: Latest projections show a stronger warming trend across Aotearoa New Zealand. Latest projections for mean annual temperature are 0.2–0.3°C higher than the previous projections by mid-century and 0.6–0.9°C higher by the end of the century.

Hot days: In the latest projections, the projected number of hot days for the North Island exceeds that of the previous projections by increases of 3 to 6 days at mid-century and by increases of 8 to 17 days by the end of the century.

Average rainfall: Greater increases in summer rainfall (up to 9% wetter) are projected for most regions (particularly the north and east of the North Island) under the latest projections compared to previous projections by the end of the century under the high climate impact scenarios. In winter, drier winter conditions are experienced across all regions; South Island regions are projected to be 17–25% drier under the latest projections compared to previous projections by the end of the century under the high climate impact scenarios.

Extreme rainfall: Latest projections show a consistent increase in extreme rainfall across most of Aotearoa New Zealand compared to the previous set. A larger increase in extreme rainfall is projected for the North Island in the latest projections than in the previous projections, from +8.2% in the previous projections to +16.5% in the latest projections by the end of the century under the high climate impact scenario.

Drought (potential evapotranspiration deficit): Although potential evapotranspiration deficit (PED) is projected to increase across Aotearoa New Zealand as the climate changes, the latest projections consistently show lower PED values than the previous projections across all regions. This suggests that the latest climate projections are less pessimistic about future drought severity. While both sets of projections show increasing PED in the future, the projected annual deficit values are at least 20 mm lower in the more recent downscaled projections, irrespective of the time period or climate impact scenarios considered.

Solar radiation: Latest projections show decreasing solar radiation (increasing cloudiness) over the Southern Alps and increasing solar radiation (decreasing cloudiness) in most other regions, whereas the previous projections are more mixed and spatially variable across both islands.

Temperature

Average temperature

Average temperatures are projected to increase across Aotearoa New Zealand

Increases in annual average temperature are projected to be largely uniform across the country out to the end of the century, with slight gradients from north to south and from east to west (**Figure 2.2**). The North Island is projected to experience slightly greater warming than the South Island.

Under the two scenarios considered, by 2050 mean temperatures in Aotearoa New Zealand are projected to increase by 0.8°C (low climate impact scenario) to 1.4°C (high climate impact scenario) above the 1995–2014 baseline, and 0.8°C (low climate impact scenario) to 3.0°C (high climate impact scenario) by 2090. This warming trend is largely consistent across the country, with an increased rate of warming projected towards the north and for regions at higher elevation in the South Island. By the end of the century under SSP3–7.0, the five districts projected to experience the greatest annual average warming are Kaikōura, Mackenzie, Kawerau, Whakatāne and Rotorua.

The latest projections show stronger warming than previous models

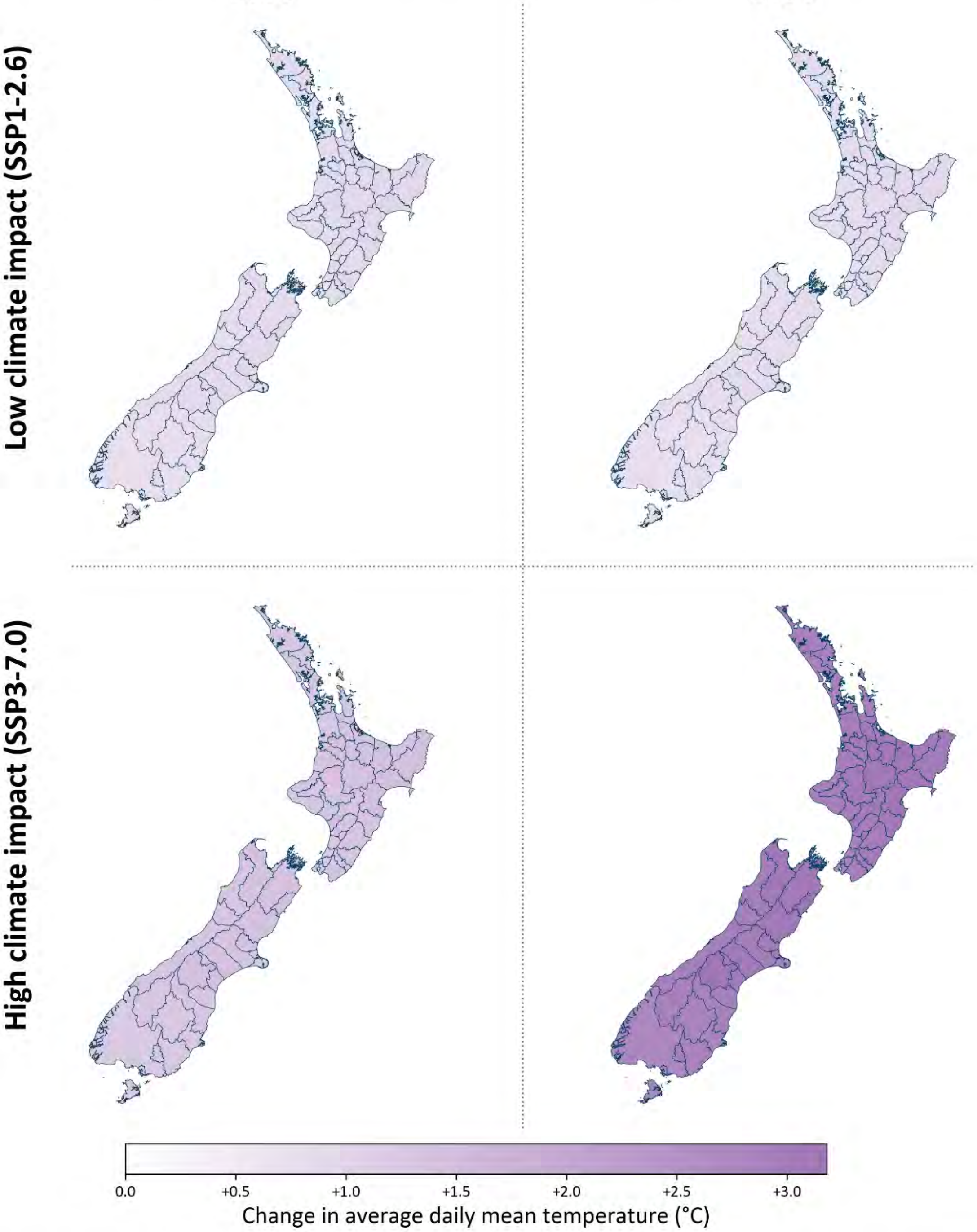
These latest CMIP6 projections show a stronger warming trend across Aotearoa New Zealand compared to the previous set of downscaled projections produced in 2018 based on the Coupled Model Intercomparison Project 5 (CMIP5) projections.[21] The current projections for mean annual temperature are 0.2–0.3°C higher than the previous projections by mid-century and 0.6–0.9°C higher by the end of the century.[22] In terms of seasonal differences, the current projections show greater summer warming than the previous projections across all scenarios. For the end of the century under a high climate impact scenario, summer warming is projected to be 0.9°C greater in the current projections compared to the previous projections.[22]

Table 2.3: Mean projected change (and range across the six CMIP6 models) in daily mean temperature for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Daily mean temperature	+0.8°C (+0.4°C to +1.3°C)	+1.4°C (+0.9°C to +1.9°C)	+0.8°C (+0.6°C to +1.5°C)	+3.0°C (+2.0°C to +3.8°C)

Source: Ministry for the Environment

Figure 2.2: Change in average daily mean temperature by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Number of hot days

Days over 25°C are projected to increase, particularly in northern and inland areas

As average temperatures increase, the number of hot days, defined as days with a maximum temperature of over 25°C, is also projected to increase. Historically, on average fewer than 15 hot days occur each year along the western coast of the South Island, whereas up to 27 hot days per year occur in inland areas of the South Island and across the North Island.[18]

For the two scenarios considered, by 2050, the multi-model means show an increase in the average number of hot days of 9 more days (low climate impact scenario) and 16 more days (high climate impact scenario). In 2090, the multi-model means show an increase of 8 more days (low climate impact scenario) and 39 more days (high climate impact scenario).

Generally, northern and inland areas of Aotearoa New Zealand are projected to experience the greatest increases in the number of hot days, with greater increases experienced in the North Island than in the South Island (**Figure 2.3**). The districts projected to experience the greatest increase in the number of hot days by the end of the century under SSP3–7.0 are Tauranga (87 more hot days), Far North (87 more hot days), Kawerau (86 more hot days) and Whangārei (86 more hot days).

The latest projections show more hot days than previous models

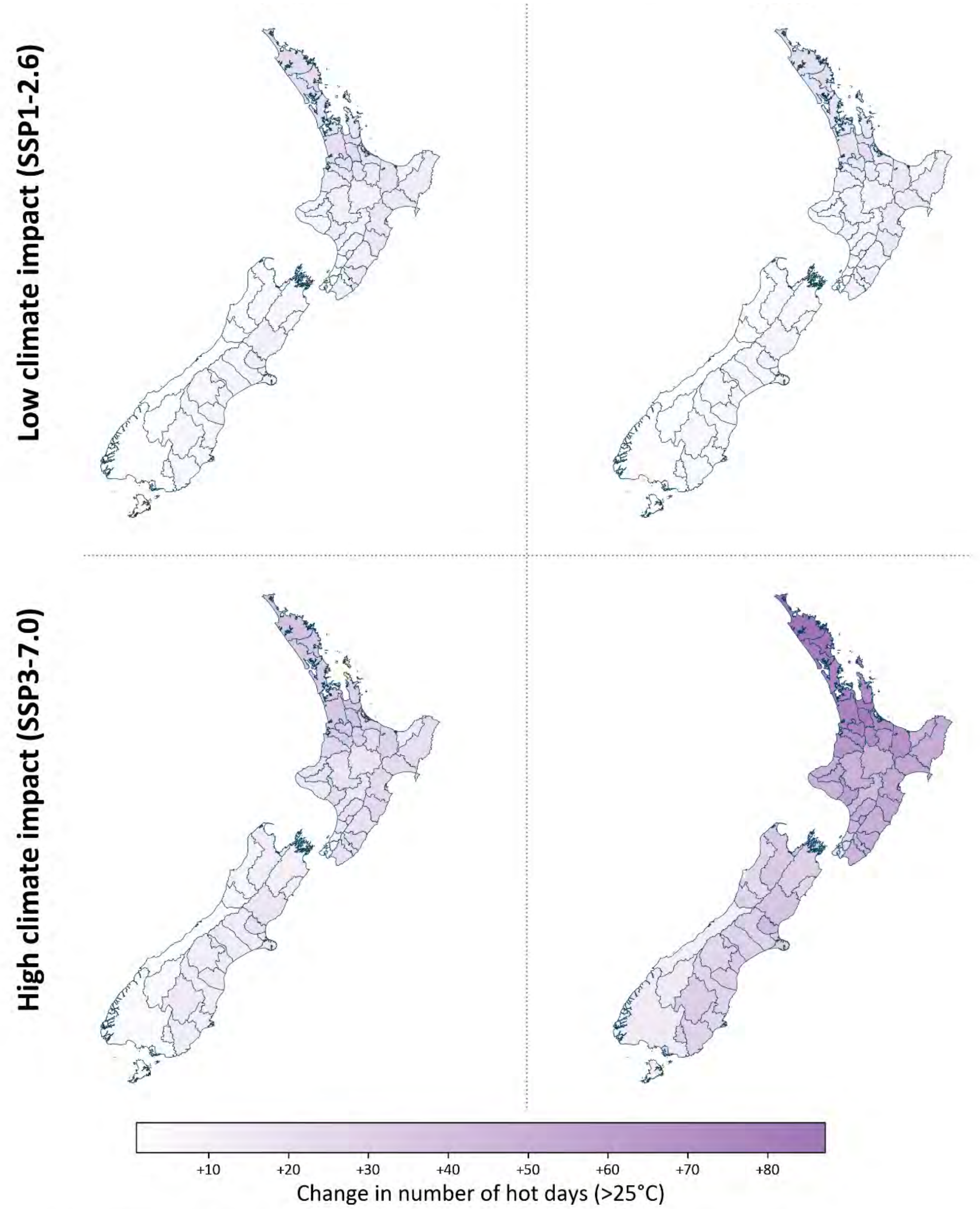
These estimates of increased hot days are higher than the previous downscaled projections across most regions of the North Island, in line with the greater projected overall warming in the current projections. In the current projections, the projected number of hot days for the North Island exceeds that of the previous projections by increases of 3 to 6 days at mid-century and by increases of 8 to 17 days by the end of the century.[22]

Table 2.4: Mean projected change (and range across the six CMIP6 models) in the number of hot days (>25°C) for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Number of hot days (>25°C)	+9 (+5 to +16)	+16 (+9 to +24)	+8 (+5 to +16)	+39 (+24 to + 54)

Source: Ministry for the Environment

Figure 2.3: Change in annual number of hot days above 25°C by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Number of cold nights

The number of cold nights below zero degrees is projected to decrease

As average temperatures rise, the number of cold nights, defined as nights when minimum temperatures drop below 0°C, is projected to decrease in frequency across the country. For the two scenarios considered, nationally, on average, there are projected to be 9 fewer (low climate impact scenario) or 14 fewer (high climate impact scenario) cold nights in 2050, and 9 fewer (low climate impact scenario) or 28 fewer (high climate impact scenario) cold nights in 2090.

The number of cold nights is projected to decrease much more (that is, greater warming) in regions that already experience cooler temperatures, particularly those at higher elevations in both the North and South Islands (**Figure 2.4**). Reduced snow cover and reduced albedo[vi] in winter months likely contribute to the greater reduction in cold nights in these regions.[23] In 2090 under SSP3–7.0, Mackenzie District is projected to experience the greatest decrease in cold nights (54 fewer cold nights per year), followed by Queenstown-Lakes (50 fewer) and Central Otago (43 fewer).

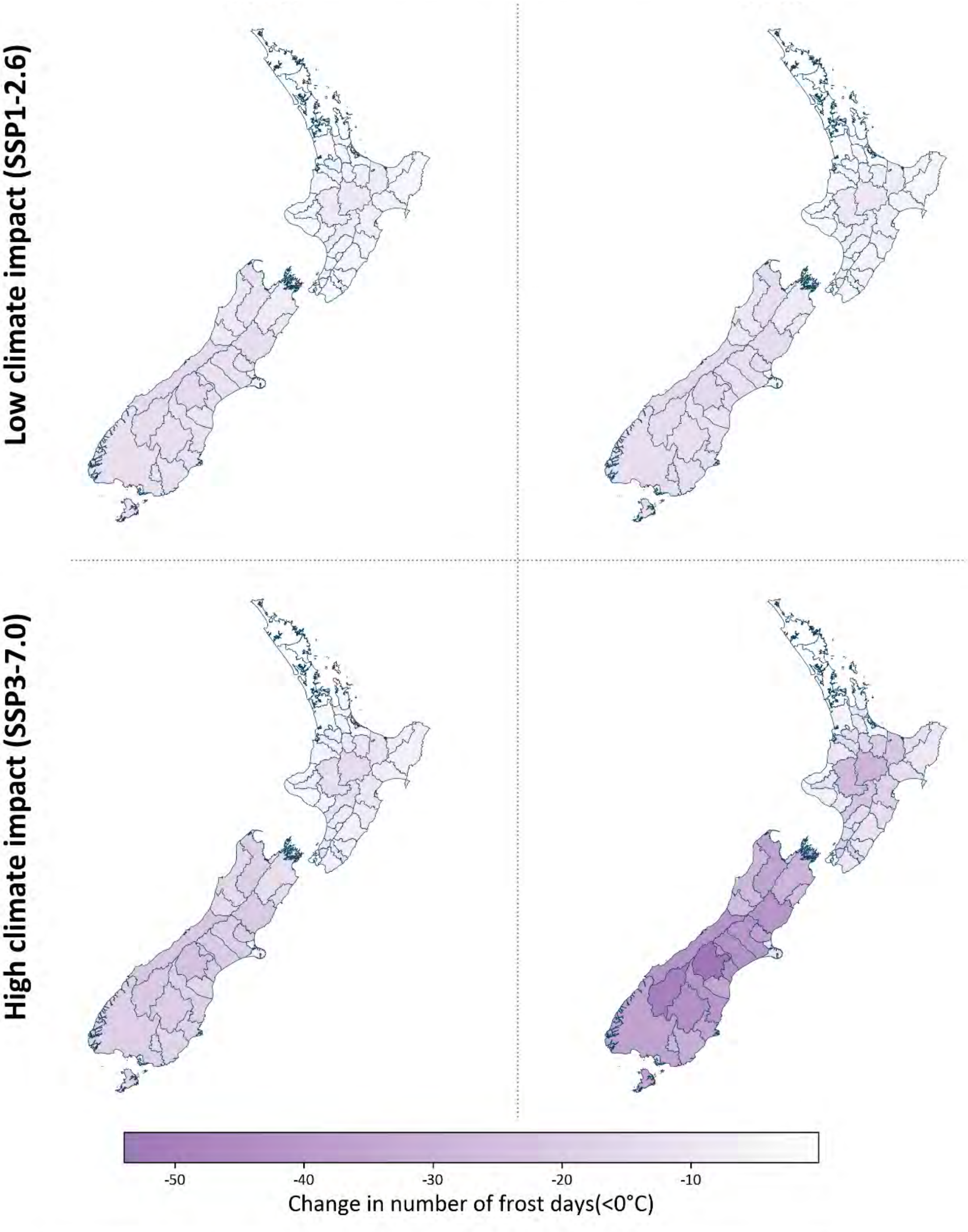
Table 2.5: Mean projected change (and range across the six CMIP6 models) in the number of cold nights (<0°C) for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Number of cold nights (<0°C)	-9 (-4 to -11)	-14 (-9 to -18)	-9 (-7 to -14)	-28 (-20 to -32)

Source: Ministry for the Environment

[vi] Albedo is a measure of the percentage of sunlight that a surface (in this case snow) reflects away.

Figure 2.4: Change in annual number of cold nights (frost days <0°C) by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Rainfall

Average rainfall

Regional and seasonal rainfall patterns are projected to shift

Precipitation projections are highly variable by region and season. The Ministry for the Environment notes that by 2090 the overall pattern is for reduced annual rainfall in the North Island, particularly in the north and the east, as well as in the north and the east of the South Island. Increased annual rainfall is projected for the west and south of the South Island by 2090.[24]

Seasonal changes will be larger than annual changes, with strong regional contrasts

The largest rainfall changes by the end of the century will be observed for particular seasons rather than annually. In summer, relatively large increases in rainfall are projected for some regions, such as parts of Northland, the central North Island and parts of the South Island by 2090 under a high climate impact scenario (**Figure 2.5**). The districts with the greatest projected increases in summer rainfall are Waimate (17% increase), Waitaki (13% increase) and Kaipara (12% increase). Some regions are also projected to experience small decreases in summer rainfall, such as Buller (4% decrease) and Ōpōtiki (3% decrease). In winter, relatively large increases in rainfall are projected for the west coast of the South Island, whereas reduced rainfall is projected for the eastern and northern parts of both islands (**Figure 2.6**).[23] The districts with the greatest projected increases in winter rainfall are Invercargill (20% increase), Westland (20% increase), Gore (15% increase) and Southland (15% increase). The districts with the greatest projected decreases in winter rainfall are Kaikōura (20% decrease), Kaipara (19% decrease), Far North (17% decrease) and Hastings (17% decrease).

The spatial pattern of changes in total annual rainfall under high climate impact scenarios is similar in both the previous and current downscaled projections. Both sets of projections show increased rainfall across the West Coast and Southland and decreased rainfall in the eastern lee of the Southern Alps, in the eastern and central North Island and in Te Taitokerau/Northland.[22] Both sets of projections also agree that these regional trends will intensify (that is, greater increases or decreases) as climate impact scenarios increase from low to high climate impact.[22]

There are seasonal and regional differences in the latest projections with summer projected to be wetter and winter drier than in previous models

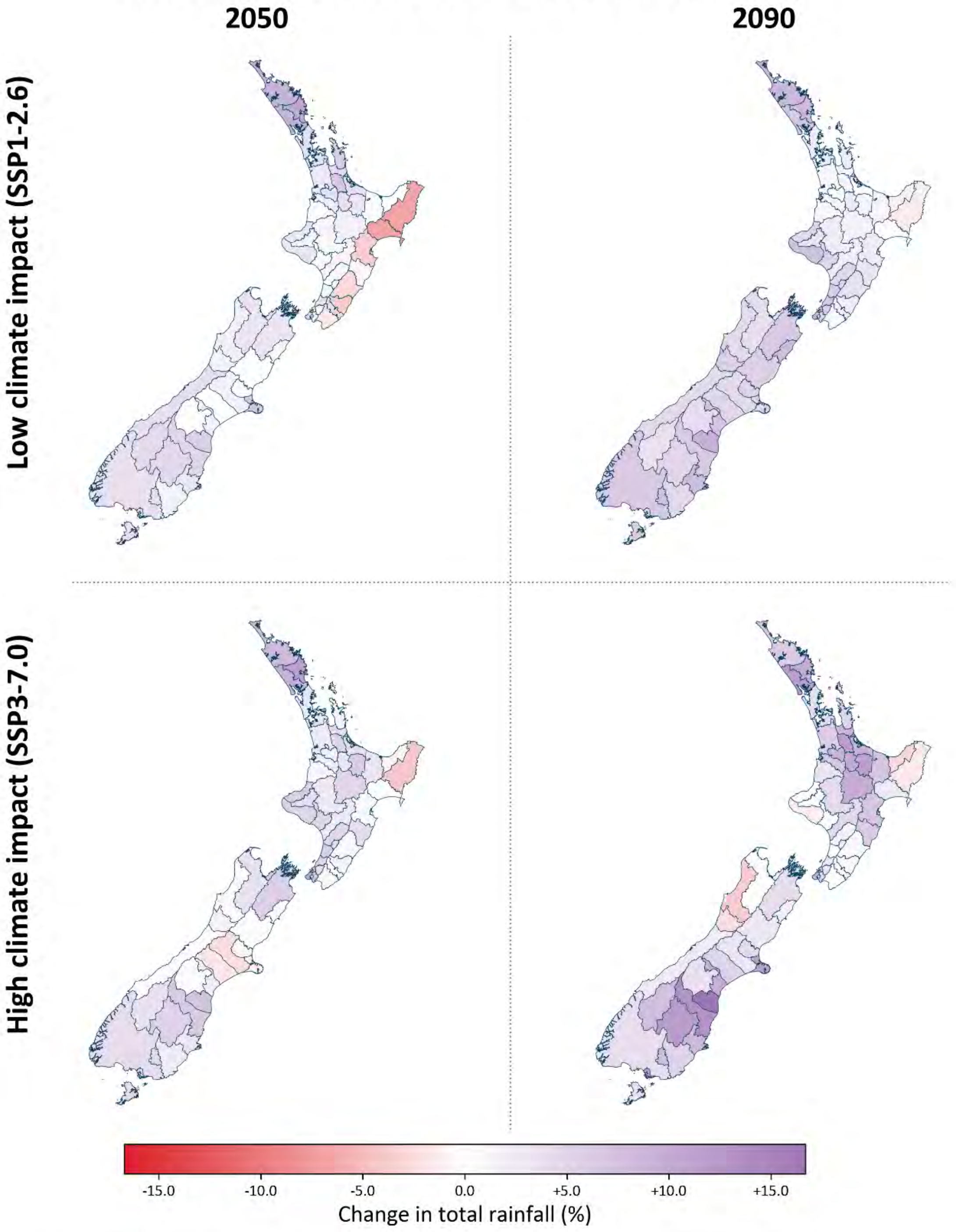
While the annual projections for total rainfall are broadly comparable, there are seasonal differences at the local and regional levels between the previous and current downscaled projections. Greater increases in summer rainfall (up to 9% wetter) are projected for most regions (particularly the north and east of the North Island) under the current projections compared to the previous projections, by the end of the century under the high climate impact scenarios. The greatest divergence between the two sets of projections is in winter, with drier winter conditions experienced across all regions; South Island regions are projected to be 17–25% drier under the current projections compared to the previous projections by the end of the century under the high climate impact scenarios.[22]

Table 2.6: Mean projected change (and range across the six CMIP6 models) in average rainfall for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Average rainfall	+0.2% (-3.1% to +5.3%)	-0.2% (-10.4% to +5.8%)	+1.4% (-1.3% to +5.1%)	-1.1% (-6.1% to +10.4%)

Source: Ministry for the Environment

Figure 2.5: Change in total summer rainfall by territorial authority (for 2050 and 2090, in two climate impact scenarios)

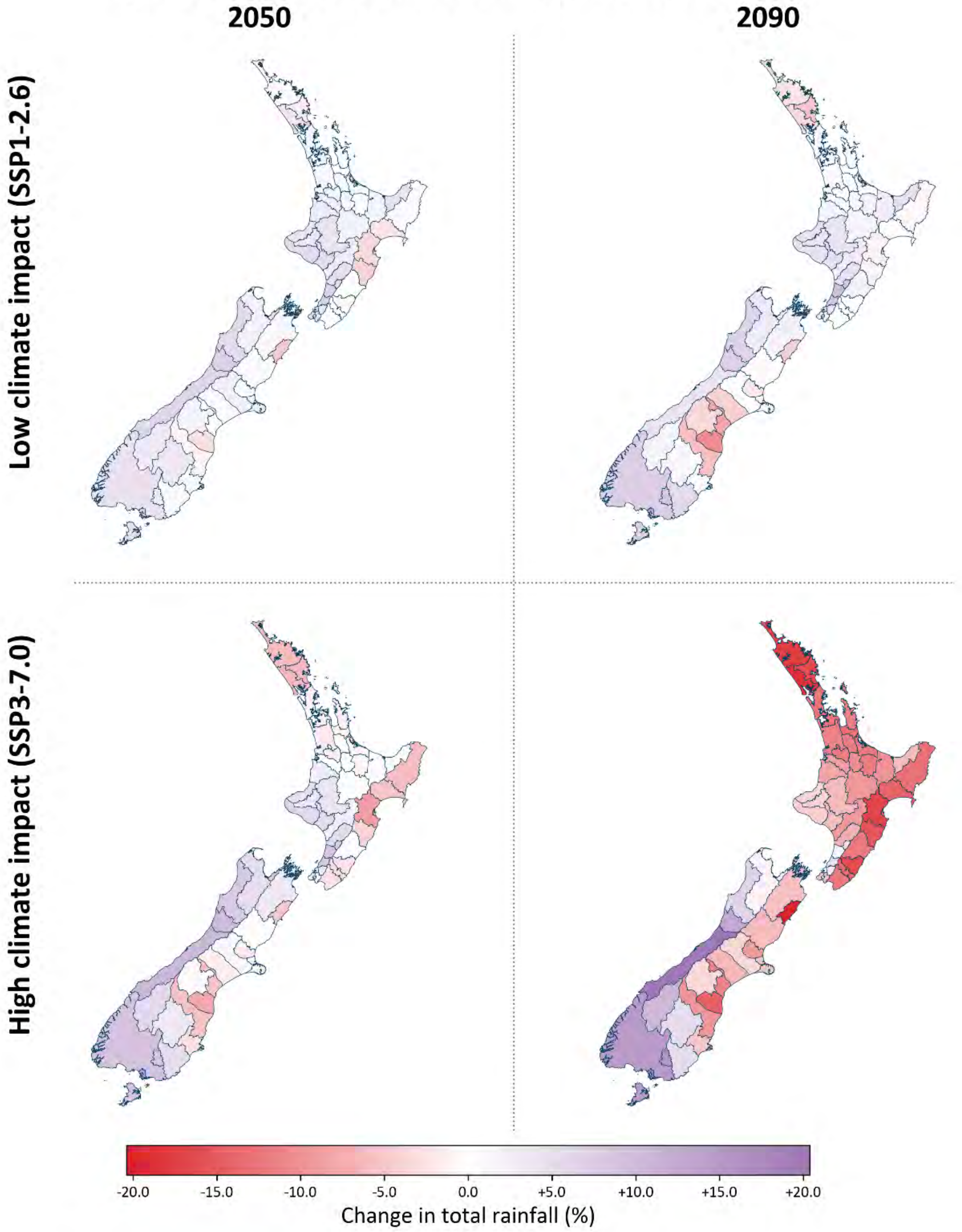


Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Figure 2.6: Change in total winter rainfall by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Extreme rainfall

Increases in extreme rainfall are projected almost everywhere under all scenarios

Extreme rainfall is the 99th percentile of the daily rainfall distribution from 1995 to 2014, representing the three wettest days each year on average. Extreme rainfall events are influenced by temperature because a warmer atmosphere can hold more moisture.

Under the two scenarios considered, the multi-model means for extreme rainfall project an increase of 4.52% (low climate impact) and 5.24% (high climate impact) by 2050 nationally. By 2090, the multi-model means indicate extreme rainfall increases to be 4.42% (low climate impact) and 10.42% (high climate impact).

Relatively large increases in extreme rainfall are projected almost everywhere in the country, particularly in the west and south of the South Island (**Figure 2.7**). By 2090 under SSP3–7.0, the districts with the largest projected annual increase in extreme rainfall are Invercargill (25% increase), Gore (22% increase) and Southland (16% increase).

The latest projections show an increase in extreme rainfall compared to previous models

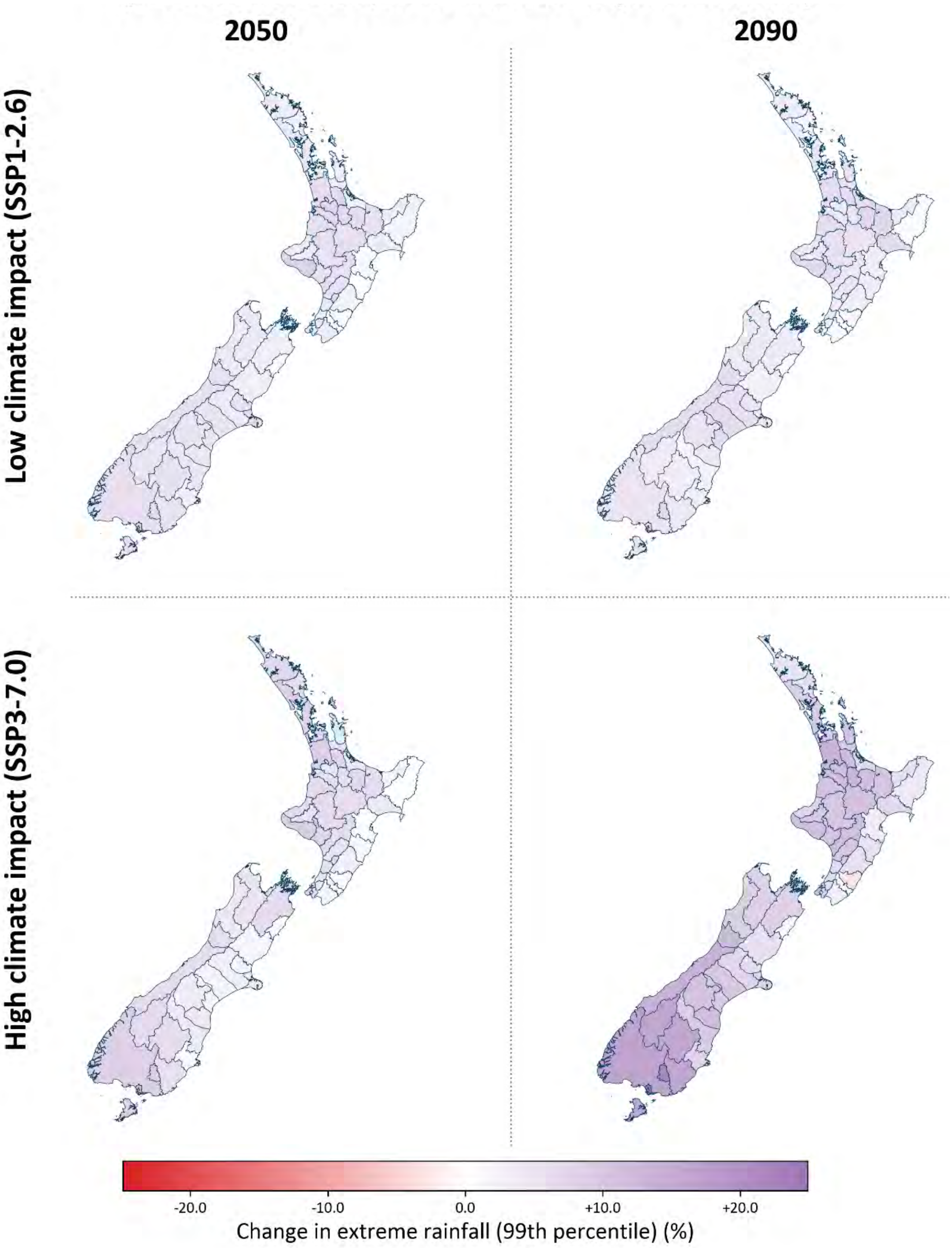
Overall, the most recent downscaled projections show a consistent increase in extreme rainfall across most of New Zealand compared to the previous set. Notably, however, a larger increase in extreme rainfall is projected for the North Island in the current projections than in the previous projections, from +8.2% in the previous projections to +16.5% in the current projections for the end-of-century high climate impact scenario.[22]

Table 2.7: Mean projected change (and range across the six CMIP6 models) in extreme rainfall (99th percentile) for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Extreme rainfall (99th percentile)	+4.5% (+1.2% to +10.4%)	+5.2% (-0.3% to +12.1%)	+4.4% (+1.9% to +9.2%)	+10.4% (+4.2% to +24.8%)

Source: Ministry for the Environment

Figure 2.7: Change in extreme rainfall (99th percentile) by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Drought (potential evapotranspiration deficit)

Projected drought intensity increases most in already drought-prone regions

Drought is projected using the potential evapotranspiration deficit (PED), which represents the annual difference between potential evapotranspiration and the amount of water actually available in the soil.[vii] PED changes are largely based on, and consistent with, projected changes in temperature and precipitation patterns. Changes in other climate variables (solar radiation, relative humidity and wind) also influence calculated PED changes, but to a lesser degree.

Projected future changes in PED are largest in the already drought-prone northern and eastern coasts of the North and South Islands (**Figure 2.8**). For the scenarios considered in this assessment, by 2050, annual average PED is projected to increase by 25.2 mm (low climate impact) and 32.7 mm (high climate impact) – that is, an additional 25- to 33-millimetre deficit in rainfall. By 2090, annual average PED is projected to increase by 19.8 mm (low climate impact) and 61.2 mm (high climate impact). By 2090 under the high climate impact scenario, the districts with the greatest projected increases in annual average PED are Kaikōura (+139 mm), Masterton (+123 mm) and Napier (+112 mm).

The latest projections suggest there may be less drought than previously anticipated

PED is expected to increase across all regions of Aotearoa New Zealand, driven by a warmer and often drier future climate in both sets of downscaled projections (the current and the previous projections). However, there are significant differences between the two sets of projections, with the current projections consistently showing lower PED values than the previous projections across all regions. This suggests that the latest climate projections are less pessimistic about the future evaporative drought severity Aotearoa New Zealand is likely to experience.[22] While both sets of projections show increasing PED in the future, PED is lower in most regions in the current projections than in the previous ones. The projected annual deficit values are at least 20 mm lower in the more recent downscaled projections, irrespective of the time period or climate impact scenarios considered.[22]

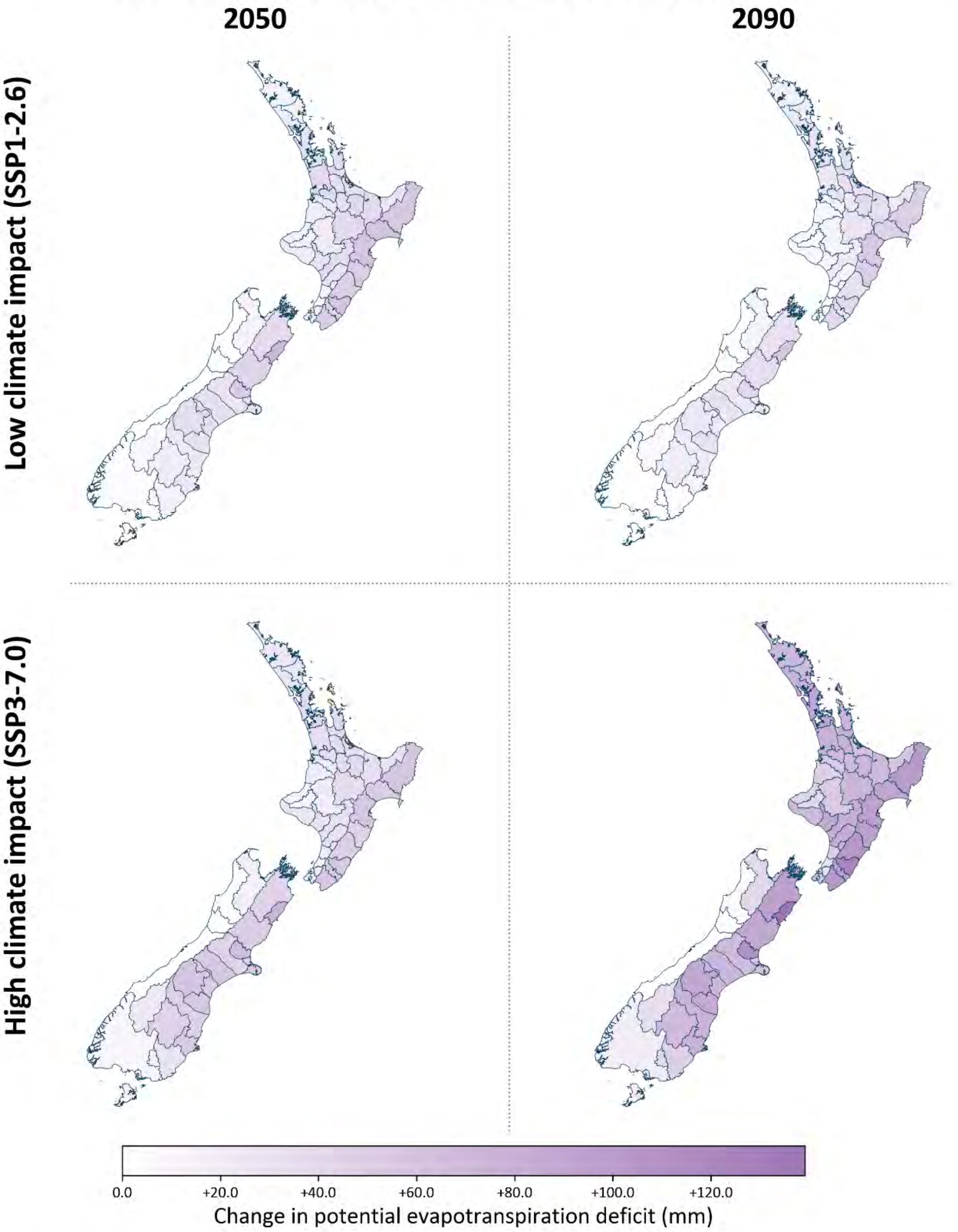
[vii] Positive potential evapotranspiration deficit (PED) value means there is not enough water in the soil to meet a plant's maximum growing needs.

Table 2.8: Mean projected change (and range across the six CMIP6 models) in potential evapotranspiration deficit for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Potential evapotranspiration deficit	+25.2 mm (+12.0 mm to +39.5 mm)	+32.7 mm (+4.8 mm to +72.4 mm)	+19.8 mm (+7.5 mm to +32.7 mm)	+61.2 mm (+28.0 mm to +83.5 mm)

Source: Ministry for the Environment

Figure 2.8: Change in annual potential evapotranspiration deficit by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Other climate variables

Strong winds

Strong winds are projected to change unevenly across the country

Strong winds are those that exceed the 99th percentile, determined by ranking daily values over the projection period, and represent the typical wind speed on one of the windiest days of the year.

By the end of the century under SSP3–7.0, the largest increases in 99th percentile daily wind speed are projected for Waimakariri (+3%), Waimate (+3%) and Timaru (+3%). Some districts are also projected to experience a decrease in 99th percentile daily wind speed, such as Whangārei (-4%), Far North (-4%) and Kaipara (-4%) (**Figure 2.9**).

The latest projections show smaller changes in strong winds for the South Island

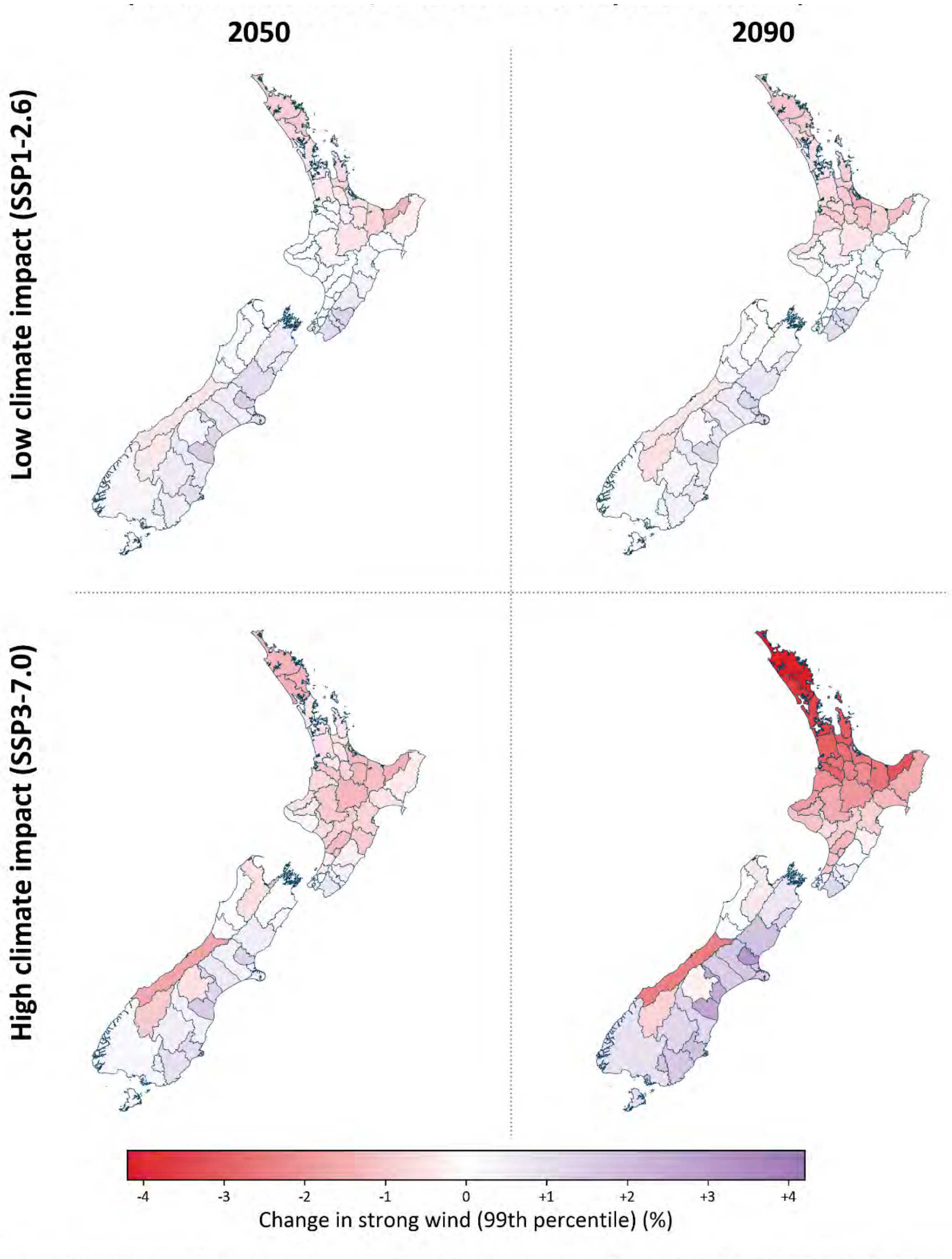
Both the previous and current downscaled projections for strong wind show decreases across the north of the North Island and an increase across most of the South Island. However, the regional differences are not yet well understood and further work is needed.[22] Regionally, the current projections regularly show smaller changes in strong winds than the previous projections across the South Island (2%–5% lower for the end of the century under the high climate impact scenarios).[22]

Table 2.9: Mean projected change (and range across the six CMIP6 models) in strong winds (99th percentile) for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Strong winds (99th percentile)	+0.2% (-0.8% to +2.0%)	-0.3% (-1.2% to +1.5%)	0% (-0.4% to +0.8%)	-0.4% (-1.7% to + 1.0%)

Source: Ministry for the Environment

Figure 2.9: Change in annual strong wind by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Solar radiation

Future projections show decreasing solar radiation over the Southern Alps and increases everywhere else

Solar radiation, which is dependent on astronomical factors as well as rainfall and cloudiness, is around three to four times higher in summer than in winter. The highest solar radiation levels are typically recorded in the Nelson–Marlborough and Central Otago regions during summer, and in the northern North Island and Nelson–Marlborough regions during winter.[18]

Solar radiation is projected to decrease (meaning increased cloudiness) over the Southern Alps and to increase (meaning decreased cloudiness) almost everywhere else (**Figure 2.10**). Annually, by the end of the century under SSP3–7.0, the districts with the greatest projected decrease in solar radiation are Westland, Mackenzie and Queenstown–Lakes, while the districts with the greatest projected increase in solar radiation are Ruapehu, Rangitīkei and Whanganui.

The latest projections show slightly greater increases in solar radiation

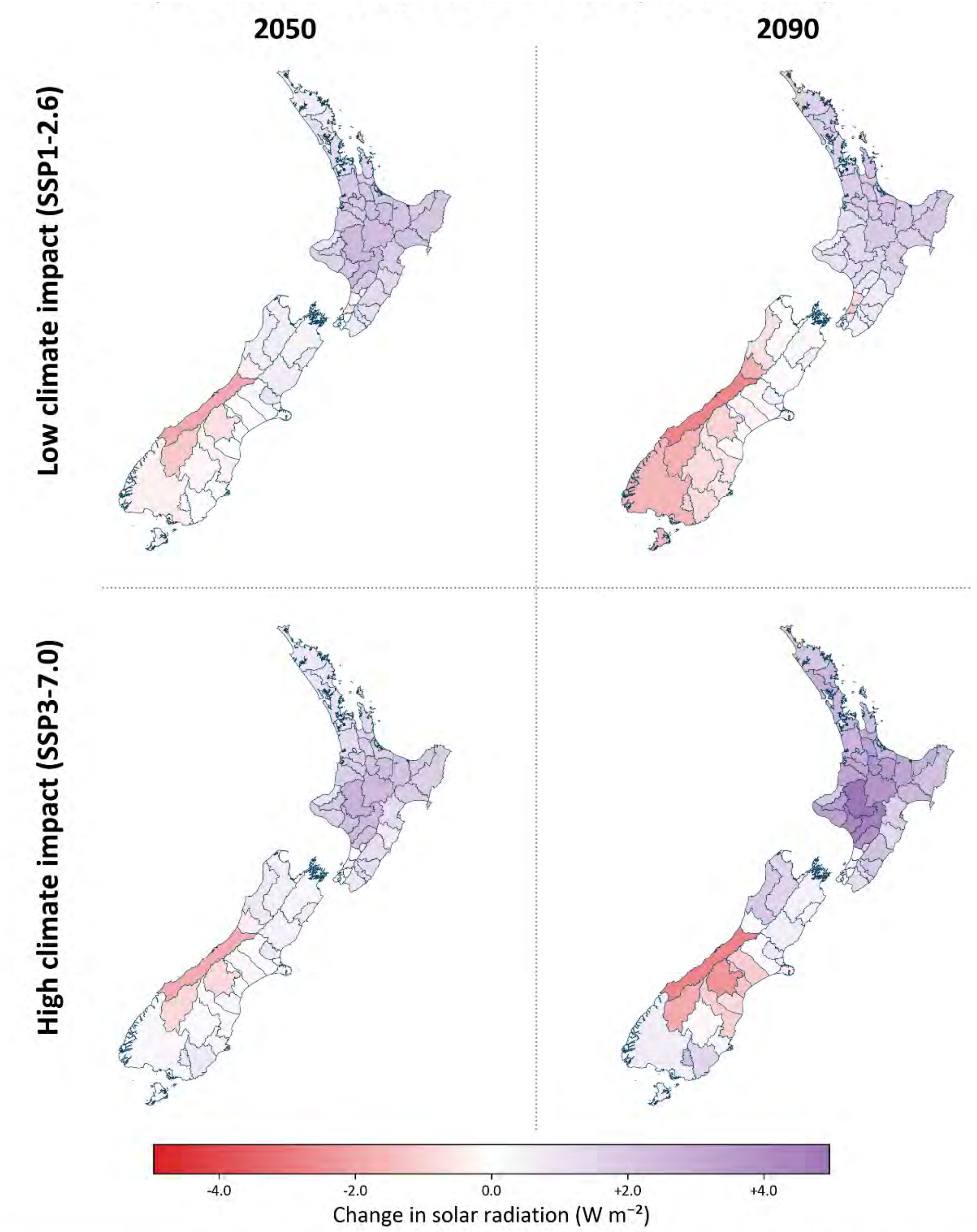
There are some notable spatial differences between projections for solar radiation in the current projections as compared to the previous projections. The current projections show decreasing solar radiation over the Southern Alps and increasing solar radiation in most other regions, whereas the previous projections are more mixed and spatially variable across both islands.[22] Overall, the current projections generally show slightly greater increases in solar radiation than the previous projections.[22]

Table 2.10: Mean projected change (and range across the six CMIP6 models) in incoming solar radiation for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Incoming solar radiation	+0.6 W m^{-2} (-1.1 W m^{-2} to +2.1 W m^{-2})	+0.7 W m^{-2} (-1.7 W m^{-2} to +2.9 W m^{-2})	+0.1 W m^{-2} (-1.8 W m^{-2} to +2.3 W m^{-2})	+1.1 W m^{-2} (-0.4 W m^{-2} to +2.6 W m^{-2})

Source: Ministry for the Environment

Figure 2.10: Change in annual average solar radiation by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Toitū Te Whenua – Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Relative humidity

Humidity is projected to decline across most of Aotearoa New Zealand

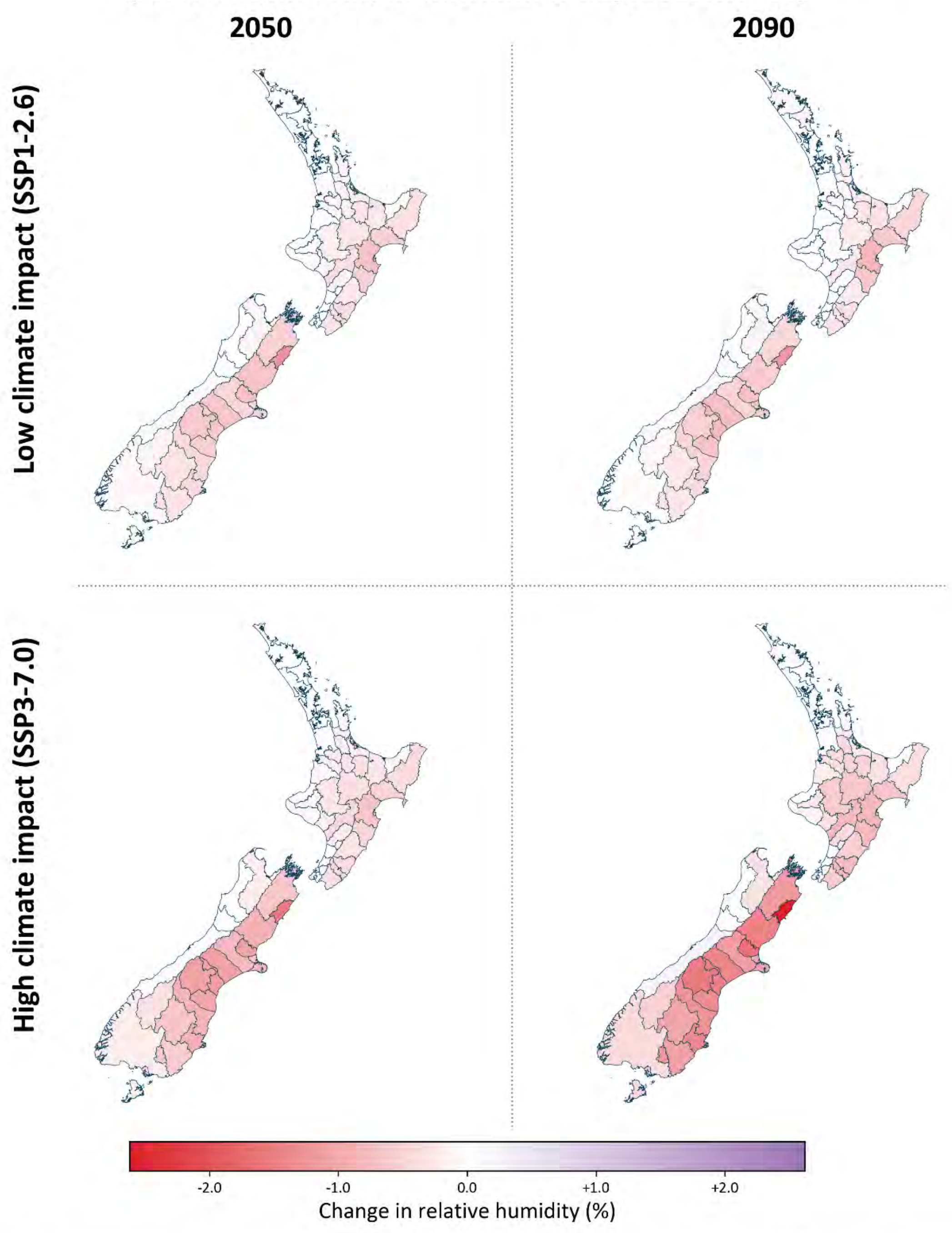
Relative humidity, which is a function of rainfall, temperature and solar radiation, is projected to reduce almost everywhere, with the largest decreases in the South Island (**Figure 2.11**). The exceptions are the West Coast of the South Island and part of the lower North Island, where no change or a small increase is projected. By 2090 under SSP3–7.0, the districts with the greatest projected decrease in annual average relative humidity are Kaikōura, Waimakariri and Mackenzie.

Table 2.11: Mean projected change (and range across the six CMIP6 models) in average relative humidity for 2050 and 2090 under two climate impact scenarios, relative to the 1995–2014 baseline

Climate variable	Change in 2050		Change in 2090	
	Low climate impact	High climate impact	Low climate impact	High climate impact
Average relative humidity	-0.3% (-0.1% to -0.5%)	-0.4% (-0.1% to -1.0%)	-0.3% (-0.2% to -0.4%)	-0.6% (-0.3% to -0.9%)

Source: Ministry for the Environment

Figure 2.11: Change in annual average relative humidity by territorial authority (for 2050 and 2090, in two climate impact scenarios)



Source: Climate Change Commission, using data from the Ministry for the Environment and Land Information New Zealand

Note: Projections for 2050 and 2090 represent 20-year averages for the periods 2041–2060 and 2081–2100, respectively, with all changes calculated relative to the 1995–2014 baseline (centred on 2005).

These maps show the multi-model mean. Individual models may show different projections for the climate variable shown. See *Projecting how the climate may change* for discussion of the multi-model mean.

Sea-level rise

Sea-level rise (SLR) is accelerating globally and around Aotearoa New Zealand

Globally, mean sea level increased by 0.20 m between 1901 and 2018. The average rate of SLR was 1.3 mm per year between 1901 and 1971, which then increased to 1.9 mm per year between 1971 and 2006, and to 3.7 mm per year between 2006 and 2018.[3] Sea level rose 0.21 m on average across Aotearoa New Zealand between 1901 and 2020. Splitting the record into approximately two equal periods of 60 years shows that the rate of SLR around the coastline doubled since 1960.[7]

Median projections show continued SLR under both low and high climate impact scenarios

Percentiles are used to quantify the distribution of the various SLR projections for each climate change scenario, with the median representing the 50th percentile. Median SLR for the wider Aotearoa New Zealand region for the low climate impact scenario (SSP1–2.6), based on the latest projections and relative to the 1995–2014 baseline, is projected to reach 0.2 m in 2050 and 0.4 m in 2090. For the high climate impact scenario (SSP3–7.0), median SLR is projected to reach 0.2 m slightly earlier (in 2045) and to reach 0.6 m in 2090.[7] These projections could be higher – see **Table 2.12** for the full range of scenarios.

Table 2.12: Summary of approximate year when absolute sea-level rise heights could be reached using projections for a central location in Aotearoa New Zealand (relative to the 1995–2014 baseline)

SLR (metres)	Year achieved for SSP1–2.6 (median)	Year achieved for SSP3–7.0 (median)
0.2	2050	2045
0.3	2070	2060
0.4	2090	2070
0.5	2110	2080
0.6	2130	2090
0.7	2150	2100
0.8	2180	2110
0.9	2200	2115
1.0	>2200	2125
1.2	>2200	2140
1.4	>2200	2160
1.6	>2200	2175
1.8	>2200	2200
2.0	>2200	>2200

Source: Reproduced from the Ministry for the Environment's *Coastal hazards and climate change guidance*[7]

Although these values represent absolute SLR, regions within Aotearoa New Zealand will also be affected by vertical land movement. Relative SLR, or the net rise from a combination of both the absolute SLR and local vertical land movement, represents the net rise in sea level relative to the local land surface or sea-bed elevation on which assets and people are placed. This makes it a more useful measure for understanding local and regional impacts, as each region needs to adapt to the local relative SLR. More information on relative SLR can be found in the Ministry for the Environment's 2024 *Coastal hazards and climate change guidance* and on the NZ SeaRise platform.[viii]

[viii] The NZ SeaRise project is a five-year research programme, funded by the Ministry of Business, Innovation and Employment and carried out by Te Herenga Waka–Victoria University of Wellington, GNS Science, NIWA, University of Otago and the Antarctic Science Platform. The estimates produced included the effect of local upward or downward movement of land on sea-level rise. Find it at: https://searise.nz/

Climate hazards and exposure

Introduction

Increased exposure to hazards but impacts depend on vulnerability

The climate projections discussed above increase the exposure of people, places and assets to climate hazards. However, being exposed to a hazard only gives an indication that the element in question, like a home, business or piece of infrastructure, might be at risk of being damaged. The exact impacts will depend on how exposed and vulnerable the element is to the hazard. To make an assessment of the risks from climate change, it is necessary to consider who and what might be exposed to these hazards.

A new national assessment provides baseline estimates of exposure

To support the risk assessment and to provide a baseline for future risk assessments, the Commission contracted Earth Sciences New Zealand (ESNZ) to provide an assessment of the exposure of people and infrastructure to current hazards, and how that exposure could be affected in the future by different levels of warming.

The ESNZ work pulls together, and in some cases updates, exposure estimates into a single resource using a common set of future climate scenarios based on the SSPs in the IPCC's sixth assessment report (2021–2022).[25] The ESNZ report provides an overview of the potential impacts that climate change could have on people, homes, businesses and infrastructure at a national and regional level, and the following section draws upon the report focusing on several examples. The full data set can be found on the Commission’s website.

As discussed in more detail in *Appendix 1*, the low climate impact scenario (SSP1–2.6) broadly aligns with global warming equivalent of 1.5°C in 2050 and a global warming equivalent of 2°C in 2090, while the high climate impact scenario (SSP3–7.0) broadly aligns with a global warming equivalent of 2°C by 2050 and 3.5°C by 2090 (see *Appendix 1*).

Key themes from the exposure census

Many people and places are already exposed to multiple climate hazards

In addition to flooding, it is clear that significant numbers of people and places are potentially exposed to a range of hazards, landslides, rising groundwater and erosion (**Table 2.13**). As warming increases over time, this exposure will increase.[25]

Inland flooding is the most widespread hazard, with exposure rising sharply under a higher climate impact scenario

Inland flooding is currently the most widespread hazard,[ix] with 793,000 people exposed in 2020. This escalates with climate change: an additional 22,000 people (815,300 total) are projected to be exposed by 2050 in a low climate impact scenario, and an additional 49,000 (806,100 total) by 2090. In a high climate impact scenario, an additional 109,000 people (nearly 900,000 total people) are projected to be exposed to inland flooding by 2090.

Buildings follow the same trend. Currently, 590,000 buildings are exposed, with a total value of NZ$250 billion. By 2090, in a low climate impact scenario, 600,900 buildings are exposed, with a total value of NZ$255 billion. In a high climate impact scenario, exposure reaches 680,000 buildings with a replacement value of NZ$292 billion.

Currently, 27,600 km of the road network is exposed to inland flooding. Under a low climate impact scenario, this exposure is projected to increase by 700 km by 2050 and 1,400 km by 2090. In a high climate impact scenario, total exposure is 30,800 km — an additional 3,200 km compared to present levels.

Exposure to rainfall-induced landslides increases substantially for people and infrastructure

Exposure to rainfall-induced landslides is estimated to increase this century under both low and high climate impact scenarios. Population exposure increases from 95,300 currently to 110,500 in 2050 and 104,700 in 2090 in a low climate impact scenario, and up to 127,500 in a high climate impact scenario by 2050. In a high climate impact scenario, population exposure more than doubles compared to the low impact scenario to 210,000 by 2090.

Exposure of infrastructure, like roads, also increases substantially by the end of the century. Currently, nearly 11,900 km of roads are exposed to rainfall-induced landslides. This grows by the end of the century, to 12,600 km in a low climate impact scenario and 17,800 km in a high climate impact scenario.

Exposure of electricity transmission infrastructure also increases notably. Currently, 1,710 pylons are exposed in a low climate impact scenario. By 2090, this grows to 1,914 pylons in a low climate impact scenario and to 2,947 pylons in a high climate impact scenario.

Coastal inundation exposure rises sharply, putting up to NZ$36 billion worth of assets at risk by end of century

Currently, approximately 32,100 people are exposed to coastal inundation. In a low climate impact scenario, this number rises to 47,600 by 2050 and 68,100 by 2090. Exposure to coastal inundation nearly doubles in a high climate impact scenario, reaching 94,300 people

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[ix] Flooding of land by water from an atmospheric or terrestrial source (rivers, lakes, or extreme rainfall)

in 2090. Residential building exposure shows a very similar trend, with 32,500 buildings worth NZ$17 billion in assets currently exposed to coastal inundation, rising to 86,000 buildings worth NZ$36 billion by 2090 in a high climate impact scenario.

Both potable and wastewater pipes are increasingly exposed to coastal inundation: around 751 km of the potable water network is currently exposed to coastal flooding, and 736 km of the wastewater network. This grows to 1,672 km of the potable network by 2090 in a low climate impact scenario and to 2,163 km in a high climate impact scenario. Wastewater pipes have 1,416 km of the network exposed by 2090 in a low climate impact scenario and 1,782 km in a high climate impact scenario.

More people and land will experience very hot days

Most of Aotearoa New Zealand’s population is projected to experience more very hot days above 30°C (**Table 2.14**). Under a low climate impact scenario in both 2050 and 2090, almost all people experience between 1 and 10 more very hot days. In a high climate impact scenario, by 2090, 1.4 million people are projected to experience an increase of more than 10 days above 30°C, and nearly 326,000 people experience an increase of more than 20 days.

Similar trends are evident for production land cover. Approximately 108,000 km^2 of productive land is projected to see between 1 and 10 more days above 30°C in the low climate impact scenario by 2050. In the high climate impact scenario by 2090, production land cover sees 29,000 km^2 experiencing between 11 and 20 more days above 30°C, and 4,200 km^2 experiencing up to 20 more days above 30°C.

There will be more drought conditions for production land

Projected evapotranspiration deficit for production land cover shows an increased deficit from baseline in both high and low scenarios (**Table 2.15**). In 2050, in a low climate impact scenario, 38,100 km^2 experiences an increase of more than 50 mm in evapotranspiration deficit. By 2090, this reduces to 31,200 km^2.

In a high climate impact scenario, there is a shift towards a greater evapotranspiration deficit by 2090, with nearly 95,000 km^2 experiencing an increase of more than 50 mm.

Table 2.13: Estimates of people and infrastructure exposed to climate hazards at present and under low and high climate impact scenarios

Climate hazard	Element	Unit	Current (2020)	Low climate impact (SSP1–2.6)		High climate impact (SSP3–7.0)
				2050	2090	2090
Coastal inundation	Population	people	32,100	47,600	53,700	107,000
	Buildings	NZD billion	11.4	17.6	20.1	41.5
	Buildings	number	32,600	46,100	51,400	95,600
	Airports	number	12	12	12	15
	Potable water pipes	% of total length	1.16%	1.68%	1.88%	3.66%
	Roads	km	1150	1440	1550	2670
	Wastewater pipes	% of total length	1.68%	2.25%	2.44%	4.51%
Permanent coastal flooding (at mean high-water spring)	Population	people	598	856	949	7510
	Buildings	NZD billion	1.7	1.9	2.0	5.4
	Buildings	number	1620	2110	2290	9440
	Roads	km	40	44	45	233
	Wastewater pipes	% of total length	0.16%	0.18%	0.18%	0.43%
Shallow groundwater (coastal)	Population	people	302,000	323,000	331,000	385,000
	Buildings	NZD billion	98.7	105.0	107.0	124.0
	Buildings	number	204,000	218,000	223,000	260,000
	Stormwater pipes	% of total length	6.81%	7.23%	7.37%	8.51%
	Wastewater pipes	% of total length	7.83%	8.32%	8.50%	9.85%
Inland flooding	Population	people	793,000	815,000	842,000	902,000
	Buildings	NZD billion	250.0	258.0	269.0	292.0
	Buildings	number	590,000	606,000	631,000	680,000
	Electricity transmission sites	number	51	54	56	62

	Railways	km	696	721	744	816
	Roads	km	27,600	28,300	29,000	30,800
Rainfall-induced landslides	Population	people	95,300	111,000	131,000	224,000
	Buildings	NZD billion	39.2	44.7	51.7	83.4
	Buildings	number	106,000	121,000	139,000	206,000
	Electricity transmission structures	number	1710	1960	2270	2960
	Roads	km	11,900	12,800	14,500	17,900

Source: Earth Sciences New Zealand

Note: Current 2020 exposure is exposure in SSP1–2.6; there is a small amount of variation in 2020 exposure between scenarios.

Table 2.14: Estimates of population and land cover that experience a change in very hot days, under low and high climate impact scenarios

Element	Increase in very hot days (>30°C)	Low climate impact (SSP1–2.6)		High climate impact (SSP3–7.0)
		2050	**2090**	**2090**
Population (people)	Zero	18,000	5,900	0
	1 to 10 days	4,970,000	4,990,000	3,220,000
	11 to 20 days	0	0	1,450,00
	21 to 30 days	0	0	326,000
Production land cover (km²)	Zero	402	558	21
	1 to 10 days	109,000	109,000	75,700
	11 to 20 days	0	0	29,034
	21 to 30 days	0	0	4,222

Source: Earth Sciences New Zealand

Note: Values represent a change from a baseline of 2005.

Table 2.15: Estimates of production land cover that experience a change in potential evapotranspiration deficit, under low and high climate impact scenarios

Element		Change in PED	Low climate impact (SSP1–2.6)	High climate impact (SSP3–7.0)
		2050	**2090**	**2090**
Production land cover (km²)	0 to 25 mm wetter	909	601	347
	0 to 25 mm drier	30,000	31,300	4,050
	25 to 50 mm drier	39,900	45,800	9,800
	50 to 75 mm drier	30,800	29,200	22,300
	75 to 100 mm drier	7,160	2,030	30,400
	More than 100 mm drier	168	16	42,100

Source: Earth Sciences New Zealand

Note: Values represent a change from a baseline of 1995.

PART B

Chapter 3: Findings

Introduction

This chapter presents risks by domain, beginning with an overview of each domain, followed by analysis of the individual risks it contains.

This is a national risk assessment, so it takes a nationwide view of risks. There is regional variance in many domains: how severe the risk is, how exposed people are, and how ready communities are to address it differs across regions and communities. Some variances and localised situations have been used as examples of how risks are being experienced and actions already underway to address them, but those examples are not intended to be comprehensive.

Domain introductions

Each domain introduction provides a description of the domain, highlighting the characteristics that shape its unique risk profile and its interactions with other domains. These introductions also incorporate impacts on iwi/Māori and identify relevant systemic policy issues.

For each domain, the risks are presented in tables, ordered by their severity scores, their policy readiness score and their potential to influence or address other risks.

Risk analysis

Within each domain, this assessment presents analysis of each individual risk. See the section *How the risks have been assessed* earlier in this report and the Summary of method report for further information on how this analysis was carried out.

Each risk assessment outlines:

- The core components of the risk, the hazards currently affecting it or expected to do so in the future, and an overview of its overall risk profile.

  In this assessment we have considered the severity of each risk for the present day, for the middle of the century (around 2050) and for the end of the century (around 2090). While we assessed risks using two climate impact scenarios (based on different levels of global warming), risks were scored only once for 2050. This was because the difference in projected impacts between a low and high climate impact scenario by then is unlikely to be large enough to produce different scores. Our scores for 2050 assume global warming of between 1.5-2.0°C by the middle of the century – consistent with the 1.4°C of warming the world has already experienced from pre-industrial levels.[2] When scoring the severity of risks in 2090, we considered two

scenarios for different levels of global warming (as compared to pre-industrial levels) based on the latest international climate science:
  - low climate impact scenario based on global warming of 2.0°C by 2090
  - high climate impact scenario based on global warming of 3.0–3.5°C by 2090.
- Compounding and cascading factors: compounding risks involve multiple hazards occurring simultaneously or in close succession, leading to intensified impacts. Cascading risks run in chains of cause and effect and may affect multiple systems, triggered by the same hazard or hazards.
- Interactions between the risk and actions to reduce greenhouse gas emissions.
- Policy readiness, including an analysis of existing policy settings (as at 31 October 2025), their feasibility and any gaps that may limit effective risk management.

Scores for individual risks can be found at the end of the risk analysis.

Most significant risks

This report presents all risks analysed in the risk assessment and highlights whether a risk has been assessed as significant. For further detail on the most significant risks, refer to the Priorities for action report.

Box 3.1: Use of the term ‘whenua Māori’ in this report

In te reo Māori the term ‘whenua’ refers to both land and to placenta. The dual use of the term provides an insight into the interconnectedness of all things in te ao Māori (the Māori world) and the deep relationship between people and place.

The term whenua Māori is sometimes used to describe any or all land owned by iwi/Māori. However, in this report the term is used specifically to refer to land that is subject to Te Ture Whenua Māori Act 1993. This can include Māori customary land (land that is governed by Māori in accordance with tikanga Māori) and Māori freehold land.

The purpose of Te Ture Whenua Māori Act 1993 was to promote the retention, use, development, and control of Māori land as taonga tuku iho by Māori owners, their whānau, their hapū, and their descendants. The Act places significant restrictions on the alienation of land that has always been in iwi/Māori ownership, and places additional requirements and constraints on whenua Māori landowners. As a result, it can be difficult to sell whenua Māori and to borrow against it from banks and other financial institutions. This can mean that whenua Māori landowners have fewer options for adaptation in response to climate change than owners of other land types.

Whenua Māori is typically held in collective ownership. Coordination and decision-making can be challenging and time-consuming when there are large numbers of owners, making it challenging to form consensus on how land should be put to use or when to make improvements. Whenua Māori is also more likely to have poor access or be landlocked and is often marginal.

General title land owned by iwi/Māori can also require special consideration. This can include land returned as commercial redress under Te Tiriti o Waitangi/The Treaty of Waitangi settlements. Like whenua Māori, this type of land is often collectively owned, or owned by a Post Settlement Governance Entity on behalf of settlement beneficiaries, and is likely to be marginal and more vulnerable to the effects of climate change. Some whenua Māori became general land (without notice being provided to landowners) under the Māori Affairs Amendment Act 1967. The expert working group on managed retreat suggested that this land be provided the same protection as whenua Māori.

DOMAIN: Natural environment

This domain covers risks to the country's ecosystems, which provide the foundation for all other domains.

The assessment examines the risks to terrestrial, freshwater, coastal and marine ecosystems, including the species that inhabit them. It also includes a more specific risk to indigenous biodiversity from the enhanced spread of invasive pests, weeds and pathogens. Agricultural ecosystems (agroecosystems) are considered in the Sectors relying on the natural environment domain.

The risks in this domain are identified as one of the most significant in the assessment. Together, they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once.

The natural environment is the foundation upon which everything else depends. Economic activity and human behaviours have introduced pressures that largely determine the condition of the natural environment. Climate change exacerbates these effects and is already affecting the country's ecosystems through gradual changes and extreme events.

What makes this domain unique?

Natural systems face existing pressures from human activity, which are exacerbated by climate change

Climate change impacts exacerbate existing pressures on Aotearoa New Zealand's ecosystems and biodiversity, including land-use change, habitat fragmentation and pollution. Ecosystems are exposed to all climate change hazards. Major threats to biodiversity are rising temperatures, changing precipitation and storm patterns. Notable hazards include landslides, wildfire, sea-level rise and heatwaves on land and in the ocean.

There can be particular risks for some species and ecosystems, such as those that are rare or only found in limited or isolated locations that may be exposed to an extreme event (such as wildfire or storm). There is then the potential for high consequence (including reaching a tipping point or threshold), even if the event is an isolated incident. Some regions are already experiencing significant climate impacts, whereas others experience slower onset but are highly sensitive to change.

Interaction with emissions reduction

There are key links between risks to the natural environment and efforts to reduce climate change. The risk to carbon stores in Aotearoa New Zealand's forests and other ecosystems is of particular importance, due to the important role of carbon sequestration in the carbon cycle and, thus, in climate change mitigation policy and action. In some cases, efforts to improve environmental management, which is the foundation of adaptation action and improving resilience, also reduce greenhouse gas emissions, such as efforts to improve water quality. On the other hand, other actions that can have a positive effect on reducing climate change can impose pressure on ecosystems, such as hydropower infrastructure.

There are data gaps across this domain, including information about the functioning of species and ecosystems and monitoring their sensitivity and adaptive capacity.

How does this domain interact with other domains?

The natural environment provides both direct and indirect benefits to people. In addition to its intrinsic value, the natural environment underpins all life and activity in Aotearoa New Zealand through ecosystem services. Ecosystems themselves provide the *regulating services* that determine how the environment operates, such as filtering pollutants from air and water, and protecting coastlines from storm surges, providing both direct and indirect benefit to people. Also of direct benefit are the *provisioning services* that supply goods, such as food and fibre. *Cultural services* provide important non-material benefits such as connection to place and spiritual values. Underpinning everything are the *supporting services* essential to ecosystem function, such as soil formation and processes for plant growth. Thus, risks to the natural environment are, by definition, systemic risks.

There is renewed attention to the conceptualisation of ecosystems as ‘green’ or ‘natural’ infrastructure. This can help explain the connection of adaptation concerns between the natural environment and other domains. For example, wetlands and intact forests can reduce the volume of stormwater reaching adjacent areas. Any impacts on Aotearoa New Zealand’s ecosystems create cascading effects throughout the wider system and vice versa. For example, freshwater systems are exposed to intersecting risks from human water demands and industrial use, which can be affected by climate change impacts.

Impacts on iwi/Māori

For iwi/Māori, the fundamental relationship between people and environment is affected by climate change

Given the Māori worldview that people and the environment are inextricably linked, iwi/Māori consider that risks to ecosystems caused by climate change have significant impacts. They include access to natural resources, cultural identity, customary practices and knowledge systems. For example, forests both provide important resources and are a foundation of cultural identity and knowledge.

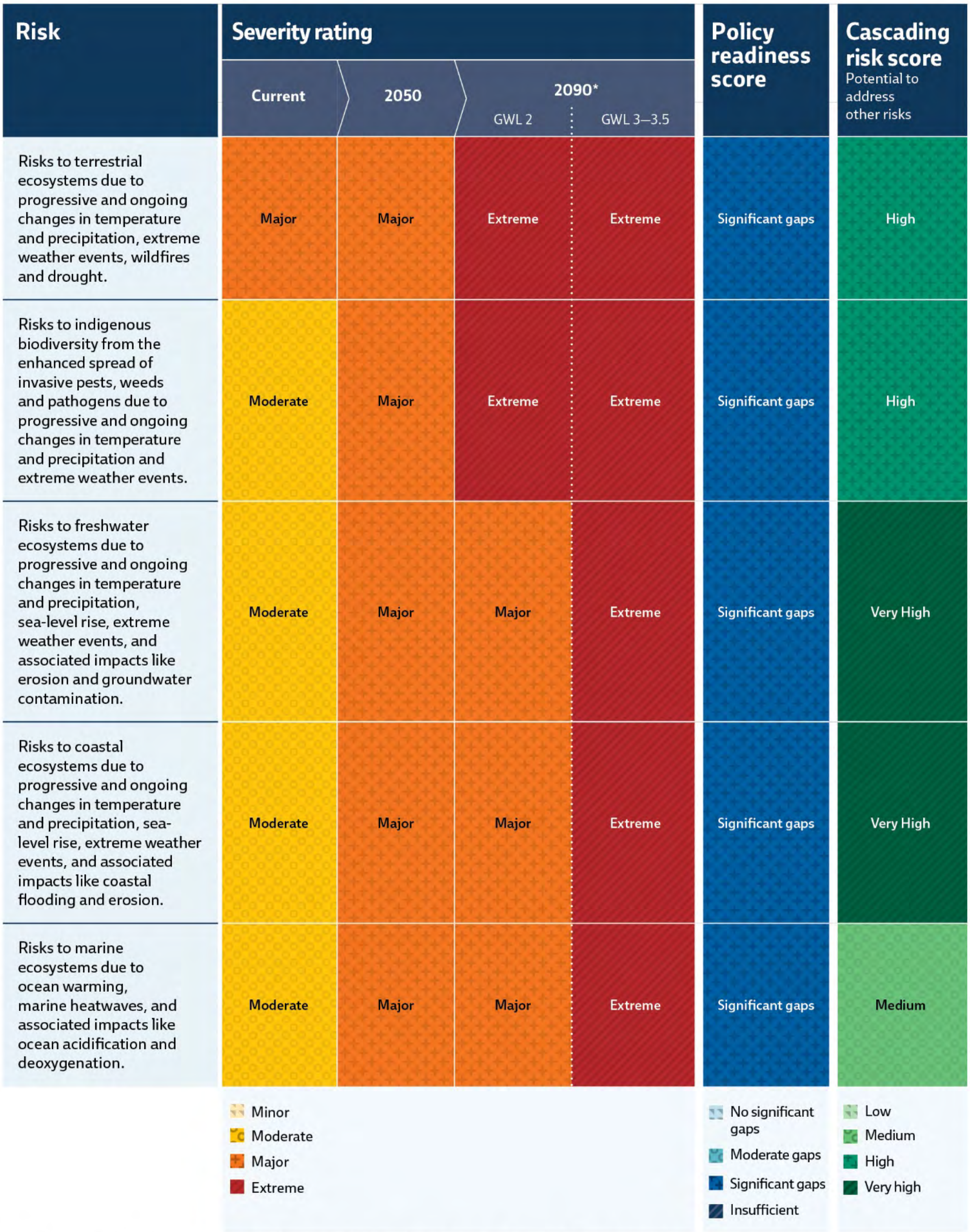
The two risks related to Māori identified in the first national climate change risk assessment in 2020 touched on connection to land and relationship with terrestrial ecosystems. The risk assessment noted that: (i) risks to Māori in part are from loss and degradation of land (due to ongoing sea-level rise (SLR) and changes in rainfall and drought); and (ii) risks to Māori social, cultural, spiritual and economic wellbeing from loss of species and biodiversity are due to greater climate variability and ongoing SLR. The effects extend to all ecosystems and, as noted in *Ngā mea hirahira o te ao Māori*, the loss of taonga (treasured, cultural keystone) species and reduced access to mahinga kai (traditional food gathering practices and places) will disrupt tikanga (custom, lore) and weaken iwi/Māori cultural identity.

Systemic policy issues

Currently, there are few policies and actions to directly support adaptation in the natural environment. While a range of environmental and natural resource management policy and legislative instruments are in place, they do not address adaptation needs comprehensively and remain fragmented and under-resourced. Where current emphasis in resource management reform and land-use planning changes have addressed climate change, these have focused on the built environment, rather than the natural environment, and therefore miss opportunities to systematically address exposure, vulnerability or resilience to climate change. Effectiveness of the limited policies, plans and actions that are in place to address climate-related risks in the natural environment is constrained by the lack of system-wide and long-term outlooks. Sound environmental management with a comprehensive focus on ecological functioning that incorporates a changing climate in a long-term outlook will support adaptation and decrease risk to the country’s natural ecosystems.

Recurrent barriers to adaptation action include lack of funding, investment uncertainty, lack of data, inadequate research support and slow implementation. The inadequacy of current environmental monitoring is well recognised but remains unaddressed. Robust monitoring programmes and further research into how ecosystems may change and function under different climate change scenarios are required to understand thresholds, tipping points and other non-linear changes to ecosystem function. Adaptation programmes and interventions are rarely comprehensively evaluated, but this is essential for understanding the effectiveness of current efforts and to inform future adaptation planning.

Table 3.1: Risk ratings for Natural environment



Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090* GWL 2	2090* GWL 3–3.5		
Risks to terrestrial ecosystems due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and drought.	Major	Major	Extreme	Extreme	Significant gaps	High
Risks to indigenous biodiversity from the enhanced spread of invasive pests, weeds and pathogens due to progressive and ongoing changes in temperature and precipitation and extreme weather events.	Moderate	Major	Extreme	Extreme	Significant gaps	High
Risks to freshwater ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like erosion and groundwater contamination.	Moderate	Major	Major	Extreme	Significant gaps	Very High
Risks to coastal ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like coastal flooding and erosion.	Moderate	Major	Major	Extreme	Significant gaps	Very High
Risks to marine ecosystems due to ocean warming, marine heatwaves, and associated impacts like ocean acidification and deoxygenation.	Moderate	Major	Major	Extreme	Significant gaps	Medium

Minor
Moderate
Major
Extreme

No significant gaps
Moderate gaps
Significant gaps
Insufficient

Low
Medium
High
Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0-3.5°C by 2090 (GWL 3-3.5).

RISK: Terrestrial ecosystems

Risks to terrestrial ecosystems due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and drought.

Terrestrial ecosystems comprise all the species and populations of animals and plants that primarily live or depend on land. This risk considers the full range of terrestrial ecosystems, with the exception of agriculture, horticulture and production forestry systems, which are covered in the *Sectors relying on the natural environment* section of this report. Climate change poses risks to terrestrial ecosystems through changes to environmental conditions, such as increased temperatures, seasonality shifts, changed precipitation regimes and discrete events, such as heatwaves, storms, wildfire and drought.

The first risk assessment (2020) highlighted the risks to terrestrial ecosystems due to increased extreme weather events, drought and fire weather.[26] Other risks highlighted were long-term composition and stability of indigenous forest ecosystems due to changes in temperature, rainfall, wind and drought as well as risks to sub-alpine ecosystems due to changes in temperature and a reduction in snow cover.[26]

Climate change is considered a key pressure for terrestrial ecosystems, along with changes in land use, adverse effects from pollution and invasive species.[27] Direct, measured impacts of climate change on terrestrial ecosystems are not well documented; most measured impacts are due to indirect impacts, such as the exacerbation of effects from invasive species.[28,29] Even so, the effects of climate change are already evident.[4]

This is one of the most significant risks as part of the combined ecosystems and biodiversity risk

The coastal, freshwater and terrestrial ecosystems risks and the indigenous biodiversity risk are all rated at major severity by 2050 and have cascading risk scores that indicate actions to address them have high or very high potential to address other risks. We combined these risks, along with the marine ecosystems risk, as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to ecosystems together satisfied the third principle of our review for significance: they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. All significant risks are highlighted in the Priorities for action report.

Risk overview

Terrestrial ecosystems are exposed, overall, to every type of climate hazard. They are affected by both changing environmental conditions and extreme events.[9] This is true across the country on all types of land under different tenure and ownership, including (but not limited to) public conservation lands. Climate change also exacerbates other pressures on terrestrial ecosystems, such as land-use change, habitat fragmentation, invasives species and pathogens.[29]

Specific ecosystems and species are variably exposed to hazards caused by climate change, depending on their geographic distribution. A global study assessing 'phytoclimates'[x] named northern Aotearoa New Zealand as one of 12 world regions that would have the most pronounced phytoclimatic changes by late century (2070).[30]

The risk to native and endemic[xi] species will continue to increase from the effects of climate change.[9] The Department of Conservation (DOC) used scenarios to assess the vulnerability of 1,145 select indigenous plants and animals, including amphibians and reptiles, bats, birds, invertebrates and plants. DOC's assessment found that by mid-century 13% of assessed plants and animals will be highly vulnerable and by the end of the century 19% will be highly vulnerable under the RCP 4.5 scenario. DOC also considered impacts under a higher RCP 8.5 scenario, which showed how greater levels of climate change are likely to put more flora and fauna at risk: 31% would be highly vulnerable by mid-century and 65% by end of century. Some animals and plants are not yet exposed to climate change but are likely to be sensitive and have lower adaptive capacity, highlighting the need for ongoing monitoring.[31]

Importantly, some of Aotearoa New Zealand's iconic approaches to environmental management and successful restoration and conservation efforts are especially vulnerable to climate change. For example, the sanctuary system, protecting threatened and rare species, comprises small, isolated populations with some species over-represented in them. These sanctuaries are at risk of loss if exposed to direct and indirect hazards caused by climate change.

Impacts for iwi/Māori include loss and degradation of land and loss of taonga species

Risks to terrestrial ecosystems caused by climate change have significant impacts for iwi/Māori. They include disrupting the physical landscape and access to taonga species, undermining whakapapa (the layering of relationships that connect people, places, and knowledge systems), tikanga and mātauranga Māori (historic and contemporary Māori knowledge). For example, ngahere (forests) are sites to harvest kai (food) and rongoā (medicinal plants) as well as for wānanga (tribal knowledge, discussion, learning) and the enactment of tikanga, kaitiakitanga (guardianship, environmental stewardship) and mātauranga Māori.[9]

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[x] Phytoclimates are localised climate conditions supporting plants within a specific area. They are important in determining the types of plants that can thrive in a particular area.

[xi] Endemism is the state of a species being found exclusively in a single geographic location, such as a specific island, region, or country.

Risks to terrestrial ecosystems due to changing temperature and precipitation

The gradual changes to temperature and precipitation patterns caused by climate change alter environmental conditions for flora, fauna and landscapes, with differing sensitivities and adaptive capacity. Shifts in the distribution and composition of indigenous forests are expected under projected climate change.[9] Some indigenous tree species, such as tōtara and rimu, have a degree of tolerance to warmer temperatures and different habitats, suggesting a degree of resilience in the short to medium term.[32] Warmer soil can have negative impacts on some species, including tuatara, affecting population sex ratios and reproductivity.[9]

Thermal squeeze is a risk for species with limited ability to move into new areas with suitable temperature ranges, including kiwi, whio (blue duck) and North Island kōkako.[9] Alpine ecosystems and high-elevation species will decline due to decreasing snow days, rising snowlines and increasing temperatures.[28,31] A mean annual temperature increase of 3°C could result in the loss of 80% of discrete alpine areas in Aotearoa New Zealand and extinction of up to half of alpine indigenous vascular plants.[9] Similarly, naturally rare ecosystems and small, isolated populations exposed to climate change and other stressors are particularly vulnerable.[28]

Risks to terrestrial ecosystems are also due to increased frequency and intensity of storms and drought

There are many examples of localised population losses of endangered fauna (lizards, birds) from extreme events. Recovery from the direct effects of events such as flooding can be slow, exacerbated by the loss of breeding habitats and nesting sites and disruption of breeding seasons.[9] Increased probability of landslides and rockslides is attributable in part to increased extreme rainfall. This has consequences for loss of soil and decreased ecosystem productivity, and sediment yield may more than double by the end of the century in some soft-rock hill country catchments, primarily from the impact of storms.[9,33]

Aotearoa New Zealand is experiencing more frequent medium-term droughts in many places.[9] Plants will become more vulnerable with increasing drought occurrence, projected for northern and eastern parts of the country. Changes in drought frequency and severity affect forest tree recruitment, disease susceptibility and mortality,[29] favouring drought-tolerant species. Restoration planting may also be at risk, as many species used are drought intolerant.[28]

Wildfire incidence and lengthening fire season pose risks to native species

In Aotearoa New Zealand, the number of wildfires is increasing, and the area burnt has been historically large in recent years.[34,35] Most Aotearoa New Zealand species and terrestrial ecosystems are not adapted to fire.[32] Those species adapted to fire, both indigenous and exotic, will be favoured as this indirect effect of climate change increases, and this may preference invasive characteristics after fire disturbances.[28,29,32,36] Recent years indicate an emerging trend of increasing wildfire incidence (number and area) and lengthening fire season at some sites.[xii,9] Wildfire risk, including that in indigenous forests, remains underappreciated across government, land managers and the general public.

Compounding and cascading factors

While climate change poses direct risks to terrestrial ecosystems, much of the risk is through the exacerbation of existing pressures. Climate change is a risk multiplier – it compounds other pressures on land environments, such as land use, habitat loss and fragmentation, ecosystem degradation, introduced species and pollution.[9,27] Plant disease occurrence in native species may increase with drought, similar to expected increased disease in some of the country's agricultural species.[28] In general, the degradation of ecosystems creates the conditions for thresholds and tipping points to be reached.[9] Drought also contributes to cascading risks, such as the build-up of dry litter that may increase the risk of fires.[37,38] Wildfire frequency and intensity may increase with more woody vegetation present on a wider variety of land-use and tenure types. Fire-tolerant weeds will have an advantage, favouring non-native species and disrupting natural succession. The Intergovernmental Panel on Climate Change (IPCC) has noted that wildfires act as a tipping point for ecosystem survival.[39]

Another threshold of concern is species extinction resulting from the accumulation of many background changes, culminating in an extinction event or reaching vulnerability thresholds. DOC notes that most of the adaptation work needed for biodiversity comprises reducing other pressures on ecosystems to increase climate change resilience.

Interaction with emissions reduction

The risks to terrestrial ecosystems from the impacts of climate change also have consequences for the carbon stored in terrestrial ecosystems, one important way that climate change mitigation and adaptation are interconnected. The carbon removal capacity of forests may decrease, and they may not remain a net sink due to the aggregate effects of altered growing conditions and extreme events. Changes to the climate could alter tree growth rates and survival, positively or negatively. Similarly, wetlands are carbon sinks, storing large amounts of carbon, but they can also become carbon sources, releasing large amounts of carbon when temperature and water availability change. The continued loss of biodiversity makes ecosystems less resilient to climate change extremes, which may further jeopardise the potential of land systems to contribute to storing carbon.

At present, field measurements indicate Aotearoa New Zealand's natural (non-planted) forests are in carbon balance.[40] Specifically, tall forests have shown both increases and decreases between measurement cycles, which began in 2002, while regenerating forests

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[xii] "Very high and extreme fire danger days likely or very likely increased at 12 and decreased at 8 of 28 sites across New Zealand" between 1997 and 2019 (as reported in 2020 and updated October 2023, per Stats NZ).

have been a small carbon sink.[40] In contrast to these bottom-up field studies, top-down inverse modelling has indicated the forest sink may be larger, especially in the indigenous forests of the southwestern South Island, but this has yet to be resolved definitively.[41,42] Understanding the trend in the vast carbon stores of the country's natural forests will require continued monitoring and thorough re-measurement of the country's forest plot network at regular intervals.

Policy readiness assessment

Currently, there are few policies and actions to support adaptation in terrestrial ecosystems directly, and the focus of resource management and land-use planning does not prioritise the exposure, vulnerability or resilience of terrestrial ecosystems to climate change.[43]

DOC's third adaptation plan prioritises eight actions across five stages with a framework that guides the level of intervention necessary.[44] The plan aims to progress adaptation and create resilience within the department's resource constraints, which, along with competing organisational and government priorities, can be a barrier.

The Government has proposed to reform the Resource Management Act 1991 with two acts: one focused on land-use planning, and the other focused on the use, protection and enhancement of the natural environment. The second, the Natural Environment Bill, establishes a framework for the use, protection and enhancement of the natural environment based on setting binding limits for air, freshwater, coastal water, land and soils, and indigenous biodiversity. Limits for human health will be set nationally, while those for ecosystem health will be set by councils "using national standards and good data".[45] It is unclear the extent to which a changing climate and adaptation can and will be addressed in a devolved system with recognised data deficiencies. More fundamentally, there is a lack of clarity about how the limits will take account of climate change risk, including exposure and vulnerability, and address systemic adaptation issues that arise in the natural environment.

Poor or contradictory land-use planning and resource management, especially without giving consideration to environmental effects and adaptation, pose major barriers to adaptation.[46] Lack of consideration for adaptation in large-scale, long-term land-use decisions is notable in multiple policies. The recently released National Adaptation Framework has little regard to adaptation needs for terrestrial (or other) ecosystems. The Fast-track Approvals Act 2024 does not require consideration be given to climate and environmental outcomes. The Afforestation on Crown-owned land proposal indicates prioritisation of exotic production forestry rather than indigenous afforestation.[47] These could lead to maladaptation[4,48] and represent a lost opportunity for an ecological restoration approach.

Current and proposed policies pose the risk of lock in, lost opportunities and potential maladaptation.

To foster resilience and avoid maladaptation, policy action would incorporate climate change considerations and adaptation needs into all land-use, land management, environmental management and conservation policies. This may include considering the effect of habitat fragmentation and development on terrestrial ecosystems and biodiversity, both directly and in the context of climate change. This would also mean considering the impacts of a dynamic future climate, and of extreme events, on ecological and environmental management.

Gaps for risk severity and policy

While risks to terrestrial ecosystems from climate change are outlined as above, there is still much to research and evaluate.[26,28,49] Monitoring data to understand the pressure, state and impacts on terrestrial ecosystems are lacking.[50,51] Both a lack of scientific information about how climate change will affect ecosystems and biodiversity and a lack of monitoring data are considered main gaps to better understanding climate change risks to the terrestrial ecosystems.

One particular area of concern is to quantify vulnerability of rare ecosystems.[28] Other areas for the next six years include more research and action on indigenous forests and biosecurity,[52] and integrated land use. Funding for researching indigenous forests has lagged that provided for exotic forestry. Investment in indigenous forests and all terrestrial ecosystem types,[44] through monitoring their status, as well as foundational studies into ecological process, sensitivity and adaptive capacity, will inform not only climate change mitigation but also adaptation.

Much of the research on climate change effects on terrestrial ecosystems relies on modelling, and some experimentation, rather than measurement. Most measurements have been conducted on the exacerbation of indirect effects (such as invasive species), and fewer have been conducted in the land environment than marine.[28,29] Long-term monitoring data are lacking for most species and ecosystems, including species distribution maps and understanding sensitivity and adaptive capacity to changing environmental conditions.[28] Research to understand climate change impacts and adaptation is one of DOC's 10 research themes to address threatened species management, all of which are also interrelated.[49]

More information on ecosystem processes under changing environmental conditions is needed. For example, the impacts of climate on ecosystem processes such as carbon uptake and storage remain unknown in Aotearoa New Zealand. Other key unknowns are invertebrate vulnerability, sensitivity of rare plants, water and nutrient cycle modulation, and pollination services along with impacts on mahinga kai (food gathering practices and places) and culturally significant resources.[28]

Monitoring and evaluation after events occur and interventions undertaken are also lacking, obscuring further understanding of response and adaptive capacity. The effectiveness and success of adaptation efforts need to include tracking ecological and social outcomes.

Summary

Climate change impacts exacerbate existing pressures on Aotearoa New Zealand’s terrestrial ecosystems and biodiversity, including land-use change, habitat fragmentation and pollution. Terrestrial ecosystems are exposed to all types of hazards. Major threats to biodiversity are rising temperatures, more heatwaves, changing precipitation (less in the north and east, more in the west and south) and extreme rainfall events. Other notable hazards are landslides and wildfire. There can be particular risks for some species and ecosystems, such as those with rare occurrence or limited or isolated distributions that may be exposed to an extreme event (such as wildfire or storm). There is then the potential for high consequence (including reaching a tipping point or threshold), even if the event is an isolated incident. The risk to carbon stores in Aotearoa New Zealand’s forests and other ecosystems is of particular importance for its connection to climate change mitigation. Data gaps include information about the functioning of species and ecosystems and monitoring their sensitivity and adaptive capacity.

Growing interest and activity in community restoration and conservation efforts of terrestrial ecosystems are not matched by comprehensive or coordinated adaptation efforts at the national level. The need for coordinated land-use planning and collaboration between local and central government has been identified. However, across many key policy frameworks, little regard is paid to adaptation needs of terrestrial ecosystems in a changing climate. When it is considered, it is usually within the context of response and recovery to extreme events (where people live and work), rather than changing environmental conditions.

Risk scorecard: Terrestrial ecosystems

Risks to terrestrial ecosystems due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and drought.

Identified as one of the most significant risks as part of the combined ecosystems and biodiversity risk.

	Score	Rationale
Risk severity		
Now	Major	Terrestrial ecosystems and biodiversity are already under considerable pressure from pests and habitat loss, which is exacerbated by exposure to climate change hazards. Individual and ecosystem vulnerability to changes in environmental conditions.
2050	Major	Environmental conditions expected to change substantially, especially in northern parts of the country, affecting which plants can thrive and survive. Impact of extreme events alongside changes to environmental conditions. Significant vulnerability among indigenous species.
2090*	Extreme GWL 2	High vulnerability among indigenous species to changes in environmental conditions, as well as exposure to extreme events.
	Extreme GWL 3–3.5	High vulnerability among indigenous species to changes in environmental conditions as well as exposure to extreme events. Potential loss of majority of alpine and rare ecosystems and loss of taonga. Cascading effects of potential loss of indigenous forests.
Policy readiness		
Overall assessment	Significant gaps	A lack of systemic, long-term approaches to land use, management and adaptation threatens locking in maladaptive outcomes, underscoring the need to act now for future resilience.
Cascading risk		
Overall assessment	High	Addressing this risk has high overall potential to address others in the assessment, including the risks to freshwater ecosystems, indigenous biodiversity, forestry, horticulture, pastoral agriculture, tourism, buildings and water infrastructure.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Indigenous biodiversity (from invasive species and pathogens)

Risks to indigenous biodiversity from the enhanced spread of invasive pests, weeds and pathogens due to progressive and ongoing changes in temperature and precipitation and extreme weather events.

This risk addresses the impacts of climate change on Aotearoa New Zealand's indigenous biodiversity from the enhanced spread of invasive pests, weeds and pathogens. It focuses on climate-driven threats across terrestrial, freshwater and marine ecosystems, excluding direct impacts on native species or invasions caused solely by non-climate factors.

Aotearoa New Zealand's biodiversity is globally unique, with high levels of endemism and ecological significance. These ecosystems support essential services, such as water purification, carbon storage and cultural identity, particularly for iwi/Māori communities. Climate change intensifies existing pressures, such as habitat loss, fragmentation and predation, by enabling invasive species to expand their range and impact. This updated assessment builds on the first national climate change risk assessment (2020), which identified invasive species as one of the two most significant risks in the Natural environment domain.

This is one of the most significant risks as part of the combined ecosystems and biodiversity risk

The coastal, freshwater and terrestrial ecosystems risks and the indigenous biodiversity risk are all rated at major severity by 2050 and have cascading risk scores that indicate actions to address them have high or very high potential to address other risks. We combined these risks, along with the marine ecosystems risk, as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to ecosystems together satisfied the third principle of our review for significance: they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. All significant risks are highlighted in the Priorities for action report.

Risk overview

Risks from invasive species threaten indigenous ecosystems

Climate change is intensifying the spread and impact of invasive weeds, pests and pathogens across Aotearoa New Zealand's indigenous ecosystems. These threats affect terrestrial, freshwater and marine environments, disrupting ecological balance and endangering native species, ecosystem services and cultural values, particularly for iwi/Māori communities.

In the near term (to 2035, Shared Socioeconomic Pathway (SSP) 2–4.5), expansion of invasive insects and pathogens in warmer regions like Te Taitokerau/Northland and Bay of Plenty is projected. Increased extreme rainfall events and resulting flooding may further accelerate the dispersal of aquatic weeds in lowland freshwater systems, increasing pressures on native biodiversity.[53]

By mid-century (2035–2060), milder winters and longer warm seasons may allow invasive mammals and insects to extend breeding seasons and shift their ranges, potentially colonising new areas (under a SSP2–4.5 scenario). Similar climatic changes may also influence some terrestrial pathogens by improving environmental suitability and transmission conditions; however, these responses are highly pathogen-specific, and projections remain more uncertain than for invasive mammals and insects. Climate change may also increase the establishment risk of marine invasive species and pathogens in northern coastal waters. However, quantitative, location-specific projections for most marine invasive species and pathogens in Aotearoa New Zealand are currently limited or lacking, reflecting gaps in species-specific modelling, baseline distribution data and understanding of ecological responses to climate change.[53]

By late century (beyond 2060), the cumulative pressures from invasive species, habitat degradation and climate change could drive ecosystems beyond critical thresholds (under a SSP3–7.0 scenario). While precise projections of irreversible biodiversity loss are lacking, assessments highlight that native species may be outcompeted or habitats degraded beyond recovery if warming continues unabated.[27]

Changes in climate encourage the survival and spread of invasive species

Warmer temperatures and increased humidity are enhancing the reproduction, survival and dispersal of invasive organisms. In terrestrial ecosystems, milder winters can extend the active season or reduce mortality for invasive insects and mammals. For example, some invasive wasp populations thrive in Aotearoa New Zealand in part because of the mild climate, facilitating very high densities.[54] Studies even link warmer winter and spring temperatures to higher wasp abundances.[55] Meanwhile, the distribution of the Argentine ant (*Linepithema humile*) has long been modelled to expand under warming, with increasing temperatures and reduced rainfall projected to delay colony collapse.[56]

Pathogens bring an increased risk of infections to indigenous species

Pathogens such as myrtle rust (*Austropuccinia psidii*) and Dothistroma needle blight (*Dothistroma septosporum*) show increased risk under future climate scenarios, particularly with rising temperatures.[57] Observations in pōhutukawa (*Metrosideros excelsa*) suggest more frequent and severe infections, especially during warm, humid seasons.[58]

Freshwater ecosystems and species are under increasing pressure from invasive fish and weeds

Freshwater ecosystems are under growing pressure from invasive fish and aquatic weeds. Brown trout (*Salmo trutta*) are expanding into cooler upland streams, displacing native galaxiids (*Galaxias spp.*).[59] Koi carp (*Cyprinus carpio*) remain one of the most damaging freshwater pests, degrading water quality, uprooting vegetation and outcompeting native fish like īnanga (*Galaxias maculatus*).[60] Invasive weeds are widespread in Aotearoa New Zealand and can form dense underwater mats that shade out native species.[61]

Invasive species and pathogens are bringing risks to marine ecosystems

Marine ecosystems are increasingly affected by invasive species and pathogens. The exotic Caulerpa seaweeds (*Caulerpa brachypus* and *C. parvifolia*) now blanket more than 1,500 hectares of the upper North Island seabed, forming dense mats that smother native seagrass, seaweed, shellfish and other benthic life, disrupting essential habitats for fish and shellfish.[62] Warming seas may also elevate the risk of harmful algal organisms, such as *Gambierdiscus* spp., which produce ciguatoxins.[63] Meanwhile, the parasite *Bonamia ostreae*, which infects flat oysters (*Ostrea chilensis*), continues to be a significant biosecurity concern: legal controls are in force to limit its spread, reflecting persistent risk to wild and farmed oyster populations.[64]

Impacts on iwi/Māori communities include loss of taonga species, customary harvests and whakapapa connections

Iwi/Māori communities remain particularly vulnerable to climate-driven invasive species due to the cultural significance of native biodiversity and limited access to adaptation resources. Invasive species threaten taonga species such as mānuka and pōhutukawa, undermining mātauranga Māori (historic and contemporary Māori knowledge), customary harvests and food sovereignty. Iwi/Māori are disproportionately affected by biodiversity loss and biosecurity threats yet face barriers to participating in adaptation planning due to under-resourcing and limited organisational and community capacity.[65] Adding to these barriers is often the lack of mandate or legislative requirements for iwi/Māori participation. The degradation of native ecosystems also impacts whakapapa (the genealogical layering of relationships that connect people, places, and knowledge systems) connections and the ecological integrity of place, with iwi and hapū calling for stronger recognition of Māori-led climate strategies and governance roles in biosecurity and conservation.[32]

Tipping points may occur if invasive species dominate ecosystems

Environmental tipping points may occur when invasive species dominate ecosystems, leading to abrupt shifts in species composition and function. For example, widespread kauri dieback (caused by the soil-borne pathogen *Phytophthora agathidicida*) in drought-stressed forests could trigger forest collapse. In freshwater systems, koi carp (*Cyprinus carpio*) are known to disturb sediments and alter nutrient dynamics, but at present there is limited evidence that climate-driven increases in carp will trigger irreversible ecosystem shifts in Aotearoa New Zealand.[66] However, national risk assessments note that highly disruptive species, including those that increase sediment disturbance, remain priority climate-related biosecurity risks.[26]

Confidence in directional trends is high, but uncertainties remain about future hazards

In terrestrial ecosystems, the confidence in directional trends, such as increased pest survival, pathogen spread and invasive range expansion, is relatively high.[18] However, uncertainties remain about when and how these changes will interact, particularly when it comes to multiple hazards (such as drought, disease and invasion) that could compound each other in complex ways. National reporting acknowledges that long-term ecological monitoring, particularly for multi-hazard interactions, is still limited.[27]

Compounding and cascading factors

In terrestrial systems, invasive weeds such as gorse and old man’s beard are expected to expand under warming temperatures, altered fire regimes and ongoing habitat fragmentation,[67] increasing their ability to colonise forest margins and suppress native regeneration. Forest pathogens, including kauri dieback (*Phytophthora agathidicida*), further interact with drought and heat stress by increasing canopy loss and reducing carbon storage, which can amplify regional climate feedbacks and create conditions more favourable for additional pest and disease establishment.[68]

Freshwater ecosystems face similar compounding and cascading risks. Invasive aquatic plants such as Canadian pondweed (*Elodea canadensis*), oxygen weed (*Lagarosiphon major*) and hornwort form dense submerged beds that disrupt thermal structure, oxygen dynamics and nutrient cycling; these impacts can worsen the impacts of climate-related extreme events such as floods and droughts, contributing to eutrophication, hypoxia and loss of native invertebrate communities. These weeds already occupy extensive areas of lakes and rivers and can rapidly expand following disturbance events.[69]

Marine environments also experience interacting pressures. Invasive macroalgae and fouling organisms, most notably the Mediterranean fanworm (*Sabella spallanzanii*) and the Asian shore crab, colonise hard substrates, reduce indigenous biodiversity and impair aquaculture operations. Their spread is facilitated by warming seas, nutrient enrichment and increased maritime activity.[66] Such species can alter benthic habitat structure and create pathways for secondary marine invasions.

Across all ecosystems, biological invasions amplify the effects of climate stressors. Fire and drought increase forest vulnerability to weeds and pathogens; floods disperse aquatic weeds that then worsen water quality; and warming oceans increase the establishment likelihood of marine invaders. These interactions reinforce each other, increasing the risk of ecological degradation and reducing the resilience of native species and habitats.[26,50]

Interaction with emissions reduction

If not carefully managed, some actions that contribute to emissions reduction efforts in Aotearoa New Zealand can unintentionally increase invasive species risks. Afforestation using exotic species like *Pinus radiata* may create habitat for invasive mammals and increase exposure to pests such as Dothistroma needle blight, which infects radiata pine and is projected to remain a significant disease risk.[70] Wetland restoration, while valuable for carbon capture and native habitat recovery, could interact with freshwater biosecurity risks. Several non-native aquatic plants such as *Lagarosiphon major* and hornwort (Cord weeds) are already monitored by DOC in restored waterways.[71] Adaptation planning should take into account interactions like these with emissions-related and other environmental goals and outcomes.

Policy readiness assessment

Aotearoa New Zealand has a solid foundation of biosecurity and biodiversity policy, but adaptation efforts remain uneven, particularly in addressing climate-driven invasive species risks. The Biosecurity Act 1993 provides mechanisms such as National Pest Management Plans, yet it contains no explicit climate change provisions. Recent reviews highlight that biosecurity preparedness does not fully account for climate-driven pest expansion, particularly in marine and freshwater environments.[72]

The first national climate change risk assessment identified invasive species and pathogens as a climate change risk and the national adaptation plan outlined broad priorities, but detailed measures like climate-informed surveillance and resilience planning are still emerging.[70] Programmes such as Tiakina Kauri show promise through multi-agency collaboration and mātauranga Māori integration, yet broader pest management is limited by funding and coordination gaps.[73]

Local governments vary in capacity, with some adopting international climate standards (such as ISO 14090/14091). Community-led initiatives, such as neighbourhood groups involved in predator control, habitat restoration and native planting, play a vital role in early detection of biodiversity threats, yet they face challenges due to inconsistent long-term funding.[74] Māori-led adaptation is progressing through iwi strategies and culturally grounded practices like rāhui (temporary ritual prohibition or constraint), though many face barriers to full policy implementation.[65]

Private sector engagement is growing: hundreds of businesses have joined the Ministry for Primary Industries' (MPI's) Biosecurity Business Pledge, committing to strengthen their biosecurity practices.[75,76] However, while the network supports operational risk management, systemic integration of climate-driven biosecurity risk into corporate strategies remains less clearly formalised.

Gaps for risk severity and policy

Aotearoa New Zealand lacks fully integrated, climate-informed approaches to managing invasive species and pathogens across terrestrial, freshwater and marine ecosystems. The first national climate change risk assessment identified invasive species as a major risk and highlighted significant knowledge gaps, including limited integration of climate projections into biodiversity and biosecurity planning and insufficient understanding of multi-hazard interactions.[26]

At the regional level, some Regional Pest Management Plans (RPMPs) are undergoing updates. For example, Northland's 2017 plan is under review, indicating that elements of existing plans may not yet reflect the most recent climate-related risk priorities.[77] However, the extent to which RPMPs nationally incorporate future climate scenarios is uneven.

The Department of Conservation (DOC) also notes that climate change is exacerbating invasive species pressures. Conservation planning faces constraints due to gaps in ecological data, monitoring coverage and climate-informed forecasting tools, which limit long-term risk modelling.[78] Collectively, these findings indicate that while Aotearoa New Zealand has strong biosecurity foundations, there is no fully integrated, cross-ecosystem, climate-informed pest and pathogen framework. Current systems are not yet aligned to address emerging, climate-driven invasive species and pathogen threats.

Summary

Climate change is accelerating the spread of invasive weeds, pests and pathogens in Aotearoa New Zealand, increasing pressure on indigenous biodiversity. Rising temperatures, humidity and extreme weather events are enhancing the survival and dispersal of invasive species and pathogens across land, freshwater and marine ecosystems. These changes are disrupting native species and threatening ecosystem services such as carbon storage, water quality[18,28,79-81] and cultural practices tied to mātauranga Māori.[82-84]

Without stronger intervention and investment, invasive species and pathogen pressures will be amplified by climate change, placing native ecosystems at continued risk. Climate hazards will exacerbate biodiversity loss from these threats, and current institutional, legislative and economic frameworks are not structured to respond adequately.[81] Biosecurity experts also highlight a critical need for more integrated climate-biosecurity planning, as warming conditions shift pest distributions and increase the risk of ecosystem disruption.[53,85]

Risk scorecard: Indigenous biodiversity (from invasive species and pathogens)

Risks to indigenous biodiversity from the enhanced spread of invasive pests, weeds and pathogens due to progressive and ongoing changes in temperature and precipitation and extreme weather events.

Identified as one of the most significant risks as part of the combined ecosystems and biodiversity risk.

	Score	Rationale
Risk severity		
Now	Moderate	Impacts are already noticeable, particularly from invasive species and pathogens, with moderate present-day risk that could rise due to difficulty in eradication and potential for widespread ecological damage.
2050	Major	Climate constrained animal and plant pests and pathogens will expand in range and abundance, along with potential for new invasive pathogens that increase vulnerability of indigenous biodiversity.
2090*	Extreme GWL 2	Climate-constrained animal and plant pests and pathogens will further spread in range and abundance, causing increased loss of indigenous biodiversity and new introductions of invasive species and pathogens.
	Extreme GWL 3–3.5	Cumulative pressures from invasive species, habitat degradation and climate change could drive ecosystems toward critical thresholds. Ongoing new introductions of invasive species and pathogens. Impacts especially pronounced for Māori communities and taonga species.
Policy readiness		
Overall assessment	Significant gaps	While foundational policies are in place, the system lacks climate integration, long-term funding and cohesive planning, making it unfit for the scale and urgency of climate-driven invasive species risks.
Cascading risk		
Overall assessment	High	Addressing this risk has high overall potential to address others in the assessment, including the risks to terrestrial, freshwater, coastal and marine ecosystems, and fisheries, forestry and tourism.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Freshwater ecosystems

Risks to freshwater ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events and associated impacts like erosion and groundwater contamination.

Freshwater environments in Aotearoa New Zealand have many forms[86] and support a diverse array of species, many of which are endemic. Freshwater environments impact many things New Zealanders value, such as taonga species and areas to swim and gather food.[86] Most of the indigenous freshwater fish and freshwater bird species in Aotearoa New Zealand have been classified as either threatened with extinction or in danger of becoming threatened,[86] with climate change adding additional pressure.

The first risk assessment identified risks to riverine ecosystems and species from alterations in the volume and variability of water flow, increased water temperatures and more dynamic morphology (erosion and deposition) due to changes in rainfall and temperature (N3); risks to wetland ecosystems and species, particularly in eastern and northern parts of Aotearoa New Zealand, from reduced moisture status due to reduced rainfall (N4); risks to lake ecosystems due to changes in temperature, lake water residence time, and thermal stratification and mixing (N6); and risks to terrestrial, freshwater and marine ecosystems due to increased extreme weather events including drought and fire weather (N7).[26] For the second risk assessment, these are combined in a broader risk to freshwater ecosystems due to changes in the level and timing of precipitation, rising temperature, increased extreme weather events and sea-level rise (SLR).

This is one of the most significant risks as part of the combined ecosystems and biodiversity risk

The coastal, freshwater and terrestrial ecosystems risks and the indigenous biodiversity risk are all rated at major severity by 2050 and have cascading risk scores that indicate actions to address them have high or very high potential to address other risks. We combined these risks, along with the marine ecosystems risk, as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to ecosystems together satisfied the third principle of our review for significance: they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. All significant risks are highlighted in the Priorities for action report.

Risk overview

Impacts from climate change will alter Aotearoa New Zealand's natural water cycle and freshwater ecosystems

Climate change is expected to alter the amount and timing of rain and snow that freshwater systems receive. There will also be changes to how much water is stored in the soil, snow, glaciers and aquifers, how much water evaporates back to the atmosphere, and how much flows through streams and rivers to the coast.[87] SLR will push the zone of influence of tides further inland, affecting lowland rivers, estuaries, wetlands, coastal lakes and groundwater, increasing exposure to saltwater intrusion. Inland aquifers, rivers and lakes will be altered by changes to precipitation patterns. Greater levels of soil erosion will increase sediment entering waterways, and nutrients lost from soils may increase. The consequences of this will lead to increased bacterial and algal growth with cascading impacts to freshwater plants and animals.

There are a number of specific risks in freshwater ecosystems. River systems and species, as well as lakes and lake species, are affected by rising temperatures, changing seasonal weather patterns and extreme weather events. Risks to groundwater, lowland rivers, coastal lakes and freshwater wetlands are due to the influence of SLR (increasing zones of tidal influence and more frequent inundation from storm surges). Risks to freshwater wetlands and wetland species will arise from changing weather patterns, rising temperature and extreme weather events, including wildfire.

There is some uncertainty about how freshwater environments may change or adapt due to climate change. However, climate change is expected to alter the hydrological system, particularly under higher-emissions scenarios.[88]

Changes in air temperatures may affect freshwater habitats, even leading to species extinctions

Water in rivers, lakes and wetlands may be at risk of warming, although mechanisms for water temperature increase are complex. Rising temperature may affect the distributional range of many species, as well as nutrient cycling and primary productivity. Temperature rises can lead to low oxygen levels in water and fish kill events.[89,90] Warmer and drier summers are projected to reduce some lake levels and raise water temperatures, influencing the growth of cyanobacteria and algal blooms.[32] Rising water temperatures may also result in potential dead zones in deeper lakes. Climate change is extending periods of lake stratification and weakening upwelling, with major ecological effects, especially in sensitive lake margins, which are biological hot spots.[28,91]

Rising temperatures over this century are likely to alter freshwater habitats and could result in localised extinction events for species that are unable to adapt or move. Seasonal changes in temperature might also result in movement of some fish populations, or changes to spawning and migration timing or success. Autumn mean air temperature change may contribute to the vulnerability of some taonga species.[92] Higher altitude species may be particularly vulnerable, as they may be disproportionately affected by climate change. Many other species are more generalists in terms of habitats and food sources, which may support resilience to a changing climate, though it may still reduce overall biodiversity.[28]

Changes to snow and ice, along with glacier loss, affect freshwater environments

Changes in snow and ice cover affect the amount and seasonal timing of water in freshwater environments. The volume of ice in Aotearoa New Zealand's glaciers has shrunk by 42% between 2005 and 2023,[93] and many glaciers will not survive the 21st century due to rising temperatures.[94] As glaciers decline and these environments become more like rain-fed systems, competition from downstream species increases, and species highly adapted to glacier-fed flows are likely to decline.[50]

Some areas may become drier, while others may experience increased rainfall

In some parts of the country, river and lake water levels may reduce and become drier as rainfall decreases and evaporation increases. However, in other parts, like the West Coast of the South Island, lakes and rivers are likely to experience increased water flow as rainfall increases.[88] Projections vary greatly from region to region – see *Chapter 2: Climate change in Aotearoa New Zealand* for more information on regional variability.[95] This variability will also affect wetlands, with some projected to receive decreased rainfall and others increased. This could result in some wetlands permanently changing state (for example, becoming shallow ponds or lakes) or drying out due to evaporation.[28] Ephemeral tarns and wetlands may be particularly exposed, threatening the unique plants, animals and microorganisms in those habitats.

Effects on fish species from rainfall changes and flooding may include migration changes and loss of populations

Changes to river flows may alter fish species' migration patterns. Floods are a signal for many fish species to migrate, so the change in height and variability of floods may also affect species' migration patterns.[50] Flood events will also have an impact on ecosystems. They can wash out and destroy fish eggs that are laid in vegetation in or beside a waterway. Fish species requiring specific rainfall regimes and water-level changes will also have limited tolerance for projected changes in the frequency, intensity and predictability of rainfall.[32] The intensity and frequency of heavy rainfall events is projected to increase, so flood magnitudes are expected to increase.

Changes in erosion and sedimentation may lead to harm for plant and animal life in freshwater systems

Changes in rainfall patterns and extreme weather events will increase erosion and sedimentation of waterways. Rivers in Aotearoa New Zealand have some of the highest sediment yields per unit area in the world. Sediment loads may increase by 1% to 233% by 2090, depending on future emissions pathways.[33] In some freshwater systems, such as lakes or large rivers, high winds can increase turbidity and influence water mixing, with a negative effect on aquatic life. Projected future increases in sedimentation resulting from changes in flow rates, erosion and flood events will adversely affect aquatic ecosystems through smothering stream beds, increasing turbidity and decreasing optical clarity.[33]

Effects of SLR include moving saltwater into freshwater environments

SLR will influence inland groundwater levels and quality, with potential flow-on effects,[96] and increase exposure to storm surges, moving saltwater further into coastal freshwater environments.[50] Even small changes in salinity can affect freshwater species and habitats, such as īnanga (whitebait). Changes in salinity can also have significant negative effects on zooplankton in coastal lakes, whose resilience to temporary incursions of sea water may be insufficient if incursions increase in frequency or duration following SLR.

Effects from wildfires include increased pollutants and effects on water flow and temperature

Increasing wildfires can also degrade freshwater quality and habitats. For example, wildfire can occur in wetlands and impact freshwater species there.[97] Wildfire can mobilise pollutants during and after a fire, threatening water quality, and can result in increased water streamflow, sediment and temperature.[98,99]

Effects on animals relying on freshwater systems depend on migration patterns and weather changes

The ability to migrate or disperse between habitats will likely determine the resilience of animals relying on freshwater environments to climate change. This varies widely among systems and species.[28] Tuna (longfin and shortfin eels), piharau/kanakana (lamprey), whitebait species including īnanga, kōaro, banded kōkopu and the kāeo/kākahi (freshwater mussel) are highly vulnerable species.[92] Their vulnerability stems from interacting climate factors, including annual and seasonal precipitation levels, autumn temperature and number of very hot days annually.[92] Severe climate change impacts could drive nine native freshwater fish species to extinction and cause substantial declines in another eight.[100]

Impacts for iwi/Māori communities include effects on cultural practices and identity

The degradation of freshwater systems and biodiversity affects iwi/Māori communities, and iwi/Māori identity and cultural practices. One of the key impacts of climate change is likely to be on access to taonga species and mahinga kai (food gathering practices and places). This poses a threat to iwi/Māori food resilience, tikanga, and the transmission of intergenerational knowledge. Healthy waterways are important for whanaungatanga (kinship, relationship links), kaitiakitanga (guardianship, environmental stewardship), recreation, and access to wāhi tapu (sacred sites) and wāhi tupuna (ancestral sites) along, upon, and within the waterways. Many waterways are considered to be tupuna with ancestral connections to marae, hapū and iwi. Degraded freshwater ecosystems and the threatened loss of native species impact mauri (life principle or force) and the connection and wellbeing of many iwi/Māori.[86]

Compounding and cascading factors

Freshwater systems are exposed to intersecting risks from human water demands and industrial use

Aotearoa New Zealand’s freshwater ecosystems are already exposed to a range of pressures from human activity, amplified by climate impacts. Conservation and restoration efforts are having some success, but some rivers and lakes continue to degrade, and numerous species are highly vulnerable.[50,86]

Climate change may increase the demand for water and human impacts on freshwater ecosystems. Hydroelectricity and the primary sector are the two largest users of freshwater. Increasing water demand in the electricity or primary sectors may coincide with decreasing water availability and could be further heightened under more extreme emissions scenarios (see risks to electricity and telecommunications infrastructure and risks to electricity supply in the *Built environment* domain and risks to pastoral agriculture and horticulture in the *Sectors relying on the natural environment* domain).[101]

Interaction with emissions reduction

Within Aotearoa New Zealand, land-use changes designed to improve water quality can also reduce greenhouse gas emissions. Recent work underscored the extent of the challenge to improve water quality indicators and showed that large reductions in greenhouse gas emissions occur in tandem.[102] Whereas trees can improve freshwater quality and habitat diversity, they can also interact with the hydrological cycle to reduce flows.[103] Restoration of wetlands may sequester carbon and improve the resilience of freshwater ecosystems by providing habitat, filtering nutrients and sediment, and buffering high rainfall events.[104]

Further development of hydroelectricity infrastructure to produce low-emissions energy may affect river flows and aquatic life. Likewise, flood-protection measures, increased water storage or other water management infrastructure may also potentially affect water flows negatively, including water quality and aquatic life. This highlights the importance of aligning adaptation actions with other environmental and emissions goals, to avoid unintended consequences.

Policy readiness assessment

Current and proposed policies may be inadequate to protect freshwater environments

Freshwater policy has been in a state of flux in recent years; however, it is not clear that current or proposed settings will sufficiently address climate change challenges. The Resource Management Act 1991 (RMA) and several national policy statements set direction but are currently under reform, and the ongoing status of these instruments is unclear. The National Policy Statement on Freshwater Management 2020 (NPS-FM) currently has a key policy that freshwater is managed as part of Aotearoa New Zealand’s integrated response to climate change. Councils must consider foreseeable impacts of climate change when setting resource limits and setting environmental flows and levels. Central to the NPS-FM is Te Mana o te Wai, a hierarchy of obligations that prioritises, in order, water bodies and freshwater ecosystems; the health needs of people; and social, economic and cultural wellbeing, now and in the future. This can inform action in a changing climate. This principle is currently under review as part of freshwater and resource management reform. The hierarchy of obligations has been excluded from resource consent decision-making while the freshwater policy framework is being revised,[xiii,105] with the Government signalling an intent to elevate economic and development uses of water.

There may be effective actions to reduce vulnerability of freshwater environments

There are many actions that may be effective in reducing the vulnerability of freshwater ecosystems to climate change. Rivers are generally managed to prevent flooding, but river channels have become more restricted over time. Existing flood management systems will increasingly come under pressure as extreme rainfall intensity and frequency increases. Improved resilience of freshwater systems can be supported by adopting nature-based management approaches, including ‘space-to-move' river management practices.[106] The Resilient River Communities joint initiative has been investigating possible nature-based solutions that could be implemented across Aotearoa New Zealand.[107]

Limiting further freshwater degradation and restoring freshwater and terrestrial ecosystems can contribute to improved climate change resilience. Enhancing riverbank vegetation can slow erosion and provide shade and cool water for freshwater species. Maintaining minimal standards for river flows and water quality will support freshwater biodiversity, and better research and monitoring of water extraction and use will improve understanding of sustainable extraction levels under different water levels (in rivers and lakes). Restoring and conserving wetlands will have additional co-benefits of regulating water during storm events or SLR, filtering nutrients and absorbing carbon.[50]

Barriers to implementing freshwater adaptation include uncertainty around investment and project coverage

There are diverse views on what good outcomes for freshwater look like and how best to achieve them.[108] While there have been numerous investment programmes to improve freshwater systems and biodiversity conservation, it is not yet known how effective these investments will be, or whether funding is targeted towards areas that will support overall ecosystem resilience (as opposed to only part of a catchment area or a small number of charismatic species).[109,110]

[xiii] The Resource Management (Freshwater and Other Matters) Amendment Act 2024 excludes the hierarchy of obligations in the National Policy Statement for Freshwater Management (NPS-FM) from consideration in resource consenting as of 24 October 2024 while a review and replacement of the NPS-FM is undertaken.

Data, research and modelling are under-resourced, leaving gaps in accountability and risking maladaptive practices

Monitoring data, research and modelling tools to support freshwater and biodiversity management are fragmented and under-resourced.[111] There are gaps in Aotearoa New Zealand's monitoring systems that limit the ability to make informed decisions. There are also difficulties in collating data collected by regional councils to build a national-level picture of freshwater quality.[110]

There is no public organisation with accountability for addressing shortfalls in information about freshwater quality at the national level, to consider how it will be funded and to decide the systems and tools necessary to collect quality data.[109] Successive policy changes mean there is currently no agreed set of priorities between central and local government for freshwater ecosystem management.

If current proposed changes to resource management and freshwater management legislation do not appropriately consider climate change, there is the potential to lock in maladaptive practices, such as damaging land-use practices, ecologically insensitive flood protection infrastructure, over-extraction of freshwater sources and insufficient biodiversity conservation.

Gaps for risk severity and policy

While data exist and understanding is growing, more work is needed to better understand how complex freshwater ecosystems will respond to climate change. The Ministry for the Environment, Department of Conservation and Earth Sciences New Zealand all highlight the lack of information of how climate change effects will unfold for freshwater systems, plants and animals, including thresholds and tipping points. There are critical data gaps in the understanding of current water use from all sources, the impact of current levels of water extraction, and whether this is sustainable under different climate change scenarios. Improved knowledge is needed about human-induced pressures on freshwater systems and biodiversity, including how they interact and intensify in places and over time with a changing climate. Likewise, understanding how quickly freshwater ecosystems are changing in response to pressures and how resilient they are to the ongoing effects of human activities and a changing climate is needed to identify where interventions are most needed. Better support for mātauranga Māori (historic and contemporary Māori knowledge) is crucial, including resourcing of iwi/Māori research to develop the evidence base. Quantifying the benefits of freshwater for multiple values, including social and economic wellbeing, will better inform trade-offs.

There is regular environmental monitoring and reporting on selected freshwater and freshwater biodiversity indicators at regional and national levels; however, there remain gaps in research and data in key areas to inform policy development and assess the effectiveness of policies. There is a lack of evaluation of national policies, regional plans and local projects and actions to understand their effectiveness and impact. Also required is analysis into the uncertainty and usage of models that councils use to inform policymaking for freshwater management. Key data are held by different groups and not shared; data can also be inconsistent, making it difficult to assess the impact of adaptation action.

Summary

Climate change is already affecting Aotearoa New Zealand's freshwater ecosystems, and it is projected to worsen over the century. Increasing storm, drought and wildfire events, changing precipitation and temperature patterns, and SLR will alter the quantity and quality of freshwater from place to place in varying ways. There are multiple connections between this risk and other domains, particularly on human wellbeing and economic prosperity and on te ao Māori (the Māori world). The data gaps for this risk could make decisions on how to act challenging. Without good information about recent and projected impacts, long-term planning and proactive responses, the severity of this risk could increase and the implications for communities, economy and environment would be wide-ranging.

Past and current policy responses for the freshwater environment are unlikely to reduce the risk of climate-related impacts to the freshwater environment. Data availability, coordination and inadequate investment also inhibit the policy response to this risk. Future policy responses may prioritise hard infrastructure to protect communities from flooding, but lock in has reduced adaptive capacity of waterways and the species that rely on them. Aotearoa New Zealand could improve its policy readiness through its current and planned actions to reduce the risks of climate-related impacts to the freshwater environment. Based on the assessment of the current policy setting and actions, this risk will worsen over time under both the low- and high-emissions scenarios.

Risk scorecard: Freshwater ecosystems

Risks to freshwater ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events and associated impacts like erosion and groundwater contamination.

Identified as one of the most significant risks as part of the combined ecosystems and biodiversity risk.

	Score	Rationale
Risk severity		
Now	Moderate	Exposure and adaptive capacity vary, but many species are already stressed, amplified by changing environmental conditions and increased extreme events. Life in waterways already degraded – some species can move but others are more vulnerable.
2050	Major	Vulnerability increases; risk of irreversible changes. Sediment loading increasing due to increased frequency and severity of storms.
2090*	Major GWL 2	Threat of irreversible changes. Sediment loading increasing due to increased frequency and severity of storms. SLR will influence inland groundwater levels and quality, with potential flow-on effects, with increased salinity affecting freshwater species and habitats.
	Extreme GWL 3–3.5	Increase in both progressive changes and extreme events. Significant impacts for iwi/Māori given impacts on taonga species, traditions and customs. SLR will influence inland groundwater levels and quality, with potential flow-on effects, with increased salinity affecting freshwater species and habitats.
Policy readiness		
Overall assessment	Significant gaps	Moving and fragmented policy landscape with little accountability. Major shortfall in addressing climate-related risk that can be controlled.
Cascading risk		
Overall assessment	Very high	Addressing this risk has very high overall potential to mitigate other risks in the assessment, including the risks to coastal, marine and terrestrial ecosystems, indigenous biodiversity, fisheries, pastoral agriculture, tourism, buildings, water infrastructure and mental health.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Coastal ecosystems

Risks to coastal ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like coastal inundation and erosion.

Aotearoa New Zealand's coastal ecosystems lie at the dynamic interface where land and sea interact, encompassing marine and terrestrial components influenced by coastal processes,[xiv] including dunes, estuaries, wetlands, mangroves, saltmarshes, coastal vegetation and nearshore (tidal) habitats (such as sea grass and kelp beds). This zone hosts some of the nation's most distinctive ecosystems, with high levels of ecological productivity and biodiversity, much of it endemic. It also provides ecosystem services vital to communities, industries and cultural practices. Coastal ecosystems buffer storm surges and flooding, support taonga species and recreation, and in some habitats contribute to carbon sequestration.[50,112-114]

Climate change is amplifying stress on these systems through multiple interacting climate drivers. These include sea-level rise (SLR), increasing sea surface temperatures, marine heatwaves, ocean acidification, increased air temperatures, changing precipitation patterns, more intense and more frequent extreme weather events such as heavy rainfall, and storm surges.[50,115-117] Their combined effects are degrading already-stressed ecosystems and increasing the vulnerability of species, infrastructure and culturally significant sites. Because coastal ecosystems underpin multiple ecological and social systems, degradation of these environments can cascade across other domains, including freshwater and marine ecosystems, indigenous biodiversity, fisheries, tourism, built infrastructure and human wellbeing.

The first risk assessment identified risks to coastal ecosystems and biodiversity due to ongoing sea-level rise and extreme weather events as one of the most significant risks.[26] Evidence now shows clearer and earlier signals of biodiversity decline, ecosystem disruption and increasing exposure of communities and taonga to compounding hazards.

The coastal environment is also exposed to non-climate pressures such as land-use change, catchment sedimentation, contaminants, dredging, reclamation, invasive species and historical habitat loss. Climate change does not create these pressures but intensifies their

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[xiv] Aotearoa New Zealand's marine and terrestrial components influenced by coastal processes typically include:

- *The coastal marine area (CMA):* The seaward boundary/limit runs from Mean High Water Springs (MHWS) out to 12 nautical miles (nm), which aligns with the outer limit of New Zealand's territorial sea; that is, the foreshore, seabed, and water between the high tide line and the outer limits of the territorial sea.
- *Adjacent land areas:* dunes, estuaries, wetlands, coastal vegetation, habitats, and species near the coast that are influenced by coastal processes (such as salt spray, tides, or coastal erosion). The landward extent of the coastal environment beyond MHWS varies regionally.

consequences, pushing some ecosystems closer to thresholds beyond which recovery becomes difficult or impossible. Climate change is accelerating physical, chemical and biological changes at scales and speeds beyond historic variability, driving threats to habitats, species and ecological processes.[50]

This is one of the most significant risks as part of the combined ecosystems and biodiversity risk

The coastal, freshwater and terrestrial ecosystems risks and the indigenous biodiversity risk are all rated at major severity by 2050 and have cascading risk scores that indicate actions to address them have high or very high potential to address other risks. We combined these risks, along with the marine ecosystems risk, as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to ecosystems together satisfied the third principle of our review for significance: they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. All significant risks are highlighted in the Priorities for action report.

Addressing risks to coastal ecosystems also has very high potential to reduce multiple other risks assessed in this report, including risks to freshwater, marine and terrestrial ecosystems, indigenous biodiversity, fisheries, tourism, buildings and mental health, because coastal ecosystems regulate coastal hazards, support biodiversity and fisheries productivity, and provide natural protection from flooding and erosion. Coastal habitats such as wetlands, dunes, mangroves and seagrasses stabilise sediments, support biodiversity and buffer coastlines from hazards such as flooding and erosion.[112,113,118,119]

Risk overview

Risks from sea-level rise, coastal erosion and groundwater rise

SLR is the most pervasive, progressive and committed driver of coastal change over long time frames.[120,121] Even small increments in SLR substantially increase the frequency and severity of coastal inundation and erosion. In many areas, the first threshold occurs when high tides begin to inundate low-lying ecosystems annually, seasonally or monthly. This is often decades before extreme SLR milestones occur (for example, before mean sea level reaches the 0.5 m mark), because vertical land movement and local geomorphology exacerbate exposure.[120-122] By 2100, mean sea level around Aotearoa New Zealand is projected to rise substantially under higher-emissions scenarios, with local outcomes modified by vertical land movement.[7,17,121,123] Under these conditions, some estuarine and dune systems may approach ecological thresholds where erosion and sediment reworking outpace recovery.[118,124-126]

Northern and eastern regions, such as Te Taitokerau/Northland, Bay of Plenty and Hawke’s Bay, face earlier and more severe exposure to SLR not only due to lower elevation and softer geology but also because regional tidal range influences how soon extreme sea levels and related impacts are reached, with smaller tidal ranges tending to bring high-water thresholds forward as sea level rises.[120,121,127] East Coast estuaries and lagoons are exposed due to soft sediments and catchment pressures. Southern regions, including Southland and Canterbury, contend with the compounded challenges of SLR with vertical land subsidence and intensified coastal erosion.[122,124] West Coast sandy systems face erosion under high-energy wave climates.[124-126]

Erosion is accelerating at soft-sediment coastlines, dune systems and cliffed coasts, reducing habitat area and altering sediment supply to estuaries and beaches. At the same time, rising groundwater can inundate soils, cause vegetation dieback, mobilise contaminants and alter wetland function.[96,112] Across Aotearoa New Zealand, low-lying coastal wetlands, estuaries and dune systems are already experiencing inundation and salinisation, which leads to waterlogging and loss of intertidal zones.[112,121] The compression of habitat between the encroaching sea and fixed infrastructure (commonly referred to as coastal squeeze) drives persistent habitat decline.[119] Where hard structures prevent inland migration, saltmarshes and wetlands lose their ability to retreat and regenerate, reducing resilience and carbon sequestration potential.[113,114,119]

Risks from increasing sea surface temperatures, marine heatwaves and ocean acidification

Although primarily marine, these hazards strongly affect coastal ecosystems due to the tight coupling between land–sea processes.[116,117,128,129] Warmer seawater and frequent marine heatwaves lead to shifts in species distributions, kelp canopy loss, altered primary productivity and changes to food webs.[50,130-136] Estuarine and nearshore species such as seagrass, shellfish, juvenile fish and benthic organisms are sensitive to warming and low-oxygen events. Ocean acidification reduces carbonate availability for shell-forming species, including pipi, tuangi, mussels and juvenile pāua in estuarine mouths and nearshore nurseries.[128,137]

The combined effects of increasing sea surface temperature, ocean acidification and marine heatwaves are already triggering ecological change, including reduced kelp biomass and greater turf algae dominance,[135,136] altered fish community composition, heat stress for coastal and intertidal species, higher disease prevalence in shellfish and displacement of cold-adapted species southwards.[134,138] Increasing evidence shows that two consecutive summers of severe marine heatwave conditions can cause multi-year kelp forest collapse, for example, undermining habitat stability. Ocean acidification thresholds for some shellfish larvae are projected to be reached in mid-century in parts of the southern Exclusive Economic Zone (EEZ), with consequences for coastal replenishment.[128,129,139] Northern regions show the strongest warming and most frequent marine heatwaves.[131-133] Southern coasts have greater ocean acidification exposure, affecting deep estuarine channels and nursery habitats.

Risks from extreme rainfall, storm events and changing precipitation

Extreme weather events compound gradual SLR, with storms (including surges), cyclones, heavy rainfall and extreme wind events damaging coastal ecosystems directly and indirectly.[7,122,124,140] Flooding events drive saltwater into freshwater wetlands, disrupting plants and invertebrates.[112,141] Sediment mobilisation, pollutant loads and debris deposition during floods increase turbidity, impair light availability for seagrass and kelp, and alter benthic habitats (habitats at the lowest level of a body of water), degrading estuarine and wetland habitats and affecting shellfish and fish recruitment.[118,125,126,142] Higher-intensity rainfall leads to increased catchment sedimentation, short-term loss of oxygen (anoxia) in estuaries, stratification and heat-driven low-oxygen events, and storm-driven erosion of dunes and beaches.[118,142,143] Sediment from extreme rainfall can also overwhelm estuary recovery, taking years to clear. When storm events become too frequent, dunes lose their ability to rebuild and coastal wetland vegetation fails to recover between events, leading to chronic degradation in these areas.[7,124,125] Meanwhile, projected increases in storm intensity and frequency are expected to raise maintenance costs for coastal defences and infrastructure, and can exacerbate erosion around hard-engineered structures, potentially locking in responses that protect built assets in the short term but undermine natural coastal processes and ecosystem resilience as well as further degrading ecosystems.[7,124]

Changing precipitation also affects freshwater inflows, altering salinity gradients important for estuarine species.[118,144] In some catchments, reduced low-flow volumes in dry summers intensify the influence of marine heat and salinity stress on estuarine ecosystems.

Coastal species may reach multiple thresholds

Coastal ecosystems are highly sensitive to changes in salinity, sedimentation and hydrodynamics.[112,118,119] Many species have narrow ecological tolerance and exhibit multiple thresholds, where incremental changes lead to abrupt shifts.[145,146] For example, saltmarsh and mangrove species in coastal wetlands may drown or suffer reduced productivity from SLR and/or prolonged inundation,[112,119] and dunes and dune vegetation collapse when erosion thresholds are surpassed.[147] Salinity intrusion and altered estuarine hydrodynamics can contribute to regime shifts that fundamentally alter estuarine food webs.[118,148] Adaptive capacity depends on local geomorphology and land-use context: undeveloped coastlines with natural sediment supply and space for landward migration are more resilient, whereas built-up areas with fixed infrastructure have only limited ability to adapt.[119,125] Ecological restoration, such as dune replanting and wetland rehabilitation, provides some adaptation potential but requires sustained investment and management alignment with dynamic coastal processes.[149]

Increased risks to coastal environments are projected across the next century

By 2050, under a mid-range (Representative Concentration Pathway (RCP) 4.5) scenario, tens of thousands of hectares of wetlands are projected to face increased inundation or salinity, and coastal squeeze will intensify where hard structures prevent natural migration.[112,116,119] By 2090, with SLR exceeding 0.8–1.0 m under high-emissions scenarios, much of Aotearoa New Zealand's estuaries, dune systems and intertidal habitats may transition or be permanently lost.[7,17,121] The ecological effects include drowning of saltmarshes, reduction of sediment supply and loss of nursery habitats for fish and shellfish. These transitions diminish ecosystem function and weaken natural protection from flooding.[7,147,149]

Iwi and hapū may experience threats to mahinga kai and taonga species, leading to cultural and spiritual losses

For iwi and hapū, coastal ecosystems are interwoven with mahinga kai (food gathering practices and places), whakapapa (the genealogical layering of relationships that connect people, places, and knowledge systems) and kaitiakitanga (guardianship, environmental stewardship). Taonga species such as tuna, īnanga, pipi and harakeke are vital to food security/systems, cultural identity and intergenerational knowledge and practices.[32,150,151] Coastal inundation and erosion associated with rising sea levels and more intense and frequent storm events threaten marae, urupā (burial grounds) and mahinga kai (food gathering places), several of which are already experiencing increased coastal inundation and shoreline loss, particularly in low-lying areas.[124,152,153] Cultural and spiritual losses occur long before physical loss, as access, safety or ecological function diminishes.[124,152] For iwi/hapū, changes affecting taonga species disrupt tikanga linked to seasonal harvest cycles, wānanga (seminar, place of learning, tribal knowledge, discussion, learning) and intergenerational learning, while contamination events may reduce access to safe kaimoana (seafood). Many iwi and hapū are already developing coastal management plans and strategies grounded in mātauranga Māori (historic and contemporary Māori knowledge), but gaps in resourcing and in meaningful inclusion within statutory governance and decision-making processes persist.[144,154,155] See *RISK: Loss of access to taonga species* in Ngā mea hirahira o te ao Māori for more information.

Compounding and cascading factors

Coastal environments face multiple intersecting risks and may pass thresholds earlier than projected

Coastal systems face simultaneous changing environmental conditions and climate change-related hazards, intensifying impacts. For example, high sea surface temperatures combined with heavy rainfall reduce oxygen levels in estuaries; SLR amplifies storm-surge flooding and erosion; marine heat waves increase the vulnerability of kelp forests that are then damaged by storms; reduced sediment supply (due to river modifications) limits natural shoreline recovery after erosion; and extreme rainfall combined with storm surge can cause prolonged inundation and pollutant runoff into estuaries.[118,142] Combined pressures mean some ecosystems may pass irreversible thresholds earlier than physical climate metrics alone would suggest.

Additionally, many coastal systems already sit close to ecological limits because of land-use intensification, historical reclamation, urbanisation, drainage modification, pollution (including trade-waste[xv] discharges), altered sediment regimes and invasive species. Sediment and nutrient runoff from agriculture and forestry reduce water quality and hinder habitat resilience.[142,156] Climate change amplifies existing pressures. For example, where estuaries are already nutrient-stressed, heatwaves can trigger algal blooms that cause further oxygen depletion.

Socio-economic and demographic trends, such as population growth in coastal settlements, expanding infrastructure, intensifying land use, tourism demand and housing pressure intensify competition for coastal space. These factors may potentially undermine restoration and retreat initiatives. Coastal iwi/Māori communities, many in low-lying areas, have fewer relocation options due to constraints on whenua Māori (including tenure limitations – see **Box 3.1**), strong cultural ties to ancestral land and limited alternative housing or financial resources.[153,157-160] As a result, these communities may face disproportionate cultural losses. Population growth and coastal property development increase exposure and pressure to maintain hard protection measures such as seawalls.[125,161,162] The combination of these pressures interacts with climatic drivers, accelerating ecological decline and increasing inequities in adaptation outcomes.

Interaction with emissions reduction

Actions that reduce greenhouse gas emissions or remove greenhouse gases from the atmosphere can both reduce and increase risks. For example, restoring and protecting coastal wetlands, mangroves and seagrasses enhance carbon sequestration, providing dual adaptation-mitigation benefits.[113,114] Such habitats absorb carbon dioxide (CO_2) and enhance biodiversity while buffering storm surges, but these habitats are also highly threatened by SLR and erosion. Emissions reduction infrastructure (such as coastal renewable energy) will be most effective when it considers ecosystem impacts and adaptation.

Hard protection structures installed as adaptation measures may undermine wetland or dune migration, worsening long-term ecological decline. These structures, such as seawalls, may hinder habitat migration, reducing carbon storage capacity.[113,114,119] This underscores the value of an integrated approach that considers adaptation and carbon storage together.

[xv] Trade waste refers to liquid waste from industrial or commercial premises discharged into public wastewater systems.

Policy readiness assessment

National policy foundations are useful, but preparedness and speed of implementation are limited

Aotearoa New Zealand has laid foundations for responding to this risk through scientific programmes and key pieces of legislation and national direction, but policy implementation and delivery remain inconsistent and long-term adaptation underdeveloped. Coastal ecosystems receive less regulatory protection than terrestrial ecosystems, and marine-freshwater-land interactions tend not to be managed cohesively. Existing planning and regulatory systems may favour static or defensive adaptation (e.g. seawalls) rather than ecosystem-based or dynamic approaches (e.g. dune restoration, living shorelines, assisted migration) and, even if there is uptake, it is slow.

Nationally, key pieces of legislation and national direction include the Resource Management Act 1991 (currently undergoing reform),[xvi] the New Zealand Coastal Policy Statement (2010),[163] the Climate Change Response Act 2002, the National Adaptation Plan (2022)[70] and conservation and fisheries legislation. Scientific programmes include the SeaRise Programme,[17] the Aotearoa New Zealand Coastal Blue Carbon Programme,[164] and the recently concluded Sustainable Seas National Science Challenge.[145] These contribute to options for adaptive planning, managed retreat and ecosystem-based management and provide a framework for integrated management but do not yet deliver the scale or speed of action required to meet escalating climate-related risks.[46,165,166]

Despite positive momentum since the first risk assessment was published in 2020, the pace of implementation remains inadequate. Even fully implementing existing policies and programmes would not prevent significant residual risk due to multi-hazard exposure, legacy land-use decisions and the inherent pace and scale of climate change and its ecological impacts. Many coastal management plans operate on decadal timeframes, yet high-end sea-level projections suggest critical adaptation thresholds, such as the frequent overtopping of natural beach buffers or the transition of coastal inundation from rare to annual events as SLR, could be sooner than previously anticipated.[7,120,167] The absence of a comprehensive national coastal adaptation strategy means responsibilities are often fragmented across central, regional and local levels, leading to inconsistent policies and an overlap or gaps in roles, which makes it difficult to coordinate adaptation of coastal ecosystems.[26,165,168,169]

[xvi] The RMA recognises “coastal environments” as requiring special management: RMA Section 6(a) (a matter of national importance) includes the preservation of the natural character of the coastal environment, including its ecological and geomorphological aspects. However, the RMA does not define “coastal environment” in precise terms, particularly in the landward sense, which is left to councils to determine locally.

Regional councils implement coastal hazard assessments.[7,165] There are regional variations in capacity, expertise, funding, availability and quality of data for ecological adaptation; varying social acceptance among the public; and inconsistent application of planning frameworks, decision-making criteria and adaptation guidance across jurisdictions, leading to uneven adaptation outcomes.

Iwi/Māori participation mechanisms are in place, but barriers persist

Funding, policy horizons and governance participation limitations have been identified as barriers that constrain iwi/Māori participation in coastal climate adaptation planning and decision-making. For example, government adaptation processes and institutions frequently do not adequately recognise or accommodate iwi/Māori rights, perspectives and mātauranga Māori, making it difficult for hapū, iwi and Māori communities to participate effectively in planning for coastal hazards and ecosystems. This includes limited resourcing and technical capacity to engage in adaptation processes despite disproportionate exposure to SLR, coastal erosion and impacts on culturally important coastal sites such as marae and mahinga kai (food gathering places). While regional coastal hazard assessments and guidance such as the Coastal Hazards and Climate Change Guidance[7] support local adaptation, these broader initiatives do not on their own overcome the structural barriers iwi/Māori face in securing meaningful influence over coastal adaptation strategies and related decision-making processes.[170]

Initiatives such as Future Coasts Aotearoa[115] and the Coastal Hazards and Climate Change Guidance,[7] which support regional and local adaptation planning, are often undertaken in partnership with mana whenua and iwi authorities. Iwi/Māori participation in adaptation has expanded in some regions over the past decade, through iwi-led initiatives such as the Tuhaitara Coastal Park[171] and community-based restoration under Arawai Kākāriki,[172] which blend mātauranga Māori and ecological science and frequently occur through partnerships between iwi and local government. Participation remains uneven across locations, and barriers persist in resource access, governance participation, recognition of mātauranga Māori, influence in regional decision processes and integration of tikanga-based frameworks.[124,144,151] Strengthening participation arrangements and resourcing iwi/Māori-led coastal monitoring and adaptation initiatives, including partnership mechanisms with local government, could enhance adaptation outcomes.

Gaps for risk severity and policy

There are limited data on the rate of ecosystem decline, including thresholds; insufficient long-term monitoring of groundwater rise, salinity intrusion and sediment dynamics;[118,119] patchy information on coastal species distribution and resilience; weak integration of mātauranga Māori into monitoring and decision-making processes; and few national-scale assessments of SLR-driven groundwater impacts.[118,173] Research continuity is at risk following the completion of several national science programmes in 2024, unless successor arrangements sustain long-term monitoring and collaboration.[174]

Policy gaps are equally significant. There is a lack of nationally coordinated approaches to coastal-hazard management, insufficient planning for relocation of vulnerable ecosystems or culturally important sites, and limited investment in soft protection and nature-based solutions. Dedicated, durable funding pathways for iwi-led adaptation and monitoring remain limited.[165,168,175,176] Ecosystem service valuation (such as blue carbon or flood protection) remains insufficiently quantified, limiting integration into economic decision-making.[113,114,177] Alignment between biodiversity and climate adaptation remains weak, and monitoring of implemented restoration or retreat projects is limited.[166]

Summary

Coastal ecosystems in Aotearoa New Zealand face high and escalating climate-related risks from the combined effects of SLR, warming seas, ocean acidification, erosion, groundwater rise and extreme weather, including rainfall. These hazards interact with non-climate pressures to damage biodiversity, ecological functions and cultural heritage. Because these ecosystems underpin multiple ecological, economic and cultural systems, their decline would amplify risks across several domains assessed in this report.

Risk severity is already evident and will continue to intensify through this century with risks substantially higher in the absence of accelerated and coordinated ecosystem-based adaptation, leading to substantial biodiversity loss, cultural disruption and reduced coastal ecosystem functioning. Some ecosystems, particularly estuaries, dunes and coastal wetlands, are approaching thresholds beyond which recovery or migration becomes difficult. Impacts on how iwi/Māori live in accordance with their values and preferences are profound and growing.

While policy and scientific knowledge have advanced, implementation of action lags behind the pace and scale of change. Gaps in funding and financing, institutional coordination and data hinder effective adaptation. Adaptive capacity is uneven across regions and communities, with iwi/Māori and low-income coastal populations disproportionately affected.

Addressing risks to coastal ecosystems can make significant contributions to reducing other climate-related risks, such as risks to freshwater, marine and terrestrial ecosystems, indigenous biodiversity, fisheries, tourism and buildings.

Risk scorecard: Coastal ecosystems

Risks to coastal ecosystems due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events and associated impacts like coastal flooding and erosion.

Identified as one of the most significant risks as part of the combined ecosystems and biodiversity risk.

	Score	Rationale
Risk severity		
Now	Moderate	Coastal ecosystems already affected by sea-level rise, elevated temperatures, marine heatwaves and ocean acidification. Clear early signals of biodiversity decline, ecosystem disruption and increasing exposure to compounding hazards.
2050	Major	SLR drives coastal squeeze of some ecosystems and biodiversity, intensifying environmental pressures and some regions face earlier and more exposure. Wetlands are projected to face increased inundation or salinity. Intensified flooding and habitat loss.
2090*	Major GWL 2	SLR drives coastal squeeze of ecosystems and biodiversity, intensifying environmental pressures. SLR coupled with intensified storms could severely disrupt ecosystems.
	Extreme GWL 3–3.5	High SLR leads to transition or permanent loss of low-lying coastal areas, including estuaries, dune systems and intertidal habitats. Cascading impacts, including coastal squeeze, drive further loss of critical ecosystems and the services they provide, including flood protection.
Policy readiness		
Overall assessment	Significant gaps	Despite strong intent and local successes, fragmented governance, variable implementation, funding shortfalls/under-resourcing, inconsistent environmental protections and legislative instability result in significant readiness gaps. Policy lacks scope, scale, urgency and coordination.
Cascading risk		
Overall assessment	Very high	Addressing this risk has very high overall potential to address others in the assessment, including the risks to freshwater, marine and terrestrial ecosystems, indigenous biodiversity, fisheries, tourism, buildings and mental health.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Marine ecosystems

Risks to marine ecosystems due to ocean warming, marine heatwaves, and associated impacts like ocean acidification and deoxygenation.

Aotearoa New Zealand's marine environment, which extends from the outer boundary of the territorial sea (12 nautical miles offshore) to the limits of the Exclusive Economic Zone (EEZ), covers more than 4 million square kilometres (km^2).[117] It is one of the world's largest and most ecologically varied ocean jurisdictions, spanning sub-Antarctic ecosystems, temperate bioregions, deep trench systems and seamount complexes.[50,116,117] This vast marine domain supports globally significant biodiversity, including high levels of endemism,[xvii] complex food webs and habitats, such as kelp forests, bryozoan thickets, deep-sea corals, sponge gardens and pelagic ecosystems. It embodies deep cultural, economic and spiritual connections for iwi and hapū, with kaitiakitanga (guardianship, environmental stewardship) grounded in tikanga, whakapapa (the genealogical layering of relationships that connect people, places, and knowledge systems) and mātauranga Māori (historic and contemporary Māori knowledge), that recognise the interconnectedness of people and te moana (the ocean).[50,178] The marine environment also supports the productivity of key economic sectors, such as commercial fisheries, aquaculture and tourism, which are addressed in the *Sectors relying on the natural environment* section of this report.[116,117]

Climate change is driving rapid and unprecedented physical, chemical and biological changes posing profound and escalating risks to the marine environment.[50] Key climate stressors include rising sea surface temperatures, increasing frequency and duration of marine heatwaves,[xviii] progressive ocean acidification, intensifying stratification and emerging deoxygenation. These stressors are already threatening the integrity of marine ecosystems, altering species distributions, ecosystem productivity, the structure and function of marine food webs, and the health of cultural and ecological taonga (treasured possessions, cultural keystone species).[128,129,179,180] Such climate-driven shifts interact with longstanding human pressures, accelerating ecological decline and increasing the vulnerability of marine ecosystems to compounding stressors.[117,145,146,181] While climate change does not create all the existing pressures affecting marine ecosystems, such as fishing pressure, sedimentation, nutrient runoff and invasive species, it intensifies their consequences and can amplify and accelerate ecological change and loss.

The first national climate change risk assessment identified risks to marine ecosystems from warming seas and acidification as emerging but under-characterised. Since then, new research has confirmed accelerating trends in sea surface temperature anomalies, faster warming trends, longer and more intense marine heatwaves,[130-134] declining carbonate

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[xvii] Endemism is the state of a species being found exclusively in a single geographic location, such as a specific island, region, or country.

[xviii] Marine heatwaves are prolonged periods of temperature anomalies above the 90th percentile.

saturation states[128,129] and evidence of biological thresholds reached.[134-136,145] For many taxa, including kelp,[136] shell-forming organisms[182,183] and deep-sea species, sensitivity to warming, ocean acidification and low oxygen is high while adaptive capacity remains limited due to narrow thermal tolerances, dependence on vulnerable habitat-formers, and constrained ecological niches, with ecological disruption already emerging through kelp loss, reduced calcification, and altered species interactions.[123,129,179,184] The severity and frequency of these hazards are projected to increase substantially through 2050 and 2090 under both intermediate and high-emissions scenarios.[123,129,179,184]

This is one of the most significant risks as part of the combined ecosystems and biodiversity risk

The coastal, freshwater and terrestrial ecosystems risks and the indigenous biodiversity risk are all rated at major severity by 2050 and have cascading risk scores that indicate actions to address them have high or very high potential to address other risks. We combined these risks, along with the marine ecosystems risk, as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to ecosystems together satisfied the third principle of our review for significance: they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. All significant risks are highlighted in the Priorities for action report.

Risk overview

Ocean warming is the most pervasive long-term hazard across the EEZ.[50,117] The marine domain beyond 12 nautical miles is already experiencing persistent ocean warming, with mean sea surface temperature around Aotearoa New Zealand rising by approximately 0.1–0.2°C per decade since the 1980s.[9,117,130,185] In 2022, ocean temperatures reached record highs, with some regions experiencing close to year-round marine heatwave conditions (approaching 300 days) and the highest number of marine heatwave days on record nationally.[133,134,186-188] This is accompanied by increased water-column stratification,[xix] which reduces vertical mixing, impairs nutrient replenishment, and alters primary productivity patterns, food-web structure and ecosystem functioning.[180] Temperature thresholds for many species are exceeded more frequently, increasing susceptibility to disease, predation and starvation.

Marine heatwaves have increased in frequency, duration and intensity, particularly in the past decade.[131,132,189] Severe marine heatwaves affect kelp forests (such as *Macrocystis pyrifera*), leading to canopy loss and replacement by turf algae, reducing habitat complexity

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[xix] Marine stratification is the layering of the ocean into distinct vertical layers based on differences in density, primarily driven by temperature and salinity. Less dense, warmer, and less salty water forms the top layer, while denser, colder, and saltier water sinks to the bottom. As the surface ocean warms, these layers mix less readily.

and nursery functions.[135,136] Repeated marine heatwaves can cause multi-year habitat collapse, with ecosystem level impacts cascading through trophic systems, affecting invertebrates, fish (including commercial fisheries) and top predators like seabirds and marine mammals.[134-136,138,190] By mid-century under intermediate and high-emissions pathways, marine heatwaves are projected to become substantially more frequent and intense than under lower-emissions pathways.[132,191] The increase in frequency under intermediate paths sits between the low and high scenarios – and persistent warm anomalies become much more common, though not yet globally permanent.[179,191] Under high-emissions scenarios, modelling projects very large increases in marine heatwave intensity and duration around Aotearoa New Zealand, and some regions could approach near-permanent marine heatwave conditions by the end of the century.[131,132] The permanent year-round marine heatwave conditions projected for parts of the global ocean under high-emissions scenarios (e.g. SSP5–8.5) are largely avoided under lower-emissions pathways (e.g. SSP1–2.6).[132]

Some regions are already experiencing significant climate impacts, while others experience slower onset but are highly sensitive to change

Confidence in observed and projected warming is very high, while uncertainty remains moderate regarding biological adaptation rates and food chains.[179,180,192,193] Regionally, northern and northeastern waters experience the highest sea surface temperature anomalies and longest marine heatwave durations.[117,128] Sub-Antarctic waters warm more slowly but have high ecological sensitivity, as even small temperature increases disrupt highly adapted cold-water species and primary productivity cycles. Satellite and site observations show marine heatwaves have reduced plankton diversity, displaced pelagic species (such as hoki and anchovy)[xx] and increased mortality in cold-water taxa such as sponges and corals.[134-136,194,195] Meanwhile, subtropical northern waters exhibit the most pronounced temperature anomalies and biodiversity shifts.[131,136,196] The South Pacific gyre and sub-Antarctic zones show slower physical warming but greater vulnerability to ocean acidification and oxygen decline.[129,179,197,198]

Risks from ocean acidification and reduced calcification weaken species and habitats

Ocean acidification is progressing steadily, driven by rising atmospheric CO_2, reducing pH and carbonate saturation states.[128,129,139] Acidification leads to impaired growth, weakened shells and reduced larval survival in shell-forming organisms.[128,137,139] This weakens structural habitats like bryozoan thickets and deep-sea coral gardens – key refuges for biodiversity.[128,199] Early life stages (e.g. in fish and marine invertebrates) are particularly vulnerable, with New Zealand studies showing that ocean acidification can impair larval

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[xx] Pelagic fish are species that typically inhabit the midwater and upper layers of the oceans, independent of the seabed, and often exhibit a strong tendency to school in large shoals. Examples include marlins (striped, blue and black), broadbill swordfish, yellowfin, Pacific bluefin and southern bluefin tuna.

development, settlement, and sensory function (e.g. in pāua, kina and snapper), while interacting stressors including warming and deoxygenation further constrain physiological performance and reduce resilience.[200-202] Deoxygenation, resulting from warmer stratified waters, has been observed in mid-depth ocean layers and coastal upwelling zones, constraining habitats for some species.[116,179,180,198]

High-emissions scenarios are projected to push ocean chemistry beyond tolerance ranges for some cold-adapted and calcifying species..[128,129,139] Critical ecological thresholds include loss of carbonate saturation in sub-Antarctic waters[128,129,139] and regime shifts in plankton communities that underpin the national fisheries sector.[138,195] By late century, ocean acidification is likely to threaten sensitive calcifying taxa (e.g. pteropods, coralline algae).[128,129,139] These changes threaten deep-sea coral reefs, bryozoan thickets and cold-water carbonate ecosystems, many of which are slow-growing and have limited adaptive capacity.[199]

Ocean acidification also alters plankton communities, shifting primary productivity, nutrient cycling and food availability for all species connected through the food web.[128,192,195] These shifts propagate through pelagic food webs, with consequences for fisheries, marine mammals, seabirds and coastal ecosystems reliant on pulses of offshore primary productivity.

Risks from deoxygenation and altered ocean stratification

Deoxygenation is an emerging hazard in Aotearoa New Zealand waters.[116,180] While global hot spots occur elsewhere, local observations show declining oxygen in mid-depth and stratified regions, particularly during and following marine heatwaves.[180] Low-oxygen layers reduce habitat suitability for demersal fish,[xxi] pelagic species and invertebrates, driving vertical habitat compression and altering predator-prey relationships.[180,198]

Stratification caused by warming reduces nutrient upwelling, diminishing productivity at the base of the food web.[180] In some areas, particularly where organic matter accumulates in sediments, warming and stratification can increase microbial respiration, further depleting oxygen and exacerbating hypoxic risks.[203]

Deoxygenation poses thresholds: once oxygen falls below key levels, mortality events can occur rapidly, and recovery may take years or may not occur if warming and stratification persist.[198,202,203]

[xxi] Demersal fish are species that live and feed on or near the bottom of sea, lake, or ocean floors. They inhabit environments ranging from shallow coastal waters to deep-sea continental slopes, often in rocky, sandy, or muddy habitats. Common examples include cod, haddock, flatfish (flounder, halibut), and snapper.

Risks from shifting species distributions, food-web disruption and ecological reorganisation already under way

Climate-driven redistribution of species is already under way.[180,204,205] Warmer waters facilitate range expansion of subtropical species, such as long-spined sea urchin (*Centrostephanus rodgersii*), which can transform kelp forests into urchin barrens.[196] Cold-adapting species retreat southwards or into deeper, cooler waters, reducing ecological overlap and altering community composition.[204,205204,205] Sub-Antarctic taxa are contracting and warm-temperate species are expanding.[129,179,195,204,205] Deep-sea ecosystems, though slower to respond, face long-term changes in oxygen and nutrient regimes that threaten slow-growing corals, sponges and benthic communities.[179,195,198]

Some marine ecosystems may be highly sensitive and slow to adapt to climate change

Aotearoa New Zealand's marine ecosystems exhibit high ecological sensitivity and low adaptive capacity due to their isolation, endemic species composition and limited refuge habitats.[179,180,206] Biodiversity loss and changes to food-web relationships (trophic reorganisation) undermine resilience, especially where ecosystem engineers (such as kelp, corals, bryozoans) decline.[135,136,181] Adaptation potential depends on maintaining habitat diversity, connectivity and genetic variability, but human pressures continue to erode these buffers.[146] Commercially important species such as hoki, snapper and pāua show variable adaptive potential.[134,137,138] Some may shift range or timing of spawning, while others may fail to produce enough young to sustain their populations (recruitment collapse).[134,137,138]

There are risks to taonga species, customary practices and iwi/Māori marine relationships

For iwi/Māori, increasing sea surface temperatures affect taonga species central to customary harvest, food security and cultural practices.[32,178,207,208] These changes disrupt seasonal harvests, tohu maramataka (Māori lunar calendar signals) and intergenerational knowledge transfer, and can displace species, complicating the exercise of kaitiakitanga and other customary practices. [178,207-210]

Taonga marine species – including kina, pāua, tuangi, koura, pipi, kūtae, and key pelagic finfish[32,178,207,208] – are among the most climate-sensitive risk groups in the ocean, as warming, ocean acidification and oxygen stress undermine their growth, reproduction and survival.[128,134,137] Marine taonga species embody cultural identity and intergenerational stewardship obligations.[32,178,207,208] Climate-driven declines in these species threaten not only livelihoods but also social and cultural wellbeing, including customary fisheries, cultural harvests, manaakitanga (hospitality, care for others), and tikanga (custom, lore) associated with seafood sharing.[32,211,212] As these species shift outside traditional harvesting areas, there are cultural impacts on access, kai provision and customary practices, complicating governance and access rights.[32,206] There are also cultural consequences for mahinga kai (food gathering places and practices), wānanga (tribal knowledge, discussion, learning), whakapapa (genealogy), intergenerational mātauranga transfer and the mauri (life force) and identity of ecosystems.[32,178,209,211] Some iwi have begun adapting management approaches using maramataka (Māori lunar calendar), ngā tohu o te taiao (local ecological indicators), and mātauranga–science partnerships, but resourcing constraints and lack of coordinated national frameworks limit their ability to respond proactively.[209,210]

Compounding and cascading factors

Marine systems are exposed to intersecting risks from climate change and other human pressures, amplifying ecological stresses

Marine systems are exposed to multiple climate hazards simultaneously, and the interactions among warming, ocean acidification, deoxygenation and stratification amplify ecological stress. For example, marine heatwaves intensify stratification and reduce oxygen, while acidification weakens shells and makes organisms more vulnerable to heat stress, predation and disease.[180] These combined pressures accelerate biodiversity loss beyond the effects of individual stressors.

Climate-driven changes amplify existing anthropogenic pressures: overfishing, sedimentation and nutrient loading interact with warming and ocean acidification to accelerate ecological degradation.[146,181,192,193] Warming can facilitate the establishment and expansion of invasive species by favouring their thermal tolerance and competitive advantage over native taxa, while ocean acidification weakens native competitors.[135,136,196] Loss of top predators from fishing can compound climate effects by destabilising how populations at different feeding levels are regulated (trophic control), accelerating ecosystem regime shifts.[138,146,194] Climate change interacts with these pressures, triggering tipping points such as kelp forest collapse, coral habitat loss and food web reorganisation.[146,181]

Socio-economic pressures – including global seafood demand, offshore energy expansion and shipping traffic – add further stress on marine ecosystems and orient governance systems toward commercial priorities.[213-215] These trends exacerbate marine risk by increasing exposure to exploitation just as ecosystems lose resilience.[146,206,215] These dynamics can marginalise indigenous worldviews and priorities, limiting iwi/Māori capacity to engage equitably in decision-making and exercise rangatiratanga (authority, chieftainship) in how marine resources are governed.[32,154,215,216]

Interaction with emissions reduction

Marine ecosystems sequester carbon in phytoplankton, macroalgae and deep-sea sediments burial, including significant blue-carbon potential in coastal-marine interfaces.[114,180,217] However, these systems are sensitive to warming, ocean acidification and deoxygenation, meaning carbon sequestration benefits may decline as climate change impacts intensify.[128,129,179,180] Protecting and restoring blue-carbon habitats such as seagrasses, mangroves and saltmarshes – although more coastal – indirectly enhances oceanic carbon cycles.[113,114,218] Offshore extraction (such as seabed mining or hydrocarbon exploration) undermines both carbon storage and adaptation efforts by disturbing carbonrich sediments.[214,217,219] Future offshore renewable energy (such as wind farms) could reduce emissions; avoiding disruption of sensitive habitats or migratory pathways would protect against worsening ecological stress.[215,220,221]

Increased global shipping associated with low-carbon trade pathways raises risks of biosecurity incursions and pollution, adding stress to ecosystems already affected by warming.[116,213] Conversely, protecting marine habitats and reducing cumulative stressors can support both efforts to address emissions (through carbon storage) and adaptation by enhancing ecosystem resilience.[218]

For many marine systems, adaptation options are constrained, making mitigation especially important for reducing long-term risk.[129,179,180] When emissions reduction efforts are aligned with adaptation of marine ecosystems, where possible, they will be most effective.

Policy readiness assessment

Extensive legislation and policies are in place, but are fragmented and under-resourced

Aotearoa New Zealand has a comprehensive suite of legislative instruments governing the marine domain, including the Marine Reserves Act 1971, Fisheries Act 1996, Biosecurity Act 1993 and Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012.[215,222] Collectively, these provide an important framework for climate change adaptation in marine ecosystems. The Marine Protected Areas (MPA) Policy and Implementation Plan (2005) and *Aotearoa New Zealand Biodiversity Strategy* (2020) provide strategic guidance for ecosystem protection. Together, these provide a strong statutory foundation for protection and ecosystem-based adaptive management by enabling the protection of marine biodiversity, regulating sustainable fisheries and controlling biosecurity risks, all of which are essential for enhancing the resilience of marine ecosystems to climate-driven stressors such as ocean warming, ocean acidification and shifting species distributions. Highly protected areas cover only a very small share of the marine environment, far short of international 30% commitments.[116,223]

The Moana Project and Seafood Sector Adaptation Strategy have advanced knowledge and pilot responses to marine climate change, while collaborative governance arrangements – such as those established under the Kaikōura (Te Tai o Marokura) Marine Management Act 2014, developed from the iwi- and community-led Kaikōura Marine Strategy – demonstrate emerging models for marine management.[138,145,154] However, these remain localised and under-resourced, lacking national coordination.[215,222]

While initiatives such as Sustainable Seas, iwi-led marine planning and ecosystem-based management pilots have advanced understanding, integrated action is constrained by the lack of coordination among relevant entities and a cohesive national approach, institutional fragmentation across agencies and limited momentum.[214-216] Many frameworks focus on sector-specific management – fisheries, biodiversity, minerals or marine transport – rather than cumulative climate stressors or system-level change.[215]

Iwi/Māori leadership in marine adaptation is constrained by recognition and resourcing

Iwi/Māori-driven initiatives in marine adaptation are progressing through hapū and iwi marine plans, maramataka-informed (Māori lunar calendar) monitoring, and locally driven adaptation solutions, but insufficient resourcing and inconsistent recognition of mātauranga Māori (historic and contemporary Māori knowledge) can limit their influence.[32,208] Compounding these challenges is often the lack of mandate or legislative requirements for iwi/Māori participation.[215,222,224] Overall, policy readiness remains constrained by a lack of sustained funding and inconsistent recognition of mātauranga Māori, which limits iwi/Māori decision-making and participation in marine adaptation. Many iwi and hapū have progressed marine plans, utilising maramataka-informed monitoring and locally driven adaptation solutions.[32,154,178,216] Adaptive capability exists through local tikanga frameworks, but these require formal support and alignment with statutory systems.[154,215]

Gaps for risk severity and policy

Significant data and monitoring gaps hinder precise assessment of biological thresholds and ecosystem responses, especially for deep-sea habitats, pelagic zones and the southern EEZ, relative to the scale of change.[145,195,225] Long-term datasets remain patchy; observations of marine heatwave effects across trophic levels are scarce; vulnerable habitats are insufficiently mapped; understanding of ecosystem thresholds, recovery potential and tipping points is limited; and climate projections at ecologically relevant scales are weak.[123,129,184] There is also limited integration of mātauranga Māori into national monitoring, despite the value of local ecological knowledge for detecting change.[32,208] The conclusion of National Science Challenges in 2024 created the prospect of lost continuity in collaborative marine research and monitoring without successor arrangements.[138,145,154]

There is a lack of overarching coordination and a cohesive national approach to marine issues as well as inadequate mechanisms to address cumulative effects. There are also insufficient tools for cross-agency coordination, limited pathways for initiatives, weak integration of climate-related risk into marine spatial planning, and insufficient resources for iwi/Māori marine governance, including sustained funding, technical capacity and clearly defined roles in national decision-making frameworks.[206,215,216,222] Research programmes on deoxygenation, carbonate chemistry and trophic adaptation require renewed investment.[180,193,197,198] Funding for ecosystem-based management, research into climate-resilient fisheries and iwi-led monitoring remains short-term and project-based, limiting long-term adaptation.[154,215]

Summary

Marine ecosystems in Aotearoa New Zealand face high and escalating climate-related risk from ocean warming, marine heatwaves, ocean acidification, stratification and deoxygenation.[117,129,130,132,134,179] These interacting hazards are already altering biodiversity, productivity and ecosystem function across the EEZ. Many habitats – kelp forests, deep-sea corals, bryozoans, shellfish beds – are approaching ecological thresholds that may lead to persistent or irreversible change.[128,135,136,145,199] These have flow-on effects for fisheries, biodiversity,[32,136,138,178,211] conservation and iwi/Māori wellbeing.[32,178,211] Impacts on taonga species and Māori cultural practices are profound, affecting mahinga kai (food gathering places and practices), kaitiakitanga obligations and the cultural, spiritual and economic connections that rely on healthy marine ecosystems.

Although Aotearoa New Zealand's legal and statutory frameworks lay a foundation for marine protection, fragmented legislation and implementation, and limited resourcing leave much of the EEZ vulnerable. Meanwhile, current policy delivery remains insufficient to keep track with the pace and magnitude of climate change.[206,215,226]

Accelerated, coordinated action is essential to address this risk. Dedicated marine climate-adaptation planning and the integration of mātauranga Māori could inform regulatory actions so that ecosystem-based management, long-term monitoring and iwi/Māori-led stewardship can strengthen resilience in marine ecosystems.[154,215,216,226] Actions should align fisheries, conservation and ocean policy with climate adaptation.

Risk scorecard: Marine ecosystems

Risks to marine ecosystems due to ocean warming, marine heatwaves and associated impacts like ocean acidification and deoxygenation.

Identified as one of the most significant risks as part of the combined ecosystems and biodiversity risk.

	Score	Rationale
Risk severity		
Now	Moderate	Accelerating trends of exposure to climate hazards, especially ocean warming (including marine heatwaves). Large, interconnected environment. Biological thresholds reached. Regional declines in ecological integrity.
2050	Major	Severity and frequency of climate hazards affecting marine ecosystems projected to increase substantially, including year-round elevated temperature anomalies. Expected inability for ecosystems to recover following some events and likely impacts on te ao Māori from loss of key species.
2090*	Major GWL 2	Severity and frequency of climate hazards affecting marine ecosystems projected to continue to increase substantially. Expected inability for ecosystem to recover following some events and likely impacts on te ao Māori from loss of key species.
	Extreme GWL 3–3.5	Severity and frequency of climate hazards affecting marine ecosystems projected to increase even further. Inability to recover from some impacts, ecosystem instability and serious loss of species and/or system collapse.
Policy readiness		
Overall assessment	Significant gaps	Despite strong legal scaffolding and local initiatives, the system lacks the scope, scale, urgency and coordination needed to address accelerating climate threats to marine biodiversity, resulting in significant readiness shortfalls.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium overall potential to address others in the assessment, including the risks to freshwater, coastal and marine ecosystems, fisheries, and indigenous biodiversity risk from pests and pathogens.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

DOMAIN: Built environment

This domain covers buildings and infrastructure, but affects services and how people live, move, act, work, learn and receive care.

The assessment focuses on water infrastructure (potable, stormwater and wastewater), waste management, buildings, ports and airports, road and rail networks, electricity distribution and transmission, and telecommunications and electricity generation infrastructure.

As climate change accelerates, Aotearoa New Zealand's built environment faces risks that threaten wellbeing, safety and the prosperity of its people. Buildings and infrastructure, which are the foundation of daily life and economic activity, are already being impacted by climate hazards. These impacts will intensify over time.

Vital public, commercial and residential buildings and infrastructure are at risk of damage and displacement. The consequences of this extend beyond the physical structures themselves – they affect where and how people live, move, act, work, learn and receive care.

What makes this domain unique?

Infrastructure systems are deeply interdependent

Aotearoa New Zealand's infrastructure, including electricity, water, transport and telecommunications are highly interconnected and vulnerable to cascading failures during extreme weather events. Climate change amplifies these risks, where a single hazard such as flooding can trigger widespread disruptions across multiple networks. Indirect impacts often exceed direct damage, as seen during Cyclone Gabrielle, which exposed systemic weaknesses.

Electricity is the critical lifeline utility upon which other networks depend; its failure can cascade to water supply, telecommunications, fuel distribution and transport systems. Backup systems themselves rely on fragile supply chains, compounding vulnerability during emergencies. Furthermore, restoring electricity often requires access via transport networks, meaning disruptions to roads can delay repairs and prolong outages.

Measures to increase the resilience of infrastructure are expensive and funding structures are fragmented

Adaptive capacity is constrained by ageing assets and the high cost of resilience measures. Changing design standards is a complex and lengthy process. Undergrounding electricity lines costs 5–15 times more than overhead lines[227] and reducing exposure by relocating airports or roads requires significant capital and long lead times. Often these costs are passed on to consumers, which can exacerbate already rising charges. Fragmented funding and governance gaps compound these challenges, risking lock in of vulnerabilities and escalating future costs.

Climate hazards do not impact all communities equally

Climate impacts stem from the combination of hazards, exposure and vulnerability. Vulnerability can disproportionately affect rural and lower socio-economic communities. Rural communities often rely on single access routes and can least afford to pay the additional costs associated with building in resilience or redundancies. Road closures sever essential services, compounding vulnerability. Limited financial resources make repairs, retrofits and insurance unaffordable, while energy hardship magnifies the impact of outages. These factors create a feedback loop where social inequities and infrastructure vulnerability reinforce each other. Exposure of assets is greater in areas with high flood risk, fire risk or coastal inundation risk.

Repairing damaged infrastructure can take years and communities are exposed to repeated events

Infrastructure failures have prolonged consequences. Repairs after major storms can take years, leaving communities exposed to repeated losses and escalating costs. Ports and airports lack redundancy, so failure of a single hub disrupts national connectivity and supply chains. Extended recovery periods amplify vulnerability and strain emergency response systems.

The number of people living in properties at risk of direct exposure, or who may experience isolation from climate-related hazards, will increase

Cities are the most densely populated areas because they provide access to infrastructure such as power, telecommunications, water, transport networks, ports, airports and waste systems. When populations are located near the coast, their exposure to multiple hazards increases. Urban Intelligence undertook a social vulnerability assessment, which can be found on our website, to inform the second national climate change risk assessment, looking at who is most at risk from coastal flooding. As sea levels rise, the number of people across Aotearoa New Zealand who will be exposed to, or isolated as a result of coastal inundation will increase. It may cut people off from their wider community and force a loss of access to essential services. Napier City, for example, has the highest proportion of its usually resident population currently at risk of direct coastal inundation; 12.8%, or about 8,190 people. Thames-Coromandel District has the highest proportion of population at risk of isolation, currently 49%.[228]. This exposure can compound with other climate-related hazards, including extreme weather events, heightening the chance of isolation.

How does this domain interact with other domains?

Impacts on the built environment flow through to the economy, health and the natural environment

The built environment is deeply interconnected with other systems, meaning climate hazards can trigger cascading impacts across multiple domains. Disruptions to transport networks, ports and airports interrupt supply chains, delay freight and increase costs, affecting trade and tourism. Transport disruption can hamper disaster response and recovery. Failures in infrastructure can also result in negative impacts on the natural environment, for example, the discharge of raw sewage into the marine environment.

Climate hazards affecting the built environment also pose serious health risks. Flooding and wastewater overflows can contaminate drinking water, increasing waterborne diseases, especially in rural areas. Electricity outages compromise heating and cooling, exposing vulnerable populations to heat stress or cold-related illness. Power outages can disrupt telecommunications, with implications for business continuity, income, health and education. Prolonged infrastructure failures also contribute to mental health stress and displacement, with disproportionate impacts on communities already facing social and economic inequities.

Impacts on iwi/Māori

Iwi/Māori infrastructure faces a disproportionate level of threat from climate hazards

Climate change threatens significant iwi/Māori infrastructure and locations such as marae, urupā (cemeteries, burial grounds), and papakāinga (communal housing). These sites are physical embodiments of whakapapa (the genealogical layering of relationships that connect people, places, and knowledge systems), tikanga and community cohesion, and play a central role in iwi/Māori identity, governance, ceremony and intergenerational wellbeing – functions which cannot be readily transferred to another location.

Many of these sites are in vulnerable locations such as low-lying coastal areas and flood plains. In some cases, this exposure reflects historical patterns of land marginalisation, where Māori were left with land parcels least suited to development.

Because marae often play a critical role in disaster responses, damage to marae can reduce community resilience to the impacts of climate change, while broader disruptions to transport and water systems further weaken iwi/Māori identity and cultural continuity. For more information, refer to the *Damage to Māori infrastructure* risk analysis.

Systemic policy issues

The demand for infrastructure will grow, and policy settings must enable the built environment to adapt to increasing climate hazards

Population growth, projected to reach about 6.5 million by 2048, will increase demand for infrastructure.[229] Where growth occurs will influence resilience, either enabling investment or expanding exposure in vulnerable areas.

Short-term hazard protections like stop banks and seawalls may be necessary but can create false security, encouraging development in high-risk zones and making future retreat more costly. Similarly, policy approaches that overlook adaptation risk locking in exposure and vulnerabilities and creating stranded assets. By embedding climate adaptation into systemic planning and design, Aotearoa New Zealand can proactively manage the increasing risk over the coming century.

While there are still information gaps, there is larger amount of climate hazard information for the built environment available than for other areas in this assessment.

Table 3.2: Risk ratings for Built environment

Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090*			
			GWL 2	GWL 3–3.5		
Risks to potable water, wastewater and stormwater infrastructure due to progressive and ongoing changes in temperature and precipitation, sea-level rise and increased extreme weather events.	Major	Extreme	Extreme	Extreme	Significant gaps	High
Risks to buildings due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like flooding and wildfires.	Moderate	Major	Extreme	Extreme	Significant gaps	Very high
Risks to road and rail networks due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.	Moderate	Major	Extreme	Extreme	Significant gaps	High
Risks to waste management infrastructure, including landfills and contaminated sites, due to progressive and ongoing sea-level rise and extreme weather events.	Moderate	Major	Extreme	Extreme	Significant gaps	Low
Risks to ports, airports and associated infrastructure due to progressive and ongoing changes in temperature, precipitation, wind, sea-level rise and extreme weather events.	Moderate	Moderate	Major	Extreme	Moderate gaps	Medium
Risks to electricity and telecommunications infrastructure due to progressive and ongoing changes in temperature, precipitation, wind, sea-level rise, extreme weather events and associated impacts like wildfires.	Minor	Moderate	Major	Major	Moderate gaps	Medium
Risks to the security of electricity supply due to progressive and ongoing changes in precipitation, temperature, and wind and extreme weather events.	Minor	Minor	Moderate	Moderate	Moderate gaps	Low

- Minor
- Moderate
- Major
- Extreme

- No significant gaps
- Moderate gaps
- Significant gaps
- Insufficient

- Low
- Medium
- High
- Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Water infrastructure

Risks to potable water, wastewater and stormwater infrastructure due to progressive and ongoing changes in temperature and precipitation, sea-level rise and increased extreme weather events.

Climate change presents increasingly severe risks to water infrastructure, including the supply of potable water and the management of wastewater and stormwater. This infrastructure is essential for homes, businesses and other facilities, yet they are increasingly exposed to hazards such as sea-level rise (SLR), extreme rainfall, heatwaves, river flooding and drought. These hazards are already affecting the ability to supply water, maintain water quality and prevent contamination in potable water systems. As well as leading to storm and wastewater systems being increasingly overwhelmed, failure of these systems is leading to contamination of the natural environment, and risks to human health and physical infrastructure.

This risk captures both linear infrastructure, such as pipes that transport water to and from buildings, and the treatment plants and pumping stations that process and help move water through the network. The interconnected nature of these systems means that failures in one cascade across others, amplifying impacts. Exposure of water infrastructure is heightened by location in low-lying areas, and its vulnerability is heightened by ageing assets, making climate resilience a pressing concern.

This was identified as one of the most significant risks

The risk to water infrastructure is rated at major severity in the present day, with significant gaps in policy readiness. It has a cascading risk score that indicates actions to address it have high or very high potential to address other risks. This satisfied the first and third principles of our review for significance: it presents high potential for adverse consequences now with little in place to address them, warranting immediate focus, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. For more, see the separate write-up of this significant risk in the Priorities for action report.

Risk overview

There are risks to potable water, wastewater systems and stormwater systems

This risk encompasses multiple interconnected systems, each facing distinct climate-related challenges that deepen overall vulnerability:

- **Potable water systems**: Exposed to drought-induced supply shortages, contamination risks from waterborne pathogens and treatment challenges from sediment loads and rising temperatures.
- **Wastewater systems**: Vulnerable to overflow events during heavy rainfall, infiltration of stormwater through damaged pipes and treatment failures under extreme conditions, heatwaves and SLR.

- **Stormwater systems**: At risk from increased frequency and intensity of rainfall, coastal inundation and SLR affecting discharge points and low-lying infrastructure.

Water infrastructure is already experiencing exposure to climate hazards, with measurable impacts on system performance and public health

Aotearoa New Zealand’s water infrastructure is already exposed to inland flooding and coastal inundation. Currently, about 3% of Aotearoa New Zealand’s water network is exposed to coastal inundation. In 2019, across the total extent of assets covering 102,150 kilometres (km) (potable, wastewater, stormwater), 21,173 km of pipelines were currently exposed to river flooding. Potable water was most highly exposed with 8,542 km, followed by wastewater (6,912 km) and stormwater (5,720 km).[161,230,231]

Stormwater and wastewater systems are particularly exposed to coastal inundation because both treatment infrastructure and discharge points tend to be at the lowest elevation of populated areas. Their discharges are predominantly at the coast with sensitivity to 0.3 m of SLR.[232] System design limitations and ageing assets increase vulnerability to overflow events, especially during heavy rainfall. Although waste and stormwater systems are generally separate, stormwater often enters the wastewater network either directly by illegal connections or indirectly by seeping into the system through damaged pipes or manholes. This increases the wastewater network's exposure to rainfall. Conversely, when the wastewater systems exceed their design capacity, the overflow is often directed into the stormwater system. Both storm and wastewater systems are typically designed for a 10% annual exceedance probability (AEP) rainfall event (the probability of an event occurring 1 time in any given 10-year period), but many are already under stress. Between 2021 and 2022, there were 3,121 dry- and wet-weather overflows of wastewater nationwide.[233]

Potable water systems are exposed to multiple climate hazards, leading to drought-induced supply issues (which often coincide with periods of high demand) and contamination from waterborne diseases due to rising temperatures among other impacts. For example, data indicates the summer of 2020 had one of the most severe droughts in the Auckland hydrological record, triggering water-use restrictions for the city.[234,235] There is also increased pressure on the treatment system from high sediment loads or decreased water quality due to rainfall.[50]

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By mid-century and the end of the century, climate hazards are projected to intensify

Climate hazards are projected to intensify through the middle and end of the century. For example, for every 1°C of warming, the atmosphere increases its moisture holding capacity by 7–8%.[236] This will place greater stress on water infrastructure and require more coordinated adaptation efforts.

Projected changes in extreme rainfall

Increases in the frequency and intensity of heavy rainfall events, as well as shifts in average rainfall patterns, will likely exceed the design capacity of existing stormwater and wastewater networks, leading to system overloading and reduced performance.[230] Changes in rainfall are expected to have a particularly severe impact on stormwater and wastewater systems and the essential functions they provide.[230] The impacts will range from capacity and service-level impacts to effects on treatment performance and water quality in receiving environments.[231]

The intensity of rainfall events with a 1% AEP is expected to increase nationwide.[237] In the western North Island, the number of days with heavy rain (>25 millimetres (mm)) will rise. For example, in Auckland, a 1% AEP event (an event that occurs once every 100 years currently) is projected to occur about every 60 years by mid-century. By the end of the century, this frequency could increase to every 50 years under low climate impact scenario and every 25 years under high climate impact scenario.[238]

Projected drought and temperature impacts

Dry days during spring and summer are expected to increase in the North Island and eastern South Island, alongside rising average temperatures nationwide. By 2090, drought frequency is projected to rise in eastern regions and decline in the west.[50] These changes in rainfall patterns will reduce potable water supply, while higher temperatures will degrade water quality. Warmer freshwater increases the likelihood of cyanobacteria blooms, which can make some sources unsafe for consumption.[50]

Rural communities face greater health risks from waterborne diseases. Climate change directly relates to the increased transmission of waterborne pathogens due to high temperatures, more extreme rainfall and flooding, droughts and SLR coupled with saltwater intrusion. Compared with urban areas, reported cases of cryptosporidiosis are four to six times higher, and campylobacteriosis two to four times higher. Young children and those in lower socio-economic areas are most affected.[50]

Sea-level rise and coastal inundation exposure

With 60 cm of SLR expected around 2090 under a mid-high climate impact scenario, 15,000 km of pipelines will be exposed to coastal inundation.[161] This will affect all water infrastructure but will have the greatest impact on stormwater and wastewater systems, which are highly sensitive to SLR.

Infrastructure constraints hinder adaptive capacity and may necessitate short-term hazard protection measures

The adaptive capacity of the water infrastructure depends on the ability to maintain or enhance potable water supplies, storage, increase storm and wastewater network capacity, reduce demand for potable water, and reduce inflows and infiltration of stormwater to the wastewater system. Adaptive capacity is also influenced by the ability to maintain biological and chemical treatment processes during temperature spikes.

Water networks are extensive, highly interconnected and often positioned with other infrastructure such as roads. This makes improving the resilience of the infrastructure harder. Technical constraints, especially around wastewater treatment including ageing infrastructure and capacity constraints, limit the range of adaptive approaches that can be deployed and may necessitate short-term hazard defences while long-term solutions are developed.[230,231]

Infrastructure vulnerability is likely to result in equity impacts

The vulnerability of water infrastructure is high due to a combination of factors: exposure (Aotearoa New Zealand's water infrastructure tends to be located in low-lying areas), sensitivity because of deferred maintenance and wear and tear, and limited adaptive capacity due to high costs and complex governance over water assets. This infrastructure vulnerability is not evenly distributed and is more likely to affect populations with existing inequities.[230,231]

Iwi/Māori communities face distinct spiritual impacts and disruptions to tikanga (customs) as climate change increasingly impacts water infrastructure. In rural areas, greater exposure to unsafe water supplies heightens the risk of contamination, which can directly affect marae and papakāinga (communal housing). These disruptions extend beyond physical infrastructure, undermining tikanga and the principles of the now repealed Te Mana o Te Wai policy. However, the health and wellbeing of and from water is still placed at the centre of Māori life. At the same time, many Māori communities, particularly in rural areas, have fewer resources to adapt leaving them unevenly equipped to respond to these challenges compared with other parts of the country.

Compounding and cascading factors

Water systems are exposed to multiple climate hazards

The risks to water infrastructure are complex and have a high potential to compound. These systems are exposed to multiple hazards, such as SLR and extreme rainfall, which interact in ways that amplify impacts, especially in low-lying coastal areas. For example, SLR can exacerbate river flooding by slowing the rate at which the river can drain into the sea, thereby increasing exposure through their combined effects.

Failures in one part of the system can cascade into others; for instance, when wastewater systems fail during extreme rainfall, water contaminates stormwater systems, further affecting flow effects on the freshwater and coastal environment, as well as human health.

Population growth will lead to higher demand and pressure on infrastructure

Population growth will create greater demand for water infrastructure. Aotearoa New Zealand's population is projected to reach about 6.5 million by 2048.[229] This will create greater demand for public infrastructure, including water infrastructure, as towns and cities grow. Depending on where and how this growth occurs, this could either support resilience by growing the number of users able to fund investments, or it may exacerbate climate-related risks to water infrastructure by expanding exposure in hazard zones.[50,229] Areas experiencing growth may benefit from a larger funding base but will also face intensified pressure to expand and upgrade potable water, wastewater and stormwater systems, while regions losing population may struggle to maintain oversized and ageing networks with shrinking revenue. Together, these pressures create an uneven landscape of costs, capacity and resilience, shaping where investment is feasible and where climate-related risks to water infrastructure may deepen.[239]

For more information on population shifts and displacement as a result of climate impacts, see *Social cohesion, community and cultural wellbeing*.

Resilient water infrastructure can help reduce other risks

Resilient water systems reduce flooding impacts by managing excess water to prevent it from overwhelming communities. They increase the capacity of stormwater networks, create safe pathways for water to move, and incorporate features that slow, store, or redirect runoff during extreme rainfall such as detention basins, upgraded culverts and pump stations. Resilient infrastructure can absorb peak flows and decrease system failures, limiting the depth and spread of floodwaters, protecting homes and essential services, and shortening recovery times after storms.[240,241]

Beyond flooding, resilient water infrastructure can help communities withstand a wide range of climate-driven hazards by stabilising water availability, protecting water quality and reducing environmental stress. During droughts, diversified water sources, improved storage and efficient distribution systems maintain supply and reduce pressure on ecosystems and agriculture. In heavy storms, upgraded wastewater and stormwater networks prevent contamination from overflows, safeguarding public health. Coastal protections such as tide gates and elevated drainage outlets reduce the impacts of SLR and storm surge, while well-managed surface water systems lower the risk of erosion and landslides in vulnerable landscapes.

By preventing failures in water systems, communities also avoid cascading disruptions to energy, transport and emergency services, strengthening overall climate resilience.[240,242]

Policy readiness assessment

There is limited climate adaptation in the national water reform

In Aotearoa New Zealand, water services have been largely provided by local authorities (city or district councils) and, less often, by council-controlled organisations or, in a few cases, privately. Major reforms are underway to how water is managed, and present an important opportunity to plan for and embed resilience to climate hazards. In the future, most water services will be provided by water services entities owned by groups of councils.[243]

The central government's water management reform, which is being delivered under the Local Water Done Well policy package, does not explicitly include preparing for the effects of climate change. While the reforms affect how water infrastructure is governed and how water services are delivered, they leave climate adaptation planning to local authorities and asset owners.[244] However, the reforms will affect funding streams and debt for water infrastructure investment, which could be used for resilience. The new water service entities will have higher debt caps, providing them with additional resources to invest in reducing the network's sensitivity and improving services. In the absence of clear direction from the central government, there will likely still be some fragmentation in councils' adaptive capacity.[245]

Outside of the water reforms, there is limited, specific national-level policy to address the risks to water infrastructure posed by climate change. Many individual asset owners and local authorities are planning and investing in adaptation; however, these actions are inconsistent nationally.

The reforms have particular effects on iwi/Māori

A significant change in the reform package is the removal of the requirement to give effect to Te Mana o Te Wai, which previously recognised Māori as a principal partner in water management and required early, meaningful engagement.

The amendment reduces engagement with iwi/Māori to the minimum level required under the Resource Management Act 1991, limiting iwi/Māori participation and influence in decision-making.[244] In the context of climate change, where drought, flooding and declining water quality are placing increasing pressure on already stressed freshwater systems, this shift may reduce the ability of iwi/Māori to safeguard waterways for future generations.

Constraints on service-level adjustments are complex and require more consideration

Water providers (primarily territorial authorities or water service organisations) have limited ability to reduce levels of service outside the mechanisms provided for in the Local Government Act 2002 and, now, the Local Government (Water Services) Act 2025. Decisions about whether water networks can continue to be adapted over time, retain the level of service or ultimately require full or partial retreat will be made primarily by the communities this infrastructure serves.[232] Community expectations for health, volume, reliability, safety and aesthetic standards of water services make it difficult to reduce service levels.[246] These decisions are highly complex; however, there is no clear mechanism to coordinate adaptation action for water infrastructure. The effectiveness of these decisions can be enhanced when made in conjunction with other decisions, such as with related infrastructure and population retreat.[246]

Financial and strategic limitations may prevent upgrades to infrastructure

Without clear guidance, whether it be policy or regulation, from the central government and access to finance, asset owners may lack the options or resources to improve network resilience.[247] Delays in upgrading infrastructure during regular asset renewal cycles may result in increased long-term costs associated with adapting to climate-related hazards. Furthermore, absence of strategic planning around managed retreat may lead to investment in systems that ultimately become stranded assets.[248]

Barriers to individual-level resilience remain

Individuals also face barriers to improving their own resilience. Interventions can be made in buildings, which make it easier to adapt by reducing the burden on water infrastructure. Installing rainwater tanks can support the resilience of buildings by reducing pressure on water supplies and stormwater networks, but depending on size, consenting can be difficult. Furthermore, there is limited informational support for homeowners installing greywater recycling systems.[249]

Gaps for risk severity and policy

There is limited availability of comprehensive nationwide datasets for water infrastructure. Risk analysis could be improved if there were a nationally consistent dataset for water assets.[250] Understanding how the risk to three waters assets is being managed at a national level is challenging, as there is no agency responsible for collecting and aggregating local-level hazard, exposure and vulnerability information. The assessments undertaken by local councils use different methodologies, making comparisons more difficult.

Summary

The impacts of current SLR and extreme weather events on different types of water infrastructure are already occurring, and potable water, wastewater and stormwater systems are increasingly overwhelmed. It is anticipated that this will get much worse in the future. Adaptive capacity of water networks is constrained by technical and financial factors. Choices about how to respond to the effects of climate change sit at a local level, without national policy to provide guidance or coordination about how to approach the risks facing water infrastructure.

In addition to climate hazards, demographic pressures, such as projected population growth, will increase demand for water infrastructure, potentially exacerbating exposure in hazard zones. Infrastructure vulnerability is not evenly distributed and is more likely to affect populations already experiencing social and economic inequities. Iwi/Māori communities face distinct spiritual impacts and disruptions to tikanga (customs, lore) as climate change increasingly impacts water infrastructure.

Furthermore, the interconnected nature of water systems means failures in one part of the network can cascade into others, amplifying impacts during extreme events. Without strategic planning, including consideration of managed retreat and investment prioritisation, there is a risk of creating stranded assets in areas increasingly exposed to climate hazards.

Risk scorecard: Water infrastructure

Risks to potable water, wastewater and stormwater infrastructure due to progressive and ongoing changes in temperature and precipitation, sea-level rise and increased extreme weather events.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Major	Water infrastructure is highly exposed to climate hazards, and highly vulnerable due to its degraded state. There are already measurable impacts on system performance and public health.
2050	Extreme	By mid-century, with climate hazards projected to intensify, there will be extreme stress on water infrastructure, which will be increasingly overwhelmed. Projected changes in extreme rainfall, drought and extreme heat, SLR and coastal inundation will severely impact the system. Short-term hazard defences will likely be required.
2090*	Extreme GWL 2	
	Extreme GWL 3–3.5	
Policy readiness		
Overall assessment	Significant gaps	There is limited climate adaptation integrated into the national water reforms, leaving local authorities and asset owners to lead adaptation planning. Key gaps persist, including the lack of a mechanism for water providers to adjust or reduce service levels in response to climate pressures. Without clear national guidance and reliable access to finance, asset owners may not have the options or resources needed to strengthen network resilience.
Cascading risk		
Overall assessment	High	Addressing this risk has high overall potential to address others, including the risks to buildings, coastal ecosystems, freshwater ecosystems, central and local government funding, road and rail networks, ports and airports, physical health and waste infrastructure.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Buildings

Risks to buildings due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like flooding and wildfires.

Buildings in Aotearoa New Zealand face increasing risks from climate change, which manifest through both acute hazards, such as extreme weather events including drought and wildfires, and progressive and ongoing changes like rising average temperatures and sea-level rise (SLR). These hazards threaten not only the structural integrity of buildings but also their performance, particularly in terms of temperature regulation and liveability.

The risk to buildings is significant because they serve essential societal functions. They provide shelter as homes and commercial businesses, enable access to healthcare and amenities, and support cultural and community expression. When climate-related hazards compromise a building's structure or performance, its intended use may be disrupted. For example, damage to a hospital could hinder its function as a medical facility, with cascading impacts on public health. Additionally, for many people their home is their greatest asset, and loss or significant damage can threaten their financial and psychological security. These disruptions have the potential to reverberate across social and economic systems. See the risk analysis on *Mental health* for more information.

This was identified as one of the most significant risks

The risk to buildings is rated at major severity by 2050, and has a cascading risk score that indicates actions to address it have high or very high potential to address other risks. This satisfied the third principle of our review for significance: it presents high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. For more, see the separate write-up of this significant risk in the Priorities for action report.

Risk overview

Buildings are currently exposed to climate-related hazards, which can impact their structure and performance

Buildings across Aotearoa New Zealand are currently exposed to a wide range of climate-related hazards that threaten both their structural integrity and performance. These hazards include coastal inundation and erosion, landslides, soil erosion and wildfires. One of the most significant hazards is extreme weather events, which include wind, rain and flooding – both river (fluvial) and surface water (pluvial). Progressive and ongoing hazards include rising average temperatures and SLR.

Nationally, approximately 49,700 buildings are exposed to coastal inundation.[251] Inland flooding is even more widespread, impacting over 556,000 buildings (16.2%, worth a total of

NZ$235 billion), with Canterbury, Wellington, Manawatū, Whanganui and South Dunedin particularly exposed.[18,252]

Groundwater flooding is a pressing issue in South Dunedin, where nearly one third of buildings are exposed, while landslides have historically impacted the Hawke's Bay region the most.

Heatwaves and rising average temperatures also pose growing challenges to building performance and liveability across the nation.[18,253-257] Overheating in buildings can impact the comfort of inhabitants, affecting health and wellbeing, especially if sleep is degraded. In extreme cases, heat stress from overheating in buildings can lead to premature mortality, especially among more vulnerable members of society.[258] For more information, see the *Physical health* risk analysis.

By mid-century, exposure intensifies, especially in low-lying regions. For example, Wellington currently has around 4,000 buildings exposed to coastal inundation and SLR hazards. Modelling indicates by 2050 approximately 4,800–5,200 Wellington buildings will be exposed (a 20–30% increase) as SLR and land subsidence continues.[259]

Box 3.2: South Dunedin case study

South Dunedin faces escalating groundwater threats, with up to 78% of buildings at high or medium exposure by 2060, including nearly one third highly exposed under a very high warming scenario (SSP5–8.5). These changes reflect the compounding effects of SLR, more frequent extreme rainfall and rising temperatures, which together increase both flooding hazards and the strain on building comfort and resilience.[254,257]

Half of the buildings currently face moderate or high risk of exposure to surface flooding. By late century in South Dunedin, risks become extreme under very high warming scenarios. More than 80% of buildings could be exposed to both coastal inundation and groundwater flooding, with nearly half highly exposed. Surface water flooding could affect over 60% of buildings, with more than one third highly exposed under moderate warming, and nearly half under severe warming. Overall, by 2100, the combined impacts of SLR, intensified rainfall and groundwater pressures create widespread and severe threats to building stock, particularly in exposed coastal and low-lying regions.[254,257]

The Commission acknowledges the proactive and extensive work of the South Dunedin Future programme, which recognises the need to adapt in an inclusive and meaningful way.

The level of exposure of buildings varies across regions

The level of exposure of buildings to climate-related hazards varies across districts and regions. For example, in the Otago region, approximately 5,650 buildings are exposed to coastal inundation.[256] In Auckland, around 127,590 buildings are exposed to inland flooding, with about 16,000 of those exposed to inundation of the first habited floor during a 1%

annual exceedance probability (AEP) coastal inundation event (an event that has a 1-in-100 chance of happening in any given year).[260] In the West Coast, 30.9% of buildings are currently exposed to a 1% AEP rainfall flood event, whereas in Taranaki 7.9% are exposed.[252]

Exposure is expected to increase significantly in some areas

While national exposure of buildings is expected to increase moderately, some regions will experience significant changes. For example, national exposure to a 1% AEP flood event is currently 16.2%, increasing to 18.6% under about 2°C of warming.[252] However, in the Hawke's Bay region exposure to a 1% AEP flood event will increase from 22.3% of buildings currently to 32.4% under about 3°C of warming.[xxii,252]

Under about 4°C of warming, national exposure to a 1% AEP flood event is estimated to increase to 19% of buildings, representing a total value of NZ$288 billion.[252] In areas like the West Coast and Hawke's Bay, this will increase from 30% to 35% and 22% to 34%.[20] In the Tasman and Gisborne regions, there will also be significant increases of exposure under about 3°C of warming from 20% to 27% and 22% to 28%.[xxiii,252]

There is significant variation in regional, community and individual sensitivity and adaptive capacity

Sensitivity and adaptive capacity vary across regions, communities and individuals.

- **Building factors**: Age, design and foundation type affect vulnerability. For example, buildings with concrete foundations cannot be easily relocated or raised.
- **Individual factors**: Access to financial resources determines whether individual building retrofits or improvements are feasible.
- **Community impacts**: Flooding of critical infrastructure, for example hospitals, can disrupt access to healthcare and essential services, with cascading social and economic consequences.

The level of exposure in some regions will mean adaptive capacity is very low as the level of exposure is likely beyond what can be managed. For example, in South Dunedin, it is

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[xxii] Throughout this paragraph, the original data for this level of warming was calculated using an "additional warming" approach, which measures temperature increases on top of the warming the climate has already experienced (approximately 1°C above pre-industrial levels). To make this clearer and consistent with the rest of the risk assessment, the Commission has converted additional warming into warming relative to pre-industrial. As a result, a projection of 2°C of additional warming is presented as about 3°C total warming, for example, reflecting that approximately 1°C of warming has already occurred.

[xxiii] Throughout this paragraph, the original data for this level of warming was calculated using an "additional warming" approach, which measures temperature increases on top of the warming the climate has already experienced (approximately 1°C above pre-industrial levels). To make this clearer and consistent with the rest of the risk assessment, the Commission has converted additional warming into warming relative to pre-industrial. As a result, a projection of 2°C of additional warming is presented as about 3°C total warming, for example, reflecting that approximately 1°C of warming has already occurred.

expected that in 2100, a very large proportion of buildings will be exposed to ground water flooding.[261]

For communities and regions hit hardest by climate change, the people living and working in the buildings most exposed to these hazards feel the consequences first. Extreme heat, for example, will affect regions differently, and some areas will be better equipped than others to limit its impacts. Across Aotearoa New Zealand, the East Coast of both the North and South Islands is projected to experience the highest absolute temperatures during local heatwaves. In the northern half of the North Island, lower day-to-day temperature variability means that even small increases in warming over the 21st century will translate into disproportionately higher risks for building occupants.[6]

Engineering thresholds may be exceeded by climate-related hazards within the next few decades, particularly in flood and coastal inundation zones

Engineering thresholds are typically based on assumptions about maximum water levels, wave heights and flood recurrence intervals. The impacts of climate change increase uncertainty for these assumptions. SLR, more frequent extreme rainfall and storm surge, and coastal inundation and erosion pose threats to buildings, even if they are designed to withstand 1-in-100-year events. As Aotearoa New Zealand experiences these conditions more often, eventually a building's engineered limits will be surpassed.[262]

Modelling also suggests that future climates could include tropical cyclones, which could produce winds that exceed the design thresholds in the building wind code.[263] Design wind speeds could be exceeded, especially in already high-wind regions like coastal headlands, ridges and funnelling valleys. Local topographic speed-up (hills, escarpments, gaps) could amplify those winds beyond what standard wind zones assume.[264]

Risks to iwi/Māori include locations exposed to flooding and coastal erosion and inundation

The location of many iwi/Māori communities in exposed coastal areas and climate change-induced pressures will challenge the capacity of some iwi/Māori to adapt.[18] Historically, many marae have been positioned in locations where it was easy to access kaimoana (seafood) and to engage in trade and transport with other hapū and iwi, which corresponds with low-lying coastal land. This proximity to the ocean makes marae and associated urupā (burial grounds) exposed to coastal inundation and erosion. A 2021 study quantified the number of coastal marae: 191 are situated within 1 km of the coast. Of these, 6 marae are currently exposed to a 100-year extreme sea level (ESL) event.[153]

Risk to buildings may affect connectivity to whenua (land) and the foundation of tūrangawaewae (a place to stand, where there is belonging through rights of occupation and whakapapa), with both direct hazard impacts and indirect consequences from adaptation measures like relocation.[18] When repeatedly damaged, these sites can lose their functional capacity to host community gatherings, coordinate emergency response or maintain tikanga (customs, lore). Repeated disruptions may lead to the erosion of intergenerational knowledge transmission and tikanga-based governance. For more information, see *Damage to Māori infrastructure*.

Papakāinga (communal Māori housing) developments offer a promising model for resilience. For example, a Whakatāne-based initiative includes houses with solar photovoltaic (PV) systems, batteries and a shared electricity grid. Each home is capable of generating 35 kilowatts of electricity a day. This development also includes shared facilities and wraparound services.[265] Not only do these developments support community living and connection, but they will also likely prove resilient to extreme weather events and other climate-related impacts.

Moreover, marae play a vital role in climate change emergency response because they are trusted community hubs where people naturally gather for safety, information and support. Their cultural significance strengthens social cohesion, which is essential when coordinating evacuations, distributing resources or caring for displaced whānau (families). Many marae already operate as emergency shelters, combining local knowledge with practical infrastructure to respond quickly and compassionately during crises. In a changing climate, their role as resilient, community-led response centres becomes even more important.[175]

Compounding and cascading factors

The risks to buildings are likely to be deepened by a wide variety of social and economic factors

There are cascading risks to buildings in Aotearoa New Zealand, which reflect the deep interconnectedness between buildings, society and the economy. Damage to buildings, whether residential, commercial or critical infrastructure, can disrupt access to essential services such as healthcare, education and retail, with cascading impacts on public health, economic activity and community wellbeing. Damage to healthcare facilities, such as hospitals and general practice clinics, can hinder access to essential services, exacerbating physical and mental health challenges, especially during climate-related emergencies.

For many people, their home is their main financial asset and around two thirds of households own their home.[266,267] This means that risk to residential buildings can be a fundamental risk to financial security and mental health. Moreover, insurance is becoming more expensive and more tightly tied to location as climate risks increase. Insurance retreat appears to have already started for some properties at high risk.

A significant factor is the shift towards risk-based insurance pricing

While residential insurance remains generally available, even in highly exposed areas, affordability is declining for many property owners. The Reserve Bank notes that a withdrawal of insurance availability for high-risk properties is likely to occur only gradually, but there is a clear trend of insurers moving towards a greater use of risk-based pricing for residential property insurance. In general, a long-term trend towards risk-based pricing poses challenges for insurance availability and affordability for higher risk properties.[268] For more information on insurance, see the *Insurability of assets* risk analysis.

Populations with social vulnerability face disproportionate climate-related risks

Regions where social vulnerability overlaps with high building exposure face disproportionate climate-related risks. One assessment shows that Napier City currently has 12.8% of its population containing characteristics that might make them vulnerable,[xxiv] while Gisborne has less than 1%.[228] Under 1.0 m SLR (likely to be reached around 2100 under a mid-range emissions scenario), Buller District's population with characteristics that might make them vulnerable could jump from 8.2% to 31.7%,[228] compared to less than 10% in Tauranga.[228] These inequities highlight the urgent need for targeted adaptation in areas where vulnerability and exposure are high.

Individuals with limited financial resources may also be unable to afford repairs, retrofits or insurance, increasing their vulnerability to climate-related hazards. This economic strain can lead to long-term displacement, loss of livelihoods and reduced adaptive capacity.

Buildings are highly interconnected to other aspects of the built environment. For example, risks to road and rail networks could compound risks to buildings, as they could further prevent access and/or use of buildings.

Interaction with emissions reduction

Aotearoa New Zealand has a put a strong emphasis on electrification as part of its efforts to reaching net zero emissions by 2050. To manage the resulting increase in electricity demand, energy efficiency is pivotal. In the context of buildings, there are several opportunities for energy efficiency, such as energy-efficient appliances or design features like warm roofs, which can go hand in hand with adaptation as they improve ventilation and reduce overheating risk. Making use of distributed renewable energy resources such as solar panels is a further opportunity. Implementing these measures not only reduces emissions but also enhances the adaptive capacity of buildings. For instance, solar panels paired with battery storage can improve energy independence, ensuring buildings retain access to electricity during network outages.

Policy readiness assessment

There are some national-level policy actions in place to address risks to buildings

The Government has included actions in both the emissions reduction plan and national adaptation plan that directly address risks to buildings. For example, Aotearoa New Zealand's second emissions reduction plan outlines measures to make it easier for people to retrofit their buildings.[269] Retrofitting can involve measures to improve the resilience of

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[xxiv] The Urban Intelligence report details this evidence as the total percentage of their usually resident population at risk of direct exposure under present-day conditions as a percentage of their total population.

buildings. The national adaptation plan also includes specific actions that aim to update regulatory requirements to ensure buildings are designed and constructed to withstand more extreme climate hazards.[270] These actions are currently active with the goal of having property-level research complete and aspects of the Building Code identified for updating by 2026 and a regulatory framework in place to update minimum building standards by 2028.

There are also local government and regional initiatives

At the local level, local and regional councils are working to better understand the specific risks buildings in their districts/regions face. Around 15 local/regional councils have produced district/regional climate change risk assessments, which quantify some risks to buildings in the area. Examples include the Hawke’s Bay Climate Change Risk Assessment and the Southland Climate Change Impact Assessment.[271,272] However, it is unclear how these might translate into subsequent adaptation action on the ground. Local governments face significant capability and funding challenges in managing climate-related risks to the built environment, including buildings and infrastructure, and current institutional arrangements make adaptation difficult.[270]

Within the private sector there is also substantial work underway

Organisations such as the Building Research Association of New Zealand (BRANZ) and the New Zealand Green Building Council (NZGBC) are actively contributing to understanding and addressing building-related risks. For instance, concerns about overheating following the 2021 H1 insulation changes prompted the Ministry of Business, Innovation and Employment (MBIE) to commission BRANZ to conduct research. It was found that overheating is affected by various building design factors, and the Building Code currently lacks performance standards for overheating. Work is ongoing to respond to the findings.[273] For more information on the growing risk to physical health from heatwaves and other climate-related hazards, see the *Physical health* risk summary.

The Government has recently made legislative changes

The Resource Management (Consenting and Other System Changes) Amendment Act 2025 strengthens councils’ ability to decline consents or impose conditions on new developments in hazard-prone areas.[274] This will act as an interim measure to help regions avoid developing in hazard zones until wider resource management reforms are implemented, though it is too soon to know how local authorities are applying it or the impact it is having in practice. For example, in the year since devastating flooding in Auckland in 2023, 1,415 new housing consents have been granted in flood plains. That is more than 10% of all new Auckland homes consented in that time.[275]

The Emergency Management Bill and Planning Bill also present opportunities to enable areas at risk of climate hazards to be avoided. However, currently the Emergency

Management Bill does not mention climate change and the Planning Bill does not link to adaptation plans.

Shifting approaches to compensation could have social and economic impacts

The Government has indicated it will shift from direct compensation towards measures that address genuine hardship.[276] An independent reference group, established to test policy options, provided recommendations on Government proposals on matters such as property buyouts in high-risk areas (enabling managed retreat), and there have been indications that future policies may reflect risk signals more accurately in the market.[168] No final decisions have been made. When they are they could have significant social and economic impacts. Any resulting policy could have a significant impact on lock in of risks to buildings, including where and how rebuilding occurs, shaping exposure and potentially entrenching vulnerabilities.

Significant barriers to action and effective adaptation remain, including lack of knowledge and legislative gaps

Despite these efforts, significant barriers to effective adaptation remain. These include a lack of awareness and understanding of sustainable design principles, and a lack of mandatory requirements. Current actions and policies do not address these barriers.

A key shortfall is that the Building Act 2004 and associated Building Code do not adequately account for climate change.[263] As foundational pieces of the legislative aspects of buildings, this gap presents a significant risk for locking in vulnerabilities. It is also unclear how the Building Act 2004 will interact with the recent Resource Management (Consenting and Other System Changes) Amendment Act 2025, particularly regarding building in areas exposed to significant natural hazards. Alignment between these legislative frameworks is important.

Even with action, some level of risk is likely to remain, and managed retreat is likely the best option in some places

The nature of some buildings and the level of exposure in some locations means some risk is going to remain, despite protection and accommodation action. In some cases, such as buildings with concrete foundations or in entire communities like South Dunedin, exposure levels may exceed what is manageable, even with targeted resilience measures. Managed retreat from some areas may be necessary, or be the only viable option, but there is currently no framework, guidance or funding to support this. See the *Risk to social cohesion, community and cultural wellbeing* for more information.

Gaps for risk severity and policy

It remains unclear what climate-resilient building design should look like in the Aotearoa New Zealand context, and, in turn, what kind of building code framework is needed to support more resilient, future-proof structures. While exposure data for inland flooding and coastal inundation is readily available, information on other climate-related hazards, such as wildfires, landslides and erosion, is less developed. Even where data does exist, it is often difficult to access, with financial barriers limiting the ability of individuals and organisations to obtain it. The way public research organisations are currently structured further restricts the accessibility and sharing of this information. Moreover, research is needed to determine how financial institutions and government authorities can support the financing of adaptation measures.[18]

At the time of writing there is little publicly available information regarding the Resource Management (Consenting and Other System Changes) Amendment Act 2025, to clarify and strengthen councils' ability to decline land-use consents or impose relevant conditions where there is significant natural hazard risk.[274] There are also gaps around the capacity and capability of the construction workforce to respond to the impacts of climate change, such as heatwave impacts on labour productivity.

Summary

Buildings play a vital role in Aotearoa New Zealand's social and economic systems, and the risks they face from climate change are already significant. These risks are expected to increase over time, moderately at the national level, but substantially in certain regions. The ability to respond effectively is highly dependent on the level of exposure, the characteristics of the building and individual or community circumstances.

While national-level policies such as those in the emissions reduction plan and national adaptation plan directly address some risks to buildings, a residual level of risk is likely to remain, despite action. This presents a major challenge that Aotearoa New Zealand is not yet prepared to manage. Current policies do not sufficiently address key barriers to adaptation, such as gaps in sustainable design awareness, legislative misalignment, data accessibility and lack of mandatory resilience standards. They also do not close data gaps identified in previous assessments.

Without coordinated national action, these shortfalls could lock in vulnerabilities and exposure, and could result in serious social and economic consequences.

Risk scorecard: Buildings

Risks to buildings due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like flooding and wildfires.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Buildings are already experiencing increased exposure to hazards, which is impacting their structure and performance. Continued development in highly exposed areas is increasing vulnerability.
2050	Major	Exposure intensifies, especially in low-lying and flood-prone areas. Likely that some communities will need to fully relocate due to escalating risks.
2090*	Extreme GWL 2	By 2090 adaptive capacity will be very low in some regions as the level of exposure is likely to be beyond what can be managed. Under both scenarios the impacts of climate change are expected to require relocation or extensive protection (including physical adaptation of existing buildings) for some communities.
	Extreme GWL 3– 3.5	
Policy readiness		
Overall assessment	Significant gaps	Due to workforce limitations, inadequate legislative coverage and continued development in hazard-prone areas, overall readiness remains significantly constrained.
Cascading risk		
Overall assessment	Very high	Addressing this risk has very high overall potential to address others in the assessment, including the risks to the stability of the financial system, central and local government funding, insurability of assets, mental health, physical health, water infrastructure, social cohesion, social infrastructure and community services, and tourism.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Road and rail networks

Risks to road and rail networks due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Climate change poses significant risks to Aotearoa New Zealand's road and rail transport networks, which enable the movement of people and goods and provide access to lifeline utilities such as airports, ports, electricity, telecommunications and water infrastructure. These networks are critical for national connectivity and economic activity. Elements of road networks include roadways, bridges, tunnels, pavement, drainage systems and corridors. Rail networks include railway lines, sleepers, ballast, overhead lines and service paths.

The risk to road and rail networks arises from more frequent and intense extreme weather events, and ongoing sea-level rise (SLR). These hazards can cause temporary disruption, permanent damage and, in some cases, necessitate relocation of infrastructure. The first national climate change risk assessment identified this risk as major.[26] Since then, new evidence shows increasing exposure and vulnerability, particularly in flood-prone areas and regions already facing socio-economic challenges.

This was identified as one of the most significant risks

The risk to road and rail networks is rated at major severity by 2050, and has a cascading risk score that indicates actions to address it have high or very high potential to address other risks. This satisfied the third principle of our review for significance: it presents high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. For more, see the separate write-up of this significant risk in the Priorities for action report.

Risk overview

Road and rail transport networks enable national connectivity

Road and rail systems are essential for moving people and goods around Aotearoa New Zealand. They also provide access to lifeline utilities such as airports, ports, electricity, telecommunications and water infrastructure. Road and rail disruption has cascading effects on economic resilience and community wellbeing.

Road and rail transport networks are already exposed to climate hazards, especially floods and landslides

Flooding and landslides caused by extreme weather events are the most consequential hazards affecting linear transport networks.[277] Around 19% of the road length is exposed to a 1% AEP flood event (a flood that has 1-in-100 chance of occurring in a given year). Over 1,500 kilometres (km) of railway (over a third of the network)[278] and 26,800 km of roading (over a quarter of the network) are currently exposed to flooding.[251,279] Coastal exposure is significant, with an estimated 2,100 km of road network within the 1–1.5 m elevation zone, so will likely be exposed to SLR, coastal inundation and erosion.[280] Between 2004 and 2008, there were 78 recorded events of railway tracks buckling due to extreme heat.[281]

Climate-related disruptions are costly and long-lasting

Recent events illustrate the scale of impact. For example, primarily as a result of landslides, around 0.2% of the road network was impacted by the 2023 storm events in Auckland, costing approximately NZ$390 million to repair,[282] with works continuing more than two years later.[283] This demonstrates that, despite the relatively low area of network being impacted, even small percentages of network damage can result in major financial and social consequences.

These hazards will intensify by mid-century and the end of the century, requiring relocations or closures

By 2050, vulnerability of road and rail networks is heightened as exposure to landslides, flooding, hot days, coastal erosion and inundation, and increased intensity and frequency of storm and wind events is projected to increase.[284]

Under a high climate impact scenario by 2090, 2,710 km of roads and 180 km of the rail network are projected to be exposed to coastal inundation.[285] This escalation underpins the shift from a major to an extreme risk rating, coupled with the projected intensity and frequency of extreme weather events and SLR. These hazards will necessitate the relocation or closure of some linear transport infrastructure. For example, several roads in New Brighton, Christchurch, are projected to see significant disruptions where access may be lost under 0.5 m of relative SLR (under Shared Socioeconomic Pathway (SSP) scenario 2–4.5 (median) at 2090).[286]

Regional vulnerability is uneven, and some areas are already experiencing issues from climate extremes

Levels of exposure, sensitivity and adaptive capacity of the road network differ, with some regions facing heightened levels of vulnerability. All Aotearoa New Zealand regions contain a range of road types located within the 0–3 metres (m) coastal elevation zone, but often already socio-economically less advantaged regions are facing the brunt of climate extremes. Canterbury currently has the greatest level of exposure with over 3,900 km of roads within the 0–3 m elevation zone (out of ~16,000 km), followed by Waikato with 2,500 km.[162]

Torrential rain in Mangamuka, Te Taitokerau/Northland, caused surface flooding that closed State Highway 1 for more than two years, isolating communities and disrupting freight routes.[287]

Regional variations in the levels of railway exposure and sensitivity are also evident. Across all regions, railway track segments situated within 0–3 m of mean high-water amount to nearly 73 km (out of ~400 km); a significant portion of the network exposed in low-lying coastal areas. Hawke's Bay has the longest length of railway tracks in the coastal elevation zone (~19 km) followed by Bay of Plenty (~10 km) and Canterbury (~8 km).[162]

Adaptive capacity varies by location and road ownership

Resilience depends on factors such as alternative access routes, road classification (national, local, private) and funding availability. Mountainous, coastal or island communities may rely on one road for all access. If that road is damaged, the entire community may be cut off, delaying emergency response and recovery and access to essential services like healthcare and supermarkets. For example, Cape Palliser Road is the only access route connecting Ngawi to the wider Wairarapa region and, of the 35 km road, 16 km of it leads to Ngawi along the coastline, which is already experiencing significant erosion.[288]

National roads typically receive more funding and maintenance and are prioritised during recovery efforts, so tend to be more resilient. However, local and private roads, which receive limited funding, may not be maintained to the same standards and are less resilient. Underfunded areas may lack the resources to build resilient infrastructure or respond quickly to damage.[289]

Iwi/Māori communities face heightened isolation risk from road closures

Risks to road and rail networks will significantly affect iwi/Māori, related to the geography in which Māori live, work and own assets. The Commission heard iwi/Māori perspectives on this during case study visits to Te Taitokerau/Northland. Further detail is available in the Te Taitokerau/Northland case study report.[290]

About 25% of iwi/Māori live in rural areas, and iwi/Māori comprise one-third of those who live in the most remote areas of Aotearoa New Zealand[291] where road closures sever access to essential services. This creates disruptions to the ability of iwi, hapū and whānau to connect with whenua (land).

A high proportion of the Tairāwhiti Gisborne population is Māori and the region is exposed to extreme precipitation as a result of storm events, with five instances in one year (2021–2022) of road and bridge damage, isolating communities.[292] Post-Cyclone Gabrielle, almost all rural roads were closed, with closures lasting weeks, leaving communities isolated for this period and disrupting pakihi (business/trade) through the inability to get goods to market. Restoration works are costly and ongoing two years later. Gisborne District Council notes that the total cost to restore the local roading network to its pre-cyclone condition has been assessed at NZ$465 million. However, to build back stronger and more resilient, the total cost is estimated to be NZ$725 million.[293]

Infrastructure thresholds for heat, rainfall and storms are already being tested

There are clear engineering and performance thresholds that linear infrastructure design will not withstand. Design limits for heat, rainfall and wind events are increasingly being tested. There are no publicly available data specifying the exact number of railway line closures due to climate-related extremes in Aotearoa New Zealand. However, heat restrictions and disruptions caused by high temperatures are a recurring issue, especially during summer months. In 2024, the main cities of Auckland and Wellington both saw train cancellations due to railway line heat stress, impacting people's ability to access the city centre and commuters' ability to access their workplaces.[294,295]

Additionally, more than 200 points of damage have been recorded (including a major slip north of Helensville) on the Te Taitokerau/Northland branch of the main freight railway line following Cyclone Gabrielle and the Auckland Anniversary events of 2023.[296] Questions about the affordability of repeated repairs are becoming central to adaptation planning.

Compounding and cascading factors

Multiple hazards amplify disruption to linear transport networks

Climate change events do not occur in isolation. Extreme rainfall, landslides and coastal inundation often occur in quick succession, compounding impacts on road and rail networks. When one hazard damages infrastructure, recovery delays increase vulnerability to subsequent events. For example, isolated communities in the outer Marlborough Sounds were cut off by landslides for at least six months in 2021[297] and were impacted again by extreme weather events in 2022 and 2025.[298]

Essential services are also compromised, including electricity, water and internet services

The core cascading risk is that climate-driven damage to one part of the road and rail transport network can rapidly generate widespread, multi-sector disruption because these systems lack redundancy and are tightly interdependent. For example, a single landslide can cut off communities for days, disrupt freight and force detours of hundreds of kilometres, amplifying economic losses.

Moreover, when road access is lost, access to maintenance and repair of other critical services such as electricity, water and internet connectivity are often disrupted. This is due to these services running within or alongside roadways, impacting productivity and general access if damaged. This interdependency means transport outages can cascade into broader infrastructure failures, compounding challenges for isolated communities and slowing recovery efforts.[228]

Prolonged recovery magnifies impact, especially for vulnerable populations

Prolonged transport disruptions leave households and businesses exposed to repeated losses. Extended closures force detours and inefficient routing. These indirect effects escalate maintenance and repair costs and strain resilience across the economy.

The consequences are especially pronounced for populations who lack alternative transport options, such as low-income groups, the elderly, women and people with disabilities, who could then face heightened barriers to accessing healthcare, employment and education.[299-302] Climate-induced transport outages exacerbate existing inequities, particularly for women, who can face distinct mobility challenges related to safety, affordability and accessibility. In this way, climate change not only stresses physical infrastructure but also magnifies social inequities, reinforcing systemic vulnerabilities that compound over time.[303]

Interaction with emissions reduction

Climate mitigation initiatives can enhance adaptation efforts. For example, the Ngā Ūranga to Pito-One section of Te Ara Tupua in Wellington combines coastal protection with active transport infrastructure. The project creates a resilient coastal edge to safeguard the coastal road and rail assets while also providing a walking and cycling path between Wellington city and Lower Hutt. Future mitigation measures, such as cycle lanes integrated into seawalls or electrified rail upgrades, could further reduce emissions while improving resilience to inland flooding and coastal inundation and erosion.[304] In combination, these approaches reduce the risk of embedding exposure to future hazards within the infrastructure system while strengthening alignment with long-term emissions reduction and adaptation goals.

Policy readiness assessment

There are foundations in place, but implementation lags behind

Aotearoa New Zealand has established a policy foundation for addressing climate change risks to its land transport infrastructure through the New Zealand Transport Agency Waka Kotahi (NZTA) Climate Change Policy for Land Transport Infrastructure Activities. This policy embeds climate-related hazard considerations into planning, design, construction and maintenance of transport infrastructure, but its mandatory application is limited to NZTA-led projects. Local councils may adopt it voluntarily, creating inconsistency in implementation. There is currently no direct funding or financing mechanism for local government to support adaptation activities, which limits the policy's practical outcomes.[305]

Adaptation planning signals ambition, but there are limitations

NZTA's climate adaptation plan, Tiro Rangi: our climate adaptation plan,[306] a key action from the national adaptation plan, sets 2050 as the goal for a resilient land transport system that enhances wellbeing and liveability. It outlines foundational actions such as improving risk understanding, embedding adaptation into investment decisions, ensuring evidence-based planning and integrating te ao Māori perspectives. However, for transport infrastructure, investment in resilience is not aligned with the scale of risk.

The Roads of National Significance initiative presents a potential opportunity to enhance adaptive capacity, especially if new roads are designed with resilience in mind. Publicly available information does not clearly indicate how much of a priority resilience is, but it is considered. The impact of these roads on network resilience will depend heavily on their location and usage, as well as whether regional roads are similarly considered in resilience planning.[307] An example underway is the Northland Corridor (Brynderwyn Hills) initiative.

Endorsed by NZTA, this project aims to deliver a long-term solution to improve resilience during extreme weather events, while also enhancing productivity and supporting future housing development.[308]

Local and regional councils are carrying out their own climate risk assessments, with some incorporating adaptation strategies. Councils such as Christchurch City, Waikato Regional, Otago Regional, Bay of Plenty Regional and Auckland Council are leading efforts to identify vulnerabilities in road and rail networks, including landslides, buckling rail lines and loss of road access. Auckland Transport, for example, has implemented a Climate Change Technical Policy that requires climate hazards to be considered in infrastructure design.[309]

Despite these promising initiatives, the lack of consistent central government policy and funding and financing support continues to hinder widespread implementation.

Barriers such as funding and financing limitations, inconsistent uptake and gaps in planning slow effective action

Key barriers include a lack of dedicated funding and financing streams for local adaptation, inconsistent uptake of climate policies and gaps in governance and long-term planning.[310-312] These challenges delay action and threaten locking in vulnerability. Addressing these barriers involves integrated planning, cooperation across sectors and ongoing investment in both physical infrastructure and knowledge systems. Moreover, there are no specific policies addressing the unique impacts of this risk on iwi/Māori communities.

Urgency is required for coordinated national action

Aotearoa New Zealand faces a critical window to avoid locking in climate-related risks to its road and rail networks. Continuing to invest in and support major transport infrastructure in areas increasingly exposed to natural hazards reinforces development in these locations. This not only perpetuates future exposure but also diminishes opportunities to build resilience into the transport system. Coordination and the commencement of long-term planning could occur relatively quickly but would require a shift away from business-as-usual practices.

A strategic regulatory and planning shift in how infrastructure is sited and developed is important to prevent escalating future costs and repeated damage. Although maintenance and repair activities for linear transport are funded through the Government Policy Statement for Land Transport, these interventions would enhance adaptation outcomes if they embed resilience from the outset. Without this, there is a chance of repeated damage from extreme events and escalating future costs.[313]

Gaps for risk severity and policy

Several of the data gaps listed under the built environment domain in the first risk assessment and relevant to road and rail networks remain. These include consistent hazard information at a national scale, interdependencies and interactions between infrastructure sectors, and limited data sharing between road controlling authorities and network utility organisations. While flooding and SLR data is comparatively robust, other hazards remain under-researched. For example, national evidence of the number of railway line buckling events and the disruption they cause is lacking.

For policy readiness, data gaps include high resolution and updated infrastructure locations, conditions and vulnerability to inform resilience priorities; uncertainty and variability in climate change projections at the localised level to enable localised policy interventions; and difficulty in assessing parts of the network following natural hazard events for policy response.[281]

Summary

Road and rail networks in Aotearoa New Zealand are increasingly exposed to extreme weather events such as storms and heatwaves, and associated impacts such as flooding and rainfall-induced landslides. They are also exposed to SLR-induced coastal erosion and inundation. These hazards have caused costly and long-lasting disruptions, even when only small portions of the network are affected. Under higher warming scenarios, exposure to coastal inundation, inland flooding and other hazards will increase significantly by mid-century and the end of the century, especially in low-lying and coastal regions, driving the risk from major to extreme.

While Aotearoa New Zealand's national policies and actions articulate a vision for climate adaptation in transport infrastructure, implementation remains uneven and under-resourced. Current frameworks lack dedicated funding and financing streams and consistent local implementation. Without accelerated action, critical transport networks will remain vulnerable to climate-related disruptions, and the gap between policy ambition and practical resilience will persist.

The upcoming six years before the next risk assessment represent a critical window to avoid locking in vulnerability. Addressing this risk involves integrated planning and the prioritisation of resilience in infrastructure investment. Without these steps, escalating costs, repeated damage and social inequities will compound over time.

Risk scorecard: Road and rail networks

Risks to road and rail networks due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Infrastructure is already highly exposed to flooding and landslides. Some regions and communities are more exposed than others and are already experiencing disruptions, resulting in short-term isolation. Extreme heat is a concern for rail.
2050	Major	Widespread short- to medium-term disruptions are expected as the frequency and intensity of extreme weather events increases. Levels of service may change. Disruptions are likely to reinforce existing inequities, particularly for rural communities.
2090*	Extreme GWL 2	Increasing extreme weather events are likely to stretch capability to respond and recover network capacity. Severe floods and landslides may cut off communities and take considerable time to repair. SLR, coastal erosion and coastal inundation may severely impact coastal road and rail assets.
	Extreme GWL 3–3.5	
Policy readiness		
Overall assessment	Significant gaps	There are foundations in place, including the Climate Change Policy for Land Transport Infrastructure Activities, but implementation does not align with signalled ambition. Barriers delay action and threaten to lock in vulnerability.
Cascading risk		
Overall assessment	High	Addressing this risk has high overall potential to address others in the assessment, including the risks to electricity and telecommunications infrastructure, ability of the emergency management system to respond, businesses and public organisations, central and local government funding, physical health, ports and airports, water infrastructure and tourism.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Waste infrastructure

Risks to waste management infrastructure, including landfills and contaminated sites, due to progressive and ongoing sea-level rise and extreme weather events.

Waste management infrastructure, including landfills and contaminated sites, are at risk from extreme weather events and ongoing sea-level rise (SLR). This includes the consideration of risks to a range of landfill infrastructure, such as landfill gas (LFG) flares, LFG to energy turbines, leachate treatment facilities, monitoring equipment and wells for LFG extraction. It also considers climate change-related risks due to the absence of or insufficient infrastructure at landfills and contaminated sites.[xxv] There is robust international research documenting the significance of the potential contamination risks from landfills and contaminated sites. Many of these risks will be intensified by climate change. Since the first national climate change risk assessment, there is also new evidence documenting the level of climate change exposure to many landfills in Aotearoa New Zealand.

As climate change intensifies, the potential that waste management infrastructure may fail threatens both human and ecosystem health. Leaching landfills, for example, can contaminate land, leading to ecosystem degradation, cultural and public health risks and economic disruption.

Risk overview

Landfills already have a high level of exposure

Within Aotearoa New Zealand, there is sound evidence to show that landfills have a high level of climate change exposure. The National Landfill Climate Change Exposure Assessment (2024) assesses the exposure to three climate-related hazards: coastal edge proximity (as proxy for coastal erosion),[xxvi] coastal inundation, and river and surface flooding.

Overall, 3,233 landfills were assessed in Aotearoa New Zealand as part of the National Landfill Climate Change Exposure Assessment, with 56% identified as being potentially exposed to one or more of the three climate-related hazards. The assessment also identified that 5% were potentially exposed to all three hazards.[314]

While the assessment does not provide explicit mid-century projections, exposure is expected to increase as sea levels rise and extreme rainfall events intensify.

[xxv] The wider consideration of community-based resource recovery depots or services, kerbside waste collection services and the offshore export of recycling for resource recovery purposes is considered out of scope.

[xxvi] Coastal erosion is the loss of land due to coastal processes such as waves and tidal currents wearing land away over time. There is currently no nationally consistent dataset for coastal erosion. Therefore, coastal edge proximity has been applied as a proxy for susceptibility to coastal erosion. In contrast, coastal inundation is the flooding of normally dry, low-lying coastal land due to extreme high-water levels.

Exposure to hazards differs regionally, but exposure increases considerably by the end of century

The National Landfill Climate Change Exposure Assessment does not assign timeframes to SLR scenarios; however, the Commission has used a mid-point of 0.8 m from the assessment as a proxy for end-of-century conditions. Under this scenario, the number of landfills exposed to coastal inundation increases by 53%, with 442 sites nationally at risk. Auckland currently has the highest number of sites exposed, rising from 87 to 97 landfills, while Bay of Plenty experiences the largest increase, from 10 to 52 sites.[314]

River and surface flooding represents the most widespread hazard, with approximately 1,100 landfills already exposed to floodplains or surface water inundation. Intensification of rainfall and higher flood levels are expected to substantially increase this exposure, particularly in Canterbury and Waikato, where extensive river systems intersect with landfill sites. Other regions, including Manawatū–Whanganui and Wellington, also show notable concentrations of flood-exposed landfills.[314]

Coastal erosion and scour present a different but equally pressing risk. Around 350 landfills are currently located within proximity to erodible coastal margins, leaving them exposed to containment failure as shorelines retreat. This hazard is most acute along the West Coast and Taranaki, where dynamic coastal processes and soft geology heighten exposure, but Te Taitokerau/Northland and Bay of Plenty also face elevated risks. While exposure to erosion and scour is an issue for fewer landfills than flooding, erosion and scour can have disproportionately severe consequences, as structural failure may lead to direct release of waste into sensitive coastal environments.[314]

Site sensitivity to climate change impacts varies significantly based on historical and engineering factors

Regional variation in the location and sensitivity of landfills and contaminated sites may reflect different historic land-use patterns. Site sensitivity varies due to waste type, containment design, maintenance and location. Historic landfills are often more exposed because they are near water bodies or lack containment.[315] Even modern landfills with impermeable liners can still be vulnerable to climate impacts.[316] Changes in climate also have the potential to alter the speciation,[xxvii] mobility and risks associated with contaminants.[317]

[xxvii] The speciation of contaminants refers to the process by which the chemical form or state of a contaminant changes in the environment. Contaminants, such as heavy metals, organic compounds or other pollutants, can exist in various chemical forms, or species, and the specific form a contaminant takes can significantly affect its toxicity, mobility and persistence in the environment.

Improving the adaptive capacity of contaminated land is constrained by lack of information

Remedial action has the potential to reduce the risks to landfills and contaminated sites, and the surrounding environment. These actions may involve the provision of containment systems to address the contaminant source(s). These containment systems may operate ex situ and/or in situ. Currently, the ability to remediate risks to landfills and contaminated land is limited by gaps in our understanding of contaminated site locations, and a lack of awareness regarding the waste composition or contaminants contained within sites.[318]

Climate change sub-risks include contamination, ecosystem damage, cultural and health risks, and economic disruption

There are a number of potential climate change sub-risks associated with waste management infrastructure, including landfills and contaminated sites:

- *Water contamination:* Overloaded leachate systems and rising groundwater can spread pollutants into land, waterways and coastal areas.
- *Pollutant spread:* Flooding mobilises hazardous substances like heavy metals into soils and sediments, harming ecosystems.
- *Ecosystem damage:* The dispersal of toxic waste and contaminants into the environment may disturb the natural biological balance within ecosystems and inhibit self-purification processes.
- *Health impacts:* Contaminated water and waste increase risks to public health, including exposure to pathogens.
- *Cultural harm:* Pollution affects iwi/Māori wellbeing and traditional practices, undermining kaitiakitanga (guardianship, environmental stewardship) and oranga (health).
- *Infrastructure vulnerability:* Extreme weather can damage landfill structures and restrict access, disrupting operations.
- *Stability risks:* Saturated waste may cause structural failures, posing safety hazards.
- *Economic disruption:* Environmental contamination can reduce tourism and hinder waste services during crises.

Risks to iwi/Māori due to contamination may affect customary practices and health

Waste and contaminated land sites in Aotearoa New Zealand can perpetuate inequities for iwi/Māori, particularly in health and wellbeing.[319] Māori wellbeing is deeply interconnected with the health of the environment. Contamination of land and waterways is likely to cause harm to Papatūānuku (earth, earth mother), impact kaitiakitanga obligations and undermine waioranga (health, wellbeing). These sites often overlap with areas of cultural significance, including mahinga kai (food gathering sites), meaning pollution disrupts not only physical health but also cultural identity, practices, and intergenerational connections to place.

Leachate and waste runoff can contaminate kaimoana (seafood) and other food sources, threatening livelihoods, food security, and the holistic wellbeing of Māori communities.[270,320,321]

Compounding and cascading factors

Climate-driven hydrological extremes cause contaminant mobilisation

Increasingly frequent heavy rainfall and flooding events intensify the mobilisation of waste and hazardous substances from landfills and contaminated sites. These hydrological extremes can erode landfill cover systems, disperse solid waste and transport contaminants into nearby streams, rivers and freshwater sources. As a result, climate change amplifies the risk of offsite pollution and the spread of legacy contaminants.[48,317]

Groundwater contamination leads to cumulative ecological and health risks

Once mobilised, contaminants can infiltrate groundwater systems, creating long-term and cumulative threats to aquatic ecosystems and the broader food chain. Pollutants such as heavy metals, persistent organic pollutants and industrial chemicals can bioaccumulate, leading to significant public health concerns including carcinogenicity, acute toxicity, endocrine disruption and genotoxic effects. These risks are compounded when extreme weather increases the frequency and volume of leachate generation.[48,322]

Vulnerabilities in leachate management systems can lead to contamination of ecosystems and public health impacts

Climate-induced stressors, such as extreme rainfall, rising groundwater tables and storm surges, can overwhelm or compromise leachate collection and treatment systems. When these systems fail, contaminants can escape into surrounding soils and waterways, disrupting ecological processes, degrading water quality and undermining natural self-purification functions. These failures also pose direct health risks to nearby communities, particularly where landfills are located close to residential areas or critical water sources.[323]

Road network failures cause access disruption and cascading public-health impacts

Extreme weather events can also restrict physical access to landfill sites, impeding routine operations, emergency response and maintenance activities. Flooding or storm damage may isolate communities from waste-disposal facilities, leading to accumulation of household and hazardous waste. This disruption heightens public-health risks, including increased exposure to pathogens, vectors and toxic substances, and can exacerbate physiological stress during emergency conditions.[48]

Interaction with emissions reduction

Waste generation is a direct consequence of natural resource use.[324] Reducing waste volumes not only reduces emissions, but also reduces climate-related risks to landfills. As countries become wealthier, industrialisation and urbanisation increase, along with changes in housing and consumption. This often leads to more municipal solid waste generated per person.[323] United Nations modelling shows that municipal solid waste is closely linked to gross domestic product (GDP) growth.[323] Unless the relationship between GDP growth and waste generation is disrupted, and Aotearoa New Zealand moves towards circular waste minimisation practices, high waste volumes and landfill reliance will continue to drive climate-related risks. Reducing waste generation not only cuts methane (a potent greenhouse gas) from landfills, but also lowers the upstream emissions created when materials are extracted, manufactured and transported. Breaking the link between economic growth and rising waste volumes can reduce both landfill methane and the wider emissions footprint of Aotearoa New Zealand's consumption.

Policy readiness assessment

Policy enables risk evaluation but policy action is narrow

Existing adaptation policy, including New Zealand's National Landfill Climate Change Exposure Assessment, the Contaminated Sites and Vulnerable Landfills Fund, and related remediation criteria under the Waste Minimisation Act 2008, support the evaluation of risks for landfills and contaminated sites. However, policy action is narrow and mainly focuses on landfill exposure for flooding, leachate management and methane release. Climate change risks to contaminated land remain largely unaddressed due to limited data on site conditions and contaminants.[18,314,325]

Funding is available but will not effectively address this risk

Although the revised NZ$30 million Contaminated Sites and Vulnerable Landfills Fund offers some support, it will not be sufficient to address the level of additional risk posed by climate change to landfills and contaminated sites. There are approximately 20,000 potentially contaminated sites across Aotearoa New Zealand. It is highly likely that NZ$30 million will be insufficient to remediate all 20,000 sites.[326]

The fund's purpose is to help councils and landowners clean up historic landfills and contaminated sites exposed to extreme weather. There are institutional and regulatory shortcomings that make it difficult for councils and landowners to undertake clean-up initiatives, despite funding availability. Thus, while the fund helps with remediation, it does not fully address the long-term adaptation needs for contaminated land and exposed landfill sites.[327,328]

Action has fallen short of addressing exposure and there is a significant policy gap

While the policy itself is enabling, action has fallen short in addressing the exposure of contaminated land and has not resulted in a clear pathway to ensure the risks to landfills are assessed or addressed.

Policies in this space enable risk evaluation and funding support, but they fall short of establishing a clear, comprehensive pathway to address climate-related risks to contaminated land and landfills. The consequential shortfall of policy action to address the climate-related risks from landfills and contaminated sites is significant.[314,328,329]

Immediate policy action could reduce cumulative and long-term risks

Given the complexity of the legislative and institutional barriers with managing contaminated land, and the long lead times required for site remediation, immediate policy action is important. For example, because councils interpret and implement regulation and standards differently, developers and landowners face inconsistent processes across regions.

Without urgent policy action, the cumulative and long-term risks to ecosystems, human health and cultural values will intensify. Enhanced monitoring, particularly of groundwater, stormwater and ecosystems, is also needed for sites directly exposed to climate-related hazards.[26]

Gaps for risk severity and policy

As mentioned above, in 2010, 20,000 potentially contaminated sites were estimated, but less than 2,000 had been confirmed as contaminated.[326] This number can now be expected to be much higher due to more sites being exposed under climate change, a lack of data on the number of contaminated sites, the number of contaminated sites in hazardous locations continuing to increase, and the exposure of contaminated land sites to climate change typically remaining unrecognised.

Importantly, contaminated land risk assessments will need to bridge the regulatory division created through regional council and territorial authority contaminated land management. Addressing the underlying policy issues that limit the effectiveness of Aotearoa New Zealand’s contaminated land management framework will likely be a prerequisite for effective contaminated land adaptation action. The establishment of a polluter pays model could be incorporated into this to address funding and financing issues and reduce the occurrence of new orphan site contamination issues.

Alongside addressing the shortcomings of the current contaminated land management framework, attention also needs to be given to the assessment of risk, management and remedial action to address climate change-related risks to landfills. This includes evaluating not only the sites themselves but also considering the related risk to surrounding social and ecological environments.[330] Local authorities do not currently have the tools and resourcing required to address the issues raised in the Climate Change Landfill Exposure Assessment to achieve risk reduction.

Summary

In the first risk assessment, there was limited evidence but high agreement that waste infrastructure is already at risk and will increase in future. There is now sound evidence to show that Aotearoa New Zealand's landfills have a high level of climate change exposure. Yet the national scope of climate change exposure to contaminated sites remains unknown, despite having the potential to be widespread.[326]

While related adaptation policy is enabling, policy action has not successfully addressed the climate change exposure for contaminated land, nor provided a clear pathway to ensure the risks to landfills are assessed or addressed. An extension of policy action is now necessary to ensure risks from climate-exposed landfills are assessed and addressed through remedial activity. The consequential shortfall in policy action to address the climate-related risks to landfills and contaminated land is significant.

Risk scorecard: Waste infrastructure

Risks to waste management infrastructure, including landfills and contaminated sites, due to progressive and ongoing sea-level rise and extreme weather events.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Washout and failure of some landfills are already occurring. The full impact of hazards on waste infrastructure will take time to be revealed and understood.
2050	Major	Landfills and contaminated sites face growing climate-related risks, especially from SLR and increased rainfall, which can cause toxic leaching and structural failures. Intensification of rainfall and higher flood levels are expected to substantially increase exposure.
2090*	Extreme GWL 2	Exposure increases considerably, particularly from coastal inundation and river and surface flooding. As hazards increase in severity and frequency, health, environmental and cultural impacts will be significant, including threats to ecosystems and taonga (treasure) species, with Māori communities particularly affected.
	Extreme GWL 3–3.5	
Policy readiness		
Overall assessment	Significant gaps	Policy action largely focuses on landfill-related threats such as flooding, leachate management and methane emissions, while threats to contaminated land remain mostly unaddressed. Institutional and regulatory barriers continue to make remediation difficult for councils and landowners, even where some funding is available.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, but it has strong connections to the risks to central and local government funding and water infrastructure.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Ports and airports

Risks to ports, airports and associated infrastructure due to progressive and ongoing changes in temperature, precipitation, wind, sea-level rise and extreme weather events.

Ports and airports are vital infrastructure that support daily life, economic activity and equitable access to essential services. However, they face increasing climate-related risks that could severely disrupt operations, reduce economic activity and exacerbate existing inequities.

Current climate-related risks vary for ports and airports and will increase in the future as warming occurs and they are impacted by climate-related hazards. Hazards including sea-level rise (SLR) and coastal inundation threaten the physical integrity of facilities, operational continuity and economic viability of critical transport infrastructure and the operations that rely on them. Addressing this risk has flow-on effects to others in this assessment, including ensuring supply chains remain open and Aotearoa New Zealand can maintain a thriving tourism sector.

Risk overview

Exposure of ports and airports varies by location and infrastructure type

Climate-related risks are already evident for ports and airports. The exposure of ports and associated infrastructure is influenced by factors such as geographic setting, wharf height, weather conditions, tidal ranges, channel depth and operating ranges for cranes and machinery. These differ across ports throughout Aotearoa New Zealand. For airports, location, runway and terminal height, weather conditions, stormwater management and operating ranges may determine levels of risk.

Currently, ports across Aotearoa New Zealand are facing storms and the hazards they generate including intense rainfall and flooding, which can undermine productivity and infrastructure integrity.[331] Their exposure is heightened due to the frequency and intensity of these events, but also by inland flooding, which disrupts access, and coastal inundation, which directly impacts port facilities.

Airports and their associated infrastructure face similar challenges. Storm-related hazards, particularly flooding, are already affecting operations. As of 2019, 20 airports are exposed to inland flooding. In addition, 13 airports, covering a combined area of 3.5 km^2 are also exposed to coastal inundation at present-day mean sea level.[18,161]

Risk intensifies by mid-century from extreme weather events and the hazards they generate

At mid-century, risks intensify. At 2050, a low climate impact scenario will significantly increase the frequency of coastal inundation at ports at very low elevation, impacting critical infrastructure. Associated infrastructure, like petroleum storage, will be exposed to the same hazards but further research is needed to determine scale.[18]

For both ports and airports, heatwaves may cause thermal stress (expansion or shrinking of a material due to change in temperature) on infrastructure such as pavements, rails, mechanical equipment and storage tanks. This may increase maintenance costs as warming occurs and impacts temperature-sensitive supply chains such as food and medication.[332]

Some airports are located within highly exposed zones for coastal inundation. Airports situated within 0–1.5 m above the current mean high water spring mark (see *Technical glossary* for definition) are particularly exposed. With rising sea levels, such airports could periodically be inundated by mid-century (this does not assume permanent inundation). This includes parts of Auckland and Wellington airports.[8]

Ports are fixed, low-lying infrastructure built at the coast, so relative SLR (including vertical land movement, where land may rise or fall due to plate tectonics) is what determines risk, not SLR alone. Subsiding (sinking) land can double the rate of relative SLR, and this is the case for the land around Wellington. For example, at CentrePort, Wellington's port, it is projected that SLR with vertical land movement will result in relative SLR of 0.28 m at 2050 under a low climate impact scenario.[17]

By the end of the century risk severity is major under lower levels of warming, and likely to become extreme under higher levels of warming

By the end of the century, risks are more severe, and multiple hazards compound this risk. SLR is progressive and ongoing, so will be higher in 2090 than in 2050 under both a low and high climate impact scenario at the end of the century, and may result in permanent inundation, particularly for low-lying ports such as Greymouth, Whanganui and Westport.[18]

The higher the level of warming, the higher SLR and associated coastal inundation will be. This will render many ports and airports at risk of permanent inundation if adaptation measures are not taken.[333] For example, under a low climate impact scenario (under the 2090 timescale), relative SLR of up to 1.14 m is projected (with vertical land movement) at the Napier Airport in Hawke's Bay.[17] Under a high climate impact scenario, 1.26 m of SLR (with vertical land movement) is projected by 2090.[17]

Entire ports are unlikely to be completely inundated by 2090, but it is important to consider the influence of relative SLR, which results in higher than the global average rates of inundation. Moreover, storm surges combined with SLR could disrupt operations and damage infrastructure in key locations, including Napier, Tauranga and Nelson.[17]

Multiple hazards compound the risk, including coastal erosion, flooding, strong winds and heat

Major airport operators are aware of coastal erosion, exacerbated by SLR and extreme weather events.[334,335] Exposure of airports to coastal inundation is likely to increase by 2050 and 2100 with an estimated 14 airports exposed in 2100 under a high climate impact scenario.[18] Due to their coastal locations, storm surges and SLR impacts are projected for Auckland and Wellington international airports, and major domestic airports in Tauranga, Hawke's Bay, Nelson and Dunedin.[286]

For both ports and airports, increased wind speeds and changing patterns may impact operations and schedules, particularly in exposed regions.[18] The increased exposure of airports to strong winds could damage airport ground equipment.

Airports are exposed to extreme heat, which can affect runway pavements through softening and thermal stress, and aircraft take-off performance. The number of very hot days is projected to increase under a high climate impact scenario.[18]

Cascading failures exacerbate this risk, potentially disrupting supply chains and emergency responses

Airports are interconnected with surrounding infrastructure, such as access roads and airports, making them vulnerable to cascading failures. Ports, airports and their associated infrastructure are nationally significant infrastructure assets, and their disruption due to climate events could have widespread economic and social consequences. This interacts with risks in the economy and governance domains, including risks to the disruption of supply chains and emergency management response capability.

Sensitivity and adaptive capacity vary among ports and airports, depending on age, condition and design

The sensitivity of ports and their associated infrastructure is driven by their operational characteristics, and the design, condition and age of structures, buildings and equipment. Adaptive capacity is also driven by port design, road and rail access, management and governance, and the availability of funding for delivering adaptation action.

The sensitivity of airports is driven by several factors, including the condition and design of airport assets and infrastructure and operational requirements. Design, access and governance impact the adaptive capacity of airports as well. The adaptive capacity of port and airport infrastructure varies considerably around Aotearoa New Zealand. Some airports are investing in plans to address key risks, whereas others face a lack of finance as a major hurdle, limiting their adaptive capacity.[336] Major airports tend to have a higher adaptive capacity than smaller airports.

There may be significant risks for the iwi/Māori economy

Ports and airports are vital for economic activity as they connect goods and services with markets. This risk poses threats to the success of the Māori economy, as the disruption of port and airport operations could impact exports from the country such as logs from forests owned by iwi/Māori or agricultural products from farms owned by iwi/Māori.[337] Iwi/Māori businesses are becoming increasingly more involved in exporting, and contribute approximately 5.6% of the national export total. Iwi/Māori exports are dominated by the primary sector and manufactured goods from the primary sector. The disruption of port and airport operations could have a negative impact on exports.[338]

Māori tourism businesses showcase iwi/Māori culture to the world and are significant employers in communities throughout Aotearoa New Zealand. They contribute over NZ$1.2 billion to GDP.[339] Ports and airports exposed to climate-related hazards will have flow-on impacts for iwi/Māori-owned tourism operators, reducing visitor numbers with resultant economic losses.[340]

Climatic and infrastructure-related thresholds may be reached

Climatic and infrastructure-related thresholds may be exceeded, exacerbating this risk. SLR will be exacerbated under higher warming scenarios, and particularly impacts this risk given low-lying coastal infrastructure. Relative SLR exceeding 0.5 m will lead to regular inundation of critical infrastructure, requiring significant adaptation or relocation.[286]

Thresholds may be also reached that exceed engineering and performance limits for ports and airports. Extreme storm events that are above the threshold for current design standards could pose significant risks to ports and airports, disrupting operations and causing catastrophic damage.[341] For airports, runway and pavement materials may degrade faster under increasing temperatures, particularly during prolonged heatwaves.[342] For both port and airport infrastructure under certain thresholds, 'hot days' are more frequent, heatwaves are more intense and infrastructure cannot withstand these pressures.

Compounding and cascading factors

Supply chain reliance on ports and airports make them critical nodes, and there are risks to the visitor economy

Aotearoa New Zealand relies on a six-continent supply chain and 'just in time' delivery, making ports and airports critical nodes. Damage to these nodes will disrupt access to critical goods, delay trade and tourism, and strain alternative transport networks during infrastructure failures. Moreover, the visitor economy, the environment in which visitors, local businesses and service providers interact, may be impacted. Auckland Airport is a critical hub for incoming and outgoing international flights.[343] Climate-related disruptions to international airports may have significant impacts on the visitor economy.

When these assets fail, the disruption quickly spreads. Flooded access roads isolate facilities, power outages halt fuelling and cargo operations, and digital system failures ripple through supply chains. These operational breakdowns then cascade into wider economic impacts: delayed imports and exports, stranded passengers, fuel shortages and congestion across freight networks, while also affecting workforce availability and emergency response. The result is a compounding, system-wide vulnerability where physical hazards, infrastructure fragility and interdependencies amplify each other.

There are associated biosecurity and ecosystem risks

Warming waters may allow invasive marine species to thrive as ships dock at ports. Species like Mediterranean fanworm, clubbed tunicate and wakame Asian kelp have been found in Canterbury ports, posing risks to local marine ecosystems.[253] For more information, see the *Marine ecosystems* and *Indigenous biodiversity from invasive pests and pathogens* risk analyses.

Interaction with emissions reduction

Climate mitigation actions could decrease the magnitude of this risk for ports and airports. As some consumers seek to reduce their emissions, they may reduce their travel load and source goods locally or choose lower-emissions methods of delivery such as shipping.

Infrastructure upgrades for climate resilience could align with emissions reduction initiatives, such as transitioning to energy-efficient facilities. It is important that these activities follow best practice and are supported by robust monitoring and evaluation. Electrification of port and airport operations may be a key mechanism to reduce emissions and can be implemented through retrofitting with adaptation in mind.[344] In practice, this may look like elevating electrical infrastructure, including enough battery storage for emissions reduction and emergency backup, and future-proofed capacity planning.

Strengthening port infrastructure and encouraging freight and passenger shipping could further enhance resilience and lower emissions, if it supports passengers and freight to shift from higher-emissions transport alternatives.

Policy readiness assessment

Funding is available but not targeted at ports and airports

The NZ$200 million Regional Infrastructure Fund (Budget 2024) supports flood resilience projects, including projects identified in the Before the Deluge 2.0 business case by Te Uru Kahika.[46] While not explicitly focused on ports and airports, a total of NZ$15.3 million has been allocated to Hokitika Airport and port facilities in Greymouth and Westport.[345]

Bottom-up adaptation is under way as operators are taking steps to reduce climate-related risks

In the absence of a detailed approach to reduce the physical risks of climate change for ports and airports, individual operators are taking proactive steps to reduce both exposure and vulnerability. Auckland Airport is investing in flood prevention and drainage upgrades, while the Port of Lyttelton is assessing the impacts of SLR and storm surges. Westport Airport is undergoing a relocation process to prepare for future climate hazards, with feasibility confirmed and planning underway. These actions reflect a bottom-up approach to resilience, supported by local councils and long-term operational planning.[346-348]

Cross-sector coordination is emerging

Cross-sector efforts are shaping the broader infrastructure resilience landscape. The New Zealand Lifelines Council's vulnerability assessment[349] highlights interdependencies across systems. Tools like the Deep South Challenge's adaptive decision-making guidance[350] provide infrastructure providers, including ports and airports, with frameworks to address compounding climate-related risks. These outputs highlight the need for clearer policy inclusion, targeted investment and coordinated planning.[349-351]

Barriers to effective adaptation include a lack of resourcing, leadership and long-term planning

There are several barriers to be addressed before adaptation of ports and airports can occur effectively. These include a lack of access to information to understand risks and resources to act (funding and other resources like skilled people), and a lack of long-term infrastructure planning.[310,312,352,353]

Engagement with iwi/Māori is occurring in some areas

Some resilience initiatives involve iwi/Māori, demonstrated through engagement and involvement in master planning. For example, relocation of the Westport Airport is being planned as part of the Resilient Westport initiative, and the relevant councils have been working collaboratively with iwi/Māori.[354]

Change is needed over the next six years, but strategies are absent

In the upcoming six years before the next risk assessment, there is a need to strengthen the resilience of ports and airports through targeted adaptation measures. These may include strategic relocation (requiring significant land availability for airports and underwater depth specifications for ports), and measures that strengthen interdependent transport systems. The absence of a national ports strategy and a system-wide measure of criticality (the level of need to adapt) hampers efficient investment and planning, risking poor infrastructure placement and delayed decision-making and investment. A coordinated, systems-based approach would help to ensure adaptation efforts are timely, equitable and effective in safeguarding these critical assets against intensifying climate impacts.

Gaps for risk severity and policy

There are several data gaps that could cause impacts of this risk to be more consequential than currently understood. Further assessments are needed to determine the scale and extent of associated infrastructure exposure to hazards – this data may be collected by ports and airports but is not publicly available. Moreover, national models do not capture the local drainage networks suitably; projections are needed of changing wind patterns and their impact on aviation and shipping; and there are gaps in data on private sector adaptation measures, particularly for smaller operators in the sector. Further assessment/s are needed of interdependencies between ports and airports, their supporting infrastructure and linear transport networks.

High-resolution and updated infrastructure data on the locations, condition and preparedness of ports and airports would be beneficial. The uncertainty and variability in climate change projections at the localised level for ports and airports makes assessments difficult.

Summary

Ports, airports and associated infrastructure face moderate but escalating climate-related risks, driven by SLR and extreme weather events. Current impacts include inland flooding impacting access routes and storm damage at ports and exposure of 14 airports to coastal inundation at present-day sea levels. By mid-century, under a low climate impact scenario, risks intensify: more frequent coastal inundation, heat stress on pavements and equipment, and operational disruptions. By the end of the century, under high climate impact scenarios, SLR of 1.14–1.26 m could lead to inundation of low-lying ports and airports, with cascading consequences for trade, tourism and community access to goods and services. Confidence in these projections is high, though local variability and drainage data gaps remain.

Policy readiness is limited. Some facility-level adaptation is underway, such as Auckland Airport's drainage upgrades and Westport Airport's relocation planning. There is no national ports strategy. Barriers include resource constraints, governance gaps and misaligned planning tools. Engagement and/or partnership with iwi/Māori is emerging but is not consistently embedded in adaptation policy. Without coordinated national action in the upcoming six years (before the next risk assessment), critical infrastructure will remain vulnerable and adaptation will be reactive.

Risk scorecard: Ports and airports

Risks to ports, airports and associated infrastructure due to progressive and ongoing changes in temperature, precipitation, wind, sea-level rise and extreme weather events.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Hazards, particularly flooding and rainfall, are already impacting ports and airports, undermining productivity and infrastructure integrity. Disruptions pose major threats to emergency access, trade and tourism. Smaller facilities often lack adaptive capacity.
2050	Moderate	Exposure will increase with warming. Further hazards such as coastal inundation and SLR will impact critical infrastructure, particularly at low-lying ports and airports.
2090*	Major GWL 2	Risk increases to major due to the increasing frequency of extreme weather events and other hazards, such as SLR and coastal inundation. These infrastructure types have some adaptive capacity but are difficult to relocate away from exposed coastal locations, for example.
	Extreme GWL 3–3.5	Due to further exposure to extreme weather events, SLR and coastal inundation, the risk increases to extreme with 3°C of warming. The higher score reflects instability above 2°C of warming.
Policy readiness		
Overall assessment	Moderate gaps	Without national guidance or coordinated policy, ports and airports face coverage gaps; however, adaptation options exist and some are being implemented by operators.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium overall potential to address others in the assessment, including the risks to businesses and public organisations (from supply and distribution disruptions), road and rail networks, and tourism.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Electricity and telecommunications infrastructure

Risks to electricity and telecommunications infrastructure due to progressive and ongoing changes in temperature, precipitation, and wind, sea-level rise, and extreme weather events and associated impacts like wildfires.

Climate change poses significant risks to electricity and telecommunications infrastructure, primarily through increased exposure to changes in temperature, rainfall, snow and extreme weather events including extreme wind events and increased fire weather. This summary is focused specifically on telecommunications infrastructure and electricity transmission and distribution infrastructure. Risks to generation infrastructure and electricity supply are covered in the *Electricity supply* risk analysis.

Electricity and telecommunications infrastructure are foundational to the functioning of modern society and the economy. Electricity infrastructure includes substations, and both underground and overhead distribution and transmission lines. Telecommunications infrastructure encompasses copper, fibre and cellular networks, including exchanges and cabinets, and towers. These systems enable essential services such as communication, emergency response and business operations, making their resilience to climate-related hazards a national concern.

Electricity infrastructure is particularly critical due to its interconnected role in enabling other systems, including telecommunications. Damage to electricity infrastructure can therefore have broader systemic impacts.

Risk overview

Electricity and telecommunications infrastructure is already at risk from climate hazards

Electricity infrastructure in Aotearoa New Zealand is already exposed to multiple climate-related hazards. At current sea levels, approximately 122 kilometres (km) of transmission lines and 180 associated structures nationally are exposed to coastal inundation with a 1% annual exceedance probability (AEP).[161] Flooding risk is not confined to coastal areas; inland exposure is also significant, with around 21% of sites within the national grid susceptible to a 1% AEP flood event.[251] In addition to flooding, wildfire poses an emerging threat. Transpower's 2023–2024 aerial survey indicates that between 5% and 10% of transmission lines (up to approximately 1,100 km) are located in zones with high wildfire exposure.[355] These figures highlight that electricity infrastructure is already operating in an environment where climate hazards are material and increasing, underscoring the need for proactive adaptation measures.

In 2023, the greatest exposure of Chorus's telecommunications network is to river (fluvial) and surface water (pluvial) flooding. River flooding presents the highest exposure rates across most asset types, including 32,988 (12%) underground utility boxes and 12,181 km (18%) of regional fibre cabling. Surface water flooding is also a widespread hazard, impacting 28,292 (10%) underground utility boxes and 9,144 km (14%) of regional fibre. By contrast, exposure to coastal inundation is limited, affecting only 1% across all asset categories, except key exchange sites, which have 0% exposure. No sites are currently identified as at risk from sea-level rise (SLR).[356]

Distribution networks are vulnerable to climate hazards, particularly in coastal locations and areas prone to landslides, high winds and flooding. On Kawau Island, the Vector electricity network exemplifies this risk: its coastal setting and challenging terrain leave it especially susceptible to damage. Repairing the 312 electricity connections would come at considerable cost if damaged due to the need to helicopter supplies to the island. Climate-related impacts necessitate repairs due to damage to essential infrastructure.[357]

Electricity distribution networks are particularly vulnerable to extreme wind events. High winds can exceed the structural design limits of poles and lines, leading to direct damage, or cause trees and other debris to fall onto the network, resulting in outages and costly repairs. Climate projections for Aotearoa New Zealand suggest that while the overall number of very windy days may decline, regional differences are pronounced. In the South Island, wind intensities are projected to increase, especially during winter months, amplifying risks to electricity infrastructure. Conversely, the North Island is expected to experience a reduction in wind intensity, though exposure remains significant in certain areas. These regional variations highlight the need for tailored resilience strategies to safeguard electricity networks against evolving wind hazards.[236]

At mid-century climate-related hazards are projected to increase

By the mid-century, climate-related hazards are projected to intensify, increasing the exposure of electricity infrastructure. Wildfire zones could expand significantly, with estimates suggesting that 20–25% of transmission lines may fall within highly exposed areas by 2040.[251] Flooding exposure also grows over time. Between 2029 and 2042, under a scenario of about 2°C of warming, about 25% of electricity sites within the national grid are expected to be exposed to a 1% AEP inland flood event.[251] This trend continues later in the century; between 2056 and 2074, under about 3°C of warming, the proportion of sites exposed to the same flood hazard rises slightly to 26%.[251] These projections indicate that both wildfire and flooding hazards will increase in intensity and frequency, reinforcing the need for adaptation measures that address multiple hazards simultaneously.[xxviii]

By 2040, the Chorus telecommunications network's exposure profile remains dominated by pluvial and fluvial flooding, though the proportions of affected assets are largely unchanged

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[xxviii] Throughout this paragraph, the original data for this level of warming were calculated using an "additional warming" approach, which measures temperature increases on top of the warming the climate has already experienced (approximately 1°C above pre-industrial levels). To make this clearer and consistent with the rest of the risk assessment, the Commission has converted additional warming into warming relative to pre-industrial. As a result, a projection of 2°C of additional warming is presented as about 3°C total warming, for example, reflecting that approximately 1°C of warming has already occurred.

from 2023. The most notable increases occur in exposure to coastal inundation from SLR. Coastal inundation exposure increases across several asset types, such as underground utility boxes, rising from 2,610 (1%) to 4,723 (2%), and terminal enclosures, which increases from 162 (1%) to 264 (2%). As well as this, small numbers of assets begin to be affected by SLR for the first time; however, exposure to SLR is still less than 1% across all asset categories, except key exchange sites, which have 0% exposure.[356]

End-of-century exposure will become more extreme, especially to electricity infrastructure

By the end of the century, the exposure of electricity infrastructure to climate hazards becomes even more pronounced. Under a scenario of approximately 2.5°C warming with 0.6 m of SLR, between 0.3% and 0.4% of transmission line structures could be exposed to extreme coastal inundation.[355] Inland flooding risk also escalates significantly. By around 2076, under about 4°C of warming,[xxix] nearly 29% of electricity sites within the national grid are projected to be exposed to a 1% AEP inland flood event.[251] These figures underscore the long-term vulnerability of electricity networks to both coastal inundation and inland flooding, highlighting the need for forward-looking adaptation strategies that account for multiple hazards and assets with inherently long lifespans.

There is no national-level quantitative data available for telecommunications infrastructure exposure at the end of the century.

Electricity and communication networks are both resilient networks, but electricity networks are currently more vulnerable than telecommunications networks

Both electricity and telecommunications networks are resilient. They have redundant pathways that limit damage to the networks. They also have relatively high adaptive capacity that allows network operators to quickly restore service when damage occurs.

Currently, electricity networks are more vulnerable than telecommunications networks, partly due to the latter's redundancy from multiple independent service providers (for example, fixed phone/internet and mobile) and increasing use of underground fibre. For example, if a cell phone tower fails due to an extreme weather event, an alternative means of communication can be provided via the fibre network. Additionally, fibre, which is now replacing the copper network, can be undergrounded, which helps to increase its resilience during inland floods and coastal inundation.

[xxix] The original data for this level of warming was calculated using an "additional warming" approach, which measures temperature increases on top of the warming the climate has already experienced (approximately 1°C above pre-industrial levels). To make this clearer and consistent with the rest of the risk assessment, the Commission has converted additional warming into warming relative to pre-industrial. As a result, a projection of 2°C of additional warming is presented as about 3°C total warming, for example, reflecting that approximately 1°C of warming has already occurred.

This contrasts with the high cost of undergrounding electricity lines, which is 5 to 15 times more expensive per kilometre than maintaining overhead lines. While undergrounding offers benefits like increased safety and resilience to some but not all hazards, the high cost makes it prohibitive for widespread implementation.[227] However, emerging technologies such as distributed generation like microgrids, vehicle to load and solar photovoltaics (PV) with battery storage could reduce sensitivity at the community/individual level. This would also likely address some of the cascading impacts to electricity infrastructure.

Vulnerability varies significantly across regions, and the cost of building additional resilience is passed on to consumers

Vulnerability varies significantly across regions. Areas like Queenstown, Hawke's Bay, parts of Hokianga and New Plymouth are dependent on a single transmission line for supply.[349]

Remote communities are likely to be disproportionally impacted due to long networks servicing fewer customers.[358] According to the Commerce Commission, electricity prices are set to rise, with regional variation reflecting infrastructure investment needs and exposure to climate hazards. For example, Wellington will see a moderate increase of NZ$10/month (national average) in the first year, followed by NZ$5/month annually. In contrast, parts of Te Taitokerau/Northland may face steeper increases of NZ$25/month initially, rising to NZ$15/month annually thereafter. These differences are largely driven by the level of investment required, the number of consumers over which costs are spread and regional exposure to climate-related hazards such as SLR and extreme weather events.[359]

Communities and individuals are highly sensitive to electricity disruptions

Communities and individuals are highly sensitive to disruptions but may also possess high adaptive capacity. Electricity is essential for daily life and emergency response, while telecommunications are vital for communication during crises. People and businesses rely on electricity. While most will be inconvenienced when outages occur, others rely on it, including people who require electricity for medical devices. However, energy resilience through technologies such as microgrids or roof-top solar with battery storage could reduce the sensitivity of communities, individuals and businesses.[360,361]

Iwi/Māori face heightened risk due to geographic factors

Impacts on iwi/Māori can be related to the geography in which Māori live, work and own assets. About 25% of iwi/Māori live in rural areas, and iwi/Māori comprise one-third of those who live in the most remote areas of Aotearoa New Zealand.[362] Rural and isolated areas are less likely to be well served by infrastructure, including electricity and telecommunications infrastructure.[363,364]

The electricity and telecommunications network is essential for business

Reliable electricity and telecommunications networks are essential for businesses due to their role in productivity, competitiveness and economic resilience. The operation of these networks enables businesses to operate efficiently, innovate, reach global markets and adapt to disruptions. As climate-related risks and digital demands increase, the importance of robust, resilient infrastructure will only grow. The business sector's resilience is critical during disruptions, as demonstrated in recent extreme weather events such as the North Island Severe Weather Events.[365-367]

Compounding and cascading factors

Climate hazards may cause financial pressures and regional inequities

More frequent and extensive damage from climate-related hazards is expected to result in increased operating and capital expenditure, particularly for electricity infrastructure.[48] These rising costs are likely to exacerbate existing regional inequities, as areas facing repeated climate events will also bear higher infrastructure investment burdens.[359] This financial pressure compounds vulnerability, especially in regions with fewer consumers over which to spread costs.

Critical services depend on electricity, and outages impact daily life

Electricity outages can quickly disrupt essential aspects of daily life because many critical services depend on continuous power.[368] For example, people and businesses rely on electricity to maintain a level of comfort, cook food and to conduct business, including by maintaining connection to the internet. The potential for loss of refrigeration during outages threatens food safety and supply by allowing rapid bacterial growth and interrupting cold-chain logistics. Power cuts also jeopardise temperature-sensitive medicines and medical equipment, creating risks for people who rely on refrigerated pharmaceuticals or electrically powered health devices.[369]

There are significant transport network dependencies

Risks to road and rail networks can compound risks to electricity and telecommunications infrastructure. Linear transport networks are critical for accessing infrastructure for maintenance and emergency repairs. When transport routes are disrupted, outages may be prolonged and resilience compromised.

Interaction with emissions reduction

As Aotearoa New Zealand transitions towards a low-emissions economy and net zero by 2050, the electrification of various sectors will significantly increase the country's reliance on electricity. As reliance grows, so does the potential impact of disruptions caused by climate-related hazards. This heightened sensitivity amplifies the magnitude of risk to electricity and telecommunications infrastructure. There are also opportunities here – energy resilience from a more distributed electricity network as the adoption of renewables expands, such as through rooftop solar, is a co-benefit from emissions reduction efforts.

Policy readiness assessment

There are indirect and direct government policies, plans and actions to address risks to electricity and telecommunications infrastructure

Electricity and telecommunications are lifeline utilities and, as such, are supported by a mix of direct and indirect government policies and plans. Indirect initiatives include Te Waihanga The Infrastructure Commission's 30-year infrastructure strategy (2022–2052) and the development of a National Infrastructure Plan.[370] Direct actions include amendments to the Electricity (Hazards from Trees) Regulations 2003.[371] There are several national adaptation plan actions relevant to electricity infrastructure, such as the Transpower Adaptation Plan and reviewing electricity and gas networks' management of climate-related risk and resilience.

For telecommunications, central government action is more limited. Key initiatives are focused on digital connectivity programmes such as Ultra-Fast Broadband, the Rural Broadband Initiative, the Mobile Black Spot Fund and the Remote Users Scheme.[372]

Local government and the private sector are actively looking to address risks to electricity and telecommunications infrastructure

Local councils have begun integrating climate-related risk into district or regional-level risk assessments, including exposure of electricity and telecommunications infrastructure. Electricity and telecommunication businesses are also integrating adaptation and resilience into their asset management strategies. For example, Chorus has a Sustainability Report, released in 2023, which notes that their recent assessment of flooding risk for their network assets is informing their future asset management plans.[356] Vector's climate-related financial disclosure includes strategies to minimise the risks to their network from climate change.[373]

Box 3.3: Redclyffe substation

As infrastructure assets are long-lived, it is likely that some risk will always remain. However, recent case studies show there are viable options for addressing this residual risk in some instances. Cyclone Gabrielle highlighted the vulnerability of critical infrastructure. Flooding at Transpower's Redclyffe substation triggered widespread outages as the majority of Hawke's Bay's electricity is provided via interconnection at the Redclyffe grid exit point. In response, Transpower and Unison (a Hastings-based electricity distribution network company) opted to rebuild the substation on the same site with elevated ground levels and updated equipment. This approach is likely to cost up to NZ$35 million and be completed within 2–3 years. The alternative of building a new substation at a different location, along with the associated transmission lines and network development, could take 10 years with an estimated cost of over NZ$200 million.[374]

Significant barriers to action and effective adaptation remain, including coordination, funding and regulatory/policy gaps

Despite active engagement, significant barriers remain. Current policies, plans and actions do not address the current lack of coordination and access to information, funding barriers, outdated standards, and regulatory barriers, including the overlap and uncertainty arising from some regulation. Of these, funding and regulatory barriers are the most significant because they directly impact which parts of these networks get built, upgraded and protected.[26]

There are several government-led initiatives under way to set minimum standards for how resilient infrastructure, including electricity and telecommunications, should be. They include the Emergency Management Bill (proposed to replace the Civil Defence Emergency Management Act 2002) and the proposed National Policy Statement for Natural Hazards 2025. However, these efforts have not been well coordinated. Telecommunications stakeholders have highlighted that the different pieces of work do not line up well, which creates confusion.[375] For example, some standards and requirements clash or do not work well together, making it harder for infrastructure providers to know what to do.[375]

This lack of alignment undermines the resilience of infrastructure. Resulting lower levels of resilience can lock in vulnerabilities, especially for assets that last a long time. For example, most power cables have a design life of between 20 and 30 years.[376] It is possible to improve the resilience at the time of construction of some assets, but that is not always the case, and retrofitting may be required. Starting with strong, well-aligned standards is important, particularly for assets that cannot easily be upgraded later.

Gaps for risk severity and policy

While quantitative exposure data exist, for electricity and telecommunications infrastructure, this is currently limited to primarily flooding. There is limited information on how exposed telecommunications infrastructure is to climate hazards, especially for the end of the century and for cell phone towers. While there is a strong understanding of the exposure and sensitivity of electricity infrastructure to climate change, more research is needed to understand long-term risks under different climate scenarios.[18] The exposure of telecommunications infrastructure is not well covered in Aotearoa New Zealand research and data; there is no national-level data on how these sites might be affected by SLR.[370] Wildfire risk is still a relatively new area of research in Aotearoa New Zealand, and there are knowledge gaps around how it could affect electricity and telecommunications infrastructure.

Summary

Electricity and telecommunications infrastructure are being affected by climate change, particularly through extreme weather events. Because most quantitative data focus on flood hazards, it is difficult to comprehensively assess exposure to all climate-related risks. Currently, electricity infrastructure appears more vulnerable than telecommunications, though this may shift as technologies and adaptive measures evolve.

Disruptions to these systems have significant flow-on effects across the built environment, society and the economy. Vulnerability also varies by region; some areas depend on a single supply line, while others have fewer consumers to support infrastructure costs. Increasing electrification may heighten national reliance on electricity and increase sensitivity to climate hazards, though it could also lead to a more distributed network.

As lifeline utilities, electricity and telecommunications are the focus of various government and private-sector efforts to address climate-related risks. However, barriers remain, especially around coordination and funding. These challenges could lock in long-term vulnerabilities. While some assets can be upgraded later, others cannot, making strong, well-aligned standards essential from the outset.

Risk scorecard: Electricity and telecommunications infrastructure

Risks to electricity and telecommunications infrastructure due to progressive and ongoing changes in temperature, precipitation, and wind, sea-level rise, and extreme weather events and associated impacts like wildfires.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Networks are experiencing some resilience issues, particularly in remote regions; however, overall, the networks have high adaptive capacity. Electricity networks are more vulnerable than telecommunications networks.
2050	Moderate	Exposure to hazards may lead to increasingly widespread short-term disruptions, or long-term where disruptions to transport networks make repair challenging. The most notable increases in exposure mid-century are due to coastal inundation from SLR, coupled with an increased dependence on electricity supply.
2090*	Major GWL 2	Exposure becomes more pronounced. More widespread short- to medium-term disruptions to electricity supply can be expected, which also impact telecommunications. Impacts will be more severe in remote regions that are hard to access for repairs, those already experiencing inequities and those exposed to multiple hazards.
	Major GWL 3–3.5	
Policy readiness		
Overall assessment	Moderate gaps	Electricity infrastructure benefits from detailed policy and private sector action, but there is more limited action for telecommunications. Gaps in coordination and access to information, funding and regulatory barriers and outdated standards contribute to moderate gaps overall.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium overall potential to address others in the assessment, including the risks to the ability of the emergency management system to respond, electricity supply, horticulture and water infrastructure.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Electricity supply

Risks to the security of electricity supply due to progressive and ongoing changes in precipitation, temperature, and wind and extreme weather events.

Electricity is a cornerstone of modern life in Aotearoa New Zealand, underpinning essential services, economic activity and daily living. As climate change accelerates, understanding its implications for electricity generation becomes increasingly critical to ensuring long-term energy resilience. This assessment focuses on risks and opportunities from the changing climate to electricity generation infrastructure and activity, including hydro, wind, solar, geothermal and thermal (fuelled by fossil gas, coal and diesel) sources. It also considers imported inputs to generation, such as fuel and critical infrastructure components.

While electricity networks are covered in a separate assessment, it is important to note that the most acute climate change-related risks to electricity supply interruptions lie in the networks rather than in generation. Generation risks from a changing climate are generally moderate and manageable, with adaptation pathways available.

Risk overview

Current exposure of generation assets is minor

Climate change affects electricity generation through altered weather patterns (such as precipitation and wind), temperature extremes and increased frequency of extreme weather events. These impacts vary across generation types and regions. While Aotearoa New Zealand experiences dry hydrological years that can challenge electricity supply security,[377] the direct exposure of electricity generation assets to climate impacts remains relatively minor.

Hydro, wind, solar, geothermal and thermal face moderate and manageable risks, with adaptation pathways available to maintain reliability and performance.

Much of this assessment assumes continuity in the broadly winter-peaking nature of electricity demand. While climate change is expected to increase summer electricity use at the margin, particularly through greater demand for cooling, available evidence does not suggest a shift to a predominantly summer-peaking system by mid-century. Any increase in summer demand is expected to be gradual and may improve alignment with generation availability, particularly from hydro and solar resources, which typically peak in spring and summer.[378] As a result, changes in seasonal demand patterns are not expected to materially increase risks to electricity supply to 2050.

Many of the challenges discussed below, such as dry-year risk and regional supply constraints, are longstanding features of Aotearoa New Zealand’s electricity system. Climate change is expected to incrementally alter the frequency, severity or distribution of these risks, rather than create wholly new system vulnerabilities.

Impacts on hydro generation are variable to 2050, but increased dry periods may affect reliability

Hydropower is particularly sensitive to changes in precipitation and seasonal flow patterns. Detailed catchment-based modelling to 2050 indicates a seasonal shift in inflows from spring and summer, heading into winter, for the large South Island snow-fed catchments. Based on current demand patterns and allowing for modest future shifts (as outlined above), this change may improve the reliability of hydro generation in meeting seasonal electricity demand.[18,377] However, an increase in the frequency and severity of dry periods may reduce reliability.[377,379,380] Flood intensity and frequency may increase slightly by 2050 in some catchments.[377,379] Warmer temperatures and longer dry spells may lead to algal blooms or the proliferation of freshwater pests, raising maintenance costs and reducing generation efficiency.

Wind generation is exposed to variability in wind patterns to 2050, but modelled changes may help align generation with demand

Wind energy is exposed to variability in wind patterns and extreme weather events. Slight increases in average wind speeds in 2050 across the country may benefit overall generation.[377] Stronger winds in winter and weaker winds in summer could help align generation with demand.[377] However, extreme storms can damage turbines, and prolonged calm periods may reduce output, posing reliability challenges.

Solar generation faces minor risks

Solar energy faces relatively minor risks, primarily related to temperature and air quality. Very hot days may slightly reduce solar panel efficiency, particularly for rooftop installations affected by the urban heat island effect.[379,381,382] High heat can reduce the voltage solar panels can produce, making them less efficient.

Wildfire smoke and dust storms can substantially reduce solar irradiance, leading to temporary drops in output.[383,384] The preference for flat land can result in solar farms being constructed in flood-prone plains; however, flood-resilient designs can mitigate risk.

Geothermal generation faces some seasonal and demand risks from high temperatures and water scarcity

The electricity sector benefits from geothermal baseload reliability, making it a stable contributor to meeting demand despite climate variability. Geothermal plants are influenced by ambient temperature and water availability. High temperatures can reduce cooling efficiency, especially for air-cooled systems, leading to lower output during peak heat periods.[385,386] Droughts and competition for water resources may impact groundwater recharge, affecting the sustainability of geothermal reservoirs.[387] These risks tend to be more pronounced in summer, when electricity demand is lower and the system is less stressed. Operational adjustments and cross-sectoral or catchment-based resource planning, such as integrated water management strategies, could help mitigate these impacts.

End-of-century exposure is currently unknown

There is no current information about end-of-century exposure for electricity supply, particularly how exposure would change under increased levels of warming.

Thermal generation is exposed to both physical and transition risks

Thermal power plants, particularly those relying on water for cooling, face operational constraints under climate change. Higher river temperatures and reduced water availability can limit cooling capacity and reduce output.[388,389] Reliance on fossil fuels is increasingly challenged by fuel availability and decarbonisation efforts, introducing financial and operational uncertainties. Timely investment in renewable capacity and flexible alternatives is needed to support system resilience and affordability.

There are risks from intersecting supply chain and demand disruptions, but there are also opportunities

Climate change introduces systemic risks to electricity generation through supply chain disruptions and shifting demand patterns. However, it presents opportunities to better align generation with seasonal demand and enhance resilience through distributed energy technologies. Climate-related hazards may disrupt supply chains for imported fuels and critical components used in electricity generation. This vulnerability affects all generation types and could impact system reliability. Climatic changes may also shift electricity demand patterns. Warmer winters could reduce heating demand, while hotter summers may increase demand for cooling and irrigation, both of which would better align demand with generation.[390,391]

Regional climate variation and transmission constraints may increase supply and demand mismatches

Regional climate variations will influence electricity generation differently across the country. The North Island is trending drier, while the South Island is getting wetter.[392] Demand is concentrated in the North Island, while a large share of existing and potential renewable generation resources, particularly hydro, are located in the South Island.[377] With limited capacity to transmit power north, there is a risk of increasing regional mismatch between supply and demand.

Adaptive capacity is moderate to high, but infrastructure assets may be more vulnerable

Aotearoa New Zealand’s electricity generation sector has a relatively high level of adaptive capacity. This reflects the electricity system’s ability to respond to climatic variability through a range of mechanisms over time, rather than reliance on any single asset or fuel source. This capability is underpinned by abundant renewable energy potential and a mature institutional electricity system. In the near to medium term, thermal generation continues to play a role in managing dry-year risk. Over time, this role is expected to be increasingly complemented or replaced by diversification of generation technologies, geographic dispersion of renewable resources, storage and demand-side flexibility.[377]

However, this adaptive capacity is not without limits. Many generation assets, particularly older hydro and geothermal plants, are reaching the end of their design lives and may be more vulnerable to climate-related stressors.[393,394] While wind and solar resources are more geographically dispersed, their siting is often constrained by land availability and consenting processes, which may limit climate resilience.

Expansion of the generation mix across a range of generation technologies, supporting resilience through diversification, is well under way. Significant additions of wind, solar and geothermal capacity have occurred since the first risk assessment. Larger, well-resourced entities are beginning to integrate climate projections into long-term planning, but this practice is not yet widespread. Realising the sector's full adaptive potential will require coordinated investment, modernisation and planning.[395-397]

Impacts on iwi/Māori include investments and supply disruptions

While climate-related risks to electricity supply may not present uniquely high or disproportionate impacts for iwi/Māori relative to some other risks, both direct and systemic considerations warrant attention. Climatic changes or events impacting generation infrastructure that iwi/Māori own or have invested in could affect revenue streams and economic resilience.[xxx] Remote communities, which often have relatively high Māori populations, may be more likely to experience supply disruptions.[398,399]

New technologies can improve resilience

Technology trends also offer opportunities to improve resilience.[400] The cost of distributed energy resources such as rooftop solar and batteries continues to decline, making them increasingly accessible.[401] With appropriate policy support and infrastructure, these technologies can help households and communities reduce peak demand, enhance energy sovereignty and improve resilience to climate-related disruptions. Ensuring equitable access to these technologies could also help address energy hardship and reduce exposure to outages across socio-economic groups.

Compounding and cascading factors

Dependence on electricity is increasing in Aotearoa New Zealand

As Aotearoa New Zealand continues to electrify its economy, which is important to achieve emissions reductions, dependence on electricity will increase substantially.[402] This heightened reliance means that any disruption to electricity supply, whether from

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[xxx] Examples include Tuaropaki Trust and Ngāti Tūwharetoa, who have geothermal interests; Tupu Tonu, a joint venture partner in a Northland solar project; and the Māori land incorporation Taheke 8C, which is developing hydro and geothermal projects as part of an energy hub on their land near Rotorua.

generation or networks, could have more widespread and severe consequences. Electrification of transport, heating and industrial processes increases the criticality of electricity as a lifeline utility, and therefore the importance of investing in resilience.[349] For example, electric buses, trains and construction equipment require reliable access to electricity, and outages could hinder mobility, emergency response and economic activity.

Socio-economic trends put further pressure on these issues

An ageing population is more vulnerable to heat stress and cold, making reliable electricity for heating and cooling essential.[403-405] Energy hardship is also a growing concern, with lower-income households more likely to experience negative impacts during outages.[406,xxxi] Such households would stand to benefit the most from the energy cost savings associated with rooftop solar and battery storage, which can reduce reliance on centralised supply and provide backup during disruptions, yet are often less able to invest in such resilience measures.[407]

Urbanisation and population growth in certain regions may strain local electricity infrastructure, especially where climate impacts are more severe. Conversely, rural and remote communities may face challenges in accessing resilient energy systems, particularly if infrastructure investment is uneven.[395,397]

Interaction with emissions reduction

Emissions reduction actions, particularly the electrification of transport, heating and industrial processes, are expected to increase overall electricity demand. This could amplify exposure to supply disruptions if generation and network resilience do not keep pace. Conversely, efforts that expand renewable generation and diversify the electricity mix (such as wind, solar and geothermal) can reduce reliance on thermal generation (fuelled by coal, gas and diesel) and associated transition risks such as fuel price volatility, exposure to carbon pricing, and regulatory and/or policy changes. Land-use changes for carbon sequestration, such as reforestation in erosion-prone catchments, may also provide co-benefits by reducing flood risk to hydro assets.[395,397,408]

However, rapid deployment of renewables without integrated spatial planning could introduce new exposures, such as siting solar farms in flood-prone areas. Overall, mitigation and adaptation objectives are closely linked: successful decarbonisation will require coordinated investment in flexible generation, storage and transmission upgrades to ensure resilience under changing climate conditions.[26,408,409]

[xxxi] Research indicates some 30% of households face energy hardship, with the severity of the issue prompting MBIE focus.

Policy readiness assessment

Aotearoa New Zealand’s policy framework for adapting electricity generation to climate change is currently limited and fragmented

Policy readiness to support adaptation in the electricity generation sector remains limited. Few government policies or actions are specifically targeted at addressing climate-related risks to electricity generation infrastructure. However, broader initiatives, such as emergency management reforms and infrastructure funding targeting flood management, may still support resilience outcomes.[410]

Evidence of private sector adaptation readiness is limited; however, progress is occurring to some degree for actions relating to deploying small controllable energy devices. These include home batteries, electric vehicle chargers, smart appliances and rooftop solar. They help balance supply and demand (technically referred to as distributed flexibility resources), diversifying the generation mix and upgrading networks. This appears driven more by economic signals in the electricity system than climate adaptation motives.[411-413]

Barriers include limited organisational capacity and poor coordination between energy and other infrastructure sectors

Barriers to adaptation include the lack of a clear and coherent national approach for adaptation planning and implementation, organisational capacity and capability, and coordination between energy infrastructure and other infrastructure types such as transportation networks.[414,415] The Fast-track Approvals Act 2024 exemplifies some of these issues, as it does not explicitly require climate or environmental considerations in its decision-making process. As a result, projects approved under this framework may not support positive adaptation outcomes, potentially locking in long-term exposure to climate-related risks.[46]

Energy policy does not currently integrate adaptation outcomes that could improve readiness. For example, finalisation of the National Energy Strategy, which the Government has indicated it still intends to publish, could provide an opportunity to integrate climate resilience by integrating spatial planning systems and risk assessment guidance for physical infrastructure.

Climate-related disclosure requirements provide some guidance for large gentailer firms but may be insufficient for enabling widespread action.[416] Translating high-level warming scenarios into plant-specific impacts may be challenging, especially for smaller, less-resourced firms outside mandatory reporting requirements. Expanded guidance and tools could help bridge this gap and support more effective and inclusive resilience planning.

Coordinated adaptation responses with other systems are required

Electricity generation is deeply interconnected with other systems. The sector operates within the broader energy system. This requires considerations such as the provision of fuels for thermal generation. Generation plants also interact with other infrastructure types, including roads, telecommunications, electrical networks and water systems, like irrigation. To ensure a coherent and coordinated approach to building resilience in electricity supply, it will be important for adaptation planning to adopt a systems-level perspective that acknowledges these interdependencies.

Gaps for risk severity and policy

Gaps remain in understanding risks beyond 2050, especially how they differ by climate impact scenario. Evidence on risks to solar generation and distributed energy resources is limited. Visibility into private-sector adaptation is also low due to non-standardised reporting, confidentiality, fragmented governance and insufficient data-sharing between major sector participants such as large generators and local government.[415]

Summary

Climate change in the form of temperature changes, wind and floods poses risks to electricity generation. Present day, these are largely manageable. The increasing importance of electricity to Aotearoa New Zealand, socio-economic issues such as energy hardship and ageing population trends may compound risks. With proactive planning, targeted investment and system-wide coordination (particularly across networks and infrastructure), Aotearoa New Zealand can adapt effectively.

While there is limited government policy targeting this risk, the ongoing expansion of new renewable generation and distributed consumer energy resources such as rooftop solar, driven by market forces, puts the country in a strong position to improve electricity supply resilience. When paired with strategic upgrades to transmission and distribution networks, these developments can enable greater integration of renewable capacity and enhance system flexibility. Together, they represent a meaningful pathway to strengthening electricity supply resilience in a changing climate.

Risk scorecard: Electricity supply

Risks to the security of electricity supply due to progressive and ongoing changes in precipitation, temperature, and wind and extreme weather events.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Most generation types face manageable risks, with adaptation pathways available to maintain reliability and performance. Electricity is critical infrastructure; however, disruptions are more often caused by network failures than generation issues.
2050	Minor	Climate change-related shifts to wind and water (affecting wind and hydro generation) remain minor to 2050, especially in a rapidly diversifying generation system. Reliability issues are likely to be becoming apparent, but adaptive capacity is moderate to high.
2090*	Moderate GWL 2	Threat of extended dry periods affecting hydro generation, creating security of supply challenges after mid-century. The additional variability in weather patterns and changes to extremes towards the end of the century constitute a moderate risk to generation, even with a more diverse generation mix.
	Moderate GWL 3–3.5	
Policy readiness		
Overall assessment	Moderate gaps	Government policy addressing this risk is limited. Gaps remain in organisational capacity, capability and coordination between energy infrastructure and other sectors. Nonetheless, the growth of renewable generation and distributed energy resources such as rooftop solar strengthens the country's prospects for improving electricity supply resilience.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, but it has strong connections to risks to electricity and telecommunications infrastructure.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

DOMAIN: People, health and communities

This domain relates directly to the wellbeing of individuals and communities.

This part of the risk assessment focuses on risks to physical health, mental health, social infrastructure, social cohesion, and community and cultural wellbeing, and the ability of the emergency management system to respond to the future impacts of climate change.

Climate change presents risks to the health and wellbeing of individuals, families and communities. People are already experiencing disruptions to their daily lives as a result of climate-related extreme weather events, including displacement from their homes. These disruptions, along with the impacts of ongoing, gradual changes, have associated impacts on physical and mental health. Such events will become more frequent and severe as the climate changes, while progressive and ongoing changes like sea-level rise will increasingly impact people over time. This exposure to climate hazards will continue to impact people, society and culture directly, while the resulting consequences and changes will have wider indirect impacts, such as restricting earning potential, ability to pursue daily habits and activities, and access to critical services.

Ultimately, the effects of climate change in any domain have impacts on people, with ramifications for their wellbeing, identity, autonomy and sense of belonging. Across the board, these impacts will be felt most strongly by people and groups who are already sensitive to them or experiencing structural inequities.

What makes this domain unique?

The health and wellbeing of people and communities are interconnected, and there are strong links between the risks in this domain

Climate change can impact the health and wellbeing of people and communities in numerous ways. For example, physical injury or illness may occur from direct exposure to an extreme weather event such as a flood, wildfire or heatwave, resulting in an adverse impact on physical health. Physical health impacts can also occur as a result of climate-related impacts on the things that determine people's health, like housing quality and access to health and other types of social and community services. Physical isolation from social infrastructure and social services may also exacerbate mental health challenges, affect people's sense of belonging and identity, and perpetuate inequity, adversely impacting social cohesion.

Physical and mental health are strongly linked. For example, chronic illness or long-term injuries can increase anxiety and stress, and affect self-esteem, contributing to declining mental health. Mental health challenges can also negatively impact physical health. This is both because poor mental health can make it harder for people to look after their physical health, and because prolonged stress can cause physical problems and increase the risk of developing certain conditions (such as heart disease).

Climate hazards will increasingly cause displacement and restrict access to land, homes, cultural assets and heritage sites. As a result, communities may experience diminished physical and mental health, loss of belonging and identity, and adverse economic conditions. It is likely that these impacts will exacerbate existing inequities, which in turn will have implications for social cohesion and community wellbeing.

Climate hazards do not impact people and communities equally, and are likely to compound existing structural inequities

Certain groups, such as children, older people, some iwi/Māori, people with pre-existing medical conditions and some disabled people have greater physiological sensitivity to the health impacts of climate change, particularly those associated with extreme heat. These groups may also be less mobile and have greater difficulty evacuating during extreme weather events and, because of their reduced mobility, may be more likely to live in flat, low-lying areas that are more exposed to flood events.

Some people may be hit harder than others by climate change due to pre-existing challenges such as poor health, or low income or education levels. This can mean they are less able to change their circumstances to adapt or to influence decision-makers. Some people have very limited options to avoid negative impacts of climate change and can get left behind as others adapt. This can happen when people with the financial resources to do so move out of harm’s way, while others who cannot move remain in a hazard zone – where they can be hit by repeated events.

Often such disadvantages are a result of long historic and structural factors that are beyond the ability of individuals to change. This means climate change-related impacts are very likely to exacerbate existing structural inequities, including for iwi/Māori and Pacific peoples. Due to a variety of historical and structural factors, iwi/Māori experience higher rates of mortality and morbidity than non-Māori across a wide range of health issues and determinants. Iwi/Māori and Pacific peoples also experience existing inequities relating to access to care (including a greater existing burden of disease) and economic deprivation. Against this backdrop, climate-related health and social impacts will have disproportionate impacts on iwi/Māori and Pacific peoples unless specific steps are taken to avoid this.

How does this domain interact with other domains?

Many of the risks to people, health and communities flow on from risks in other domains, particularly the Built environment and Governance domains

Climate hazards can trigger cascading impacts across multiple domains. When climate hazards adversely impact the built environment, including people’s homes and the infrastructure they rely on (such as transport networks and electricity and telecommunications infrastructure), the health and wellbeing of people and communities is negatively impacted. For example, wastewater overflows during flood events can contaminate drinking water and increase the rates of waterborne diseases. Damage to transport networks can result in communities being cut off and unable to access essential services (with resulting impacts on physical and mental health). Prolonged infrastructure failures and service disruptions, along with repeated events that damage people's homes, can contribute to mental health stress and a loss of community wellbeing and social cohesion through displacement, as people start to move away from the community in response. These impacts disproportionately affect communities already facing social and economic inequities.

Loss of access to land, along with temporary or permanent displacement, impacts economic wellbeing and perpetuates existing inequities. This has implications for social cohesion and community wellbeing, as well as physical and mental health. Insurance retreat occurs when the likelihood of damage from natural hazards increases, and insurance becomes more and more costly before being withdrawn altogether. Insurance retreat in certain locations would lower the appeal of the area for those who are able to live or set up business elsewhere, contributing to displacement and a loss of social cohesion. Climate change-related economic pressures, particularly in agricultural communities, may also have adverse impacts on community cohesion.

The ability of people and communities to respond to the risks they face is directly influenced by the trust they have in institutions. Repeated or overlapping events, such as successive floods that drive housing displacement, are compounded by rising living costs, housing insecurity, and uneven access to health and social services. Together, these factors can erode trust in institutions and weaken collective recovery capacity. When climate and recovery decisions are delayed or perceived as unfair, such as inequitable buyouts or inadequate communication, feelings of powerlessness and moral injury increase. This can create feedback loops where social cohesion, institutional trust and mental wellbeing decline in tandem.

Impacts on iwi/Māori

Exposure to sea-level rise, coastal erosion and managed retreat present existential threats to some iwi/Māori communities who live on or near their ancestral lands. Climate change-induced displacement, coastal erosion and managed retreat risk severing iwi/Māori connections to whenua, threatening identity, sustained practice of tikanga (customs, lore) and intergenerational wellbeing. Disconnection from whenua (land), marae and taonga sites erodes intergenerational mātauranga Māori (historic and contemporary Māori knowledge) transmission, undermining iwi/Māori identity, wellbeing and whakapapa-based relationships with place. This can lead to identity shocks and intergenerational anxiety, disrupt tikanga and weaken whanaungatanga (relationships, kinship).

Iwi/Māori face increased health risks from climate change due to systemic inequities in housing, healthcare and infrastructure, along with exclusion from health governance and climate planning. These factors increase vulnerability to heat, disease, poor air and water quality, displacement and distress, particularly for wāhine Māori (Māori women),[417] disabled Māori and rural whānau. Food insecurity, nutritional decline and the loss of access to mahinga kai (food gathering places) are increasingly intensified by the degradation of ecosystems. Ecological and economic pressures exacerbate pre-existing health inequities among some iwi/Māori, who already face higher rates of respiratory, cardiovascular and metabolic conditions.

Systemic policy issues

The exposure and sensitivity of people and communities to climate change-related impacts will increase over time, putting additional pressure on already stressed systems

Several demographic shifts and trends have implications for the risks in this domain. Aotearoa New Zealand's population is projected to reach about 6.5 million by 2048.[229] More than 90% of people are projected to live in urban areas (which are mostly located in coastal areas) by 2050. It will be essential to consider climate change-related impacts when planning and managing this growth (and associated infrastructure) to avoid increasing exposure to climate-related risks.

As communities are displaced and property values decline in affected areas, it may become more common for people move into cheaper, poorer quality rental housing. This may pose additional risks. People who rent their homes generally experience poorer health and wellbeing outcomes than homeowners. Some may even be driven to move into areas that are becoming increasingly exposed to climate hazards (with associated risks) because property values are declining in those areas and there is a lack of affordable alternatives.

Aotearoa New Zealand also has an ageing population. Population projections show that the percentage of older adults (65+ years) is projected to almost double from 16.6% in 2023 to about 28.2% by 2073. Older adults are more sensitive to climate change-related impacts due to their increased physiological sensitivity. They also have increased reliance on access to social infrastructure and community services and on strong social networks and bonds for support.

Recent extreme weather events and the COVID-19 pandemic have also exposed gaps and pressure points in a health system that is already under stress. Systemic under-resourcing and weak coordination are major barriers to addressing climate-related physical and mental health risks. Aotearoa New Zealand's health system already struggles to meet demand and will need to increase its adaptive capacity to cope with a higher proportion of people who are injured or unwell as a result of climate change-related impacts.

Table 3.3: Risk ratings for People, health and communities

Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090*			
			GWL 2	GWL 3–3.5		
Risks to mental health, identity and belonging from trauma and chronic stress and anxiety due to progressive and ongoing sea-level rise, extreme weather events and associated impacts like flooding and landslides.	Major	Major	Major	Extreme	Insufficient	Low
Risks to the ability of the emergency management system to respond to the increasing frequency and scale of climate change impacts in Aotearoa New Zealand and the Pacific region.	Major	Major	Major	Extreme	Significant gaps	Low
Risks to social cohesion, community and cultural wellbeing from the displacement of individuals, families and communities due to progressive and ongoing sea-level rise, extreme weather events, and associated impacts like flooding and landslides.	Moderate	Major	Extreme	Extreme	Insufficient	Low
Risks to physical health from illness and injury due to progressive and ongoing changes in temperature and precipitation, extreme weather events, and associated impacts like heatwaves and flooding.	Moderate	Moderate	Major	Extreme	Significant gaps	Low
Risks to social infrastructure and community services due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like flooding and landslides.	Minor	Moderate	Major	Major	Significant gaps	Low

- Minor
- Moderate
- Major
- Extreme

- No significant gaps
- Moderate gaps
- Significant gaps
- Insufficient

- Low
- Medium
- High
- Very high

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*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0-3.5°C by 2090 (GWL 3-3.5).

RISK: Mental health

Risks to mental health, identity and belonging from trauma, chronic stress and anxiety due to progressive and ongoing sea-level rise and extreme weather events and associated impacts like flooding and landslides.

Mental health encompasses both wellbeing and psychological distress, shaped less by individual factors and more by wider social and environmental conditions such as income, housing, culture and community connection.[418,419] Climate change is intensifying existing pressures on mental health, driving anxiety, grief and trauma through extreme weather, displacement and uncertainty about the future.[420] Those most affected and at risk of climate-related mental distress are iwi/Māori, Pacific peoples, disabled people, the elderly, migrant and rural communities and youth. Without early, coordinated adaptation, climate change is likely to deepen distress, widen inequities and further weaken the collective wellbeing on which Aotearoa New Zealand's resilience depends.

This was identified as one of the most significant risks as part of the combined social and community wellbeing risk

The risk to mental health was rated at major severity in the present day, and the risk to social cohesion and wellbeing (from displacement) was rated major by 2050. Both risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to social and community wellbeing satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050 and, because of the very low base of current readiness, significant lead time is required to prepare for them. All significant risks are discussed in more detail in the Priorities for action report.

Risk overview

There are escalating mental health pressures that are amplified by climate change

Climate change presents a growing threat to the mental health and wellbeing of people in Aotearoa New Zealand, affecting not only physical safety and livelihoods but also belonging, identity and hope. Mental health is already in decline, with 13% of adults (around 564,000 people) reporting high psychological distress in 2023/24, almost triple the 2011/12 rate.[421] Climate-related risks amplify these pressures through direct, indirect and anticipatory pathways that intersect with existing inequities to widen distress.[422,423]

Across Earth Sciences New Zealand's climate projection periods (2030, 2050, 2090), Aotearoa New Zealand will experience progressively warmer temperatures and more intense and frequent rainfall.[165] By mid-century and especially by 2090, these shifts will result in larger, more frequent and more disruptive flood events, alongside growing exposure to heat and drought in many regions.[21,250] These escalating exposure patterns increase the likelihood, frequency and cumulative burden of mental health impacts arising from both direct trauma and the wider social, cultural and economic disruptions that follow.

Structural inequities are driving vulnerability

Climate-related mental health risks arise primarily from structural inequities rather than individual fragility.[424,425] Distress rates are highest among iwi/Māori, Pacific peoples, disabled people, young people and those in low-income or rural areas.[426] Migrant and elderly groups share many of the same risk factors.[74] These inequities reflect deprivation, poor housing and limited access to culturally appropriate care.[419,421] The mental health system is reactive and under-resourced, with more than 1 in 10 adults reporting unmet need for support.[421]

Direct, indirect and anticipatory stressors compound harm over time

Climate change acts as a risk multiplier affecting mental health. Repeated extreme weather events can cause trauma and grief, while ongoing uncertainty about recovery, housing and livelihoods can erode people's sense of safety and belonging.[422,427] Progressive and ongoing changes, such as sea-level rise (SLR), and loss of culturally significant places further undermine identity and collective resilience.[32] People and communities facing existing social and economic inequities are most affected. Without coordinated, equity-focused adaptation, climate change is likely to accelerate Aotearoa New Zealand's mental health crisis, exacerbating inequities and weakening the collective wellbeing on which effective adaptation depends.[428]

Mental health effects of climate change are often delayed and cumulative.[420,429,430] Acute distress following a disaster can evolve into chronic stress when uncertainty about insurance, housing or recovery persists.[431,432] Repeated exposure, such as successive floods or droughts, can retraumatise affected populations and progressively erode trust in institutions.[428]

Floods, heatwaves and droughts trigger trauma, anxiety and chronic stress

Direct exposure to floods, storms, droughts, fires or heatwaves can trigger trauma, anxiety and depression.[422,427,430] Indirect impacts, such as economic disruption, housing loss and weakened community ties, undermine belonging and trust.[431-433] Anticipatory stress, including climate anxiety and grief about perceived inaction, is especially high among young people.[430,434,435] Repeated or overlapping events re-traumatise affected populations and erode confidence in recovery systems.[428,436]

Extreme rainfall and flooding are the strongest documented drivers of psychological harm, linked to higher rates of post-traumatic stress, anxiety and substance use.[422] For example, after the 2023 North Island Severe Weather Events, affected residents reported ongoing stress a year later.[432,436] Anxiety about homes and loved ones and how they will fare during extreme weather events are heightened during the event, and ongoing personal struggles are evidenced in the aftermath.[433]

Rising temperatures and more frequent heatwaves heighten irritability, aggression and suicide risk, especially for people with severe mental illness.[437] Rural communities are likely to face heightened strain from drought and environmental degradation.[438] They can also face particular social isolation challenges and difficulty accessing health services. However, some rural communities have support in place. For example, Rural Support Trust Te Taitokerau's model centres on supporting people with direct assistance, such as coordinating mental health support, connecting growers with financial and advisory services, responding to local emergencies and arranging social functions between farmers.[290] For more information, refer to the Primary sector resilience and early adaptation section of the Commission's Te Taitokerau Northland case study.

Adaptive capacity and resilience are strengthened by strong social cohesion, cultural identity and access to housing

Adaptive capacity and resilience depend on social cohesion, cultural identity and equitable access to healthcare and housing. Culturally grounded wellbeing models such as Te Whare Tapa Whā and community-led adaptation can strengthen belonging and mutual aid, reducing distress and enhancing recovery.[439,440]

Risks for iwi/Māori include inequities and cultural disruptions

The risk of mental health impacts for iwi/Māori is significant, particularly given the compounding challenges experienced across multiple domains, and similar concerns apply to other communities that may be more vulnerable to climate-related stressors.[441] For more information, see the *Increased Māori health vulnerabilities* risk analysis.

The natural environment has traditionally been an essential source of sustenance, wellbeing and identity. Research shows a strong association between Māori identity and enhanced sense of environmental connection, and personal connectedness to the environment has the greatest influence on feelings of environmental distress. Systemic and systematic forces coupled with distress from environmental degradation perpetuate inequality and inequity for iwi/Māori.[442]

Climate change also threatens both mental health and cultural continuity. Flooding, SLR and coastal erosion endanger marae, urupā (burial grounds) and papakāinga (housing), disrupting tūrangawaewae (standing place) and collective identity.[32,165,443,444] Iwi/Māori already experience barriers to health access and culturally inappropriate care, factors that amplify exposure during high-stress periods, including climate emergencies.[320]

Compounding and cascading factors

Intersecting stressors create feedback loops that weaken resilience

Climate-related mental health risks do not occur in isolation; they interact with social, economic and institutional stressors in ways that amplify harm over time. Repeated or overlapping events such as successive floods, prolonged recovery and housing displacement create cumulative psychological strain and re-traumatisation, especially for communities with limited support networks or financial resilience.[428,432,436] These pressures are compounded by rising living costs, housing insecurity and uneven access to health and social services, which together erode trust in institutions and weaken collective recovery capacity.[419,424,445] When climate and recovery decisions are delayed or perceived as unfair, such as inequitable buyouts or inadequate communication, feelings of powerlessness and moral injury increase, particularly among young people and those most affected by climate anxiety.[430,431,433,435,xxxii] As climate hazards intensify, these intersecting stressors could create loops where social cohesion, institutional trust and mental wellbeing decline in tandem, constraining both adaptation readiness and long-term societal resilience.

Interaction with emissions reduction

While research directly linking emissions reduction actions and mental health is limited, emerging evidence shows that visible, equitable climate action can reduce distress by fostering trust, hope and a sense of agency, particularly among young people.[435] Conversely, emissions reduction measures perceived as inequitable or disruptive can heighten anxiety and erode social trust. Well-designed low-emissions initiatives, such as green and blue infrastructure projects, active and public transport systems, and energy-efficient housing, can simultaneously reduce emissions and enhance mental wellbeing by improving living conditions, social connection and belonging.[446-448] Community-led projects, such as neighbourhood hubs, further strengthen social cohesion and cultural identity.[449] Embedding wellbeing and equity in climate policy design can therefore lower climate-related mental health risks while supporting Aotearoa New Zealand’s broader adaptation and emissions reduction goals.

Policy readiness assessment

Current frameworks acknowledge risk but lack funded, coordinated delivery

Climate-related mental health risks are recognised in national policy but remain weakly addressed in implementation. The Government Policy Statement on Health 2024–27 identifies mental health as a priority and commits to expanding access, prevention and early intervention, yet it does not explicitly incorporate climate-related drivers or resilience

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[xxxii] Climate anxiety is defined by UNICEF as heightened emotional, mental or physical distress in response to dangerous changes in the climate.

objectives. The national adaptation plan and health national adaptation plan acknowledge mental health and wellbeing as key concerns, and the latter proposes an assessment of climate impacts on mental health.[70,426] However, neither plan provides a funded or mandated programme for delivery. Broader policy frameworks such as Kia Manawanui Aotearoa, Pae Ora reforms and the Government Policy Statement on Health lack mechanisms to embed climate-related wellbeing outcomes. No agency holds clear accountability for post-disaster psychosocial support or climate-anxiety prevention. Independent analyses conclude that Aotearoa New Zealand's health adaptation settings remain fragmented, under-resourced and without intersectoral coordination.[450] Consequently, policy coverage is partial and largely declaratory, with limited translation into funded action.

Systemic under-resourcing and weak coordination constrain effective adaptation

Systemic under-resourcing and weak coordination are major barriers to addressing climate-related mental health risks. Aotearoa New Zealand's mental health system already struggles to meet demand, with 94% of psychiatrists reporting inadequate resourcing,[451] alongside persistent workforce shortages.[452] Fragmented policies and implementation limit capacity to respond to rising climate-related distress.[450] Māori and Pacific wellbeing frameworks remain under-recognised, despite demonstrated effectiveness in disaster recovery.[436] The sector's limited influence over housing, transport and environmental policy further constrains proactive, equitable adaptation.[450]

Early investment will help to avoid systemic lock in and missed co-benefits

Action in the upcoming six years before the next risk assessment is critical to prevent long-term lock in of system deficits. Without early investment, adaptation programmes will continue without integrating or addressing mental health or wellbeing outcomes, while also missing major co-benefits. Workforce growth requires long lead times, meaning training and funding decisions should be made as soon as possible. Although policies acknowledge mental health in principle, resourcing, mandates and coordination remain insufficient. Adaptation measures for mental health lack a defined institutional home within the Pae Ora structure, and local government capacity and mandate for community wellbeing has weakened. Clear national accountability and coordination between Health New Zealand Te Whatu Ora and the Ministry of Health Manatū Hauora, and sustained funding for iwi, hapū and community-based initiatives are required. Upcoming reviews of the Health Strategy, Kia Manawanui and the health national adaptation plan offer immediate opportunities to embed wellbeing, resilience and equity within climate-health policy.

Gaps for risk severity and policy

There is moderate to high confidence in the overall assessment of current climate-related mental health risk. This confidence is supported by strong international evidence and emerging Aotearoa New Zealand case studies. However, confidence in the precision of national estimates and future trajectories is lower due to limited data and specific long-term monitoring and studies. Implementation of the health national adaptation plan action to deliver an assessment of climate impacts on mental health would help to address many of these gaps.

Summary

Climate change is projected to significantly worsen mental health outcomes in Aotearoa New Zealand, increasing both acute distress following extreme events and chronic stress linked to displacement, housing insecurity and climate anxiety. Those already facing structural barriers and inequities, including iwi/Māori, Pacific peoples, disabled people, rural communities and youth, will bear the greatest burden. Current systems are not prepared to manage these increasing risks, as the mental health sector is under-resourced, reactive and poorly integrated alongside nil-to-limited input into adaptation planning. Without near-term investment in improving the structural conditions that influence mental health, workforce capacity, culturally grounded care and coordinated policy and action, climate change is likely to deepen psychological distress and erode collective wellbeing across generations. Embedding consideration of wellbeing and mental health in broader climate adaptation policies and actions will help to reduce this risk.

Risk scorecard: Mental health

Risks to mental health, identity and belonging from trauma and chronic stress and anxiety due to progressive and ongoing sea-level rise, extreme weather events, and associated impacts like flooding and landslides.

Identified as one of the most significant risks as part of the combined social and community wellbeing risk.

	Score	Rationale
Risk severity		
Now	Major	Direct exposure to extreme climate events has already been linked to higher rates of anxiety, depression and post-traumatic stress. Increasing event frequency heightens this risk, while indirect exposure, such as witnessing global disasters or perceiving inadequate climate action, also contributes to climate anxiety. Increasing impacts of events expected to create equity considerations, especially for communities previously affected by disasters.
2050	Major	
2090*	Major GWL 2	Increased frequency of extreme events and higher temperatures and the direct and indirect impacts of these, along with equity considerations, will likely result in widespread trauma, anxiety and depression.
	Extreme GWL 3–3.5	Very frequent severe events are likely to have serious adverse impacts on the mental health of a large proportion of the population, likely putting intense pressure on an already struggling mental health system (contributing to a reduction in adaptive capacity).
Policy readiness		
Overall assessment	Insufficient	Current policies, plans and actions lack detail, funding and mandate, and implementation is challenging. Inadequate resourcing and coordination are major barriers. Even if implemented, major parts of the risk remain unaddressed.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it has strong connections to the risks to social cohesion, community and cultural wellbeing.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Emergency management system

Risks to the ability of the emergency management system to respond to the increasing frequency and scale of climate change impacts in Aotearoa New Zealand and the Pacific region.

Strong emergency management saves lives and livelihoods, reduces injuries and trauma, limits damage to homes and businesses, and supports long-term health, economic and social conditions in communities. Often thousands of people participate in the response to extreme weather events, in challenging conditions.

Climate change presents risks to the ability of the emergency management system to respond to an increasing frequency and scale of concurrent, compounding and cascading climate change impacts in Aotearoa New Zealand and the Pacific region. Aotearoa New Zealand already faces significant natural hazard risks, and climate change is projected to increase the frequency, severity and spatial extent of climate-related natural hazard events. It will also increase the risk of multiple hazard events occurring at the same time, stretching the capacity of the emergency management sector to respond.[18] Aotearoa New Zealand provides and receives disaster assistance across the broader Asia-Pacific region.

The need to improve the emergency management system has been recognised, and the system is being reformed. However, some reforms have been delayed.

In addition to the increased demand for emergency management services, infrastructure critical to the delivery of those services may be damaged during extreme weather events such as floods, fires or landslides, as well as by gradual, ongoing impacts such as sea-level rise (SLR) and coastal inundation.[18]

This was identified as one of the most significant risks

The risk to the emergency management system is rated at major severity in the present day, with significant gaps in policy readiness. This satisfied the first principle of our review for significance: it presents high potential for adverse consequences now, and there is little in place now to address them, warranting immediate focus. For more, see the separate write-up of this significant risk in the Priorities for action report.

Risk overview

Aotearoa New Zealand is already experiencing extreme weather events, and there is increasing exposure to climate-related risks

Climate change is already increasing the intensity, frequency and duration of extreme weather events such as extreme heat, intense rainfall and wildfires. Additionally, past and current planning decisions to allow development in exposed locations means much of Aotearoa New Zealand's built environment is exposed to climate-related natural hazards such as SLR and more frequent extreme weather events, and this exposure will increase as the climate changes.[11] During a 1% annual exceedance probability (AEP) rainfall event (an event which has a 1% chance of happening in any given year), 754,000 people (15% of the population) and NZ$235 billion worth of buildings are currently exposed to flooding. This exposure increases to 902,000 people and NZ$288 billion worth of buildings with about 4°C of warming[xxxiii] (as compared to 2024).[251] This increased exposure of the population will likely result in more people being in harm's way during extreme weather events, increasing the scale of the emergency management response needed and putting strain on the emergency management system.

Aotearoa New Zealand has already experienced concurrent, compounding and cascading extreme events. The 2023 North Island Severe Weather Events collectively became the most severe and destructive weather events in Aotearoa New Zealand's recent history. Fifteen people lost their lives.[11] One study found that Cyclone Gabrielle would have dumped about 10% less total rainfall and 20% less peak hourly rainfall in a world without anthropogenic climate change, while a 2°C warmer world would result in a comparable total increase in storm rainfall (a further 10%) but with about a 30% increase in the peak hourly rate.[10] The events demonstrated that the emergency management system becomes overwhelmed in situations where multiple regions are experiencing near concurrent emergency events. The Report of the Government Inquiry into the Response to the North Island Severe Weather Events (2024) found that the current emergency management system is not fit-for-purpose and must change to meet the reality that Aotearoa New Zealand is facing more frequent and severe weather events.[453]

Climate hazards are projected to increase, and may limit the ability of the emergency management system to respond

Aotearoa New Zealand's emergency management system is exposed and vulnerable to climate hazards such as SLR, flooding, wildfires, extreme heat and landslides. These climate hazards will become more frequent and severe over time. There are several distinct risks to the ability of the emergency management system to respond. These risks are projected to increase in severity over the course of the century and to be more severe under a high climate impact scenario than under a low climate impact scenario.

Regional interdependence and extra demand are placed on Aotearoa New Zealand for humanitarian response

In addition to the increased demand in response to domestic extreme weather events, extra demand is likely to be placed on Aotearoa New Zealand's capacity to provide emergency

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[xxxiii] The original data for this level of warming was calculated using an "additional warming" approach, which measures temperature increases on top of the warming the climate has already experienced (approximately 1°C above pre-industrial levels). To make this clearer and consistent with the rest of the risk assessment, the Commission has converted additional warming into warming relative to pre-industrial. As a result, a projection of 2°C of additional warming is presented as about 3°C total warming, for example, reflecting that approximately 1°C of warming has already occurred.

response services to its regional neighbours, and vice versa. Aotearoa New Zealand provides humanitarian aid, including disaster assistance, to the broader Asia-Pacific region. Demand for this assistance will likely increase as the climate changes and extreme weather events become more frequent and intense.[18,454] The projected increase in extreme weather events globally may also limit the support available to Aotearoa New Zealand from other countries in the region during a crisis.

Infrastructure disruption limits emergency response and causes distress for isolated communities

The ability of the emergency management system to respond to severe weather events can be impacted by disruption to transport and telecommunications networks caused by the event. For example, during Cyclone Gabrielle, challenges in communicating information between parts of the emergency response and in providing warnings to the public were exacerbated by the loss of some communications systems and the lack of backup systems. Cyclone Gabrielle also caused significant damage to electricity infrastructure, telecommunications, bridges, roads, water services and other critical infrastructure, hampering coordination of the rescue effort and causing distress for isolated communities.[11] The 2025 winter floods at the top of the South Island damaged roads and led to phone and internet outages, which meant some people were unable to call emergency services.[455,456] See risks to *Road and rail networks* and *Electricity and telecommunications infrastructure* for more information.

The emotional toll on frontline workers increases vulnerability to this risk

An increase in the frequency and severity of extreme weather events will also increase the demands on emergency management personnel. This could affect the health, safety and emotional wellbeing of emergency management workers.[18] Frontline workers are often members of the affected communities and have connections to local people and places that can cause emotional distress as they carry out their work responding to disasters.[457] During the 2023 North Island Severe Weather Events, council staff with emergency management duties often worked long hours in highly stressful situations, which was detrimental to their wellbeing.[11] One report noted that the local councils' emergency management staff have been traumatised by the event. A number have resigned, some have left the region entirely due to public backlash and councils are having trouble recruiting their replacements.[458]

Cumulative events affect long-term wellbeing, risking physical and mental health

A study on the experiences of decision-makers and information providers during recurring flood events in Westport found that the recurrent nature of the floods intensified the exhaustion experienced by those involved, with some still experiencing exhaustion and stress long after the event, leading to physical illness and poor mental health.[457]

Iwi/Māori respond to climate change events, but can be impacted in ways not usually recognised by mainstream disaster risk reduction assessments and practices

Māori infrastructure is often mobilised to secure community wellbeing in the aftermath of disasters; however, this may itself be affected by climate change.[18] Some of the most effective and rapid responses to the North Island Severe Weather Events were coordinated and carried out by iwi/Māori. Iwi/Māori provided manaaki (hospitality, support), critical equipment, response and wellbeing support, money and facilities for welfare to people in their rohe (district or territory), and in some cases responded more effectively than councils (through early activation of marae and community structures and networks).[11] Similarly effective responses and significant community support were facilitated by iwi/Māori in the aftermath of the Canterbury and Kaikōura earthquakes and the floods in Edgecumbe.[459,460]

Iwi/Māori have strong leadership and networks as well as community and cultural values and practices, which contribute to resilience to climate-related hazard events. However, iwi/Māori can be impacted by extreme weather events in ways that are not usually recognised by mainstream disaster risk reduction assessments and practices, which tend to prioritise the built environment (for example, roading infrastructure, electricity networks, and homes) and overlook the wider interests of iwi/Māori, such as impacts on the connected ecosystem. Other impacts not typically recognised by mainstream risk assessment processes relate to mana (authority, power) and mauri (life force, vital essence) and can include impacts on taonga species (culturally significant flora and fauna), mahinga kai (food gathering practices and places) and wāhi tapu (sacred sites).[461] For more information see *Ngā mea hirahira o te ao Māori*.

Compounding and cascading factors

Increasing complexity of future hazards will place additional strain on the emergency management system

As the climate changes, the likelihood of multiple climate-related hazard events occurring at the same time or in quick succession will increase. There is also an increased likelihood of a climate-related hazard event overlapping with another natural hazard event requiring an emergency management response (such as an earthquake). As discussed above, these compounding and concurrent natural hazard events will place additional strain on the ability of the emergency management system to respond.

Demographic changes may increase this risk

Other social, economic and demographic trends that may influence this risk include population growth, particularly in urban areas. Over 86% of New Zealanders live in urban areas and that proportion is projected to increase to over 90% by 2050 (mostly in coastal areas),[4] which will increase exposure to SLR and coastal flooding. Changes to the composition of different demographic groups in Aotearoa New Zealand may also contribute to increased vulnerability. For example, older people (aged 65 or older) are more likely to have mobility challenges that affect their ability to evacuate from areas affected by extreme weather events.[462] Population projections show that the Aotearoa New Zealand population is ageing, and the number of older adults aged 65+ years in Aotearoa New Zealand is likely to increase to nearly 2 million by 2073.[74] Both these trends will likely increase demand on the emergency management system.

Policy assessment

There is system reform under way

The Report of the Government Inquiry into the Response to the North Island Severe Weather Events (2024) found that the current emergency management system is not fit-for-purpose. The Government has indicated it intends to pass a new Emergency Management Bill in 2026, and Cabinet has agreed to a series of policy proposals following public consultation for the new Bill. The proposals aim to deliver on commitments made following the Government Inquiry into the Response to the North Island Severe Weather Events.[463,464]

Community and iwi/Māori roles in emergency management may be strengthened

One of the Government's proposed objectives for the new legislation is to strengthen the role of communities and iwi/Māori in emergency management,[464] a role that has often gone unrecognised as iwi/Māori have historically largely not been included in official emergency management legislation and documentation.[465] The discussion document for the Emergency Management Bill also puts forward options to strengthen and enable iwi/Māori participation in emergency management, including through legislation.[466]

There is a parallel work programme under way to improve the system

The Emergency Management System Improvement Programme seeks to implement changes following the Government Inquiry into the Response to the North Island Severe Weather Events.[466] Cabinet accepted all the high-level recommendations made by the Inquiry. It approved 15 actions across five focus areas, and an investment and implementation roadmap has been prepared.[466]

Despite policy progress there are barriers, including delays in legislative reform and systemic and operational barriers

There have been some delays to the implementation of emergency management actions included in the first national adaptation plan.[46] These delays have largely stemmed from the Government's decision not to proceed with the 2023 Emergency Management Bill, which was deemed not fit for purpose.[46] The National Emergency Management Agency has noted that until there is clarity around what the emergency management legislation will provide for, other work to support the emergency management system will not be able to progress.[46] The new Emergency Management Bill is still in development, and the Emergency Management System Improvement Programme is still in the early stages, so implementation is some way off.

Under the current emergency management system, barriers to more effective adaptation action include a lack of investment in readiness planning and a lack of involvement of communities and key organisations in planning activities.[11]

There are opportunities to take on board recommendations to improve the emergency management system now

The Emergency Management System Improvement Programme and the new Emergency Management Bill represent key opportunities to ensure Aotearoa New Zealand has an emergency management system that can respond to an increasing frequency, scale and intensity of extreme weather events as the climate changes. However, there is potential lock in of risks and loss of opportunities if these work programmes do not adequately take on board the lessons learned from the 2023 North Island Severe Weather Events or adequately consider the impacts of future climate change.

It is not possible to make a comprehensive assessment of the effectiveness of the reforms at this stage

Because these work programmes are at relatively early stages, it is difficult to make a comprehensive assessment of the potential shortfall in addressing this risk, as it is not yet clear how successful they will be in making the necessary improvements to the emergency management system.

The objectives for the new legislation are to strengthen the role of communities and iwi/Māori in emergency management; provide for clear responsibilities at national, regional and local levels; enable a higher minimum standard of emergency management; minimise disruption to essential services; and ensure agencies have the tools to be effective in an emergency.

These changes, combined with an Emergency Management System Improvement Programme, aim to deliver on commitments made in response to the Government Inquiry into the Response to the North Island Severe Weather Events.

This would address some of the improvements needed, including addressing the historical omission of the role played by iwi/Māori in official emergency management legislation and documentation.

However, any further delays to the implementation of relevant work programmes could amplify future risks to the emergency management system. This strengthens the case for action in the following six years until the next national risk assessment.

Gaps for risk severity and policy

There is robust evidence and agreement that increasingly frequent and severe extreme events will strain Aotearoa New Zealand's emergency management capability. The 2023 North Island Severe Weather Events provide a useful case study of the impacts of cascading and compounding hazard events on Aotearoa New Zealand's emergency management system, but further research exploring the impacts of these events on the integrity of emergency management systems is still needed. The ongoing consequences for the emergency management workforce is also an area requiring further study.

There is good evidence of actions being undertaken at the national level to make improvements to the emergency management system. It is less clear how the actions will specifically contribute to improving the emergency management system's ability to respond to the kind of coincident, cascading and compound hazard events that will occur more frequently as the climate changes.

Summary

This risk is already present, with the 2023 North Island Severe Weather Events demonstrating that the emergency management system is under stress. Reviews of the response to the North Island Severe Weather Events have concluded that the current system is not fit-for-purpose and lacks the capacity or capability to deal with the kind of significant, complex, widespread events impacting multiple regions that will become more prevalent as the climate changes. Additionally, impacts on the emergency management workforce are already being felt with staff experiencing burnout and resigning, and councils having trouble recruiting replacements. This risk could increase in severity over the course of the century and may be particularly severe in 2090 under a high climate impact scenario.

The Emergency Management System Improvement Programme and the new Emergency Management Bill represent important opportunities to address this risk. However, these work programmes are in the early stages, and it remains to be seen to what extent they will produce the necessary changes to the emergency management system. There is potential lock in of risks and loss of opportunities if these work programmes do not adequately consider the future impacts of climate change, which strengthens the case for action in the next six years.

Risk scorecard: Emergency management system

Risks to the ability of the emergency management system to respond to the increasing frequency and scale of climate change impacts in Aotearoa New Zealand and the Pacific region.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Major	Strain on the workforce, including burnout, recruitment issues and loss of experienced staff after the North Island Severe Weather Events is reducing the ability to respond effectively to climate hazards, with the greatest impacts falling on communities already affected or recovering.
2050	Major	Increasing international and domestic demand for emergency management as extreme events intensify is expected to stretch resources, and concurrent events are likely to exceed the system's capacity to cope, especially if problems with the current system persist.
2090*	Major GWL 2	
	Extreme GWL 3–3.5	The expected increase in frequency of significant, multi-hazard and concurrent events will be even greater under a high-emissions scenario and will exceed the coping capacity of the emergency management system to respond, especially if problems with the current system persist.
Policy readiness		
Overall assessment	Significant gaps	Although important national-level reforms are under way, they are in the early stages, and it is unclear whether they will deliver the necessary improvements to an emergency management system currently not fit for purpose.
Cascading risk		
Overall assessment	Low	Addressing this risk has low potential to address others in the assessment, though it has a strong connection to the risks to physical health.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Social cohesion, community and cultural wellbeing

Risks to social cohesion, community and cultural wellbeing from displacement of individuals, families and communities due to progressive and ongoing sea-level rise, extreme weather events and associated impacts like flooding and landslides.

Climate change presents risks to social cohesion, community and cultural wellbeing from displacement of individuals, families and communities due to climate change impacts. Extreme events such as flooding, erosion and landslides, or ongoing, gradual changes such as sea-level rise (SLR), may result in some currently inhabited locations becoming uninhabitable. In addition to being displaced from their homes, people may also be displaced from cultural assets and cultural heritage sites. Displacement and internal migration within Aotearoa New Zealand may also be accompanied by immigration into the country, particularly from neighbouring Pacific countries.

Although it can also have positive outcomes and can be a necessary solution in the face of repeated exposure to hazards, displacement presents risks to social cohesion and community and cultural wellbeing, both for those who are displaced and for those who remain behind, as well as for the communities that displaced people move into. This risk considers both the impacts on those who move away and the impacts on the community left behind. When people are displaced or mobilised, they can suffer trauma from leaving familiar surroundings, social and cultural bonds being disrupted, and challenges associated with resettlement. Mobilised populations will change the composition of, and relations between, communities; impact housing and labour markets; necessitate adjustments to regional development planning; and alter demand for essential services and other resources.[18] Those who remain behind may experience a sense of loss and abandonment as the environment changes and the community shrinks,[467] and similar trauma from the breaking of family, social and cultural bonds. As a community reduces in size, essential services and job opportunities may also be reduced. Planning and managing relocation well, working together with the affected communities, can help to reduce these impacts.

This was identified as one of the most significant as part of the combined social and community wellbeing risk

The risk to mental health was rated at major severity in the present day, and the risk to social cohesion and wellbeing (from displacement) was rated major by 2050. Both risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to social and community wellbeing satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050, and because of the very low base of current readiness, significant lead time is required to prepare for them. All significant risks are discussed in more detail in the Priorities for action report.

Risk overview

There is high exposure to climate hazards in Aotearoa New Zealand, particularly around coasts and rivers

Communities around Aotearoa New Zealand are exposed to climate hazards such as SLR, flooding, erosion and landslides. Intensification of development along coastal areas and concentration of the population in these areas through urbanisation are increasing the number of people exposed to these hazards.[18] Around 750,000 New Zealanders (15% of the population) currently live near rivers and in coastal areas already exposed to extreme flooding, including major urban centres and 500,000 buildings worth more than NZ$145 billion.[9] This exposure will increase over time due to population growth and climate change. Many cultural heritage sites are in coastal low-lying areas that are exposed to erosion and inundation.

Exposure to these climate hazards is projected to increase over the course of the century, and to be greater under a high climate impact scenario than a low climate impact scenario.

Climate hazards can lead to displacement, disrupting social cohesion, cultural ties and community wellbeing

Exposure to coastal inundation and extreme weather events can disrupt people’s daily lives and cause stress, impacting social cohesion and community wellbeing. Some people may be impacted to such a degree that they decide to move away from the community, or whole communities may be displaced once the risks from climate hazards reach a point where they become intolerable. This displacement will disconnect people from their land, homes, communities and livelihoods, and the security, networks and cultural values and assets associated with them.[9]

International migration to Aotearoa New Zealand may have further implications for social cohesion

Additionally, SLR represents a direct and imminent threat to the ability to sustain viable livelihoods in some low-lying Pacific Island countries.[468] Aotearoa New Zealand is one of the main destination countries for Pacific peoples. Many Pacific communities already have strong and longstanding connections and roots in Aotearoa New Zealand. An increase in migration to Aotearoa New Zealand from overseas may have implications for social cohesion, including for migrants themselves, although the relative scale compared to other sources of migration is unclear and the potential impacts of increased international migration are less well understood.

Displacement can disrupt social and cultural networks that are vital before, during and after extreme events

Social and cultural networks, assets and relationships within communities are particularly important prior to, during and in the recovery process after extreme events. As a community shrinks due to displacement, disruption of these networks can increase the sensitivity and decrease the adaptive capacity of the community to respond to future events.[18] Communities and individuals that are most likely to be sensitive to this risk include:

- those with livelihoods that depend on the natural environment, such as farmers and rural communities – for more information, see the *Sectors relying on the natural environment* domain
- individuals reliant on strong social networks and bonds for support, such as older people[18]
- iwi/Māori because of their close social, cultural and spiritual connections to the natural world,[469] meaning that disruptions to the physical landscape may sever whakapapa-based relationships with wāhi (place), undermining the transmission of mātauranga Māori (historic and contemporary Māori knowledge) and tikanga (customs, lore) Māori – for more information see *Ngā mea hirahira o te ao Māori*
- renters and people who are more socio-economically disadvantaged, as they may not have the means to relocate away from at-risk communities without outside assistance.[470]

Exacerbation of existing inequities could increase the overall sensitivity of the community to climate hazards

This risk is likely to exacerbate existing inequities. In communities where climate change impacts are driving people out of the area, declining appeal of the area may unexpectedly increase its affordability, which may result in a higher proportion of people living in the area who are renting or who are more socio-economically disadvantaged.[427] This could change the socio-economic structure of the community and increase the sensitivity of the community to climate hazards.

The way in which displacement occurs is likely to impact the sensitivity of the affected community to this risk. For example, proactive managed retreat that takes place before a disaster is likely to impact social cohesion and community wellbeing to a lesser extent than reactive retreat from an area after a disaster has struck (where it is more likely to result in inequitable outcomes as property values decline and residents with fewer resources have fewer options available to them).[471]

There is potential to strengthen social cohesion and community wellbeing through proactive, inclusive action

Social cohesion and community wellbeing are important for resilience and adaptive capacity. If these features of community are compromised or adversely impacted, adaptive capacity is likely to be reduced.

There is an opportunity for social cohesion of communities to increase through adaptation action. For example, in South Dunedin, a low-lying area highly exposed to flooding from a combination of a rising water table, heavy rainfall, drainage and SLR, participants interviewed as part of a study shared their hopes for improved health and wellbeing in the community, with over a third of participants saying they hoped South Dunedin would become a more connected and caring community.[427] Participants identified that participation in adaptation decision-making and community-building activities and community-led development reinforce agency and self-determination within the community, which are essential for wellbeing.[427]

Iwi/Māori are already experiencing the impacts of climate hazards, and these are projected to increase with the potential need to relocate

Iwi/Māori are already experiencing impacts from climate change hazards such as SLR and extreme weather events, causing flooding and erosion that impact housing, marae and urupā (burial grounds) and cause damage to infrastructure, such as roads. Droughts and storms cause degrading water quality, water shortages during droughts, and impacts to māra kai (food gardens) and mahinga kai (food gathering places).[155]

In the near future, projected impacts include increasing severity of the impacts discussed above, water security issues, impacts on species and biodiversity, impacts on livelihoods and jobs, and the potential need to relocate marae, urupā (burial grounds) and kāinga (housing) due to SLR and flooding.[155]

Compounding and cascading factors

A loss of social cohesion and community and cultural wellbeing resulting from exposure to climate hazards may increase the sensitivity and reduce the adaptive capacity of individuals and communities to climate change impacts more generally. Therefore, this risk may have an exacerbating effect on other risks, such as mental health.

Aotearoa New Zealand's population is projected to increase from 5.29 million in 2024 to about 6.5 million by 2048.[229] The population is also highly urbanised, with over 86% living in urban areas currently and over 90% projected to live in urban areas by 2050.[4] Many of these urban communities are located in coastal areas or on flood plains. Consideration of climate change-related impacts when planning and managing this growth and the associated infrastructure is essential.

Displacement and loss of property values due to ongoing SLR and extreme weather events may also mean that renting or moving to poorer quality, more affordable housing could become more common in the future, which may pose additional risks for social cohesion and community wellbeing. Renting is already likely to become more common in the future as a result of housing prices.[472] Rental housing is generally poorer quality – older, colder, more damp and mouldy – than owner-occupied housing, and is more likely to lead to poor health and wellbeing outcomes.[473] Research also shows that housing insecurity and its consequences, such as being forced to relocate, contributes to poor health outcomes.[472]

Policy readiness assessment

There is currently no national approach for adaptation planning, retreat or relocation and the National Adaptation Framework does not provide sufficient clarity

Greater clarity is needed around roles, responsibilities and processes for adaptation planning and action, and greater coherence across the system. Decisions for how adaptation costs will be shared and met, including for managed retreat, have not yet been made. Although the Government's recently released National Adaptation Framework includes a pillar focused on cost sharing pre- and post-event, it does not indicate when or how decisions will be made around how costs will be shared. It also does not provide sufficient clarity around a process for managed retreat. A coherent national approach is needed to avoid fragmented, ad-hoc responses and increased exposure and vulnerability.

Local government has engaged with adaptation planning

The number of councils carrying out adaptation planning processes with their communities has grown significantly in recent years.[46] These processes can help to reduce the risks to social cohesion and community wellbeing by helping people understand what to expect and to have a say in the future of their community.

Local government partnerships with iwi/Māori are occurring, though this can vary by council

Where councils have carried out adaptation planning processes with their communities, these processes may include engagement and partnership with iwi/Māori. However, relationships between councils and iwi/Māori can take many different forms and some are more empowering for iwi/Māori than others.[155] The challenge of adapting to climate change reinforces the need for collaborative, empowering partnerships with iwi/Māori.[155] Additionally, iwi/Māori are engaging with their own people and developing their own climate adaptation response plans, although this is time- and resource-intensive and accessing resourcing for climate change adaptation work is often challenging.[155]

Existing adaptation approaches are ad-hoc, lacking consistency and strategic direction

In the absence of a coherent national approach for adaptation planning and managed retreat (including how it will be funded), it is difficult to carry out adaptation actions including relocation of at-risk communities. The approaches that have taken place so far have for the most part been ad-hoc. Additionally, factors such as uncertainty over when to adapt, how to design funding frameworks (including the question of how costs will be shared when property owners face losses) and public opposition to managed retreat proposals increase the political incentives for elected officials to favour short-term fixes over more effective long-term strategies. Councils and communities that have worked together to develop adaptation strategies that include managed retreat often struggle to implement these in the absence of robust planning and funding mechanisms.[474]

Relocating communities is a long-term process and proactive managed retreat that considers social cohesion leads to better outcomes

There is a long policy horizon associated with this risk, as relocating communities away from hazard zones and reestablishing them elsewhere is a long process. At this stage there is no legislation or national approach in place for managed retreat. There is evidence that in some locations, development in hazard zones is continuing to take place.[46,475] Further development in hazard zones will increase the severity of this risk over time if hazards and risk reduction are not actively considered. Planned, proactive managed retreat that considers how to preserve social cohesion and community wellbeing can have much better outcomes than reactive, post-disaster displacement and relocation.[471] There is a risk of lock in or maladaptation without early policy direction to address this risk, and the recently released National Adaptation Framework does not provide this.

Even well-developed local and regional plans cannot fully address the scale and complexity of this risk

Local and regional adaptation plans currently produced or in development, even if implemented fully, will not be sufficient to address this risk. Although community involvement in the development of these plans can help to reduce the risks to social cohesion and community wellbeing, if these adaptation plans do not also include specific measures to maintain social cohesion and community and cultural wellbeing then it is likely that the risks will remain. Additionally, it is difficult for smaller, more resource-constrained councils and communities to carry out these processes, leaving gaps in terms of national coverage for this risk.[46]

Gaps for risk severity and policy

The way in which communities will be impacted, the extent to which they will be impacted and the range of impacts they may experience are not well understood.[18] Additionally, limited evidence is available on how damage to or displacement from cultural heritage assets may impact social cohesion and wellbeing. The impact of international migration to Aotearoa New Zealand on this risk is also not well understood and, given that international migration is likely to increase substantially as the climate changes, this represents a significant gap.

It is difficult to find evidence of actions taken that relate specifically to social cohesion and community and cultural wellbeing. It is difficult to determine to what extent local and regional adaptation plans (including plans for managed retreat) will address the specific risks to social cohesion and community and cultural wellbeing that can arise from displacement.

Summary

This risk is already present, and exposure is particularly high for communities in low-lying coastal areas and along flood plains. Displacement of individuals and communities is already taking place in the wake of extreme weather events, and approaches to relocation have for the most part been reactive and ad-hoc. Exposure to SLR is also high in Pacific countries, which is likely to lead to increased international migration to Aotearoa New Zealand.

The way in which displacement occurs is likely to impact the sensitivity of affected communities to this risk. For example, planned and proactive retreat versus unplanned and reactive retreat post-event. This risk also inherently carries a risk of exacerbating existing inequities, as lower-income members of a community are more likely to be impacted. This risk is likely to increase in severity over the course of the century, becoming particularly severe in 2090, especially under a high climate impact scenario.

Aotearoa New Zealand does not currently have a national approach for adaptation planning and implementation (including for managed retreat), or a funding and financing framework. Both are essential to address the risks to social cohesion and community wellbeing from displacement, and although the Government’s recently released National Adaptation Framework includes a cost-sharing pillar, it has not sufficiently filled this gap. Although many councils are preparing adaptation plans, they often struggle to implement these in the absence of robust planning and funding and financing mechanisms. Further, the long lead times associated with this risk mean that anticipatory action is urgently needed to avoid lock in.

Risk scorecard: Social cohesion, community and cultural wellbeing

Risks to social cohesion, community and cultural wellbeing from displacement of individuals, families and communities due to progressive and ongoing sea-level rise, extreme weather events and associated impacts like flooding and landslides.

Identified as one of the most significant risks as part of the combined social and community wellbeing risk.

	Score	Rationale
Risk severity		
Now	Moderate	Some communities hit by recent extreme weather events are undergoing adaptation and displacement, which if poorly managed could harm social cohesion and community wellbeing. Impacts may be severe for few communities in the short term, but are not yet widespread.
2050	Major	SLR by 2050 will expose more communities to intolerable coastal inundation risk, driving relocation and raising equity concerns as insurance costs rise and retreat occurs. Affected communities may face economic disadvantage and major wellbeing impacts that deepen inequities.
2090*	Extreme GWL 2	Displacement from SLR, extreme weather events and rising international migration is likely to erode social cohesion and community wellbeing for long periods, especially if relocation is not well planned. These impacts will be severe and enduring for some communities and almost certain to deepen inequities for iwi/Māori and other affected groups.
	Extreme GWL 3–3.5	Under a high-emissions scenario, SLR and more extreme weather events will drive even greater displacement and long-term losses in social cohesion and community wellbeing. Severe, enduring impacts are almost certain to deepen existing inequities and disproportionately affect iwi/Māori and other groups.
Policy readiness		
Overall assessment	Insufficient	The country lacks coherent national frameworks and funding and financing mechanisms needed to address displacement risks to social cohesion and wellbeing. Councils are struggling to implement plans without national support.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address other risks, though it has a strong connection to the risks to the legitimacy of democratic institutions and mental health.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Physical health

Risks to physical health from illness and injury due to progressive and ongoing changes in temperature and precipitation, extreme weather events, and associated impacts like heatwaves and flooding.

Climate change poses significant and growing risks to physical health in Aotearoa New Zealand. These risks arise from increased exposure to extreme weather events (such as storms with associated flooding, and heatwaves), warmer temperatures and changing rainfall patterns, and the spread of vector-borne and zoonotic[xxxiv] diseases. Additionally, climate change will alter the quality of resources that support human health and wellbeing, such as food, water, outside space and clean air, as well as access to these resources.[18] New Zealanders are experiencing direct health impacts, including heat-related illnesses and injuries during extreme events, and will face increasing exposure to infectious diseases due to shifting ecosystems and hydrological systems.[18] These changes threaten the health, safety and wellbeing of communities across the country.

Risk overview

Climate change is a present and escalating threat to physical health across Aotearoa New Zealand

New Zealanders are exposed and vulnerable to physical health impacts from extreme weather events, as well as from ongoing gradual changes such as sea-level rise (SLR), changing rain and wind patterns, and rising average temperatures. There are several distinct risks to the physical health of New Zealanders from exposure to these climate hazards. These risks are projected to increase in severity over the course of the century, and to be more severe under a high climate impact scenario than a low climate impact scenario.

Risks to physical health from extreme weather events such as heatwaves, wildfires and flooding are becoming more frequent, severe and widespread

Climate change is increasing the frequency, intensity and geographic spread of extreme weather events such as heatwaves, wildfires and flooding, which pose serious risks to physical health. Extreme heat is one of the fastest-worsening hazards globally, with one study attributing up to a third of recent heat-related deaths to human-induced climate change.[476] Each 1°C rise in temperature is linked to significant increases in heat-related illness (18%), mortality (35%) and cardiac-related deaths.[477] Although Aotearoa New Zealand's climate is temperate, the effects of heat are associated with relative rather than absolute temperatures and this means that people can experience negative health effects even with modest increases in seasonal temperature, particularly given that the country's infrastructure is not sufficiently prepared to cope with extreme heat.[478,479] In Aotearoa New

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[xxxiv] Zoonotic diseases are diseases that can be transmitted to humans by non-human vertebrate animals.

Zealand, the hottest days of the year have increased in temperature by more than 0.5°C over the past 20 years for many regions. While the east coast of both islands experiences higher absolute temperatures during local heatwaves, lower levels of day-to-day temperature variability in the northern half of the North Island will equate to larger risks as the climate warms (as the impact of unusually high heat will accumulate over time, particularly if the nights are warm as well).[6]

Wildfires threaten lives and property, degrade air quality and contribute to long-term respiratory and cardiovascular health issues.[477] Flooding can cause physical trauma or loss of life, contribute to household dampness, which exacerbates respiratory conditions such as asthma, and disrupt access to health services and medications.[480] Studies have shown that hospitalisation rates remain elevated for months following major flood events.[481]

Risks to physical health from water-borne, food-borne, zoonotic and vector-borne infectious diseases are increasing in prevalence

Health impacts can occur due to contamination of drinking water in the wake of extreme weather events and through contact with contaminated floodwaters, with research showing an increase in hospital admissions for children with gastroenteritis after heavy rainfall events.[477] Parts of Aotearoa New Zealand have also seen an increase in the occurrence of bacterial and gastrointestinal diseases such as leptospirosis and cryptosporidiosis during flood events,[477] and stagnant water can provide a breeding ground for disease vectors such as mosquitoes.[480] Higher temperatures can also lead to increased exposure to bacteria and parasites such as campylobacter and cryptosporidium, which thrive in a warmer climate.[18]

An increase in average temperatures will make Aotearoa New Zealand’s climate more suitable for exotic vectors, encouraging their migration and the resulting transmission of disease, particularly in the north of the North Island.[18] Climate change increases the risks associated with a number of mosquito-borne and tick-borne diseases, which are currently absent from Aotearoa New Zealand, including West Nile virus, dengue fever, Murray Valley encephalitis, Japanese encephalitis, Ross River virus and Barmah Forest virus.[423]

Drought, heavy rainfall events and changing weather patterns are compromising the availability and quality of food and drinking water

Warmer temperatures and changes in rainfall patterns can impact water quality and availability, causing contamination and/or shortages. Heavy rainfall events can also cause pollutants, parasites and/or bacteria to run off into water sources and contaminate them.[18] Drought places pressure on water sources, reducing water supply, and may increase exposure to cyanobacteria and toxic algae through increased eutrophication[xxxv] as a result of low water levels.[18] Additionally, higher temperatures will increase freshwater toxic blooms[4]

[xxxv] Eutrophication is a process that occurs when a body of water becomes enriched with nutrients, increasing the amount of plant and algae growth.

as well as toxic marine algae, the latter of which can cause contamination of shellfish and impact the health of people who consume it.[423] See the *Water infrastructure* risk analysis for more information.

Changing weather patterns and ongoing SLR may impact food availability and quality, leading to nutrition-related risks to human health.[18] Droughts, floods and changing weather patterns increase the risk of crop disease, food spoilage, shortages and contamination. Food security is also susceptible to disruptions in trade flows or production in other countries.[482] Although Aotearoa New Zealand is a net food producer, some key foods, such as wheat, maize, rice, sugar, and coffee, which New Zealanders consume in large quantities, cannot be grown in Aotearoa New Zealand, or the country does not produce enough to meet demand. Currently, some of these foods are imported from only a small number of places, making food security susceptible to disruptions in trade flows or production in those countries.[482] Changes in air and water temperatures, rainfall patterns and extreme events can also alter the geographic and seasonal occurrence of bacteria, viruses, parasites, fungi and other pests and chemical contaminants that can impact food safety.[423]

There may be a reduction in cold-weather-related mortality, but this will likely occur alongside increased heat-related illness and mortality

Cold-weather related mortality may reduce due to warmer winter temperatures. In Aotearoa New Zealand, about 1,600 more deaths occur in winter than in summer.[18] However, mortality rates are influenced by various factors, including temperature, influenza levels, household crowding, moisture levels and the thermal performance of buildings.[18] Reductions in cold-weather-related mortality in winter are likely to occur alongside increased heat-related illness and mortality in summer.[483]

Children and older people have greater physiological sensitivities to health impacts

Children and older people have greater physiological sensitivity to the health impacts of climate change. Older people, infants, people with pre-existing medical conditions and some disabled people are physiologically more likely to be affected by changes in maximum daily temperatures, with age being the greatest risk factor for heat-related mortality.[18] These groups are also more sensitive to the impacts of other extreme events such as floods and wildfires, as they may have more difficulty evacuating.[74]

Existing health inequities will likely be exacerbated, particularly for iwi/Māori and Pacific peoples

Climate change impacts will exacerbate existing health inequities. In Aotearoa New Zealand, there are pervasive health inequities for iwi/Māori, who experience higher rates of mortality and morbidity than non-Māori across a wide range of health issues and determinants.[484,485] Iwi/Māori also experience existing inequities relating to health and access to care (including a greater existing burden of disease), economic deprivation, and social and political marginalisation.[484] For example, hospitalisation rates for cardiovascular disease in 2018–

2020 for Māori were almost double the rates for non-Māori, and the cardiovascular disease mortality rate for Māori was more than double that for non-Māori.[486] For more information, see the *Increased Māori health vulnerabilities* risk analysis.

Pacific peoples also experience longstanding health inequities, which are linked to inequities in access to healthcare as well as wider determinants of health, such as employment, housing and education. These health inequities are associated with a difference in life expectancy, with the life expectancy for Pacific peoples being 5.5 years lower than for Europeans.[439]

Climate change-induced extreme heatwaves and more frequent and intense flooding events are likely to increase these risks.

Certain groups are at higher risk from climate change

Climate change will also disproportionally impact many disabled people. This is due to societal factors such as ableism, poverty and lack of access to employment, education, healthcare and housing. These disadvantages limit the resources disabled people have at their disposal to respond to climate change impacts.[487,488] Some disabled people may struggle to evacuate during emergency events due to mobility challenges, and can face barriers to accessing medications, equipment and necessary supplies in the immediate aftermath of a disaster.[488]

Poor housing quality is another risk factor for adverse climate-related health impacts. For example, people experiencing homelessness or without access to secure housing are among those most at risk from disasters.[489]

People who work outdoors will be more exposed to heat waves and extreme heat, and therefore experience increased sensitivity to the associated health risks as a result of their occupation.[490] In 2018, 3.8% of the population aged 15 years or older were working in agriculture, forestry and fisheries, representing 5.9% of employed people aged 15 years or older.[74]

People living in rural and more remote communities are at greater risk of being isolated during an extreme weather event, due to disruptions to transport networks, electricity, water supplies and telecommunications. They may have less access to healthcare services generally, and in particular may struggle to access these services after an extreme weather event.[74]

Adaptive capacity is crucial but constrained by socio-economic and institutional factors

While changes to behaviour patterns and individual actions can contribute to reducing this risk, the actions people can take themselves are limited by socio-economic and demographic factors as well as institutional arrangements, making governance crucial, especially for health equity.[18]

The health system itself will need to strengthen its adaptive capacity to manage a higher proportion of people who are injured or unwell as a result of climate change-related impacts (for example, during prolonged heat waves).[18] This was also a challenge during the COVID-19 pandemic, which exposed key vulnerabilities and pressure points in the health system.

Early and comprehensive adaptation actions can provide health benefits as well as preventing adverse climate change impacts. For example, improving built environment planning, including for housing, and the climate resilience and thermal performance of buildings will protect against health impacts of seasonal changes in weather, as well as the increased frequency of extreme weather events.

People and households with good emergency preparedness and emergency plans in place will be more resilient to climate-related extreme weather events. This is particularly important for individuals who have pre-existing medical conditions and/or disabilities.[74] A relatively small proportion of households in Aotearoa New Zealand are prepared for emergencies, and food insecurity and poverty likely play a role in this.[74]

Compounding and cascading factors

Multiple climate hazards may occur simultaneously and result in compounding risks to physical health. For example, a period of extreme heat may overlap with a period of drought, increasing negative health impacts because water is not available for use in cooling.

There are a number of demographic shifts that also have implications for this risk. Aotearoa New Zealand has an ageing population, which will exacerbate the risks to physical health from climate change over time. Population projections show that the percentage of older adults (65+ years) is projected to almost double from 16.6% in 2023 to about 28.2% by 2073.[491]

Iwi/Māori are making up an increasing proportion of Aotearoa New Zealand’s population over time.[491] If existing health inequities are not addressed, it is possible this demographic change will result in increased vulnerability of the overall population to this risk.

The homeownership rate in Aotearoa New Zealand is projected to continue decreasing, from 60% in 2023 to 48% in 2048.[492] This may have significant impacts for the risks to physical health from climate change, because renters typically have poorer health outcomes than homeowners, in part due to the poor-quality older housing that is more affordable for renters.[472]

Interaction with emissions reduction

Cardiovascular and respiratory health is strengthened by investments in active and public transport infrastructure that promote physical activity, and by reductions in air pollution from reduced use of internal combustion engine (ICE) vehicles and the elimination of industrial and household coal, gas and wood burning.[493] These improvements can reduce emissions and enhance physiological resilience to climate-related health risks.

Policy readiness assessment

The health national adaptation plan is the central policy response, but there is limited targeting of vulnerable groups

The health national adaptation plan released in October 2024 is the main vehicle through which central government is responding to this risk. It sets the strategic direction and provides national-level priority actions for health-focused adaptation to climate change.[426] It contains 25 actions, one of which is a vulnerability and adaptation assessment that is underway. The health national adaptation plan recognises that there are certain groups more vulnerable to the risks to physical health from climate change, including iwi/Māori, and includes actions to involve these 'priority populations' in designing and prioritising climate and health actions. However, it is less clear what concrete steps may be taken to reduce these existing health inequities.

Research is underway to identify risks to physical health from climate change

There is also research underway or completed that relates to this risk. Climate change scenarios for the health sector[477] have been developed by a group of health sector stakeholders and were released in March 2024. These scenarios are intended to be used by organisations in the health sector to consider and challenge their strategies and future plans. The Ministry for Primary Industries (MPI) is now conducting research to identify the highest risk locations in Aotearoa New Zealand for the establishment of Japanese encephalitis virus, so it can target ongoing surveillance. MPI is planning to publish findings by 2028.[494]

Implementation faces funding barriers and requires cross-sector considerations

The health national adaptation plan states that the Ministry of Health and Health New Zealand will work together to develop a detailed work programme that allocates responsibility for required activities to the appropriate agency.[426] A detailed work programme for the health national adaptation plan delivery has not yet been released, and funding beyond the initial vulnerability and adaptation assessment is unclear.

Another barrier identified by the health sector is that many of the adaptation actions that would have flow-on benefits for physical health are actions relating to other areas such as infrastructure and transport policy that sit outside the health sector. This means the health sector does not have the levers itself to make the changes.

The policy coverage is uncertain and incomplete, and risks lock in

Even if fully implemented, health national adaptation plan actions may leave key risks unaddressed. Without a clear delivery plan and adequate funding, it is unknown to what extent the actions in the health national adaptation plan will be implemented. Further action will be needed to avoid long-term lock in and ensure comprehensive risk reduction, including consideration of health impacts across housing, energy and transport policy.

Gaps for risk severity and policy

There is robust evidence that climate change will have adverse impacts on the physical health of New Zealanders. Areas that are currently less well-researched include the potential effects on food availability and quality, the impacts on vulnerable groups, and the risks to physical health from poor quality housing and from isolation and disrupted access to essential medication and health services. There is also a limited understanding about the cumulative effect of climate change impacts on existing health inequities, particularly for iwi/Māori.[32] See the *Increased Māori health vulnerabilities* risk analysis for more information.

Because many adaptation actions that could have benefits for the health sector sit in other domains (such as the *Built environment*), it is difficult to capture the full picture of actions that would help to reduce this risk. Additionally, because the health national adaptation plan has only recently been released, there is not yet evidence of its actions being effectively implemented.

Summary

Climate-related health risks are already affecting New Zealanders, with recent extreme weather events exposing vulnerabilities in the health system, particularly for people with high health needs, disabled individuals, older adults and those in remote communities.[46] The health system is still recovering from the COVID-19 pandemic, which left the workforce stretched and exposed systemic pressure points, and its adaptive capacity is weakened.[489] This means that if a climate hazard, such as a major heatwave, were to occur and result in a higher proportion of people who are injured or unwell, the health system may struggle to cope. This risk is expected to increase in severity over the course of the century, and may be particularly severe in 2090 under a high climate impact scenario.

The health national adaptation plan is the central government’s main response to this risk. While it outlines strategic actions, including a vulnerability and adaptation assessment, its effectiveness remains uncertain due to actions remaining unfunded and the absence of a detailed delivery plan. Even full implementation of the health national adaptation plan could leave some risks unaddressed.

Risk scorecard: Physical health

Risks to physical health from illness and injury due to progressive and ongoing changes in temperature and precipitation, extreme weather events, and associated impacts like heatwaves and flooding.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Extreme events have increased in frequency, straining a post-COVID health system with reduced capacity to adapt. Repeated service disruptions in isolated rural communities are causing lasting impacts and worsening inequities.
2050	Moderate	Increased frequency of extreme weather events and increased pressures on the health system due to an ageing population mean that moderate risks to physical health and safety will remain likely in some communities.
2090*	Major GWL 2	Higher temperatures and more frequent and severe extreme weather, combined with an ageing population, are likely to significantly and frequently compromise physical health, safety and wellbeing in many communities.
	Extreme GWL 3–3.5	Frequency and severity of extreme events will be even greater under a high GWL scenario. Higher temperatures and changing rainfall patterns will impact water availability and food security as well as the spread of vector-borne diseases, frequently compromising physical health and safety in many communities.
Policy readiness		
Overall assessment	Significant gaps	The health national adaptation plan lacks a detailed work programme for its actions, funding is a major barrier, and recent health system reforms have slowed progress. Full implementation of the health national adaptation plan could reduce some aspects of the risk.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address other risks, though it has a strong connection to the risks to mental health.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Social infrastructure and community services

Risks to social infrastructure and community services due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events and associated impacts like flooding and landslides.

Aotearoa New Zealand’s social infrastructure, comprising schools, health services, cultural institutions, sports centres and community hubs, is increasingly exposed to the escalating impacts of climate change. Climate hazards are already disrupting essential services and threatening the wellbeing of communities across Aotearoa New Zealand. As climate hazards increase in frequency and intensity, the resilience of social infrastructure becomes a critical factor in safeguarding public health, social cohesion and economic stability.

Risk overview

Social infrastructure and community services support wellbeing

Social infrastructure and community services include the social, cultural and financial services and institutions (and associated property and buildings) that support community wellbeing. These systems can help to both reduce underlying risks and aid recovery following significant events.[495] Cultural sites and artefacts are included in this definition, as well as schools, community hubs, sports centres, health services, and social and community services providers including food banks. Sub-risks include risks from physical damage to infrastructure, risks from service disruption and isolation, and risks of exacerbating economic strain, social inequities and health impacts in affected communities.

Climate hazards are already disrupting social infrastructure and community services

Increased frequency of drought, flooding, coastal inundation and higher groundwater levels are already having significant impacts on the built environment, critical infrastructure, and social and economic activities.[231]

Several communities are disproportionately at risk, with a sizeable portion of the exposed or isolated population falling into higher vulnerability groups.[228] There is limited exposure information available specifically for social and community services. However, schools, fire stations and hospitals provide a snapshot of the exposure of key facilities.

Data on 1% annual exceedance probability (AEP) coastal inundation (an event which has a 1% chance of happening in any given year) with 0.2 m of sea-level rise (SLR) expected to occur by mid-century under a mid-range scenario is available, along with landslide data. Any school, fire station or hospital that could be reached by flood waters or sit in the path of a potential landslide could be disrupted or prevent service delivery.[250] For example:

- **Schools**: 106 exposed to 1% AEP coastal inundation with 0.2 m SLR (expected mid-century) and 8 currently exposed to landslides.

- **Fire stations:** 15 exposed to 1% AEP coastal inundation with 0.2 m SLR (expected mid-century) and 24 currently exposed to landslides.
- **Hospitals:** 6 exposed to 1% AEP coastal inundation with 0.2 m SLR (expected mid-century) and 0 currently exposed to landslides. These hospitals are located in Auckland (3), Tauranga (1), Western Bay of Plenty (1) and Buller (1).

Climate change leads to increased population exposure and isolation risks

Isolation in this assessment identifies properties and communities that may be cut off from essential services, such as hospitals, schools and emergency services, due to impacts on the transport network, even before direct inundation occurs. The numbers discussed in this section result from people being cut off from social infrastructure and community services.

Approximately 150,000 people across the country (3% of the population) are at risk of being unable to access schools due to a 1% AEP coastal inundation with 0.2 m of SLR, while 213,000 people (5% of the national population) are at risk of isolation from hospitals under the same conditions.

More than 90,000 people (2% of the population) are estimated to be at risk of isolation from hospitals due to landslide risk, while 50,000 people face potential isolation from schools due to landslides.

Approximately 150,000 people (3% of the population) are at risk of isolation from fire stations due to 1% AEP coastal inundation with 0.2 m of SLR, expected mid-century. Further, an estimated 50,000 people (1% of the population) are at risk of isolation from fire stations due to landslides.[250]

Exposure is likely to increase

By mid-century, changes in temperature and rainfall patterns are expected to increase the risk of wildfires for people, infrastructure (including social and community infrastructure) and ecosystems.[496] Very high and extreme fire danger is projected to increase across Aotearoa New Zealand, particularly in Southland and Marlborough.[18]

By the end of the century, there is further uncertainty for risks to social infrastructure and community services. The risk of schools being isolated due to direct and indirect climate impacts such as flooding and/or road closures due to landslides is expected to be significant nationwide.

Though outside of the periods analysed for the risk assessment, research undertaken by Urban Intelligence indicates that by 2150, the number of people at risk of losing access to schools due to coastal inundation and landslides could increase to more than 250,000 nationwide, including more than 40% of the residents of Thames-Coromandel, Buller and Napier.[250] Projections indicate that, by 2150, fire services could be inaccessible for 400,000 people nationwide.[250] By 2150, between 350,000 and 515,000 residents could be at risk of isolation from their hospital due to coastal inundation.[250] However, projections past the end of the century carry high levels of uncertainty. Despite this, considering this long time horizon (to 2150) is useful for social and community infrastructure and services, because planning decisions often lock in specific sites for long periods.

Social infrastructure can support communities' adaptive capacity

Access to high-quality social infrastructure, such as community centres, can support the capacity of communities to adapt to climate change by fostering social cohesion and reducing isolation and vulnerability to climate hazards.[260] Conversely, adaptive capacity can be reduced if social infrastructure and community services are disrupted by direct and indirect climate-related impacts.

Adaptive capacity could be improved by making support available for people who lose access to their finances during extreme weather events, helping to reduce vulnerability in times of crisis. Cyclone Gabrielle made evident that when people cannot reach their bank accounts, meeting basic needs, such as obtaining food, can become a serious challenge.

There are risks to cultural infrastructure from climate-related hazards

This risk may have disproportionate impacts on iwi/Māori who rely on cultural infrastructure and community services for whanaungatanga (relationships, kinship) and wellbeing,[497] with compromised access and/or isolation posing significant risks.

Marae, papakāinga, urupā (burial grounds), wāhi tapu and wāhi tūpuna (sacred and ancestral places) are essential to Māori wellbeing. They function not only as physical locations but also as spiritual, relational and governance centres that support ceremony, decision-making, intergenerational knowledge transfer and the practice of tikanga (customs). These culturally significant sites are increasingly at risk from climate-related hazards such as flooding, erosion, SLR, storm surge and sedimentation, with the greatest exposure occurring in coastal, low-lying and flood-prone areas. Although many marae have proven their importance as emergency hubs during extreme weather events, they often lack sufficient insurance, retrofitting or funding to recover from climate-related damage. For more information, see *Damage to Māori infrastructure* risk.

Any disruptions to accessing cultural infrastructure and services, such as marae, are very likely to reduce capacities to cope, with significant consequences for health and wellbeing. Māori cultural sites are among the most vulnerable social infrastructure types. Of nearly 800 marae, 80% are built on low-lying coastal land or near flood-prone rivers.[498] A range of factors, with roots in historic and ongoing forms of economic and political marginalisation, are likely to exacerbate risks for iwi/Māori.[499]

Compounding and cascading factors

There are interconnected vulnerabilities linked to other social risks

Risks to social infrastructure and community services are not isolated. They can be exacerbated by other risks and can also drive additional risks. This is particularly true for risks that relate to social cohesion, inequality, and health and wellbeing. When climate hazards intersect with fragile social bonds and strained community services, they deepen community vulnerability.

Physical isolation from social infrastructure can exacerbate the impacts of extreme weather events

Physical isolation from social infrastructure and social services may exacerbate physical and mental health challenges, affect people's sense of belonging and identity, and perpetuate inequity, adversely impacting social cohesion. Disruption to critical infrastructure (water, transport, energy, telecommunications) during and after extreme weather events can have cascading impacts on access to social infrastructure and community services. Physical and social isolation from reduced access to social infrastructure and community services may also impact people's livelihoods and ability to access basic needs like food, clothing and housing.[228]

Climate change is not just a physical threat, it is a psychological one too. Event-related anxiety has been identified as a climate-related mental health challenge, for example, when people who have experienced flooding in the past feel stress and anxiety when it rains. When feelings of anxiety arise, access to social and community services can be very valuable.[257] For more information, see the *Mental health* risk analysis.

Policy readiness assessment

There is limited national policy coverage, with significant gaps

Social infrastructure is increasingly exposed to climate change impacts, yet current national strategies only partially address its adaptation needs. The national adaptation plan outlines broad goals such as supporting communities and ensuring resilient infrastructure, but the Commission's first national adaptation plan progress report highlights that significant gaps remain in terms of meeting the plan's objectives relevant to this risk.[46] While transport and water systems are mentioned, there is no direct policy guidance for safeguarding social infrastructure, leaving critical services exposed during climate-related disruptions.[70]

Sector-specific plans offer some direction, but long-term resilience is unclear

Sector-specific plans assist in illuminating the path for health and wellbeing. The health national adaptation plan acknowledges climate change as a public health issue and promotes long-term partnerships for emergency response and resilience, with a focus on health equity. Te Whatu Ora Health New Zealand's Heat Health Plans Guidelines encourage local planning for extreme heat, which can improve outcomes for vulnerable populations. Similarly, the Ministry for Social Development's recovery plan for extreme weather outlines targeted support across housing, mental health, education and community infrastructure. However, the extent to which these actions build long-term resilience remains unclear, and many are reactive rather than proactive.[478,500,501]

Local government and iwi, hapū and marae-led initiatives show strong leadership, but integration with national policy is needed

Local government and iwi, hapū and marae-led initiatives are proactively supporting community adaptation, but these efforts often lack integration with national policy. Community-led projects and evacuation plans, such as those in Kaitaia, demonstrate the importance of resilient social infrastructure during emergencies. Iwi and hapū are also restoring ecosystems and developing climate response plans to protect their people. To reduce climate-related risks to social infrastructure over the following six years before the next risk assessment, national policy may effectively support adaptation if it links to emergency planning, infrastructure investment and community wellbeing to ensure continuity of essential services in a changing climate.[155,502]

Systematic and structural challenges limit adaptation measures

Aotearoa New Zealand's social infrastructure faces growing climate pressures, while limited funding and stretched local resources make it challenging for councils, iwi organisations and community service providers to upgrade facilities such as marae, schools, clinics and community hubs.[503] Adaptation efforts can be slowed by complex governance arrangements, evolving mandates and approval processes that make it difficult to determine who should lead decisions like relocating flood-prone services or strengthening essential buildings.[504] Many social service providers are working without consistent national guidance on assessing climate impacts, contributing to varied levels of preparedness across regions. At the same time, gaps in hazard data, limited technical expertise and uneven access to climate information mean that planning for schools, health centres and community facilities often relies on incomplete or outdated risk assessments, which can make long-term resilience harder to achieve.[503]

There is limited understanding of what constitutes social infrastructure

In general, understanding of what constitutes social infrastructure is lacking, particularly when it comes to cultural and intangible assets. The Commission has defined these as including the social, cultural and financial services and institutions (and associated property and buildings) that support community wellbeing. Cultural sites and artefacts are included in this definition, as well as schools, community hubs, sports centres, health services, and social and community services providers including food banks. However, this is not the only definition used, and most of the available information focuses on school, hospitals and fire stations. This means the full range of social and community infrastructure and services is not always recognised in local and central government adaptation planning.

Present-day inaction may result in locked-in vulnerability

Communities at the frontlines of climate change can become trapped in a cycle of vulnerability, where today's inaction creates locked-in vulnerability. Without clear guidance and targeted actions to increase the resilience of social infrastructure and community services providers (particularly in locations that are increasingly exposed to the physical hazards of climate change and are grappling with social and economic challenges), resilience to this risk is likely to remain very low and future exposure may be ‘locked in’. Careful and considerate planning will be required, and consultation may be necessary, which can take time. Thus, long lead times may be required.

Gaps for risk severity and policy

There are gaps in understanding of social infrastructure vulnerabilities, psychosocial impacts, community perspectives and infrastructure dependence. While there is reasonable evidence about exposure to schools, fire stations and hospitals, other forms of social infrastructure have not been explored to the same extent. For example, the exposure of community, childcare, recreation and sports centres, shelters, museums and playgrounds is a gap.

There is a limited understanding of the psychosocial impacts of changing climate conditions on different groups in Aotearoa New Zealand. Understanding how communities perceive climate-related risks and how social infrastructure can strengthen adaptive capacity would help build resilience. There may be varying levels of dependence on social infrastructure between and within communities, which cannot be adequately represented in this assessment. Where reliance on social infrastructure is high, the more significant this risk may be for the communities involved.

The challenge of addressing climate change resilience for social infrastructure is intensified by significant data gaps that prevent policy development occurring. Bridging these gaps requires interdisciplinary research, improved data collection methods and localised approaches to ensure effective adaptation strategies.[18] A greater understanding of the relative vulnerability of exposed communities and, therefore, their likely demand for social infrastructure would be useful. Coupled with a more robust inventory of existing social infrastructure including its age and physical condition, a detailed picture of the status of these infrastructure types could be compiled and used to demonstrate areas of greatest need for investment. Standardisation of indicators, data quality and availability, and more research on socio-cultural policy options would be beneficial.

Summary

Social infrastructure encompasses social, cultural and financial institutions, along with their associated properties. These institutions and facilities can reduce risk and aid recovery in the face of disasters. Currently, these systems are exposed to climate-related risks, and this exposure is anticipated to increase in the future. However, there are data gaps, particularly relating to the exposure of community services beyond schools, fire stations and hospitals. Vulnerability is especially high for communities reliant on these services, with isolation and/or compromised access as significant risk factors. Climate-related risks to social infrastructure are extensive, affecting physical and mental health, social cohesion and economic stability.

The national adaptation plan outlines actions to enhance resilience against climate impacts; however, these do not relate specifically to social infrastructure and community services. Significant challenges hinder climate adaptation for social infrastructure and community services providers. To advance adaptation efforts, options include increasing investment in climate-resilient infrastructure and modernising community service frameworks and procedures.

Risk scorecard: Social infrastructure and community services

Risks to social infrastructure and community services due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events and associated impacts like flooding and landslides.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Social infrastructure and community services, while exposed to climate hazards, are generally able to recover from disruptions, especially as they are dispersed throughout the country. However, equity issues, particularly for iwi/Māori, are already present.
2050	Moderate	By mid-century, more frequent climate events may isolate communities and disrupt short- to medium-term access to essential social infrastructure and community services such as education and healthcare.
2090*	Major GWL 2	By end-of-century, more frequent and prolonged disruptions are likely under both GWL scenarios, with equity impacts becoming more pronounced. In particular, the risk of schools being isolated due to direct and indirect climate impacts such as flooding and/or road closures due to landslides is expected to be significant nationwide.
	Major GWL 3–3.5	
Policy readiness		
Overall assessment	Significant gaps	There is no specific national policy or coordinated implementation strategy. While community-led efforts are active, they are constrained by systemic barriers and lack of national support.
Cascading risk		
Overall assessment	Low	Addressing this risk has low potential to address others in the assessment, though it has strong connections to the risks to mental health and social cohesion.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

DOMAIN: Ngā mea hirahira o te ao Māori

This domain covers things of importance in the Māori world.

Analysis for this domain was completed by independent researchers from Manaaki Whenua Landcare Research (now part of the Bioeconomy Science Institute) and Ngā Pae o te Māramatanga Māori Centre of Research Excellence, contracted by the Commission. Their work is published in full alongside this report and can be read as a standalone Māori climate risk assessment.[505] The Commission accepts its findings, which are reflected in the conclusions of this assessment across other risk chapters in this report. The seven risks in this domain are briefly summarised here; to read the complete analysis and risk scoring rationale, refer to the full Ngā mea hirahira o te ao Māori report, available on our website.

What makes this domain unique?

Iwi/Māori communities in Aotearoa New Zealand face many of the same climate-related hazards as everyone else, but the impacts on iwi, hapū, and whānau are often deeper and more complex. This is because climate change interacts with longstanding structural factors including land tenure constraints, housing quality, environmental degradation and higher rates of pre-existing health conditions to create risks that uniquely affect Māori culture, identity, economic wellbeing and the exercise of tino rangatiratanga.

For iwi/Māori, climate impacts are not only physical or economic. They strike at the heart of cultural continuity. Losing access to marae, urupā, papakāinga or mahinga kai areas disrupts intergenerational mātauranga transfer, tikanga and the ability to live as Māori. Climate hazards that damage taonga species can erode mahinga kai practices, weaken cultural identity and worsen existing health inequities.

Ngā mea hirahira o te ao Māori translates in English to ‘things of importance in the Māori world’. Seven of these central matters are analysed in this domain. They are highly sensitive to climate stress because iwi/Māori wellbeing is inseparable from the health of the natural environment. As a result, the risks in this domain are also tightly interconnected with other risks across the assessment.

Because the risks in this domain are so interconnected with those in other domains, the full risk assessment has embedded iwi/Māori considerations into the evaluation of every risk, not just those in Ngā mea hirahira o te ao Māori. This included assessing how each risk affects iwi/Māori decision-making, equity, recovery capacity and the extent to which Māori-led strategies are supported or excluded.

How does this domain interact with other domains?

Risks of damage to Māori infrastructure

This risk examines how climate change threatens significant sites such as marae, urupā, wāhi tapu, wāhi tūpuna and papakāinga, disrupting tikanga, identity and resilience. It is closely linked to the *Built environment* domain, particularly risks to buildings, and to the *People, health and communities* domain, particularly risks to social and community infrastructure.

Risks of loss of access to taonga species

This risk assesses the impacts of climate change on access to taonga species, highlighting the threats it poses to Māori food resilience, tikanga and the transmission of intergenerational knowledge. It is closely linked to all risks in the *Natural environment* domain.

Risks of economic losses for Māori in primary industries

Iwi/Māori have significant involvement in climate-sensitive sectors like farming, forestry, fisheries and aquaculture. This risk describes the potential economic losses in primary industries from exposure to climate-related stressors such as droughts, floods, ocean acidification and new biosecurity threats, hazards that are expected to intensify under projected climate change scenarios. It is closely linked to all risks in the *Sectors relying on the natural environment* domain.

Risks of disruption to tikanga and hapū/iwi identity

This risk examines how climate change-induced displacement, coastal erosion and managed retreat risk severing iwi/Māori connections to whenua, threatening identity, sustained practice of tikanga and intergenerational wellbeing. It is closely linked to the *People, health and communities* domain, particularly risks to *Social cohesion, community and cultural wellbeing* (from displacement).

Risks of loss of Indigenous knowledge systems

Mātauranga Māori refers to the traditional and contemporary body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices. This risk concerns how climate change threatens the continuity of mātauranga Māori by disrupting the ecosystems, practices and governance structures that sustain it. It is closely linked to the *People, health and communities* domain, particularly the risk to *Social cohesion, community and cultural wellbeing*.

Risks of legal exclusion and governance failures for Māori

Government has a key role in ensuring all communities are supported to adapt to the unique climate-related challenges they face and has specific obligations to iwi/Māori under Te Tiriti o Waitangi/The Treaty of Waitangi (Te Tiriti/The Treaty). This risk concerns how legal exclusion and governance failures can undermine iwi/Māori decision-making and participation in climate adaptation. It is closely linked to all risks in the *Governance* domain, particularly the risk to the *Ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation*.

Risks of increased Māori health vulnerabilities

This risk assesses the climate-related health vulnerabilities iwi/Māori face, focusing on how structural inequities, ecological degradation and governance exclusion compound health risks and reduce adaptive capacity. It is closely linked to the *People, health and communities* domain, particularly the risks to *Physical health* and *Mental health*.

Systemic policy issues

The researchers who undertook the analysis for this domain identified several cross-cutting themes from their assessment of the seven ao Māori risks that, if addressed, would help to strengthen climate resilience for iwi/Māori.

- **Integration:** ensuring climate policies and plans consider impacts on iwi/Māori.
- **Rights-based adaptation:** embedding Te Tiriti o Waitangi/The Treaty of Waitangi obligations into adaptation governance and investment.
- **Localisation:** supporting whānau, marae, hapū, and iwi to lead adaptation planning using mātauranga Māori.
- **Systems change:** designing finance, infrastructure and policy settings that enable Māori-led adaptation and climate-positive economic futures.
- **Data sovereignty:** building kaupapa Māori data systems to track exposure and adaptive capacity at the rohe level.

These approaches emphasise locally led, centrally enabled, evidence-based adaptation, principles that are essential for an effective response not only for iwi/Māori, but for everyone living in Aotearoa New Zealand.

Combined risks to te ao Māori were identified as one of the most significant risks

All seven of the assessed risks to Ngā mea hirahira o te ao Māori were rated at major severity in 2050. Four were assessed as insufficient (the lowest score) for readiness, while three were found to have significant gaps. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risks satisfied the first two principles of our review for significance: they present high potential for adverse consequences by 2050 and, because of the very low base of current readiness, significant lead time is required to prepare for them. For more, see the separate write-up of this significant risk in the Priorities for action report.

Box 3.4: Responding to a changing climate in Te Taitokerau/Northland

Below is a summary of some of the issues that came up during kōrero across Te Taitokerau/Northland in March 2025. It reflects a visit by a team from He Pou a Rangi Climate Change Commission to build our understanding of how climate change is experienced in different places and how people are responding.[290]

Who gets hit harder by climate change?

In Te Taitokerau/Northland we heard how climate impacts are loading on top of existing socio-economic pressures. This applied across the board and was a particular issue for rural Māori communities. Finding ways to make sure all communities in the region were able to cope with the effects of a changing climate and to build their resilience was a critical issue for many we talked to.

Growing resilience in hapori Māori

In the Hokianga, communities are drawing on a history of self-sufficiency to regenerate their food systems and build resilience in the face of rising prices and the pressures of climate change. He Kete Kai Food Security Programme is supported by Far North District Council and Northland Regional Council in a collaborative and equitable model focused on community engagement.

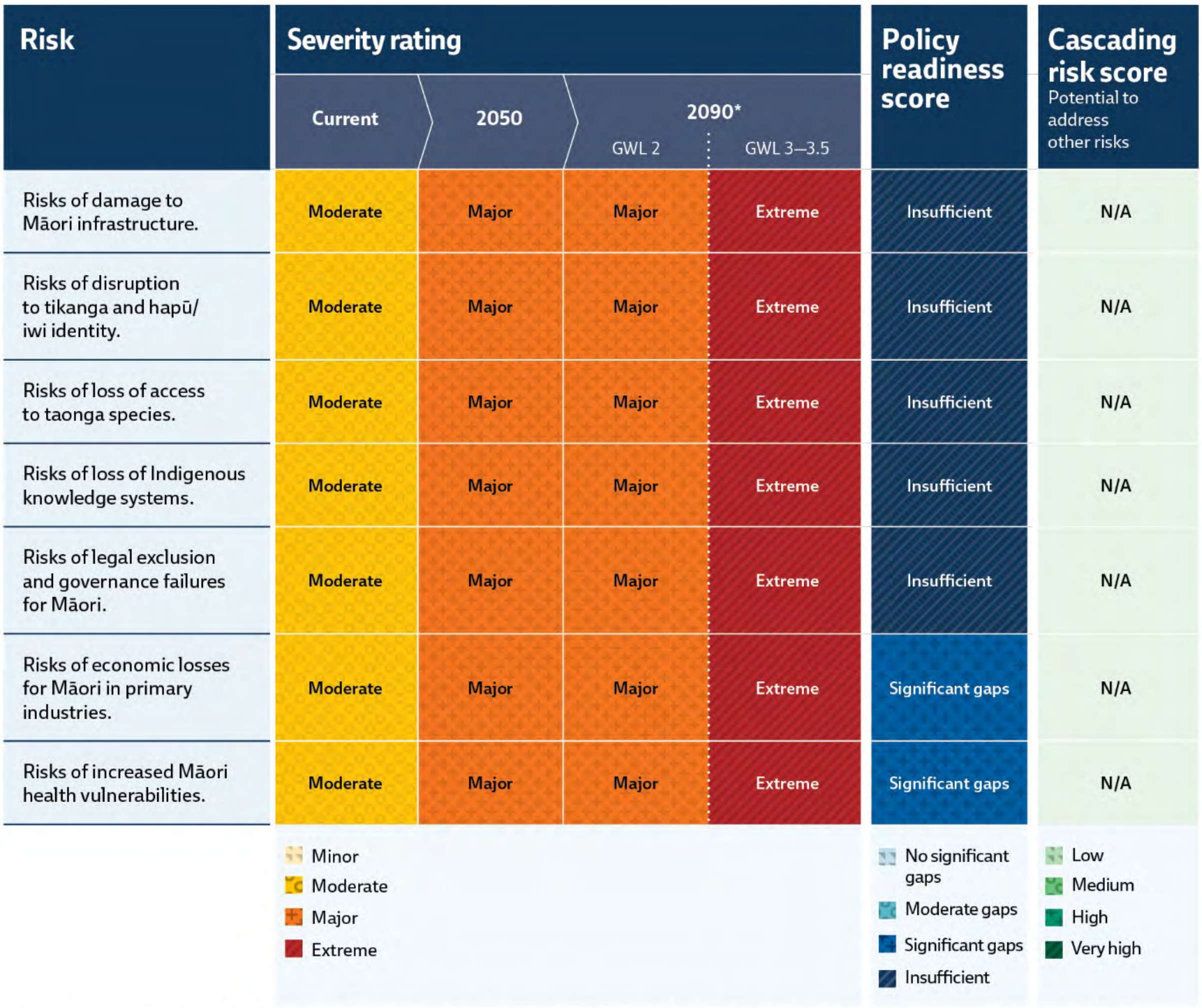
When extreme weather events happen, these communities can be particularly hard hit. When the region's stretched roading network fails, they lose access to supplies, schools, workplaces and essential services for prolonged periods.

Collaborating at a catchment level

Ngātiwai Trust Board and the Whangarei District Council are collaborating on a catchment-wide adaptation project covering a 165-square-kilometre area between Whangaruru and Oakura. This combines deep local knowledge with nature-based solutions to reduce community vulnerability to climate threats.

These east coast communities face risks of isolation, damage and loss from both coastal and river flooding in severe weather events, declining health of the moana and loss of land and heritage from sea-level rise and erosion. This threatens homes, schools, marae, ancestral lands, family farms, kaimoana and cultural heritage, including urupā.

Table 3.4: Risk ratings for Nga mea hirahira o te ao Māori[xxxvi]



Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090* GWL 2	2090* GWL 3–3.5		
Risks of damage to Māori infrastructure.	Moderate	Major	Major	Extreme	Insufficient	N/A
Risks of disruption to tikanga and hapū/iwi identity.	Moderate	Major	Major	Extreme	Insufficient	N/A
Risks of loss of access to taonga species.	Moderate	Major	Major	Extreme	Insufficient	N/A
Risks of loss of Indigenous knowledge systems.	Moderate	Major	Major	Extreme	Insufficient	N/A
Risks of legal exclusion and governance failures for Māori.	Moderate	Major	Major	Extreme	Insufficient	N/A
Risks of economic losses for Māori in primary industries.	Moderate	Major	Major	Extreme	Significant gaps	N/A
Risks of increased Māori health vulnerabilities.	Moderate	Major	Major	Extreme	Significant gaps	N/A

Severity rating	Policy readiness score	Cascading risk score
■ Minor	■ No significant gaps	■ Low
■ Moderate	■ Moderate gaps	■ Medium
■ Major	■ Significant gaps	■ High
■ Extreme	■ Insufficient	■ Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

[xxxvi] Cascading risk scores were not generated for this domain. That methodology was developed after the analysis for this domain was commissioned. In discussion with the researchers, it was agreed that adding this step may be misaligned with an ao Māori worldview where interdependence is the starting point rather than the outcome.

RISK: Damage to Māori infrastructure

This risk examines how climate change threatens significant sites such as marae, urupā, wāhi tapu, wāhi tūpuna and papakāinga, disrupting tikanga, identity and resilience. These sites are exposed to a wide range of climate-related hazards including coastal inundation and erosion, landslides, soil erosion and wildfires. This risk is closely linked to the *Built environment* domain, particularly risks to buildings, and to the *People, health and communities* domain, particularly risks to social and community infrastructure.

Māori sensitivity to damage of Māori infrastructure is high due to the central role that marae, papakāinga, urupā and wāhi tapu play in identity, governance, ceremony and intergenerational wellbeing. These sites are not merely physical places; they are physical embodiments of whakapapa, tikanga and community cohesion.[158,499,506,507] The whakapapa link to these places stretch back generations with mana whenua and mana whakahaere responsibilities and obligations. These obligations are not readily transferable to another distant location. This sensitivity is amplified by many of these sites being in vulnerable locations such as low-lying coastal areas, riverbanks and flood-prone plains. In some cases, this exposure reflects historical patterns of land marginalisation, where Māori were left with land parcels least suited to development or protection.[32,508,509]

Compounding the physical risks are spiritual, social and economic consequences. Damage to urupā, for example, can result in the disinterment or relocation of tūpuna, an act associated with profound emotional and spiritual trauma.[510] Repeated disruption may eventually render a site unviable – functionally, financially or spiritually – leading to a threshold where infrastructure no longer supports community cohesion or sustained practice of tikanga.

Māori adaptive capacity in this area is visible but uneven. Whānau and hapū have demonstrated strong local leadership, particularly in disaster response, where marae often serve as first response hubs offering shelter, coordination and support.[511] However, kāinga often remain without climate action plans and lack formal links with local authorities, limiting their access to adaptation funding or infrastructure support.[512]

Policy readiness to address the risks of damage to Māori infrastructure is uneven. There is a strong research base demonstrating the consequences of inaction and highlighting practicable solutions, and there is visible government intent to address aspects of this risk via the various resource management reforms underway. Success will depend on the extent to which Māori decision-making is provided for in these changes, and the use of various tools that may help to accelerate action.

RISK: Disruption to tikanga and hapū/iwi identity

This risk examines how climate change-induced displacement, flooding, coastal erosion and managed retreat risk severing iwi/Māori connections to whenua, threatening identity, sustained practice of tikanga and intergenerational wellbeing. Hapū/iwi and Māori identity is closely tied to place, particularly ancestral lands, waterways and coastal ecosystems. As climate change disrupts these geographies, there is growing concern about the potential disruption to tikanga and hapū/iwi identity. This risk is closely linked to the *People, health and communities* domain, particularly risks to *Social cohesion, community and cultural wellbeing* (from displacement).

Sea-level rise (SLR), coastal erosion and managed retreat present existential threats to iwi/communities living on or near their ancestral lands. These challenges disrupt the physical landscape and sever whakapapa-based relationships with place, undermining the transmission of tikanga, reo and mātauranga Māori.[499,513,514] The exposure arises not only from environmental stressors such as SLR and erosion, but also legislative, structural and policy barriers to tikanga-based pathways for adaptation, particularly for relocation or managed retreat.[155,510] Iwi/Māori wellbeing is affected by displacement, which can lead to identity shocks and intergenerational anxiety, when land degradation and infrastructure damage occur.[510]

The extent to which tikanga will be disrupted is uncertain, as impacts vary by rohe and depend heavily on local leadership, whānau cohesion and support structures. Nonetheless, repeated disruptions to access, land use and ceremony can contribute to longer-term erosion of language, values and identity, mainly where relocation or adaptation is not governed by Māori priorities.[158,511,512,515]

Current policies include principles or statements relevant to safeguarding tikanga and hapū/iwi identity but stop short of providing funding, mandates or enforcement. Proposed legislation that has been signalled by the Government as the key mechanism for managed retreat, including for iwi/Māori, remains undeveloped. As of 2025, no bill has been introduced to Parliament, and policy settings for the bill are still being developed.[465,516]

RISK: Loss of access to taonga species

This risk assesses the impacts of climate change on access to taonga species, highlighting the threats it poses to mahinga kai, food resilience, tikanga and the transmission of intergenerational knowledge. It is closely linked to all risks in the *Natural environment* domain.

Taonga species include kai such as tuna, pāua, kūtai, tuangi, kina, rimurimu and some rongoā. Losses may occur as climate change intensifies marine heat, acidification, extreme weather and sedimentation, and interacts with land-use pressures.[158,506,517] Loss of access is not only an ecological problem; it also threatens tikanga, maramataka practice and intergenerational mātauranga transmission, acts that are pivotal to iwi/Māori identity and oranga.[32,507]

Māori communities are experiencing increasing exposure to the decline of several taonga species. This exposure arises from a combination of environmental stressors, including rising sea temperatures, sedimentation and storm impacts, which are linked to climate change and land-use pressures.[518-520] In some regions, particularly coastal and lowland areas, customary harvesting practices are already being affected. For example, disconnection from tuna harvesting in Waikato has been linked to kai availability at poukai and associated practices.[520]

The focus of the assessment of this risk is on aquatic and coastal taonga species, due to their prominence in available impact assessments and community reports. However, it is crucial to acknowledge that terrestrial taonga species, such as harakeke, rātā, kiwi and other culturally significant flora and fauna, are increasingly endangered by climate change and related biosecurity challenges. Invasive species that are not yet formally recognised as biosecurity threats could also harm these taonga species, with potential impacts likely to worsen under anticipated climate scenarios. More research is essential to fully understand the cascading cultural and ecological implications for terrestrial ecosystems.

Māori adaptive capacity in this domain is strong but constrained. Several whānau, hapū and iwi are actively engaging in restoration and innovation initiatives grounded in mātauranga Māori. Examples include biodegradable spat-catching lines (taura kuku) for mussel restoration,[521] kelp forest recovery in kina-affected ecosystems[519] and the application of Māori indicator-based monitoring frameworks to assess environmental change.[515,522]

In terms of policy readiness, policy coverage is evident in specific programmes and research projects, but these are described as regional or pilot programmes, rather than comprehensive, enduring investment at the scale of the risk.

RISK: Loss of Indigenous knowledge systems

Mātauranga Māori refers to the traditional and contemporary body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices. This risk concerns how climate change threatens the continuity of mātauranga Māori by disrupting the ecosystems, practices and governance structures that sustain it. Extreme weather events destroy physical sites integral to the performance and transmission of mātauranga Māori, including wāhi tapu, wāhi tūpuna, mahinga kai and marae, leading to accelerated erosion of iwi and hapū-specific environmental knowledge and hapū/iwi identity.[158,499,506] This risk is closely linked to the *People, health and communities* domain, particularly the risk to *Social cohesion, community and cultural wellbeing*.

In the first national climate change risk assessment, this risk was identified but not fully specified. New work since then clarifies how disappearing tohu, degraded taonga species and habitats, and inadequate participation in decision-making accelerate loss. As climate events destroy such knowledge-rich environments, mātauranga Māori becomes more vulnerable.

Mātauranga Māori is inherently rohe and hapū specific, and the responses led by iwi/ Māori in their communities reflect the regionality of mātauranga. Te ao Māori cuts across all aspects of adaptation and accelerating a general understanding of mātauranga Māori through collaboration with local iwi and hapū can build more locally relevant and enduring climate change solutions.

Policy settings affecting mātauranga Māori fall into three layers: direct, indirect and enabling. Currently these policies recognise mātauranga Māori but do not secure the conditions for intergenerational transmission.[465,516] National policy instruments signal an intention to elevate mātauranga Māori and partnership, but evidence suggests this does not consistently translate into shared decision-making or resourcing in practice. Some local councils have begun to support mana whenua-led initiatives and engage with mātauranga Māori within climate and land-use planning; however, there is inconsistent resourcing and an absence of binding frameworks.[155,499,514]

Māori adaptive capacity to protect and revitalise knowledge systems is significant but currently under-supported. Iwi, hapū and whānau have developed a range of tikanga-based responses, including tohu monitoring systems,[522] tikanga-based architecture[523] and community wānanga, to reassert mātauranga Māori in planning and practice. These examples show that mātauranga Māori can support tikanga-based and ecological resilience when adequately resourced and recognised.

RISK: Legal exclusion and governance failures for Māori

This risk concerns how legal exclusion and governance failures can undermine iwi/Māori decision-making and participation in climate adaptation. The Government has a key role in ensuring all communities are supported to adapt to the unique climate-related challenges they face and has specific obligations to iwi/Māori under Te Tiriti o Waitangi/The Treaty of Waitangi. Ensuring that iwi/Māori can adapt their communities in a way that is consistent with their tikanga and aligned with their whakaaro tau will make adaptation efforts more effective. This risk is closely linked to all risks in the *Governance* domain, particularly risks to the ability uphold Te Tiriti/the Treaty in adaptation governance and implementation.

The first national risk assessment recognised cultural and institutional dimensions of risk. Since then, iwi/Māori legal and governance exposure has become evident in emergency responses to significant weather events, which has consequently influenced the analysis in this assessment. Reviews of responses to Cyclone Gabrielle found that the engagement of iwi/Māori entities in the emergency response was discretionary, and in some regions non-existent.[458,524]

The primary drivers of this risk stem less from biophysical climate models and more from political and institutional settings. While legal reforms are possible and under way in some areas, their outcomes are not guaranteed and may vary across regions and political cycles.[525,526] Iwi and hapū also experience variability in capacity and resourcing, which affects their ability to influence or engage with legal processes.[155]

Māori capacity in climate adaptation is demonstrated through a wide range of iwi-led planning, climate strategies and governance models. These include co-management arrangements in certain catchments,[527] iwi-led climate and freshwater strategies grounded in maramataka and whenua tuku iho,[522,528] and innovations in kaupapa Māori housing and disaster planning such as papakāinga, kāinga regeneration and Māori-led emergency responses.[506,511,523,529,530]

The Government Inquiry into the Response to the North Island Severe Weather Events [11] and the Ministerial Inquiry into Land Use in Tairāwhiti and Wairoa (2023)[531] both recommend Te Tiriti/The Treaty consistent governance with stronger Māori decision-making roles. The Expert Working Group on Managed Retreat (2023)[516] sets out tikanga-informed pathways. However, the status of proposed climate adaptation legislation (signalled by the Government as the key mechanism for managed retreat and in which iwi/Māori were named) remains uncertain. As of 2025, no bill has been introduced to Parliament, and policy settings for the bill are still under development.

Since this analysis was completed, the Government has introduced a new Emergency Management Bill. This bill would address some of the improvements needed, including strengthening and formalising the role played by iwi/Māori in official emergency management.

RISK: Economic losses for Māori in primary industries

Iwi/Māori have significant involvement in climate-sensitive sectors like farming, forestry, fisheries and aquaculture. This risk describes the potential economic losses in primary industries from exposure to climate-related stressors such as droughts, floods, ocean acidification and new biosecurity threats, hazards that are expected to intensify under projected climate change scenarios.[32,529,532] It is closely linked to all risks in the *Sectors relying on the natural environment* domain.

Sensitivity is amplified because Māori landholdings are often located in environmentally marginal or erosion-prone areas, where the adaptive options are more limited.[509,533] Structural constraints on whenua Māori, including fragmented titles, limited collateral and transaction costs, also continue to cap the speed of adaptation.[159]

Extreme weather events since the first national risk assessment in 2020 have highlighted current vulnerabilities. In Hawke's Bay (Te Matau-a-Māui) Māori aquaculture and horticulture operators experienced extended shut-downs due to sedimentation, infrastructure failure and lack of insurance coverage following Cyclone Gabrielle.[533] These incidents have highlighted the specific challenges Māori collectives face in accessing structured recovery support, particularly when land is held in multiple ownership or when customary governance structures do not align easily with standard funding mechanisms.[531,534]

Readiness is strongest where Māori organisations already lead end-to-end delivery and possess durable governance, balance sheets and trusted partnerships. Large iwi entities increasingly integrate climate-related risk into portfolio management, reallocating capital toward resilient land uses and co-investing in enabling infrastructure; this creates immediate absorption capacity for concessional finance, tailored procurement and streamlined consenting.[535]

Across iwi/Māori participation in farming, forestry, fisheries and aquaculture, policy coverage for climate-related economic losses has strengthened. However, alignment with iwi/Māori ownership structures, decision rights and intergenerational objectives is still uneven. Post-event reviews and land-use inquiries have sharpened focus on exposure and landscape fragility, particularly sediment, slash and roading dependencies in steep catchments, providing important signals for risk reduction, but these assessments do not, by themselves, resolve recurrent loss profiles or the financing of long-run transitions.[531,536,537] The Government's climate strategy and climate work programme set an overarching direction that may support primary industry risk reduction, particularly where agencies align investment, regulation and procurement with resilience outcomes.[538,539]

RISK: Increased Māori health vulnerabilities

This risk assesses the climate-related health vulnerabilities iwi/Māori face, focusing on how structural inequities, ecological degradation and governance exclusion compound health risks and reduce adaptive capacity. It is closely linked to the *People, health and communities* domain, particularly the risks to physical and mental health.

Māori communities experience higher rates of pre-existing health conditions, such as respiratory illnesses, kidney problems, cardiovascular disease and diabetes, than the rest of the population.[485] These inequities have been, and still are, shaped by structural determinants, including housing quality, access to healthcare and environmental degradation.

Climate change is expected to interact with these vulnerabilities in ways that increase Māori exposure to adverse health outcomes.[540-543] It may worsen these inequities through increased exposure to heatwaves, poor air and water quality, and stress-related illness.

Māori wellbeing is tightly linked to tikanga and whenua, which are highly climate-sensitive and currently under-protected in health system planning.[442,544] Climate-related displacement and environmental trauma pose serious risks to mental health that may be exacerbated for iwi/Māori by the additional impact of disruption to tikanga. However, iwi/Māori-led responses to the COVID-19 emergency suggest that tino rangatiratanga and collective identity can help buffer psychological harm. This offers lessons that may be applied to climate-related emergencies, including flooding or relocation.[545,546]

Aotearoa New Zealand's current policy architecture relevant to climate-related health vulnerabilities for Māori sits across health system reforms, the national adaptation plan, emergency management, housing quality and supply, drinking water and wastewater regulation, environmental management and social protection. Taken together, these instruments create direct, indirect and enabling levers that shape exposure, sensitivity and adaptive capacity.

Overall, policy coverage is meaningful but incomplete. It is strongest where Te Tiriti/The Treaty commitments are made operational through shared authority, sustained resourcing and enforceable standards; where exposure-reducing regulations are implemented and monitored; and where enabling levers build capability for Māori-led planning and service continuity. It is weakest where responsibilities are spread across agencies without co-decision-making; or where scale, scope and timing are mismatched to projected risk trajectories.[547,548]

Readiness is strongest in communities where kaupapa Māori providers, marae and hapū/iwi organisations are empowered to utilise tikanga-grounded approaches that can be mobilised quickly during heat, smoke, flood or contamination events.

Te reo Māori glossary

Kupu/rerenga kupu Māori	English contextual translation
awa	river, stream
hapori	community
hapū	kinship group, tribe, subtribe; a kinship group descended from a common ancestor; the primary political unit in traditional Māori society
harakeke	New Zealand flax
iwi	tribe, nation or people; a large kinship group descended from a common ancestor
kaimoana	seafood, shellfish
kāinga	home, village or settlement
kaupapa Māori	Māori approach or approaches, issues, perspectives, matter for discussion
kina	sea egg, common sea urchin
kiwi	flightless, nocturnal endemic birds with hair-like feathers and a long bill with sensitive nostrils at the tip
kōrero	conversation, speech, narrative, story
kūtae, kūtai	mussel (of several species)
mahinga kai	garden, cultivation, food-gathering practice and/or place
mana whakahaere	governance, authority, jurisdiction, management, mandate, power
mana whenua	territorial rights, power from the land, authority/jurisdiction over land or territory, power associated with possession and occupation of tribal land. Sometimes used to describe those associated with such rights/authority; or (more loosely) with tribal links to a specific area
marae	communal or sacred place that serves as a venue for whānau, hapū, iwi, and community gatherings; often a key focal point for tribal affairs
maramataka	traditional lunar calendar used to guide planting, fishing, and other activities

mātaitai/mātaitai reserve	seafood/reserves managed by iwi/Māori that provide for customary fishing and usually exclude commercial fishing
mātauranga	historic and contemporary knowledge, wisdom, understanding, skill
mātauranga Māori	historic and contemporary Māori knowledge, the body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity, and cultural practices
moana	ocean
oranga	livelihood, welfare, health
papakāinga	Māori housing or homestead generally on ancestral land
pāua	abalone, sea ear – edible univalve molluscs of rocky shores that have flattened, ear-shaped shells with a row of small holes for breathing
poukai	Kiingitanga gathering to acknowledge bereaved families, widows/widowers, discuss regional and national affairs
rātā	Metrosideros robusta (Northern), Metrosideros umbellata (Southern) – large forest tree with crimson flowers and hard red timber
reo	language, dialect
rimurimu	seaweed – a general term
rohe	boundary, district, region, territory
rongoā	traditional Māori medicine, medicinal plant, contemporary medicine
taiāpure	local fisheries in areas of special significance to iwi/Māori that typically allow for all types of fishing
taonga	treasured possessions
taonga tuku iho	heritage, cultural property, something handed down
tikanga	correct procedure, custom, habit, lore
tino rangatiratanga	self-determination, sovereignty, autonomy
tohu	sign or symbol
tuna	eel of various species, including the longfin eel (*Anguilla dieffenbachii*) and shortfin eel (*Anguilla australis*)
tūpuna, tīpuna	ancestors (singular – tupuna/tipuna)

urupā	cemetery or burial ground
wāhi tapu	sacred place, sacred site
wāhi tupuna, wāhi tūpuna	ancestral places
whakaarotau	priorities
whakapapa	genealogy, lineage; the layering of relationships that connect people, places, and knowledge systems
whānau	family, extended family, family group
whenua	land; also refers to placenta, symbolising the deep connection between Indigenous people and place
whenua tuku iho	inherited land

DOMAIN: Economy and finance

This domain covers risks to economic production – how public and private goods and services are created and distributed, and the financial system that supports saving, borrowing and investing.

Economic systems underpin how people live, earn income and pay for essential goods and services. This, in turn, affects the overall wellbeing of everyone who lives in Aotearoa New Zealand. As climate impacts intensify, the costs of adapting will influence what the country produces and how it is produced. Both gradual changes and extreme weather events will disrupt production and supply chains, creating greater uncertainty for businesses, workers and households. Understanding these economic dynamics is crucial for planning resilient responses to climate-related risks.

The assessment includes four risks, which cover the costs to central and local government, impacts on economic production from supply chain disruptions, the insurability of assets and the stability of the financial system.

What makes this domain unique?

The impacts of climate change will affect all areas of Aotearoa New Zealand's economy

All sectors of the economy are exposed either directly or indirectly to the physical impacts of climate change. Many sectors (such as agriculture, horticulture and tourism) are directly reliant on the climate for production – see the *Sectors relying on the natural environment* domain. Even small changes in the climate can have an impact on the amount, quality and location of production. Extreme events also cause disruption and dislocation of economic activity, both immediately when events occur and over time while recovery takes place.

Adapting to climate change requires investment, which will pay off

While adapting to climate change will impose costs on the economy, these investments are expected to deliver net benefits to society over the long term. Spending on adaptation measures can place pressure on the economy and will influence the willingness of central and local government, businesses and households to fund them. Significant investment is needed in collective assets, systems and public goods, which suggests a role for central and local government funding, and therefore a need to fund adaptation spending alongside spending on core service delivery, and increased costs of recovery after extreme weather events.

How does this domain interact with other domains?

Every risk will have economic consequences

This domain is affected by all the others. Every risk in the assessment has the potential to affect economic productivity, from the impacts of more dry days on the agriculture and horticulture sectors to the physical and mental health consequences of prolonged and repeated exposure to climate-related hazards affecting people's ability to work. Adaptation policies, plans and actions that directly address biophysical climate hazards are also expected to enhance the resilience of the economy.

There are strong links between the economy and governance

There are strong links between the economy and governance, with significant interactions between the risks in both domains. Confidence in the ability of institutions to govern effectively contributes to broader trust in the economy, supporting businesses and individuals to make investment choices. Fiscal challenges faced by governments may be exacerbated if they come under pressure to increase spending while revenue declines. Conversely, inaction or growing inequities driven by economic risks can trigger governance risks, creating a cycle where failures in one domain amplify vulnerabilities in the other.

Impacts on iwi/Māori

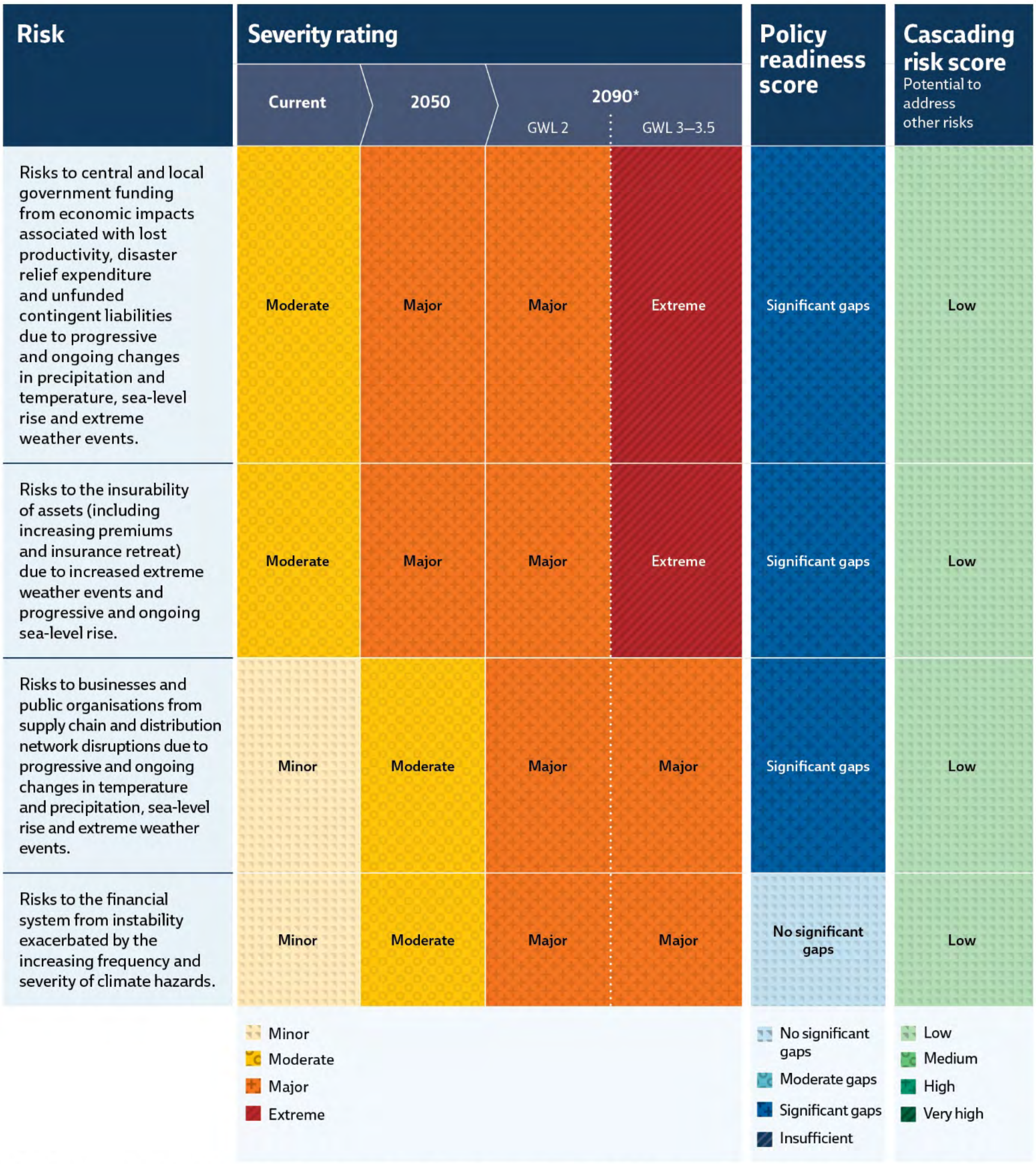
Iwi/Māori assets face significant exposure

The Māori economy could experience significant impacts due to the high representation of Māori businesses and workers in climate-sensitive industries like agriculture, forestry and fisheries. This sensitivity is amplified because whenua Māori is more likely to be located in environmentally marginal or erosion-prone areas where adaptation options are more limited. In addition, there is a misalignment between collective decision-making models for iwi/Māori land and competitive, short-term and compliance-heavy funding systems. This misalignment often results in Māori collectives being excluded from adaptation finance mechanisms. This is discussed further in *Ngā mea hirahira o te ao Māori*.

Systemic policy issues

The distribution of climate change costs and impacts between central and local government, among individuals, households, businesses and communities, and across generations, will be largely shaped by the extent and reach of government action to enable adaptation. Central government policy decisions will determine how risks are managed and costs allocated at a national level, influencing whether adaptation is proactive or reactive. Inaction or fragmented responses could amplify cascading risks across interconnected systems. Government decisions about infrastructure investment, regulatory frameworks and support for innovation will affect resilience and economic stability.

Table 3.5: Risk ratings for Economy and finance



Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090* GWL 2	2090* GWL 3—3.5		
Risks to central and local government funding from economic impacts associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to progressive and ongoing changes in precipitation and temperature, sea-level rise and extreme weather events.	Moderate	Major	Major	Extreme	Significant gaps	Low
Risks to the insurability of assets (including increasing premiums and insurance retreat) due to increased extreme weather events and progressive and ongoing sea-level rise.	Moderate	Major	Major	Extreme	Significant gaps	Low
Risks to businesses and public organisations from supply chain and distribution network disruptions due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.	Minor	Moderate	Major	Major	Significant gaps	Low
Risks to the financial system from instability exacerbated by the increasing frequency and severity of climate hazards.	Minor	Moderate	Major	Major	No significant gaps	Low

Minor
Moderate
Major
Extreme

No significant gaps
Moderate gaps
Significant gaps
Insufficient

Low
Medium
High
Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Central and local government funding

Risks to central and local government funding from economic impacts associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to progressive and ongoing changes in precipitation and temperature, sea-level rise and extreme weather events.

Responding to the increased risk caused by climate change will require additional expenditure to adapt and prepare for a warmer climate, and to respond to and recover from extreme events. Investment in adaptation measures often has high benefit to cost ratios and presents good value for money.[549] Much, but not all, of the cost of investing in adaptation will fall on central and local government as owners of public infrastructure. Decisions about how other risks are managed could also affect who pays for adaptation measures or recovery after extreme weather events. To reduce the costs from climate change, significant investment is needed in collective assets, systems and public goods, which is therefore likely to fall on government – either way governments will likely face significant and growing financial demands.

In addition to the costs imposed on central and local government, climate change could also affect the basis on which revenue is collected – taxes in the case of central government, and rates for local authorities.

This was identified as one of the most significant risks

This is one of the most significant risks because central and local government funding is coming under increasing pressure as climate change advances. This affects every part of the economy and society. The need for central and local government to respond to increasingly frequent and intense events has the potential to crowd out the funding of other core services such as health and education (services that will themselves be directly and indirectly impacted by climate change). This risk is compounded by the imbalance in current spending between disaster response and planned adaptation – including to address ongoing and progressive changes like sea-level rise. The result may push very high costs onto future generations. For more, see the Priorities for action report.

Risk overview

The costs of climate change events are already significant, and are difficult to plan for

The first risk assessment in 2020 found that "[t]he costs of climate change in New Zealand are already significant… and will only increase over time." [18] The 2023 North Island Weather Events are estimated to have cost central government around NZ$6.65 billion.[550]

Adaptation action and investment in resilience can help reduce these costs. However, as they are the result of disasters, these costs occur with little notice and limited discretion on size, so make it more difficult to plan and manage spending as part of normal government budget processes.

Costs for central government will rise over time as extreme weather events become more frequent and intense

Central and local government play a key role in recovering from extreme weather events by providing disaster relief and repairing infrastructure. Much of the cost falls on central government as it helps local governments with the costs of reinstating essential local infrastructure (60% of costs borne by central government and 40% by local government)[551] as well as the costs faced by central government directly.

It is anticipated that the costs to central government will increase over time as the number of extreme weather events and the need for proactive adaptation spending increases. The costs will also be dependent on the level of warming, with higher levels of warming associated with much higher exposure to extreme weather events. More frequent and extreme weather events will also cause greater disruption to the economy, reducing tax receipts, increasing their variability and making it harder to plan expenditure.

Climate change will increase the need for spending in other areas of government expenditure

There will likely be additional demand for healthcare spending to respond both the physical and mental health impacts of climate change. Negative health impacts also reduce labour productivity, affecting tax and the economy more generally. Extreme events could increase the number of people who need assistance from the social welfare system. These additional costs will primarily affect central government.

Impacts on the wider economy will affect tax revenues

Central and local government will likely also face reduced taxation income as extreme events often have severe short-term impacts on economic activity. Disruptions to supply chains and other changes in patterns of economic activity in response to climate impacts could also affect tax income.

Spending on adaptation should increase, but the incentives to do so are not aligned

Central and local government will also be expected to invest in adaptation measures for climate change. Successful adaptation measures will decrease the costs from extreme events, reduced taxation income, and additional health and social welfare costs. Adaptation measures often present good value for money investments with high benefit to cost ratios.[549] At the same time, the size of the investment needed is expected to grow in the near term. For instance, around NZ$5 billion could be needed over the next 10 years just for flood protection schemes.[18]

Much of the cost and responsibility for adaptation currently lies with local government, especially because many adaptation measures are very local in nature. However, a major beneficiary of these adaptation schemes is central government, because proactive investments to improve local resilience reduce the costs often borne by central government when events occur. There are currently limited formal mechanisms for sharing adaptation costs, and instead it has been done in an ad-hoc manner. This misalignment of incentives may result in underinvestment in adaptation measures.

Central government may be better placed to manage the additional spending, but it will depend on policy choices

While central government has the larger susceptibility and is subjected to multiple costs from climate change, it also has greater capacity to absorb costs, including more ability to borrow. Treasury modelling, using the 2023 North Island Weather Events as a comparator, suggests central government is relatively well placed to respond to future extreme weather events. Current net core Crown debt of around 40% of GDP is not high by international standards, but is projected to climb over time due to the effects of an ageing population reducing tax revenues and increasing the need for government spending.[550] This means the ability for central government to absorb costs, while adequate now, is likely to reduce over time, all else remaining equal.

Local government funding is already tight, and may limit its ability to adapt to climate change

Local governments are primarily exposed to the costs of adaptation including maintenance and upgrades of essential infrastructure and to some of the costs of recovering after extreme events. Many councils, especially smaller ones with small rates bases, are more sensitive to extreme events, as their budgets are already very tight or they have reached their debt limits. This limits the ability for local government to borrow to invest in adaptation measures, which could mean levels of service in other areas may have to decrease to pay for adaptation. Rates caps for local government could constrain revenue options, underscoring the value of resolving current uncertainty about the roles of central and local government funding and financing for adaptation.

Failure to act could disadvantage iwi/Māori in particular or disproportionately impact iwi/Māori

Failure to adequately plan for and adapt to climate change could mean iwi/Māori are relied upon to provide a greater level of emergency response after events (for example, marae). It is already the case that iwi/Māori services, sometimes unfunded or reimbursed rather than pre-funded, provide relief services during disasters.[552]

A greater proportion of iwi/Māori also live in local authority areas that are in a weak financial position and/or have a higher exposure to climate-related risks, such as Te Taitokerau/Northland.[150]

Compounding and cascading factors

There are multiple compounding risks likely to increase costs to government or reduce its income

This risk is an indirect and intensifying risk as most other risks identified in this assessment are expected to either increase costs that may be met by government, or directly or indirectly reduce income to government. Failure to adequately address the other risks identified in this assessment is likely to increase the fiscal risk to the Crown and the funding requirements for local authorities. While actions to adapt to climate change could require government spending, the amount required is expected to be lower than if central and local government fail to act, with many adaptation actions having high benefit to cost ratios.[553]

Exposure to this risk depends on funding choices made by central and local government, as well as the insurance industry

The exposure to this risk also depends on the choices government makes about the role of central and local government in funding adaptation actions, versus the role of individuals to take action. The extent of coverage by private insurance will also have an impact on the fiscal effect of extreme events. High levels of private insurance will reduce the fiscal risk to the government as it reduces the susceptibility of the government to the costs of extreme events. However, many costs to central and local government, such as repairing infrastructure, cannot be insured against.

Interaction with emissions reduction

Extreme events could cause funding to be allocated away from investments that provide a long-term benefit, such as adaptation and mitigation measures, towards recovery. This could reinforce a false perception that there are necessarily trade-offs between action on adaptation and mitigation, when these often are mutually supportive.

Policy readiness assessment

Central government is starting to consider the impacts of climate change

Advice from the Treasury has emphasised planning the public finances to allow enough fiscal space to absorb a potential negative shock, such as the cost of recovery after an extreme weather event.[554] Regular reporting by the Treasury is intended to ensure central government is considering long-term trends that might affect the fiscal position. However, only the cost of droughts and storms[550,555] has so far been explicitly considered.

Central government could explicitly consider the cascading effects of climate change on taxation and on social welfare and healthcare costs in their long-term reports. This is already done with population ageing on health and superannuation costs to help manage their fiscal effects into the future.[555]

Central government can also reduce the fiscal costs of climate change by identifying and implementing proactive adaptation action that reduces the costs from extreme events. This includes managing the climate change risks to government-owned assets. When extreme events do occur, the fiscal impact will also be determined by the policy choices made in response to the events.[550] If this is determined beforehand, money can be set aside to prepare so that it is available when events occur.

Decisions flowing from the National Adaptation Framework will determine the costs that fall on central government

The uncertainty around who pays for climate change adaptation – whether central government, councils, communities, or the private sector – is itself a secondary climate-related driver of this risk. Repeated attempts to resolve how these costs will be shared have not yet resulted in a way forward – see *Effective adaptation implementation* risk analysis.

The Government's National Adaptation Framework includes a pillar focused on cost sharing pre- and post-event, which sets out that "[t]he expected costs from natural hazards like floods and storms, and the costs of adapting to them, are shared across society and over time."[169] While helpful for the Government to set this out, the National Adaptation Framework does not include detail of when or how the decisions will be made around how costs will be shared. The exposure of central and local government to the costs will depend on these choices, making it hard to currently assess the scale of the funding risk. As central government currently acts as insurer of last resort in many instances, paying for recovery after extreme weather events, central government's exposure will increase the longer these decisions are left unresolved.

Local government faces challenges in planning its adaptation spending

Local government is currently facing increased spending pressures due to rising operating costs and the need to increase spending to replace ageing or degraded infrastructure. At the same time, many local councils are close to or exceeding their self-imposed debt limits,[556] limiting their ability to borrow more.

Local governments must prepare an updated long-term plan every three years, that covers the next 10 years and considers the costs each council will face.[557]

Local communities that have developed possible funding mechanisms for local solutions have not been able to progress these without central government assistance or a legislative mandate. Many councils lack the funding or borrowing capacity to implement the changes they have identified directly. This delays resilience building and increases future costs.[556]

Gaps for risk severity and policy

There are large gaps in the data on what previous extreme events have cost both local and central government, partly because there are challenges around how much of the cost is due to increased climate change risks. There have been calls to develop and maintain a dedicated database to track losses from weather disasters[558] so that the scale of the impacts is better understood.

Summary

While both local and central government are exposed to risks from extreme events, central government may be more exposed, as it faces increased costs and reduced revenues from a greater range of sources, as well as incurring large costs to support recovery.

The current mechanisms for central government to manage long-term fiscal risks are starting to consider some aspects of climate change, notably extreme events. They have yet to pick up the cascading effects on healthcare and social welfare costs or attempt to calculate the cascading effects on taxation.

Local government is recognising and planning for the costs of adaptation. However, councils are struggling to find funding as it already has high debt levels and large rates rises. There is also substantial and effectively automatic cost-sharing of post-event infrastructure-related costs.

These risks come about as a result of many more direct risks, such as the damage caused by extreme events, and are dependent on how those direct risks are managed. It will be important for managing fiscal risks for central and local government to come to an agreement on how both recovery and adaptation costs are shared between them.

Investing in adaptation carries upfront costs, but these often pay off through reduced damages.

Risk scorecard: Central and local government funding

Risks to central and local government funding from economic impacts associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to progressive and ongoing changes in precipitation and temperature, sea-level rise and extreme weather events.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Responding to increasingly severe extreme weather events is already requiring short-term re-prioritisation of funding.
2050	Major	Costs to central and local government are expected to rise by 2050, driven by the need to respond to more frequent and intense extreme weather events and the growing need for adaptation spending.
2090*	Major GWL 2	Costs on central and local government are expected to rise by 2050, driven by need to respond to more frequent and intense extreme weather events and need for adaptation spending.
	Extreme GWL 3–3.5	Significant increases in government spending required under this scenario to recover from many more frequent and intense extreme weather events and higher adaptation costs from other hazards.
Policy readiness		
Overall assessment	Significant gaps	While central government has solid, well-tested, high-level policies for managing fiscal risk, not all climate-associated future costs have been incorporated. Local governments face fewer costs but also have less ability to deal with them and there is limited policy to address this.
Cascading risk		
Overall assessment	Low	Addressing this risk in isolation was assessed as having a low overall potential to address others in the assessment, though it has strong connections to the risks to the legitimacy of democratic institutions.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Insurability of assets

Risks to the insurability of assets (including increasing premiums and insurance retreat) due to increased extreme weather events and progressive and ongoing sea-level rise.

Insurance is an important tool to protect people and businesses from the financial impacts of many acute hazards. Projected changes in the frequency and intensity of the acute hazards people and organisations insure against are causing the insurance industry to significantly increase premiums. Insurers may also reduce the risks they provide cover for, or withdraw availability altogether, referred to as insurance retreat.[559,560] These changes are likely to affect many insurance markets, including the residential market. This will decrease the ability of insurance to reduce financial hardship after extreme events, with significant flow-on effects for Aotearoa New Zealand society. Action to address climate-related risks is important to support the continuing ability of domestic insurers to diversify risk through access to global reinsurance markets.

Fundamentally, adaptation actions that increase overall resilience to climate hazards in Aotearoa New Zealand are likely to reduce the specific risk to insurability.

Risk overview

Insurability of assets will be significantly affected, but the timing and costs are uncertain

Insurability of assets includes buildings, ports and airports, electricity distribution and generation and telecommunications infrastructure. There is little uncertainty that the insurability of assets will be significantly affected as global warming levels increase and extreme weather events become more frequent, severe and widespread. However, the timing and scale of the impact on the cost and coverage of insurance is uncertain and will differ significantly by location and individual assets.

Risks to insurability will vary by regions, depending on the climate-related risks they face

The regional variances in the risk to insurability of assets will largely follow the regional variation in the risk to the underlying assets. The most significant risk is to coastal locations, followed by inland floodplains.[561] Insurance retreat is expected to happen first in coastal areas followed by inland floodplains. The timing and scale of insurance retreat in inland floodplains has not been sufficiently modelled, but recent research suggests that insurance retreat in inland floodplains from increases in extreme precipitation will occur one to two decades after insurance retreat in coastal inundation zones.[559]

The price of insurance has increased, with insurers seeing climate change as a key risk

Since 2000, the price of house insurance in Aotearoa New Zealand has increased by over 900% in nominal terms.[562] Aotearoa New Zealand currently has high rates of residential insurance uptake. However, research suggests there may be a significant level of underinsurance, and homeowners increasing their excess to help reduce the cost of premiums.[563,564] In some locations considered to have significantly increasing risk, insurance may be offered by only a single provider, reducing competition in the market and increasing the chance of overpricing. Major retail insurers increasingly see climate change as a material risk to their business, with Aotearoa New Zealand insurers ranking climate change in their top five risks.[565]

Insurers are moving towards risk-based pricing, which may exacerbate existing inequities

There is a trend towards insurers using risk-based pricing, a tool that tailors premiums to the specific risks associated with properties, rather than using broad regional averages. Risk-based pricing will provide important price signals of the risk to assets. As extreme weather events become more frequent, severe and widespread, insurers will continue to improve their ability to model specific location-based risks, and risk-based pricing will likely become the norm. Climate change will likely overtake the risk of seismic events in many locations, and the significantly increased premiums will mean households in some areas may not be able to access insurance by 2035. Risk-based pricing could also compound existing inequities if households are priced out of buying insurance and are impacted by extreme weather events.

Domestic insurers are facing much higher costs from reinsurance and global reinsurers may reduce coverage

Reinsurers play an important role in Aotearoa New Zealand's insurance market, allowing risk to be pooled globally. Reinsurance is particularly important to ensure that insurers are able to pay claims when large events occur. In 2023, there was a significant reset in the global reinsurance market, due to both global trends and domestic events including Cyclone Gabrielle. This resulted in difficulties for domestic insurers to renew reinsurance contracts, with many insurers facing significantly higher reinsurance costs.[566] Global reinsurers may reduce coverage if they assess that the risk management practices of insurers are insufficient, or if they judge that not enough action is being taken by the Government to address climate-related risks.

Iwi/Māori face unique insurance risks due to location and exposure to extreme events

Increased insurance costs can provide a price signal to encourage adoption of measures to reduce risk or relocate assets. However, this is less straightforward for many iwi/Māori asset owners, as legislative constraints on whenua Māori make it difficult to sell, and whakapapa-based relationships with place mean that the decision to relocate is not solely a financial decision. Some Māori infrastructure faces unique challenges in the insurance market.[567] For example, marae often can face exceptionally high insurance costs due to several factors, including exposure to coastal inundation and inland flooding, or being situated in remote locations that can be difficult to reach in emergencies. Marae are also excluded from publicly funded natural hazards insurance.[160]

To address these challenges, some iwi and hapū have established collective insurance schemes for marae, with some iwi subsidising premiums to provide financial relief.[568]

Compounding and cascading factors

There are multiple intersecting risks, including changes to communities and disruption to financial systems

The major driver of the risk to the insurability of assets is the underlying risks to the assets themselves. Therefore, effective reduction of the risks to the assets will reduce risks to insurability. Changes to the price and accessibility of insurance can also have significant flow-on effects. These effects can include loss of peace of mind, the breakdown or displacement of communities, changes in business investment and household spending behaviours, increases in debt and bankruptcy, fiscal risks to the Government, financial system instability and risks of exacerbating or creating new inequities.

Population growth is leading to new infrastructure being located in exposed areas

Population growth is driving demand for new housing and infrastructure. This continues the trend of increasing housing density in coastal areas, with over 65% of New Zealanders currently living within 5 kilometres (km) of the coast.[569] Without stronger measures to prevent developments in highly exposed areas, this trend may exacerbate this risk.[570]

Increasing insurance premiums may affect housing affordability

Broader issues with housing affordability, such as the current very high ratio of house values to median household incomes, could encourage first-home buyers to purchase homes in more affordable but hazardous locations. If the value of property falls due to increasing insurance premiums, these homeowners could fall into negative equity and are at higher risk of mortgage default.

Policy readiness assessment

Risks to insurance availability are under discussion, but monitoring is limited

The public is becoming increasingly aware of the risk to insurance availability due to climate change, and it is being discussed more by governments. This has resulted in some actions and policies being implemented, such as “improved monitoring of residential insurance premiums” by the Treasury.[571] The Natural Hazards Commissions (NHC) also released the Natural Hazards Portal in 2023, which is a tool for understanding natural hazard risks in Aotearoa New Zealand based on historic NHC claims.[572] However, increased monitoring of historic insurance premiums and claims is not currently at the point of delivering deep insights useful to the public. Policies also need to focus on the facilitation of transparent and accessible modelling information of future risks. This can help manage the risk to the affordability or accessibility of insurance and smooth potential impacts on the value of homes and assets.

Adaptation policies that reduce the underlying risks to assets through timely and effective adaptation measures will be crucial in reducing this risk. These are not listed here as they are captured in other risk summaries.

Barriers include complexities in the insurance industry and costs to customers

The insurance market is complex and any intervention in the market comes with trade-offs and needs careful consideration. This makes adaptation to risks to insurance availability difficult, as there are no straightforward or clear solutions – apart from taking action to reduce exposure to hazards. There are choices about how the risks and costs are shared between individuals and local or central government. Individual funding includes accepting the costs of owning assets in hazardous locations and potentially absorbing losses on property values. Potential options for funding by local or central government could include compensating property owners who are forced to relocate, or means-tested and time-bound insurance subsidies.

Policy shortfalls include a focus on improving data rather than addressing the risk

While there are actions in the first national adaptation plan related to this risk, they are focused on improving the availability of data rather than directly addressing the risk. It is important for an adaptation strategy to be developed to enable those affected to plan and determine what actions they may need to take, either now or in the future.

The Government is considering new directions and actions, but none account for effects on iwi/Māori

The Resource Management Amendment Act 2025 strengthens councils' ability to decline consents or impose conditions on new developments in hazard-prone areas. This will act as an interim measure to help regions avoid developing in hazard zones until wider resource management reforms are implemented, though it is too soon to know how local authorities are applying it or the impact it is having in practice.

The National Adaptation Framework released by the Government in October 2025 discusses risk and response information sharing, and supporting well-functioning housing and insurance markets.[169] The listed actions include developing a National Flood Map that compiles national and local data and is readily available to the public. It also lists actions to develop new hazards data sets, an update to the Natural Hazards Portal and investment in risk information to support planning and consenting decisions. The framework includes a 'pillar' built on cost-sharing pre-and post-natural hazard events. However, it is not clear how the actions in the framework will be implemented. More specific information around the timing, tools and expected roles of local government, central government, insurers and individuals is crucial to truly reduce the risk.

There do not appear to be any planned policies or actions directly related to this risk that take into account the specific effects on iwi/Māori.

Gaps for risk severity and policy

The Government has signalled that it intends to significantly improve access to extreme weather hazard information, an important tool to help manage the risk of insurability of assets.

There are many shortfalls in the modelling required to better understand this risk. This includes modelling on the timing and scale of insurance retreat for residential properties, the potential economic and social consequences of insurance retreat, or the fiscal costs to government should they choose to buy out properties subject to insurance retreat.

Summary

The affordability and accessibility of insurance in Aotearoa New Zealand is an increasing concern for many asset owners. Insurance premiums have seen significant increases in cost over the last two decades, and many residential properties are underinsured or face significant excess costs should an event occur. As extreme weather events become more frequent and severe, assets in high-risk locations will see increasingly significant price rises or full insurance retreat. This will not only have significant flow-on implications to many aspects of Aotearoa New Zealand society but also plays an important role in signalling how risks are changing, which could discourage future development in hazardous locations.

While the risk to the accessibility of insurance is recognised by the Government, the actions and policies currently in place focus on understanding the risk in greater detail, rather than directly addressing it. It is important for an adaptation strategy to be developed to enable those affected to plan and determine what actions they may need to take, either now or in the future.

Risk scorecard: Insurability of assets

Risks to the insurability of assets (including increasing premiums and insurance retreat) due to increased extreme weather events and progressive and ongoing sea-level rise.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Cost of insurance has increased significantly in recent years and affordability thresholds are already being reached, driving underinsurance and exacerbating inequities in certain communities.
2050	Major	As insurance companies' use of risk-based pricing increases, a significant portion of New Zealanders will face insurance affordability constraints. This will further exacerbate existing inequities.
2090	Major GWL 2	Risk-based pricing and insurance retreat are likely to result in many households and businesses being unable or unwilling to insure against increasingly frequent extreme weather events.
	Extreme GWL 3–3.5	Significantly increased frequency of extreme weather events and progressive and ongoing changes like SLR will result in widespread unaffordability or total insurance withdrawal in many locations. There will be significant constraints on national providers' access to global reinsurance.
Policy readiness		
Overall assessment	Significant gaps	Aside from limited actions, largely focused on increasing available information, there is no national strategy to manage insurance withdrawal, unclear governance roles and insufficient data sharing or modelling of risks, leaving Aotearoa New Zealand exposed to major financial and social risks.
Cascading risk		
Overall assessment	Low	Addressing this risk has a low overall potential to address others in the assessment, though it has strong connections with the risks to the stability of the financial system and social cohesion, cultural and community wellbeing.

Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Businesses and public organisations (from supply and distribution disruptions)

Risks to businesses and public organisations from supply chain and distribution network disruptions due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Supply chains underpin the economy in Aotearoa New Zealand, ensuring that things like food, medicine, and all other goods, parts and raw materials are available.

Climate change is amplifying risks to the functioning of supply chains and distribution networks that businesses and public organisations[xxxvii] depend on. These disruptions arise from acute hazards such as flooding and landslides as a result of extreme weather events, as well as gradual changes like sea-level rise (SLR) and shifts in seasonality. They are closely related to other risks: for example, a flood can simultaneously damage a key distribution warehouse (the building itself), sever the transport routes that supply it and trigger widespread delays as the entire supply chain reroutes goods. This risk includes domestic and international supply chains critical for goods, services and workforce mobility. Supply chain disruptions can lead to loss of output and lost productivity.

Risk overview

Climate-related events are already causing domestic disruptions to supply chains and the workforce

Climate-related events are impacting domestic operations for businesses and public organisations. Extreme weather events, such as storms and heatwaves, can damage infrastructure like roads, railways, ports and airports. Such damage can cause delays in shipments and reduce the availability of goods, parts and raw materials. Rising sea levels and coastal erosion threaten ports and storage facilities, leading to higher costs and logistical challenges for businesses and public organisations relying on domestic shipping. Weather patterns will affect business and public organisations' operations through the availability of inputs and the movement of goods domestically.[116] See the *Road and rail networks* and *Ports and airports* risk analyses for more information.

Workforce accessibility and productivity will be challenged as climate-related hazards become more severe and more frequent. Damage to transport infrastructure may make it difficult and, in some cases, impossible for workers to access their place of employment.[573] Rising temperatures may also impact workers' health and productivity. Heat stress is a

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[xxxvii] A 'public entity' is an organisation run by the government, including organisations like schools and hospitals as well as core government departments.

major concern, particularly for outdoor and manual labourers, who may be affected by reduced physical capacity, and increased fatigue and heat-related illnesses.[574]

Exposure is likely to increase across the century, disrupting supply chains and bringing more vulnerability to the system

Businesses and public organisations in Aotearoa New Zealand are already facing climate-related hazards, and this exposure is likely to intensify as global temperatures rise. The sensitivity of businesses and public organisations is influenced by the resilience of physical infrastructure, profitability of parties throughout the supply chain, material characteristics of products and regulatory frameworks.

Exposure of supply chains is likely to increase as global temperatures increase. By 2050, with a low climate impact scenario, extreme weather events will increase in intensity and frequency, with increasing chances that these will significantly disrupt supply chains.[48]

By 2090, under a high climate impact scenario, acute events such as extreme weather events will become even more problematic and consequential for supply chains and business operations, compounded by gradual changes such as SLR and coastal inundation.[575] The compounding nature of these events, combined with exposure of linear transport networks, ports and airports under high global warming scenarios, indicates significant vulnerability in the system. For more information, see the *Road and rail networks* and *Ports and airports* risk analyses.

Sensitivity is likely to impact movement of goods and energy supplies, and lead to changes in workforce and demand

Supply chains are sensitive to the condition and resilience of the infrastructure they depend upon. Climate-related extreme events like heatwaves or storms can damage roads, railways, airports and ports, resulting in delays or interruptions to the movement of goods and materials. Climate change can impact both the resilience of energy supply due to changing weather patterns affecting the supply of renewable energy, and demand for energy during extreme weather events such as heatwaves.[576]

There are also social and cultural vulnerabilities. Natural and climate-related disasters and ongoing environmental stressors can result in displaced populations. As more people relocate due to climate impacts, businesses in some areas may face workforce shortages. They may also see increased demand for certain products (like construction materials) and less demand for other products. This could lead to potentially significant disruptions to labour supply and business-as-usual operations.[577]

Adaptive capacity requires diversification and other interventions

The ability of businesses and public organisations to adapt to climate-related disruptions will depend on the resilience strategies and procedures they implement. Companies are beginning to invest in climate adaptation measures, such as diversifying supply chains to reduce reliance on specific regions or providers and strengthening infrastructure. In Aotearoa New Zealand, for example, some farmers are installing protective tunnels over berry crops to shield them from extreme weather. While this initiative is to protect the crop itself, these kinds of interventions help safeguard business continuity and distribution as climate volatility intensifies.[578]

Iwi/Māori may be more exposed to supply chain disruptions, affecting businesses and communities

Iwi/Māori have significant involvement in primary sectors, and exports in the Māori economy are dominated by primary sector goods and manufactured goods related to the primary sector.[338] This means the Māori economy could be more exposed to supply chain disruptions than the non-Māori economy, leading to financial losses.[579] There is also evidence that pakihi Māori (Māori business/businesses) have inequitable access to existing transport infrastructure, affecting both supply chains and access to export markets.[580]

Extreme hot days are projected to affect 17% of iwi/Māori-owned businesses in the future, with iwi/Māori-owned construction businesses being most exposed in terms of absolute numbers.[581] Due to the concentration of Māori business in the primary sector, data consistently show high vulnerability. Regional variations of exposure to current and future climate hazards shows that Te Taitokerau/Northland and Auckland are particularly susceptible, with Māori-owned businesses in Taranaki, Whanganui and the West Coast remaining the most exposed to extreme rainfall events.[32,581]

International disruptions will affect businesses in Aotearoa New Zealand

Many businesses in Aotearoa New Zealand are reliant on international trade for key stages of their operations. This exposes these businesses to climate-related risks in the countries they trade with. Aotearoa New Zealand’s geographical isolation heightens the risk to disruptions to supply and distribution networks, which can result in production and import delays and lost output for businesses.[582,583]

Exposure to international disruptions is likely to continue increasing to 2090 as rising global temperatures drive more frequent and severe extreme weather events overseas, disrupting the operations of businesses and public organisations. In addition to these acute events, gradual changes like SLR will further challenge the ability of businesses to maintain normal operations offshore, intensifying the long-term impact of global warming.[584]

Compounding and cascading factors

Intersecting risks include risks to infrastructure related to supply chains

This risk interacts with the risks to road and rail and ports and airports. When extreme weather events occur, they can disrupt infrastructure, such as roads, ports and warehouses, which are critical for business operations. When one system fails, it often cascades into others; damaged roads can block access to ports, port closures can delay warehouse distribution, and warehouse flooding can stall supply chains entirely. These interdependencies mean that disruptions in one part of the network amplify failures across the whole system.

Over time, as these events become more frequent and intense due to climate change, the likelihood of recurring disruptions increases, layering new stresses on top of existing vulnerabilities.[585] Rather than a single failure spreading outward, multiple hazards can converge simultaneously, compounding their impact on supply chains and amplifying economic strain.[575]

Increased resource prices (for example, energy) due to disruptions in production or transportation networks can cascade through the entire economy.[586]

Interaction with emissions reduction

Coupling emissions reduction efforts with adaptation initiatives enables a more resilient future for businesses and public organisations. For example, businesses could electrify their vehicle fleet to reduce reliance on imported fossil fuels while diversifying their transport routes to avoid highly exposed corridors. Infrastructure that is both climate-resilient and energy-efficient supports long-term business continuity and reduces exposure to both physical and transition risks.[353]

Diversifying supply chains strengthens adaptive capacity by reducing vulnerability disruptions and, when paired with climate-conscious sourcing, it also advances emissions reduction efforts.[587] Technology plays a vital role in resilience but also to reduce emissions through smarter resource use.[588]

Policy readiness assessment

Some policies are in place, but not all address supply chains

A key action in the first national adaptation plan was the establishment of the New Zealand Freight and Supply Chain Strategy (Freight Strategy). While the Freight Strategy outlines long-term goals for zero-emissions and disruption-ready freight systems, it does not include actions to directly address supply chain resilience.

Other policies can support resilience in the supply chain. For instance, the Fuel Industry Act 2020 mandates fuel suppliers to hold a minimum level of stock for petrol, diesel and jet fuel. This is intended to ensure continuity of fuel supply domestically if there are global supply disruptions. However, local and regional strategies for supply chain resilience remain underdeveloped, highlighting a gap in coordinated adaptation planning.[70,589,590]

Some businesses and organisations are introducing adaptation initiatives

Businesses and public organisations are increasingly taking the initiative to build resilience through diversification and risk assessment. Examples include crop diversification in Te Taitokerau/Northland, a regenerative tourism strategy in Queenstown Lakes and supply chain diversification in logistics businesses. These efforts are supported by cross-sectoral initiatives and guidance from organisations such as the Climate Leaders Coalition and Aotearoa Circle, which help streamline adaptation planning and reduce siloed approaches.[70,591-596]

Risks to supply chains require attention

If risks to supply chains are not addressed, they may be unable to function effectively during climate-related events, which could limit access to essential goods, particularly in remote areas of Aotearoa New Zealand. This may impact the performance of businesses and public organisations. Without incentives to support adaptation, there is a possibility that these risks become embedded over time. For example, supply chains can be disrupted when a key input is sourced from a single location that is affected by a localised climate event, interrupting production or transport.

Iwi/Māori inclusion in policies is limited

Iwi/Māori are included in some policies and initiatives, though outcomes are unclear. The Freight and Supply Chain Strategy emphasises partnerships with iwi/Māori, but measurable impacts are limited. The national adaptation plan does not specifically address iwi/Māori in its actions for businesses and public organisations. While several cross-sectoral strategies, such as Kānoa and trade-related programmes may involve iwi/Māori, they often overlook the specific risks and impacts on these communities.[70,589,597-599]

Gaps for risk severity and policy

Limited research exists on local climate-related supply chain disruptions. There is also a limited understanding of climate impacts on workers, and inadequate data on the financial effects of extreme weather disruptions and their flow-on impacts on supply chains. It is difficult to estimate the total cost of extreme weather events to businesses.

Publicly available monitoring and progress reporting on the New Zealand Freight and Supply Chain Strategy appears limited, considering its importance as a key action in the national adaptation plan. Monitoring of this risk lacks quantifiable progress markers, and there is limited evidence on the economic impacts of at-risk supply chains, infrastructure, labour and supply shortages, and networks, especially those owned by iwi/Māori.[589]

Summary

The impact of climate change on businesses and public organisations the country relies on may be significant. Although research on the impacts of climate change on supply chains in Aotearoa New Zealand is limited, it is evident that businesses, especially those in import and export sectors, face increasing vulnerabilities due to extreme weather and progressive changes. There may be a marked increase in the exposure businesses and public organisations face as supply chains are disrupted by climate-related hazards and, by 2090, these risks are likely to be significant.

There are various strategies for adapting businesses and public organisations to the risks posed by climate change, with a focus on resilience. One key strategy is the diversification of suppliers and sources, both geographically and in terms of the number of suppliers, to reduce dependence on specific regions or providers. This also means that risks posed by labour shortages at the individual operator level and supply shortages are reduced, reducing potential risks to business continuity.

Risk scorecard: Businesses and public organisations (from supply and distribution disruptions)

Risks to businesses and public organisations from supply chain and distribution network disruptions due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Currently some disruption, mainly due to extreme weather events and reliance on a six-continent global supply chain, but the system is generally resilient.
2050	Moderate	Increasing frequency and severity of extreme weather events and exposure of supply chains overseas will have greater impacts on businesses and public organisations.
2090*	Major GWL 2	With 2°C of warming, exposure is heightened (as is the case with other related risks, such as to ports and airports and road and rail networks). Increased threat of disruption to internal and global supply chains.
	Major GWL 3–3.5	Extreme weather events are likely to be the most problematic hazard. The production and movement of goods may be impacted, causing delays, reduced profits and workforce shortages.
Policy readiness		
Overall assessment	Significant gaps	Some policies in place, such as the New Zealand Freight and Supply Chain Strategy and the Fuel Industry Act 2020, but they do not support coordinated adaptation planning. Some businesses and organisations are introducing adaptation initiatives, but these often occur in siloes.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it may do so as part of a package of related actions.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Stability of the financial system

Risks to the financial system from instability exacerbated by the increasing frequency and severity of climate hazards.

A stable financial system is resilient to shocks and can be relied on to support a productive and sustainable economy.[600] Aotearoa New Zealand's financial system is fundamentally robust but as a small, open economy, it is exposed to both the international and domestic impacts from increasing frequency and severity of climate-related events. Financial stability relates to the ability of the financial system to avoid collapse if one or more systemically important institutions fail.

Risk overview

Physical risks create financial risk

The stability of the financial system is indirectly impacted by the increased physical, social and economic risks of climate change. How Aotearoa New Zealand will experience this risk is highly dependent on global warming levels. For example, if an extreme weather event results in sufficiently large insured losses, insurance companies may become insolvent, which in turn reduces stability in the financial system.[601]

Risks to financial assets may increase financial system instability

The risk of financial instability may increase if there is rapid devaluation of assets, including buildings, due to new information about the risks that assets are exposed to. This could in turn put banks and other financial institutions under pressure, such as through an increase in loan defaults. As the risk to buildings increases (see risks to *Buildings*), this will also increase the risks to the stability of the financial system.

The financial system is exposed to domestic and international effects of climate change

Aotearoa New Zealand's financial system is currently highly exposed to climate change through local changes and international markets. Aotearoa New Zealand's net foreign liabilities (the difference between what we owe the rest of the world and what the rest of the world owes us) are high compared to most other developed economies. This makes Aotearoa New Zealand particularly exposed to disruptions in global financial markets.[602]

However, access to external funding can also help smooth the impact of significant shocks to our own economy in extreme events. The Government has strong sovereign creditworthiness, making it relatively easy to borrow. This also attracts foreign investment. The Reserve Bank of New Zealand (RBNZ) also considers that Aotearoa New Zealand's banks are currently better prepared for funding market disruption than during the 2008 global financial crisis.[603]

Compounding and cascading factors

Risks to physical assets will have an intensifying effect on financial stability

Financial instability is strongly linked to risks to physical assets, the insurance sector and sectors that rely on the natural environment. The financial system is a core part of how Aotearoa New Zealand's society functions. Instability in the financial system could pose a risk to the democratic decision-making process by reducing trust in government decision-making. In turn, deterioration in democratic processes could reduce trust in financial institutions and increase premiums for domestic institutions to access global capital due to a perceived increase in political risks.

Financial instability may harm social cohesion and exacerbate inequities

Financial crises tend to exacerbate existing inequities and cause adverse impacts on physical and mental health. There could also be wider social cohesion and equity implications. Deteriorating wellbeing could in turn lead to increased lending defaults if borrowers become unable to work or lose employment due to community displacement.

Policy readiness assessment

Government policies are in place, but may not fully address risks

The impacts of climate change on the risk to financial stability have been considered in multiple Government policies and actions. The RBNZ undertook a climate stress test in 2023 to test the resilience of banks to climate-related risk. The RBNZ identified that as a result of banks going through this process, they have increased their capability in climate-related risk management.[604]

Mandatory climate-related disclosures were introduced in Aotearoa New Zealand in 2021. The intention of disclosures is to support investors and decision-makers to understand risks and encourage mainstream financial flows towards investments that are not exposed to climate-related risk. The scope of organisations required to complete disclosures has recently been reduced.

The Government, in collaboration with Toitū Tahua, the Centre for Sustainable Finance, is currently working to develop a sustainable finance taxonomy for Aotearoa New Zealand. The taxonomy is intended to give investors and everyone interacting with the market clarity and confidence on which economic activities are sustainable.[605]

While the above actions may help to better understand and identify climate-related risks to financial stability, they do not fully address the risk of it occurring. Due to the significant connection between the physical risks to assets and infrastructure and the financial system, policies that serve to reduce the underlying risks to assets and insurability will have the largest flow through to reduce this risk.

Barriers include cost of information gathering and lack of publicly available data

Despite regulations being in place requiring many Aotearoa New Zealand entities to produce climate-related disclosures, there are barriers for entities to gather the required information. Some entities have reported significant cost associated with producing the disclosures and that there is a lack of publicly available data on climate hazards that entities can use to inform their climate-related risk assessments.[606]

Risks to financial systems need to be continuously monitored over the next six years

The financial system is complex, and developing its resiliency to reduce the risk of instability needs to be continuously worked on and monitored. It is important that actions already started continue to be developed, evaluated and improved upon. Failure to maintain momentum means subsequent adjustments in asset prices are likely to be sharper and more likely to cause financial system instability.

Gaps for risk severity and policy

Increased detail and availability of data on weather patterns could help improve modelling of future changes to physical risks that could be incorporated into more suitable pricing of physical or financial assets. Increased data regarding the loan-to-value ratio of mortgages in hazardous locations could help determine the extent to which lending against these properties poses a threat to financial stability.

Additional data and research on the potential spread of financial crises between global markets could be improved to test the impacts of international natural disasters on stability in our own financial system. The impact of financial system instability on iwi/Māori does not appear to be well researched or understood, which is why there is no specific commentary on iwi/Māori considerations for this risk.

Summary

Aotearoa New Zealand’s financial system has strong foundations but is exposed to climate-related risk through local and global channels. This risk is highly interlinked with other risks, such as risks to the insurability of assets, risks affecting asset values, risk to the Government’s fiscal position and governance risks.

Stress testing of the banking sector run by the RBNZ in 2023 suggests that climate change does not pose an imminent financial stability risk but could, over time, undermine the resilience of the financial system and its ability to respond to other threats to stability.

There are some policy actions in place to address this risk. Monitoring the effectiveness of the mandatory climate-related disclosures regime and the development of a sustainable finance taxonomy will be important, as further changes may be needed to ensure these work effectively and as intended. Existing financial exclusion issues may be exacerbated by this risk. This does not appear to be considered in the existing adaptation policies; however, the RBNZ have undertaken some work in financial exclusion.

Risk scorecard: Stability of the financial system

Risks to the financial system from instability exacerbated by the increasing frequency and severity of climate hazards.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Stress testing shows banks can currently withstand shocks and Aotearoa New Zealand's financial system has high ratings internationally.
2050	Moderate	Increase in the number and severity of unexpected climate shocks, which will test financial system resilience.
2090*	Major GWL 2	Effects of frequent compounding shocks both in Aotearoa New Zealand and the rest of the world by the end of the century will make it harder for the financial system to respond appropriately.
	Major GWL 3–3.5	
Policy readiness		
Overall assessment	No significant gaps	Financial system is well-supported by policy and institutional capacity, but improving data access and addressing Māori financial exclusion would strengthen long-term readiness.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it may do so as part of a package of related actions.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

DOMAIN: Sectors relying on the natural environment

This domain covers risks to forestry, pastoral agriculture, horticulture, fisheries and tourism.

While the entire economy ultimately relies on the natural environment, the focus of this domain is on one aspect of what can also be termed the 'bioeconomy' – an economy based on use of biological resources and processes to produce products and services, including food, fibre and recreation.[607] The food and fibre sectors, along with tourism, rely on the quality and accessibility of natural resources and assets, which face multiple climate hazards.

This domain has been added to this second national climate change risk assessment to facilitate a more thorough consideration of the primary food and fibre production sectors, along with tourism. In the first national climate change risk assessment, risks to the land-based primary sector, tourism and fisheries were each considered as part of the economy domain, and were rated the third, fourth and fifth priority risks.[26] In this current risk assessment, risks to forestry have been identified as significant, and risks to both agriculture and horticulture as ones to watch.

What makes this domain unique?

These sectors have a degree of adaptive capacity, but risks accelerate throughout the century

The sectors in this domain are highly exposed to both extreme events and ongoing and progressive effects of climate change due to their intrinsic links to the environment. Similar to the natural environment, the sectors in this domain are exposed to the full range of climate change impacts and are already under pressure from environmental degradation. Negative effects are experienced now, and these are likely to increase over the course of the century.

However, the primary production sectors are under direct management practices and so have a higher adaptive capacity than natural ecosystems, at least in the short term. While the assessment found that risks to agriculture and horticulture are minor for the current time period, due to the ability to recover from climate change impacts and adapt via management practices, the risks jump to major in 2050 (rather than moving first through moderate as tourism does) for mid-century. In contrast, forestry and fisheries are deemed to have moderate risks at present, which increase to higher levels in future time periods. Without strategic action, resilience is likely to weaken in most parts of the country. For more information on scoring, see the Summary of method report.

All these considerations result in the identification of risks to forestry as significant and risks to both agriculture and horticulture as ones to watch. There is an urgent need to embed adaptation planning and action in forestry so that current decision-making and overall preparedness for long-term land use and production cycles take account of the changing climate and its impacts. An important part of this risk links to Aotearoa New Zealand's approach to greenhouse gas emissions, insofar as the country relies on carbon stored in forests to meet emissions budgets and the net zero target.

The effects of climate change are becoming more apparent in the agricultural and horticultural sectors; notably in the past few years, they have been affected by various extreme weather events, some of which have been partially attributable to climate change. Overall, at the national scale, the sectors have demonstrated capacity to recover and continue producing with strong economic returns, but the severity of risk is expected to increase substantially by mid-century – see *Risks to watch: agriculture and horticulture* in the Priorities for action report.

How does this domain interact with other domains?

The sectors in the bioeconomy are tightly interlinked with other domains. The primary production sectors provide food and fibre for New Zealanders and the tourism sector contributes to wellbeing and social cohesion by connecting people to place and culture. These sectors comprise an important part of Aotearoa New Zealand's economy. The primary sectors contribute almost 9%[xxxviii] to Aotearoa New Zealand's GDP and tourism contributes over 4%. They comprise 57%[xxxix] and 17% of the country's export value, respectively.[608,609]

The impacts of climate change on the bioeconomy sectors have implications for other domains. Climate hazards may exacerbate existing stressors in the bioeconomy, threatening production, employment and community stability, which affect people, health and communities. How the sectors in the bioeconomy respond and adapt to climate change can also influence the effectiveness of actions to reduce greenhouse gas emissions or remove them from the atmosphere (for instance, through further intensification or land-use change). Tourism risk is amplified by its interdependence with multiple sectors, particularly transport, housing, energy and conservation management, and by its interaction with multiple climatic and socio-economic drivers.

Likewise, impacts on other domains can affect these sectors. For instance, damage to infrastructure can inhibit operations for food, fibre and tourism.

[xxxviii] The primary sector's direct contribution to GDP is 8.8% from production of primary products, subsequent processing, and commercialisation industries.

[xxxix] Food and fibre exports were 57% of total exports including goods and services in the year to 30 June 2025.

Impacts on iwi/Māori

Iwi/Māori land and businesses in the bioeconomy are particularly exposed

With significant landholdings and business interests in forestry and agriculture, iwi/Māori are highly exposed to climate change hazards in the primary production and tourism sectors, such as extreme rainfall and drought, and may be disproportionately affected. For example, iwi/Māori agribusiness may face a disproportionally high risk compared to the economy as a whole due to both strong levels of participation in the sector and the exposure of pastoral agriculture.

Generally, both whenua Māori and Māori-owned land is exposed to various climate change hazards. For example, more than 60% of whenua Māori is hilly to mountainous and exposed to hazards exacerbated by climate change, especially erosion and landslides. In particular, hill country may be erosion prone, less productive and isolated from infrastructure and support. Areas such as Te Taitokerau/Northland and the East Cape may be affected by more drought and extreme weather events, disproportionately affecting both the larger iwi/Māori populations who live there and iwi/Māori-owned agricultural and forestry businesses. Likewise, impacts for iwi and Māori tourism are pronounced, given the strong cultural and economic ties to land and water, grounded in mātauranga Māori (historic and contemporary Māori knowledge), kaitiakitanga (guardianship, environmental stewardship) and relationships with specific places. The problem is likely to be exacerbated by increasing extreme rainfall events projected through mid- to late-century. Future-proofing iwi/Māori land is considered critical.

Climate change impacts on culturally important landscapes pose dual risks of economic disruption and cultural loss. On the other hand, iwi/Māori farms and businesses are often collectively owned and able to achieve economies of scale, which can be advantageous in terms of adaptive capacity.

Systemic policy issues

The legislative and policy landscape is complex but also fragmented and limited, lacking long-term planning

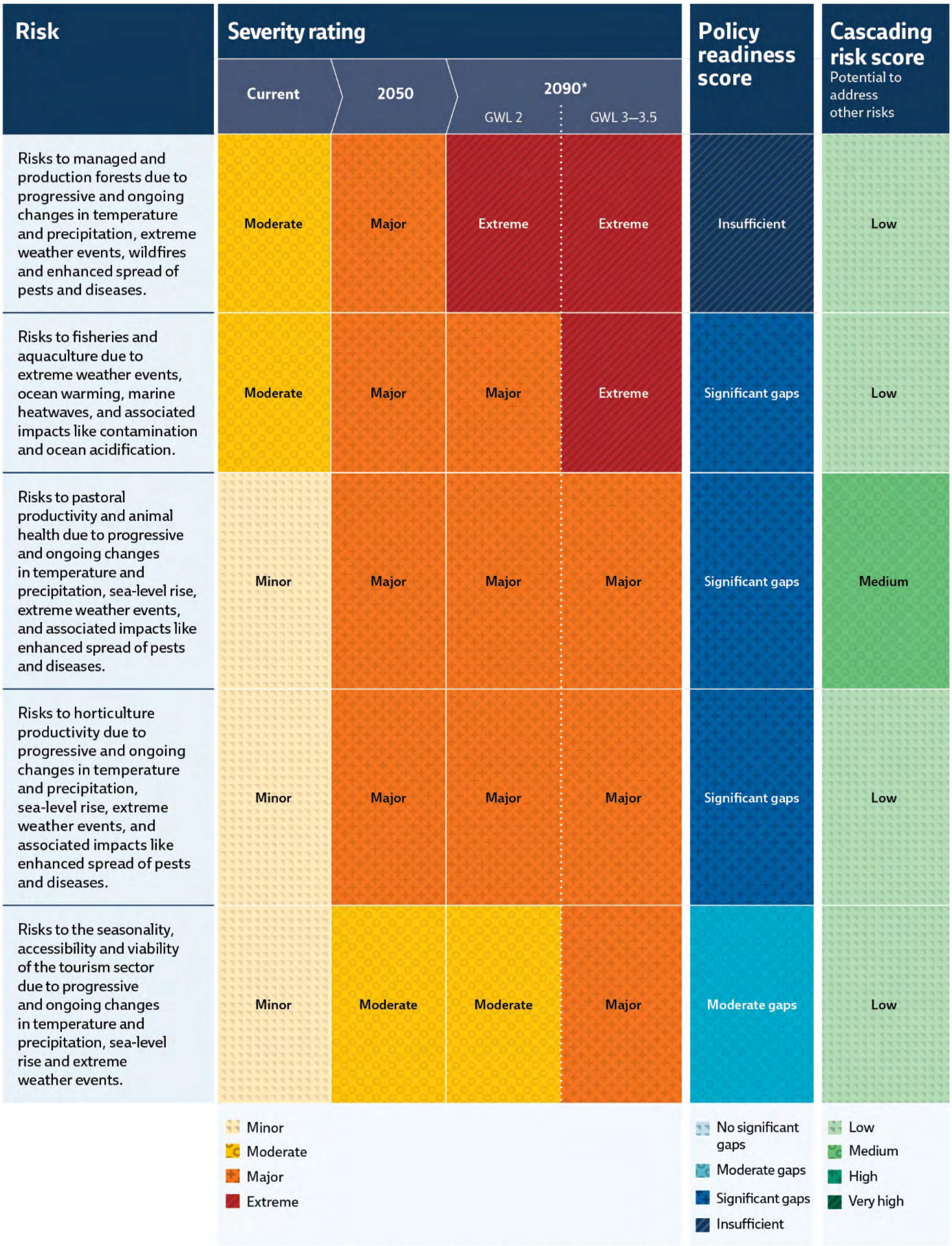
Bioeconomy sectors have various collaborative actions underway that have the potential to address current direct and indirect effects of climate change. There are also actions in the national adaptation plan and some other government programmes with potential to reduce climate-related risk in these sectors. While there is some evidence of action on climate change adaptation in these sectors, such actions tend to respond to issues as they arise (for example, recovery from extreme events) and are not typically forward looking.

Most current assessments indicate there is a lack of action on or only incremental adjustments to adaptation, particularly beyond planning for the present and near future. Incremental adjustments may lead to bigger system changes that are not effective long-term adaptation or could even be maladaptive. A coordinated approach across sectors and local and national government is required to achieve effective, long-term adaptation.

The policy environment only partially addresses the growing risks posed by climate change. National policy for bioeconomy sectors has historically prioritised growth rather than resilience. Policy prescriptions for increased economic productivity and output, such as doubling agricultural exports, rely on intensification and are largely disconnected from adaptation concerns, which could lead to unintended consequences and maladaptation.

Across bioeconomy sectors, considerable research is conducted on climate change mitigation, but research on adaptation is limited.

Table 3.6: Risk ratings for Sectors relying on the natural environment



Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090* GWL 2	2090* GWL 3–3.5		
Risks to managed and production forests due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and enhanced spread of pests and diseases.	Moderate	Major	Extreme	Extreme	Insufficient	Low
Risks to fisheries and aquaculture due to extreme weather events, ocean warming, marine heatwaves, and associated impacts like contamination and ocean acidification.	Moderate	Major	Major	Extreme	Significant gaps	Low
Risks to pastoral productivity and animal health due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.	Minor	Major	Major	Major	Significant gaps	Medium
Risks to horticulture productivity due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.	Minor	Major	Major	Major	Significant gaps	Low
Risks to the seasonality, accessibility and viability of the tourism sector due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.	Minor	Moderate	Moderate	Major	Moderate gaps	Low

- Minor
- Moderate
- Major
- Extreme

- No significant gaps
- Moderate gaps
- Significant gaps
- Insufficient

- Low
- Medium
- High
- Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0-3.5°C by 2090 (GWL 3-3.5).

RISK: Forestry

Risks to managed and production forests due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and enhanced spread of pests and diseases.

Aotearoa New Zealand’s forestry sector, comprising predominantly exotic *Pinus radiata* (Radiata pine) plantation forests, along with other species such as Douglas fir, plays a significant role in the national economy and climate mitigation strategy. The sector includes managed and production forests established for timber, fibre and carbon sequestration, covering approximately 1.8 million hectares (ha) as of 2023,[610] with projections of expansion to 3.4 million ha by 2070.[269,611] The country’s fourth largest primary export, the forestry sector export value is projected to be NZ$6.1 billion for 2025; log exports comprise approximately half of that (NZ$3.3 billion).[610] The value of forest exports is expected to rise another NZ$500 million in the next three years, to NZ$6.6 billion by 2028.[610]

Climate change risks for forestry result from exposure to and vulnerability of the managed and production forest estate (including establishment, growth (vigour), carbon storage and survivability) from various climate-induced impacts, especially extreme events, wildfire, and pests and disease, as well as changing environmental conditions. Globally, forests are already facing climate-driven risks that could undermine their collective ability to take up and store carbon over the 21st century.[612]

This is identified as one of the most significant risks

The forestry sector operates on long time horizons of a few decades to hundreds of years. Progress on adopting adaptation measures has been acknowledged as incremental, and there is a lack of ownership and leadership of the issue.[613] An important part of this risk links to carbon stored in forests to meet emissions budgets and the net zero emissions target. There is an urgent need to embed adaptation planning and action in forestry so that current decision-making and overall preparedness for long-term land use and production cycles take account of the changing climate and its impacts. The risk to forestry is rated at major severity by 2050, and the readiness rating is insufficient (the lowest score). This satisfied the second principle of our review for significance: it will present high potential for adverse consequences by 2050, and because of the very low base of current readiness, significant lead time is required to prepare for them. All significant risks are highlighted in the Priorities for action report.

Risk overview

Climate change is already affecting forests

Three main hazards pose climate-related risks to forestry – pests, wildfire and extreme weather events[614] – along with the effects of changing environmental conditions that affect tree productivity and forest ecosystem function. Climate projections for mid-century and late century correspond to the next 1–3 harvest cycles. In this time, Earth Sciences New Zealand projects increasing temperature (by at least 2°C), wetter conditions in the west and drier in the east and more extreme weather events. Exposure to extreme weather events and wildfire already occurs.

Risk to managed and production forests due to wildfire

In Aotearoa New Zealand, the number of wildfires is increasing. The 2019/20 and 1998/99 wildfire seasons remain the worst on record for number (5,994) and area burnt (17,693 ha), respectively.[34,615] The number of fires was higher for the 2023/24 wildfire year than the previous year and above the historical (1998–2022) average; the total area burnt was higher than the previous year and below the historical average.[615] The North Island consistently accounts for most of the country's wildfires in a fire season (62% in 2023/24), whereas the South Island accounts for most of the area burnt (89% in 2023/24). Te Taitokerau/Northland and Canterbury had the highest number of wildfires and greatest area burnt in the North and South Islands, respectively, in the 2023/24 fire season.[615] The most damaging fires usually occur on the east coast but they can be ameliorated by moister conditions and more favourable winds, as occurred during the 2020/21 season.[34]

Managed and production forests are exposed to fire. The annual area of plantation forest burned by wildfires has been increasing: the six-year average for 2015–2021 (1,159 ha) was approximately double previous six-year averages dating back to 1985.[616]

Areas that experience below normal soil and fuel moisture are at an increased risk for increased number of fires and area burned.[34] Drought occurrence is a good indicator of fire occurrence. Forest fire risk is higher in highly stocked stands; higher risk profiles result in higher insurance rates.[617]

Fire intensity affects forest response and recovery. *Pinus radiata* is fire adapted via seed germination from serotinous cones, which is affected by fire intensity. There is insufficient data to understand whether forests exposed to high intensity fire can regenerate sufficiently in the absence of management intervention in Aotearoa New Zealand.[618]

At the global level, a wildfire crisis has been identified and the current period named the wildfire epoch or fire age.[36] Recent years indicate wildfire incidence (number and area) increasing and the fire season lengthening at some sites in Aotearoa New Zealand.[9] Fire risk is expected to increase in many regions due to an increase in wildfire conditions, with current trends persistent until mid-century but the latter half dependent on emissions trajectories.[39,618]

A modelling study of Aotearoa New Zealand conditions under four Representative Concentration Pathway (RCP) climate scenarios found "a wildfire climate significantly more severe than the 2005–2020 period will emerge in the 21st-century" with widespread increase of low-level fires nationally and extreme fire weather occurring locally.[39] The extent of new, more severe wildfire conditions depends on future emissions, but the frequency of very extreme conditions does not and could occur at any time.[39] The longest seasons for torching or passive crown wildfires by the end of the century are projected to occur in Canterbury and Otago, along with Marlborough and Wellington.[39,619] Very extreme wildfire weather conditions could occur every 3–20 years in the Mackenzie Country, upper areas of Otago and Marlborough.[39]

Risk to managed and production forests due to extreme events

Damage from wind and high intensity rainfall can lead to large forest losses. Wind damage is already common in planted forests, and it is expected to increase. Costs to foresters include lost revenue, salvage costs and decreased property values, which may include carbon liabilities.[620] Forests on steep slopes are vulnerable to heavy rain at harvest when land is exposed, resulting in erosion and landslips. Large volumes of debris also wash down waterways, damaging ecosystems and properties downstream.[621]

Since the first risk assessment, Aotearoa New Zealand has experienced multiple extreme events, highlighting the vulnerability of the forestry sector through its sensitivity to such events and its adaptive capacity an open question.[531] The Ministerial Inquiry on Land Use conducted after Cyclone Gabrielle noted issues around damage, response and recovery.[531] Some in the forestry sector note the lack of feasibility or willingness to continue forestry operations, or plant new stands, in some storm-affected areas after Cyclone Gabrielle. This may be an example of a threshold for forestry when catastrophic effects of extreme weather events, such as landslides and erosion, impede harvesting, further forestry operations and/or replanting, and investment may vacate the sector.

More rain and more severe storms result in a higher chance of soil damage and erosion, along with sediment and debris flows and their downstream effects,[617,621] as experienced in Cyclone Gabrielle and other extreme weather events in recent years. Higher winds, projected to increase up to 10%, expose forests to breakage[617] and toppling, including large windthrow events. *Pinus radiata* is considered more susceptible to wind damage, especially in saturated soils, whereas Douglas fir is more stable due to root structure and crown characteristics. Damage from historical wind events is concentrated in older age classes, especially *Pinus radiata* stands over 30 years old.[620] In addition to catastrophic storm damage, winds can also cause dispersed damage, with large cumulative effects on wood quality and the wood volume lost.[620]

Changes in drought frequency and severity affect forest tree establishment, disease susceptibility and mortality,[29] favouring drought-tolerant species. Drought conditions decrease forest growth rates and increase fire danger. Aotearoa New Zealand is experiencing more frequent medium-term droughts, and severe droughts (1 in 20 year) may double or quadruple in frequency.[50,617,622] As a climate change impact, drought is diffuse and can have indirect effects on forests. It can occur over longer time frames and wider areas and be more difficult to detect and often in hindsight.[623]

Risk to managed and production forests due to pests and diseases

Insects, mammalian browsers and disease cause widespread and substantial tree mortality. Diseases include myrtle rust and kauri dieback disease (caused by the soil-borne pathogen *Phytophthora agathicida*) in indigenous forest, Dothistroma needle blight (*Dothistroma septosporum*), with severity worst in warm wet environments – particularly in the North Island and west coast of the South Island,[624] and red needle cast (*Phytophthora pluvialis*) in pine plantations. Dothistroma can affect growth and wood quality; annual losses have been estimated at NZ$20 million.[624] Red needle cast can reduce growth up to 40%. There is increased risk of Swiss needle cast in Douglas-fir.[617]

Climate change amplifying disease outbreaks has been identified as a top threat of climate impacts in Aotearoa New Zealand,[52] and it is almost certain climate change will create more favourable conditions for the introduction and establishment of new or novel pests.[9] Climatic conditions largely influence the distribution of these species, so their geographic ranges will shift along with altered environmental conditions caused by climate change. Warmer temperatures increase risk, in part due to expanded habitable ranges of some existing pests and diseases.[9] For example, the northern parts of the North Island are projected to become more suitable to sub-tropical pest species.[28] Insect populations can also increase as a result of improved winter survivability. Perhaps of most concern is the potential introduction of new species and pathogens, especially from warm-temperate or subtropical regions.[613,617]

Tipping points for forest ecosystems could occur depending on the extent to which temperature and precipitation changes facilitate the spread of pathogens. Increased weed competition is also considered a risk posed by changing environmental conditions.[617]

Risk to managed and production forests due to changing environmental conditions

Whereas the first risk assessment noted that increased temperatures and/or CO_2 fertilisation may result in increased productivity,[26] emerging evidence suggests this proposed benefit has not eventuated, likely due to other limitations, such as nutrients or physiological processes.[625-628] Wood density also decreases with temperature increase,[617] potentially affecting timber quality. In terms of decreasing sensitivity, fewer frost days in the lower North Island and South Island reduce risk of crop damage or loss from frost.[617]

Tree species are affected differently by changing environmental conditions, with varying sensitivities and responses to stressors and exposure to direct and indirect climate hazards. Choices such as site selection, species planted, and management and harvest regime will lock in sensitivity and adaptive capacity to changing environmental conditions as well as extreme events.

Iwi/Māori face disproportionate exposure to climate change in the forestry sector

With significant landholdings and business interests in forestry (owning approximately 40% of commercial forestry operations), iwi/Māori will be affected by the risks climate change poses to the forestry sector, including extreme rainfall, windthrow, wildfire and drought. Generally, Māori forestry operations are exposed to hazards exacerbated by climate change, especially erosion and landslides caused by extreme rainfall in hilly-to-mountainous areas. The problem is likely to be exacerbated by increasing extreme rainfall events projected through mid- to late-century. Future-proofing land owned by iwi/Māori was identified as critical in the assessment of climate change mitigation and adaptation solutions for Māori produced to supplement the first national climate change risk assessment.[32] Iwi/Māori may also be disproportionately affected by degrading growing conditions, given much whenua Māori is located on the East Coast, where drought is expected to increase.[32]

Compounding and cascading factors

Forest degradation can occur from the compounding effects of exposure to multiple hazards and/or the accumulative effects of repeated damage, such as volume loss and decreased wood quality from wind damage.[620] Multiple stressors from multiple causes combine to affect individual tree and forest stand health, sensitivity and adaptive capacity. For example, the effects of drought can compound with changed environmental conditions via repeated episodes decreasing tree vigour, reducing growth and increasing susceptibility to other stressors, such as pests and diseases. Drought will result in slower growth rates and increased fire.[617] Drought can also make trees more susceptible to attack by bark beetle and wood borer, which changes forest structure and causes mortality, carbon loss and changes in carbon cycling,[9,629] although it may decrease the incidence of some fungal disease. All of this can decrease product yields and quality.

Compounding climate change impacts set conditions for disease outbreaks. For example, the wet conditions of 2023 resulted in an increase in *Dothistroma septosporum*, requiring a marked increase in foresters' effort to fight the disease.

The forestry business sector itself can be vulnerable to climate change, depending on its adaptive capacity and sensitivity to changing environmental conditions and extreme events. Damage to external infrastructure impedes harvest and transport to customers and ports, while extreme heat conditions affect the outdoor labour force. Social licence for forestry (specifically, exotic monoculture plantations) has further eroded, in part, as a result of the damage associated with harvested forest land.[531,537]

Interaction with emissions reduction

The carbon stored in the planted and production forest estate serves an important role in meeting emissions reduction targets, acting as carbon removals to counterbalance greenhouse gas emissions. These removals are threatened when the forests are at risk. Positive (enhancing) feedback loop effects of climate change on plants and soils can lead to further release of greenhouse gases, such as from drought and wildfire. Warming temperatures can increase soil respiration, which releases more CO_2 to the atmosphere. The establishment of seedlings may also be affected under changing environmental conditions.

Historical windthrow events have damaged older age stands (radiata pine in particular), which could have implications for forests managed for longer rotations or as permanent forests.[620,629] If trees are planted in areas subject to wildfires, affected forests would release stored carbon in the form of CO_2. This could reduce the country's ability to meet its emissions budgets and the 2050 target by decreasing the amount of carbon removals. A catastrophic potential to forests and their carbon stores is posed by the introduction of pests and diseases, a particular worry for the Aotearoa New Zealand forest sector, which is carefully monitoring such events overseas.[613]

Policy readiness assessment

Few policies and actions are in place to support adaptation in forestry directly. Forestry regulations have been updated since the first national climate change risk assessment: the National Environmental Standards for Commercial Forestry aim to give councils greater control over commercial forestry by providing clear rules on harvesting practices and new requirements on slash removal from erosion-prone land. This is intended to manage the environmental effects of forestry but does not explicitly address climate change adaptation risks or needs of forests themselves.

A climate change adaptation policy for forestry or an adaptation roadmap for forestry could give guidance to forest growers,[630] and a coordinated national strategy is considered essential by the sector for its resilience across ecological, social, economic, political and technical areas.[613] Existing efforts remain largely reactive, such as the 2023 Ministerial Inquiry into Land Use in Tairāwhiti Gisborne and Wairoa.[531] While the first national adaptation plan includes actions relevant to forestry, it does not provide direction on land use nor the role of forest in adaptation. Some actions, like improving access to climate data, information and tools could support forestry adaptation if appropriately targeted.[46]

Policies and plans nominally acknowledge the needs of iwi/Māori as landowners and those with sizable forestry assets. More broadly, few details are available for how iwi/Māori perspectives and the specific effects of climate change on iwi and Māori are considered. A recent research project identified several barriers to the realisation of iwi/Māori objectives, including funding, knowledge acquisition, and infrastructure issues of geographic isolation and current Māori Land Court processes.[631]

Characteristics of the forestry sector itself present barriers to adaptation action. A review of resilience issues posed by the single species dominance of *Pinus radiata*, of which climate change is one component, found that short-term economic factors impede long-term transformation.[613] Although the risks from climate and biosecurity threats are acknowledged, change is not likely to occur until a significant external event, or crisis, forces a reactive response. The sector also believes that only decisive government leadership can drive systemic transformation, but the Government considers itself as a support partner, not leader.[613]

Many of the barriers identified over a decade ago remain relevant today, including low awareness and understanding of climate change risks and impacts, and minimal adaptation planning. Barriers to implementation were identified as a lack of tools, identifying high-risk sites and adaptation strategies, avoiding maladaptation, dealing with uncertainty and assessing economic implications of adaptation.[632] Progress has been incremental. Uptake of science is hindered by poor communication of results to the sector, lack of actionable tools and risk-based research, low community engagement in indigenous forest research and limited funding for adaptation research.[614] At the individual level, adaptation behaviour can be determined by response cost, personal risk assessment and personal experience. In Aotearoa New Zealand, a lack of belief in the effectiveness of action leads many foresters to adopt maladaptive coping strategies – either doing nothing (risk acceptance) or ceasing operations (risk avoidance).[630] Wildfire risk, in particular, including in native forests, remains underappreciated across government, industry and the general public.

Lock in risk already exists, and the potential for more lock in and the loss of opportunities continues, including over the next six years. Due to the long-term nature of forestry, decisions made today will shape forest exposure to mid- to late-century climate conditions. Risks to the current managed estate are locked in, and will continue to evolve, for the remainder of the life cycle, whether a harvest rotation if production forest or ongoing for permanent forest. Without change, current practices will embed future forest management challenges. Industry sees two main challenges: shifts in practice will take a long time, and existing investment favours the status quo.[613]

Funding for scientific forest research has lagged behind that for commercial exotic forestry. More research could be done on indigenous forests, biosecurity and integrated land use. Investment in indigenous forest – monitoring status and studying ecological process, sensitivity and adaptive capacity – will inform climate change mitigation and adaptation. Biosecurity remains a top concern, and despite both available information and awareness, there is a gap between biosecurity practice and industry needs.[52,613]

Gaps for risk severity and policy

Scientific consensus confirms climate change is affecting forests, but more research is needed to understand individual species' sensitivity and adaptive capacity, especially to stressors like heat, CO_2, water limitation and wildfire. These stressors also affect ecosystem functions like nutrient cycling and soil health.[618,625,632] More information is required on the effect of climate change impacts on the population dynamics of pests, diseases and weeds as well as their potential effect on plantation productivity.[632,633] Carbon loss from wildfire and extreme weather events also needs better monitoring. As recognised over a decade ago, no dedicated monitoring programmes exist to track climate change-related impacts on plantations. Monitoring and evaluation of adaptation efforts remain underdeveloped.[614,632] Adaptation in production forestry is still in its infancy.[630] Actions are incremental, with no major breakthroughs. Communication gaps, lack of tools and underfunded research – especially for indigenous forests – limit progress.[634]

There is a disconnect between knowledge and decision-making.[613,634] Transforming industry practice has long lead-in times, requiring more information about improved genetics, seed stock development, business opportunities and adaptive forest management.[613,632]

Summary

Forests are at risk from multiple climate hazards, including changing environmental conditions and extreme events. Exposure to these hazards varies across the country and will affect forests as the hazard occurrence intersects with their geographic distribution. These changes are already occurring and will continue to intensify through the century. There is robust evidence and high agreement that climate change already adversely affects the forestry sector and will continue to do so. More evidence is needed around the sensitivity, adaptive capacity and impacts, and their geographical distribution.

The forestry sector is aware of the physical risks of climate change and reports undertaking actions to start addressing these risks. However, progress is incremental, and adaptation is not as much a focus as climate change mitigation. Successive governments have prioritised forestry to store carbon and contribute to emissions targets, without much specific regard to adaptation. The consequences of extreme weather events have put some attention on response and recovery, but not long-term planning nor integrated or holistic land use, leading to little change to entrenched practices and preparation for changing environmental conditions and extreme events.

Risk scorecard: Forestry

Risks to managed and production forests due to progressive and ongoing changes in temperature and precipitation, extreme weather events, wildfires and enhanced spread of pests and diseases.

Identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Climate change already affecting forestry through changing environmental conditions and extreme events. Commercial forestry is not yet at its productive limits, but biotic threats such as pests and diseases are a growing concern.
2050	Major	Risks are expected to escalate due to lock in from current decisions. Productivity may plateau due to physiological constraints in changing environmental conditions. Extreme weather and biotic agents may increasingly disrupt forest systems, with adaptation becoming more difficult.
2090*	Extreme GWL 2	Risks are expected to continue to escalate due to lock in. Productivity may plateau due to physiological constraints in changing conditions. Expected increase in extreme weather and pressure from biotic agents may increasingly disrupt forest systems, with adaptation becoming more difficult. Increased biosecurity threats under changing conditions.
	Extreme GWL 3–3.5	Productivity may plateau due to physiological constraints. Increased biosecurity threats, increasing extreme events and compounding risks from multiple impacts may result in catastrophic loss. The sector may face systemic challenges with limited ability to recover or adapt.
Policy readiness		
Overall assessment	Insufficient	While the sector is aware of climate-related risks, adaptation remains secondary to climate change mitigation. Reactive responses to extreme events and entrenched land-use practices undermine long-term resilience.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it has strong connections to the risks to indigenous biodiversity and terrestrial ecosystems.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Fisheries

Risks to fisheries and aquaculture due to extreme weather events, ocean warming, marine heatwaves, and associated impacts like contamination and ocean acidification.

Marine and freshwater aquaculture, fisheries and coastal habitats face increasing risks from climate change.[116,138,635] This assessment considers the risks to fisheries, aquaculture[xl] and aquatic-based harvests from changes in the characteristics, productivity and spatial distribution of organisms due to direct impacts from climate change-related hazards including extreme weather, rising temperatures, acidification and marine heatwaves. [138,635]

The provisioning ecological services that provide food and fibre considered within this assessment provide a foundation for human livelihoods and the economy.[216,636,637] The sustainability of these services depends on maintaining healthy, functioning ecosystems. Addressing the policy shortcomings that inhibit an effective climate change adaptation response will be necessary to protect the resilience of these systems, preventing irreversible ecological change and biodiversity decline.[635,638,639]

Risk overview

Coastal ecosystems in Aotearoa New Zealand are already exposed to sea-level rise (SLR), warming seas, marine heatwaves, acidification and intensified storms, causing habitat loss, erosion and stress on native species.[116,138] These climate pressures interact with existing environmental stressors such as fishing pressure, sedimentation, invasive species and nutrient runoff; climate change does not create these pressures but intensifies their consequences for marine ecosystems and fisheries.[138,146] Combined climate stressors may lead to irreversible ecological change and biodiversity decline within the marine environment. Marine and freshwater aquaculture, fisheries and coastal habitats face increasing risks from extreme weather, rising temperatures, acidification and marine heatwaves. These risks can damage infrastructure, reduce stock survival and alter species distributions.[138,635] Warmer, nutrient-rich waters heighten the threat of toxic algal blooms, eutrophication and habitat degradation, affecting both biodiversity and ecosystem health.[117,138] Invasive species and biosecurity breaches further threaten native organisms through predation, competition and disease.[53,85,138]

Declining fish stocks and degraded habitats undermine commercial, recreational and tourism fisheries in Aotearoa New Zealand.[138,636,640] In 2020, commercial fisheries were estimated as NZ$5.2 billion in total output of gross domestic product (GDP) and a direct output of NZ$2.3 billion, and represented 0.7% of employment nationally.[636] Deepwater

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[xl] Aquaculture encompasses the systematic cultivation of fish, shellfish and other aquatic organisms (such as algae) within marine, freshwater and estuarine environments as well as on-land recirculated systems.

fisheries comprise 80% of total catches within Aotearoa New Zealand's Exclusive Economic Zone (EEZ), with a value of approximately NZ$650 million per year.[641]

The provisioning ecological services fisheries provide are essential not only for commercial enterprises but also for customary harvesting practices and recreational fishing, both of which contribute to community wellbeing, cultural identity and mental health.[32,216,642] Iwi/Māori, communities and individuals who rely on aquatic biological resources for food, employment and livelihoods are facing the immediate consequences of the accumulating pressures from climate change.[32,216,643] Recreational marine fisheries were estimated to stimulate NZ$1.7 billion in total economic activity in 2016.[640] Economic dependence on marine ecosystem services is apparent across various sectors, including employment, food production and recreational activities. Coastal tourism further accounts for 40% of the marine economy, underscoring the diverse range of economic activities that rely on the sustainability of marine ecosystem services.[644]

Climate impacts are from changing ocean currents and temperatures, and extreme weather events

Climate change impacts on fisheries, aquaculture and aquatic harvesting vary within and between biogeographical regions due to changing ocean currents transporting heat to different areas.[133,138,645] While there is broad agreement that climate change, including marine heatwaves and rising sea-surface temperatures, adversely affects fisheries, aquaculture and aquatic-based harvests, evidence is variable across species.[134,138]

Adaptive capacity is low because of extreme weather and changes in temperature and acidification

The adaptive capacity of many marine and freshwater species is generally low, particularly among those inhabiting shallow, coastal, intertidal and freshwater environments.[48,138] Exposure to increasingly severe storms, cyclones and altered oceanic conditions can be detrimental to fisheries, aquaculture and associated infrastructure because of sedimentation, vessel damage, disrupted supply chains and shifts in species distribution.[138,635] Reproductive and developmental vulnerabilities also exist. Rising temperatures and ocean acidification are disrupting spawning cues, dispersal patterns and early life stage survival of species.[128,134,137] The decline of biogenic habitats (such as coral, kelp and sponges) is further reducing biodiversity and habitat complexity, while altered predation, competition and food web dynamics are reshaping species distributions and increasing the risk of ecosystem collapse.[48,138,146] Genetic bottlenecking compounds these effects by reducing population diversity and long-term adaptive potential. Substantial uncertainties also remain regarding adaptive thresholds, ecosystem tipping points and the effectiveness of current management and adaptation strategies. These patterns are consistent with global marine ecosystem assessments that identify warming, acidification and habitat loss as key drivers of declining marine biodiversity and fisheries productivity.[48]

Risks to iwi/Māori fisheries

In addition to existing environmental pressures, climate change also directly threatens species, spaces and practices central to iwi/Māori identity and wellbeing. Taonga species hold cultural and spiritual significance for iwi and hapū, with many inhabiting freshwater, coastal and marine environments (see *Loss of access to taonga species* risk analysis).[32,646]

Māori fisheries assets also represent a multi-billion-dollar economic base. Iwi/Māori own approximately one third of Aotearoa New Zealand's marine commercial fisheries quota by volume (and 47% by value), reflecting the outcomes of Te Tiriti o Waitangi/The Treaty of Waitangi fisheries settlements, including the 1992 Fisheries Settlement (often referred to as the Sealord deal). Some of these stocks are already affected by climate change-related changes in abundance and distribution and will likely continue to be affected in the future.

There are many examples of iwi/Māori working in collaboration with Crown agencies, researchers and industry partners to understand climate change impacts, building on mātauranga Māori (historic and contemporary Māori knowledge) to develop culturally appropriate adaptation actions for fisheries, aquaculture and aquatic harvesting.[32,82-84,154,178,216,647] Examples include research partnerships such as the Moana Project, which integrates mātauranga Māori and ocean science to understand marine heatwaves and fisheries connectivity; iwi-led environmental monitoring programmes for customary fisheries; and local management tools such as mātaitai reserves (reserves managed by iwi/Māori that provide for customary fishing and usually exclude commercial fishing), and taiāpure (local fisheries in areas of special significance to iwi/Māori that typically allow for all types of fishing) that enable community-based stewardship of fisheries resources.[648]

Compounding and cascading factors

While data on stress tolerance exists for some commercially utilised species, different environmental and ecological interactions will influence tolerances and overall survival rates.

Cumulative effects on ecosystems significantly reduce their capacity to withstand additional stress, typically identified when species diversity has already been compromised.[649] Declining primary productivity and marine biomass are projected to reduce global fish stocks by up to 17% under a high climate impact scenario by 2100, while the combined effects of overfishing and climate stressors will further diminish ecological resilience and food web stability.[48] Evidence from marine ecology indicates that maintaining biodiversity and habitat complexity can enhance the resilience of aquatic ecosystems to environmental change.[146,649] Improving biodiversity may enhance the resilience of aquatic ecosystems.

The risks to marine, coastal and freshwater ecosystems highlight the connectivity of aquatic ecosystems, demonstrating compounding and system effects. Impacts of aquaculture and harvesting put further pressure on these surrounding environments. Anthropogenic inputs, such as excess available nutrients, coupled with warming waters, contribute to excessive algal growth, which depletes oxygen levels and creates dead zones and biosecurity risks.[117,138] Aquaculture can generate nutrient and waste discharges, which can lead to decreases in water quality[650] and adversely impact indigenous ecosystems.

Human use of the coastal and marine environment is fundamentally altering ecological services and interactions within coastal marine area ecosystems. Both direct and indirect pressures arise from resource use and management within this area. Examples include coastal development and extraction, pollution and runoff, which contribute to the loss of ecosystems and water quality.[50,146,207] These pressures affect species' reproduction, recruitment and survival, driving demographic shifts and changes in age structures. Species ranges may also expand or contract in response to altered environmental conditions and degraded coastal marine environment habitats.[204,205] This can result in cascading and compounding impacts across marine ecosystems, further weakening their resilience and ecological integrity.

Interaction with emissions reduction

There is increasing interest in strategies with the potential to strengthen the resilience of fisheries, aquaculture and aquatic harvesting that could also contribute to efforts to reduce greenhouse gas emissions or increase carbon sequestration.[651,652] For example, the seaweed aquaculture industry is an emerging sector with potential for carbon sequestration and methane reduction, particularly through applications such as livestock feed additives.[651,653] There is interest in farming various seaweed species due to their ecological benefits, such as nutrient uptake and limited carbon sequestration ability as well as the potential for producing valuable products like methane-inhibiting feed additives for livestock.[651]

As much of the stored carbon in the Aotearoa New Zealand EEZ is in seabeds,[217] the modification of fishing practices and harvesting techniques (such as bottom trawling) to less disruptive methods for seabeds would further support ongoing carbon sequestration and minimise ecosystem disturbance.[217,654] Marine restoration projects aiming to restore habitats such as algae and seagrass[637,652] can also contribute to improved carbon sequestration.[652]

Policy readiness assessment

Aquaculture and fisheries in Aotearoa New Zealand operate within a complex legislative and policy environment that only partially addresses the growing risks posed by climate change.[635,638,639] While there is no single, climate-specific regulatory framework for marine and freshwater resource use, a range of statutes, policy instruments and strategies provide overlapping protections, management mechanisms and indirect avenues for adaptation. The Fisheries Act 1996 is the main policy for fisheries management, built around principles of sustainability and environmental protection.[635,639] It provides tools to adjust catch limits and respond to ecological changes. In theory, this legislation could be used to manage climate-driven shifts in species abundance, distribution or spawning success; however, doing so would depend on timely stock assessments and the ongoing implementation of precautionary management practices. Sector-led initiatives such as the Seafood Sector

Adaptation Strategy have begun to assess climate-related risks to fisheries and aquaculture and explore adaptation pathways for the industry, including improved monitoring, spatial planning and climate-informed management decisions.[635]

The Resource Management Act 1991 (and associated marine planning processes) and the Marine and Coastal Area (Takutai Moana) Act 2011 are also key instruments in the management of aquaculture and fisheries, along with a range of supplementary regulations and policies[xli] which further shape environmental conditions and operational settings.

The extent to which this complicated regulatory framework upholds iwi/Māori rights and interests in fisheries and aquaculture has historically been contested. While some mechanisms exist for iwi/Māori participation, including customary management tools (such as mātaitai reserves and taiāpure) and participation in fisheries management processes, these are not yet comprehensive or climate-adaptive. Research and policy reviews have noted that statutory decision-making processes often provide limited mechanisms for integrating mātauranga Māori into fisheries and marine management decisions, and current policies only partially consider the specific effects of climate change on iwi/Māori.[224,638,655]

One of the most significant barriers to effective adaptation is the fragmentation and outdated nature of legislation that was largely developed without climate change in mind.[224,638,639] Legislation such as the Fisheries Act 1996, the Resource Management Act 1991 and the Biosecurity Act 1993 lack integrated, climate-adaptive provisions. Most fisheries regulation focuses on single-species management, with limited capacity to respond to cumulative impacts of ecosystem-level changes. This narrow focus fails to account for the cascading effects of warming oceans, species migration and shifting productivity, which require more holistic and anticipatory management approaches.[639] This limitation has been identified in fisheries governance literature, which increasingly recommends ecosystem-based fisheries management to address climate-driven shifts in marine ecosystems and food webs.

Private property rights under the Quota Management System and aquaculture settlement agreements further complicate adaptation.[656] Quota and aquaculture rights are currently treated as enduring and transferrable assets, and attempts to alter, relocate or limit them in response to climate stressors may trigger legal and financial consequences. These legal challenges can limit the responsiveness of the regulatory system and can create resistance to change from quota holders and commercial operators. Because many quota allocations derive from Te Tiriti/The Treaty fisheries settlements, including the 1992 settlement, any

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[xli] Other relevant legislation includes: Biosecurity Act 1993; Hazardous Substances and New Organisms Act 1996; Resource Management (Marine Pollution) Regulations 1998; Freshwater Fish Farming Regulations 1983; and Fisheries (International Fishing and Other Matters) Amendment Bill 2023. Supporting policy further includes: the Fisheries Industry Transformation Plan; and the National Aquaculture Strategy 2025.

substantial changes to fisheries management settings may also raise Te Tiriti/The Treaty considerations and obligations.[643,657]

Aquaculture and fisheries face a risk of climate lock in as consents, quota arrangements and infrastructure decisions are made without adequately accounting for climate risk.[635,638,639] Many farming sites and fishing rights are secured in locations or under regulations that lack flexibility to respond to warming seas, shifting species or extreme events. Delaying action will embed maladaptive decisions that are costly or politically difficult to reverse.

Gaps for risk severity and policy

Data on ecosystem-level effects remain limited and current knowledge is generally concentrated on select commercial species.[138,635] There is also uncertainty regarding appropriate responses and adaptation strategies to support these activities. Based on available evidence, the sector's capacity to adapt will likely depend on improved climate monitoring, more integrated ecosystem management approaches and greater incorporation of mātauranga Māori alongside scientific knowledge. The sector's capacity to adapt will likely depend on targeted, climate-informed actions grounded in environmental limits and mātauranga Māori.

Another key structural barrier requiring attention is the lack of integration between coastal and catchment resource management and planning.[658] Land-based sediment and nutrient inputs degrade water quality in downstream estuaries and nearshore aquaculture zones, yet upstream and downstream planning systems are rarely, if ever, aligned.[658] Unless addressed, this disconnect will continue to limit the effectiveness of interventions to restore marine environments or protect sensitive species. Alongside the creation of a more holistic approach, further investment in adaptive infrastructure, early warning systems and resilience planning would build resilience across Aotearoa New Zealand's fisheries, aquaculture and aquatic harvesting sectors. These challenges have been widely identified in marine management literature and national environmental reporting on land–sea interactions and estuarine health.[50,117,658]

Summary

Fisheries are at risk from climate change. Under the current institutional and policy settings, adaptation cannot reliably be delivered across the fisheries, aquaculture and aquatic harvesting sectors.[635,638,639] Marine and freshwater aquaculture, fisheries and coastal habitats will consequently face increasing and compounding risks from climate change. These risks may result in irreversible ecological change and biodiversity decline. This scenario has the potential to result in tangible economic and livelihood impacts for many New Zealanders.

Given the long lead times needed for infrastructure, spatial planning, workforce planning and ecosystem recovery, immediate steps are needed to integrate climate adaptation into consenting and policy reforms. [635,639] Without such measures, key opportunities to increase resilience will be lost.

Risk scorecard: Fisheries

Risks to fisheries and aquaculture due to extreme weather events, ocean warming, marine heatwaves, and associated impacts like contamination and ocean acidification.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Moderate	Climate change already affects marine and freshwater environments, including through marine heatwaves. Sensitivity and adaptive capacity are poorly understood. Iwi/Māori, who hold 50% of commercial fishing interests, are significantly impacted.
2050	Major	Risks intensify due to limited adaptation options and increasing environmental stressors. Rapid changes are possible, and most resilience depends on emissions reduction rather than adaptation in land-based systems. Sea-based harvest will be significantly more reliant upon biological and commercial adaptation.
2090*	Major GWL 2	
	Extreme GWL 3–3.5	Irreversible impacts and constrained adaptive capacity could push the sector toward extreme risk levels, affecting commercial, customary and recreational uses, with major implications for Māori interests and food systems.
Policy readiness		
Overall assessment	Significant gaps	Despite strategic initiatives and sector plans, fragmented governance, regulatory gaps and insufficient coordination are delaying meaningful adaptation, threatening long-term sustainability and resilience.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address other risks, though it has a strong connection to the risks to coastal and marine ecosystems.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Agriculture

Risks to pastoral productivity and animal health due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.

Aotearoa New Zealand's pastoral production is dominated by dairy, sheep and beef farming. The country's farming systems have developed in a relatively stable, temperate climate across the 20th century. These farming systems are pasture-based, closely coupled to the seasonal pattern of pasture growth with animals generally kept outdoors. The country's farms are diverse and exposed to a variety of climate hazards; sensitivity to the hazards also varies. Farms range from high-country sheep stations to lowland beef finishing; from low-input self-contained dairy farms to high-output dairy farms with cattle housing. Although farms vary, the underlying principle remains – all are tied to the natural world, inescapably connected to the climate and its impacts.

Nationally, there is a complicated picture of how pastoral farming may change due to climate impacts. Pasture and forage crop production form the basis of the feed supply, which underpins pastoral productivity. Pressure is placed on pastures by the ongoing and progressive effects of climate change (such as increasing temperature, sea-level rise (SLR) and changing seasonal weather), as well as by increasing frequency and severity of extreme events (such as drought and flooding) and pasture pests. The ability of farmers to manage their farm feed supply will also be impeded by the physical effects of climate change, with animal production and output affected. There will also be direct and indirect effects on animal health and welfare from climate impacts, such as rising temperatures, droughts, storms, floods and the spread of weeds, pests and diseases.

While this assessment found that risks to pastoral agriculture are minor currently, due to the ability to recover from climate change-related impacts and to adapt management practices, the risk jumps to major in 2050 (rather than moving first through moderate as tourism does). The effects of climate change are becoming more apparent in the sector, notably by various extreme weather events during the past few years, some of which have been partially attributable to climate change. Impacts are experienced at the level of individual farms, communities and regions, but overall, at the national scale, the sector has demonstrated adaptive capacity to recover and continue producing with strong economic returns. Action to address risks to pastoral agriculture is important because the severity of risk is expected to increase substantially by mid-century. Risks to agriculture have been flagged as "ones to watch" in the Priorities for action report, along with horticulture.

Risk overview

Pastoral farming in Aotearoa New Zealand faces a complex and evolving set of climate-related risks. These risks arise from a combination of climate-related hazards including SLR, changing precipitation and wind patterns, rising temperatures, pests, diseases, flooding and other effects from storms, drought and wildfire, interacting with the sector's exposure and vulnerability.

Farmers already experience the effects of climate change, and they are expected to intensify rapidly through mid-century (2050) and into the end of the century (2090). In general, climate change is expected to influence pastoral productivity through changes to pasture and forage crop production and through impacts on animal health, welfare and productivity. Vulnerability will vary seasonally among regions, sectors and businesses. People living and working on farms will also be affected, influencing the sector's capacity to adapt to the challenges of climate change. See the *Physical health* and *Mental health* risk analyses.[18,32]

Risk to pastoral productivity and animal health due to increased frequency and intensity of storms

Storms have immediate impacts on farms, including damage from inland flooding, coastal inundation, winds and erosion. Currently, approximately 1.5 million hectares of pastoral farmland is within flood hazard zones (31% dairy, 69% sheep and beef), with a net revenue attributed to that area of approximately NZ$1.5 billion (86% dairy, 14% sheep and beef).[659,660] Flooding can cause a short-term reduction in feed availability due to submerged pastures and crops or more severe loss of feed due to death of grass or crop plants under flooded water or silt. Flooding can also damage infrastructure such as fencing, farm tracks and buildings, creating challenges for farmers' ability to manage their feed supply or care for animals, as well as creating a costly clean-up. Flooding can also reduce longer-term pasture productivity, due to factors such as reduced fertility of new soils laid down by silt, or pasture and soil damage due to livestock traffic on soils waterlogged due to surface flooding or prolonged wet weather. Strong winds can damage infrastructure such as fencing or irrigation, causing short-term challenges.[661] However, if animals can be moved to safety, livestock systems are generally better able to maintain production following a flood than horticultural or arable crops. The combined effect of wind and rain or snow can place livestock under stress in outdoor systems, particularly if storms occur at sensitive times, such as calving or lambing.

Soil erosion caused by heavy rain in hill country (with its steep slopes, weak sedimentary rocks and historic clearance of native vegetation) leads to significant loss of productive topsoil. Recovery can take generations. Approximately 192 million tonnes of agricultural soil are lost due to erosion each year, with an estimated economic cost in excess of NZ$100 million.[33,662] The economic value generated from topsoil has been estimated to drop by 65% after a typical slip in hill country, and 50 years after that erosion had only recovered to 61% of the initial value.[663] Erosion is projected to increase across the country by mid-century in both low and high emissions scenarios,[33] particularly in soft-rock hill country currently at risk of erosion, such as the North Island's east coast and Manawatū-Whanganui hill country. The quantity of soil eroded is projected to increase towards the end of the century, and to a greater extent with increased emissions.[33]

Risk to pastoral productivity and animal health due to changing precipitation, temperature and drought

Pastoral productivity is sensitive to changes in precipitation and temperature.[18] Adequate soil moisture is essential for pasture production; approximately 60% of the current between-year variation in pasture production can be attributed to spring and summer rainfall.[664] Very wet or very dry conditions at key times in the year can reduce farm output for that year and beyond. Increased weather variability is likely to be consequential for pastoral farm management.[380,665]

The north of the North Island is already experiencing downward pressure on pasture growth due to climate change,[666] and poorer quality kikuyu grass, better adapted to warmer conditions, can make up 90% of a pasture at times.[667] Conditions experienced in Te Taitokerau/Northland are expected to spread further south into Bay of Plenty and Waikato, putting further pressure on pasture production and quality in one of the country's major dairying regions. While some studies have projected that pasture production will increase due to climate change, others have projected a neutral or declining effect of climate change on pasture production.[666,668] Pasture productivity has been static or declining for years, with recent evidence on the ground challenging earlier suggestions that pasture net primary production would benefit from increasing CO_2 concentrations and temperatures.[666]

Changing climatic conditions may still offer some opportunities, albeit along with increased complexity, frequency and intensity. For example, maize silage is not currently grown in one of the main dairy regions, Southland, as it has insufficient thermal time to reach maturity in the south of the South Island and high altitudes in the central North Island.[668] In a lower emissions scenario, maize silage cropping may be more viable by mid-century in Southland and the Central Plateau of the North Island, and, by the end of the century, insufficient thermal time is not likely to result in maize crop failures anywhere in the country.[668] Because maize silage is expected to mature more quickly in current regions, water requirements for the crop will shift to earlier in the season,[668] and the crop may be less vulnerable to summer dry conditions than pasture. Typically, maize silage would be utilised on dairy farms to buffer feed supply and cow diets. For dairy, approximately 20% of the diet is made up of non-pasture feed (including maize silage, other crops, byproducts and concentrates), whereas for sheep and beef the proportion of non-pasture feeds is approximately 8%.[669] Other forage crop options exist (e.g. lucerne), which could be used to buffer feed supply in sheep and beef systems.[670]

In many parts of the country summer temperatures are currently sufficiently high for heat stress to risk livestock production and welfare on some days. For example, there are currently approximately 70 days of potential heat stress for dairy cattle in the Waikato and Bay of Plenty and 80 days in Canterbury.[671] Livestock can be exposed to heat stress while grazing during the heat of the day; at times when gathered together (such as milking time, in livestock handling yards or sale yards); and during transport.[672] Rising summer temperatures and increasing numbers of heat waves are expected to increase the incidence of heat stress in livestock.[672]

The effect of drought has a particularly severe effect on production, and cascading impacts through the economy and society. Many regions of the country are already experiencing increasing frequency and intensity of dry spells and drought.[673] The value of lost production from drought is higher for dairy farms, but sheep and beef farms take longer to recover productivity, with the effect of drought carrying into future years once the drought has broken.[674]

Dairy farms typically have a greater ability than sheep and beef to buffer the effect of drought on production, through a generally greater financial ability to purchase supplementary feed, or invest in water storage and irrigation. However, the financial impact of drought on sheep and beef farms is buffered by increased sales of livestock as a management strategy to reduce feed demand, but this reduces future performance if drought continues for extended periods and breeding animals are sold.[675]

Risks to pastoral productivity and animal health due to the spread of weeds, pests and diseases

The incidence, severity and distribution of current livestock diseases of concern are likely to increase under the climate change scenarios by mid- and late-century.[676] Productivity of pastures and forage crops may also be reduced by increasing weed, pest and disease pressure. There is some evidence that the range and intensity of pest damage may already be increasing due to climate impacts.[677,678] The costs due to weeds on the country's production land (including arable and forestry) are likely to exceed NZ$1.7 billion annually.[679] New weeds to this country are emerging, such as Madagascar ragwort and Chilean needle grass, which can reduce pastoral productivity and animal heath.[680,681] Climate change is likely to change the potential range of current invasive weed species, allow other currently non-invasive species to become invasive weeds and put increasing pressure on existing biosecurity systems.[679,682] See similar risks in the other sectors in this domain and risks to *Indigenous biodiversity (from invasive species and pathogens)* in the *Natural environment* domain.

Diseases of livestock may also spread due to conditions created by climate change. By 2030, the climatic suitability for facial eczema spores is expected to increase in regional distribution and seasonal length, meaning more animals will have their health and productivity reduced by facial eczema disease. Under a higher climate impact scenario the average suitability for facial eczema will continue to increase across the century, with increasing effects on animals.[668,683] Gastrointestinal parasites, such as *Haemonchus contortus* (Barber's Pole worm; historically restricted to the North Island) are likely to spread across a greater area of the country and increase across the century under a higher climate impact scenario.[668,684]

There may be further risks to farmed animals from disease spread through contact with wild species. For example, changing migratory patterns and other climate impacts may increase exposure to avian influenza. During drought events, non-farmed animals (such as rabbits, possums, wild deer and pigs) may come into closer contact with farmed animals to access water and food, potentially transmitting diseases.[685,686]

Risk to pastoral productivity and animal health due to sea-level rise

Although often understood to be a coastal community issue, many pastoral farms will be increasingly affected by SLR. High output systems such as dairy farms are often located in low-lying areas. Currently, around 500 dairy farms (~5% of dairy farms) are exposed to a 1-in-10-year coastal inundation event, and nearly 900 (~9%) to a severe 1-in-500-year event.[687] With 0.5 metres (m) of SLR, an additional 400 and 150 farms are exposed to a 1-in-10-year and 1-in-500 event, respectively.[687]

Inundation with salt water can cause a small loss of pasture yield to complete death of a pasture, depending on the length of the exposure.[687] Mature ryegrass has some tolerance for salinity, although ryegrass seedings are more affected,[688] which could pose an issue where reseeding is required due to inundation. Coastal inundation can also damage farm infrastructure and supplementary feed supplies and can be compounded by river flooding. Animals can be lost to flood waters during a coastal inundation event or be affected by the after-effects of inundation, such as loss of feed and increased incidence of disease. The national impact may be low provided animals can be moved to safety both during and after an event. However, farms in highly exposed regions, such as Bay of Plenty, may be more vulnerable (e.g. due to limited area and resources for dealing with affected stock and reduced capacity for neighbourly support when everyone is affected), and seasonal factors may increase vulnerability (e.g. during spring with increased numbers of young stock and animals in peak production).[687] Salination of animal water supplies could also severely affect animal health welfare and performance, although specific evidence is low in Aotearoa New Zealand.

Farmland not directly affected by coastal inundation can still be affected by SLR. Sea level affects the height of the water table below the surface of the soil. As the water table rises to less than 1 m below the surface, pasture production rapidly declines from water logging and treading damage.[96,xlii] The most dramatic changes are projected within the first 1 m of SLR. Although there is uncertainty, the effect of higher water tables in the coastal zone due to SLR is projected to permanently decrease pasture productivity in some areas.[96] Areas highly affected are Hauraki District, Selwyn District, Whakatāne District, Horowhenua District, South Wairarapa District, Waimakariri District, Christchurch City and Kaipara District.

[xlii] Treading damage refers to the physical degradation of soil and pasture caused by the hoof action of grazing livestock (particularly cattle). It occurs when animals walk on or stand on soil, creating indentations, compaction, or structural damage, most commonly when the soil is wet (near saturation).

Risks to pastoral productivity and animal health due to wildfire

Animals can be directly at risk from wildfire,[689] and water pipes can be damaged by fire. Conditions that can lead to serious wildfires are projected to occur every 3–20 years in parts of the Mackenzie Country, Central Otago and Marlborough.[690] Fire risk is also increased by land management practices.[691-693]

Iwi/Māori agribusiness may be disproportionally affected

All pastoral entities will face impacts from climate change; however, iwi/Māori agribusiness may face a disproportionally high risk compared to the economy as a whole, due to high exposure of livestock farming and, in particular, hill country, which may be erosion prone, less productive and isolated from infrastructure and support. Areas such as Te Taitokerau/Northland and the East Cape region may be affected by more extreme weather events, such as drought and storms, disproportionately affecting the larger iwi/Māori populations who live there.

Compounding and cascading factors

The risks to pastoral farming outlined above will not occur in isolation but will interact with each other and occur simultaneously in many cases. For example, a destructive storm may be followed by a drought, multiplying the effects on farms. Currently, animals can be transported from affected areas, or supplementary feed can be transported to animals in affected areas. However, as these events happen more frequently or across multiple regions, the ability of the pastoral sector to manage will decrease. Non-climate-related drivers (e.g. anthelmintic drench resistance; public perceptions; commodity prices) may also amplify the risks from climate change. These combined effects will put continued downward pressure on pastoral productivity and upward pressure on costs.

Extreme events have visible effects on farming businesses and communities. However, for pastoral farming these effects come on top of more silent, progressive effects of climate change, potentially in combination with non-climate-related stressors.[694]

In the main, although pastoral farmers are currently faced with increasing impacts from climate change, they are able to react using the management tactics and strategies developed for seasonal pasture-based production systems. However, there are limits to the effectiveness of current pastoral management practices in adapting to climate-related risks. Where the pace of climate change exceeds these limits, production decreases will occur, or new practices or technologies to maintain productivity may be required that may change the way livestock is farmed in Aotearoa New Zealand.[695-697] In addition, there may be increasing social pressure on pastoral farming, should climate change impacts or responses be seen to negatively affect animal welfare or the environment.

Interaction with emissions reduction

Outcomes for emissions reduction and adaptation are interlinked but do not necessarily move in the same direction, requiring a holistic and systemic farm management approach. Without deliberate consideration of adaptation and emissions reduction objectives together, actions to do one may negatively affect the other.

If not appropriately managed, the impacts of climate change on pastoral farming have the potential to make reaching emissions targets more difficult. Increasing animal productivity from fewer animals is a key strategy for reducing emissions from agriculture, but the changing climate may put downward pressure on animal productivity and increase the number of animals needing to be farmed to maintain production. This tension may also play out through farm management: actions to reduce on-farm emissions may, in some cases, lead to increased vulnerability to climate change. For example, the Future Farm Systems study in Te Taitokerau/Northland found Cyclone Gabrielle reduced production on their low-methane farm to a greater extent than their control farm, which could recover pastures more rapidly with nitrogen fertiliser.[698] An increasing reliance on nitrogen fertiliser may result from prioritising maximising pasture growth leading into or recovering from future dry conditions, but likely at the expense of reducing greenhouse gas emissions.

From the adaptation perspective, some actions to improve farm resilience to climate change may, in some cases, increase greenhouse gas emissions. For example, a study evaluating climate change adaptations in sheep and beef farm systems found, although systems had become more resilient and profitable as a result of adapting to weather variability and extremes, greenhouse gas emissions had also increased on most farms.[670]

Climate change-related impacts on pastoral farming also have the potential to reduce agricultural greenhouse gas emissions. This could happen through trade-offs if climate adaptation imposes major changes on the sector. For example, the amount of agricultural greenhouse gases produced at a national level may reduce if the changing climate leads to adopting alternative land-use options or if animal numbers decrease.

Adaptation and mitigation could also be mutually beneficial. Some adaptation practices may also reduce emissions or sequester carbon, such as integrating trees into grazing systems, enhancing carbon sequestration. These systems can reduce vulnerability to climate extremes by protecting soil from erosion, providing livestock shelter from heat and storms, and possibly providing additional forage for drought conditions.

To increase resilience to the changing climate, while also contributing to emissions reduction, actions in the agricultural sector will need to consider integrated approaches to adaptation and emissions reduction.

Policy readiness assessment

The pastoral sectors have various collaborative actions underway that have the potential to address current direct and indirect effects of climate change. These include work related to drench resistance, facial eczema, heat tolerant breeding, resilient pastures, dry-land pastures and regenerative agriculture. There are also actions in the national adaptation plan and some other Government programmes with potential to reduce climate-related risk, like the Hill Country Erosion Programme. Large sums of money and significant resources are spent on recovery from events such as drought or floods and supporting the groups that roll out the recovery. Although adverse event recovery is a response to climate change, it is not an adaptation response and could result in a lack of real adaptation action on pastoral farms.

Adaptation policies and programmes typically address short-term adaptation needs as they arise. Most current assessments indicate there is a lack of action on adaptation on farms, particularly beyond planning for the here-and-now and near future.[696] Much of the visible adaptations are incremental improvements that do not match the scale of the risk. Incremental adjustments may lead to bigger changes in systems, such as systems creep from low-input to high-input dairy farming, which may not be an effective adaptation long term or could be maladaptive.

Farmer perception and adaptability is a factor in adaptation. Farmers regularly deal with weather variability on daily, seasonal and annual time scales. Farm systems are developed to cope with historical weather variations, including dry periods, drought and floods. Although information about climate change is available, the progressive changes in environmental conditions can seem insignificant compared to historical variation.[699] Varying by region, 39%–80% of farmers who believe climate change is occurring recognise a change in seasonal weather patterns over the last 10 years.[700] About half of livestock farmers agree they can make changes to their property to adjust to changes in seasonal weather patterns, although some farmers may perceive that they will cope with changes the way they always have.[700] Mis- and disinformation can create resistance to adaptive actions. Recent results from the Survey of Rural Decision Makers indicate that land managers who do not believe that climate change is occurring take fewer adaptation actions.[701]

Financial and infrastructure constraints can also act as a barrier to adaptation. Low profitability on sheep and beef farms can limit what is considered financially achievable. Some actions for dairy farmers can involve a high capital and operational expenditure, such as building housing facilities for dairy cows. Existing infrastructure and consents can also be a barrier; for example, a dairy shed and water consent can lock a farm in that land use for the life of the dairy shed or consent. Increasing irrigation of pasture land can lead to maladaptive outcomes, such as increased environmental impact, increased business cost structure, dependence on water availability and reduced, rather than improved, adaptive capacity of farm businesses.[665,702]

Barriers to adaptation include limitations to research and extension. Because of the often complex links between on-farm adaptation and emissions reduction, discussed above, coordinated approaches are needed. However, there is an imbalance in agricultural climate change research funding, with the majority of focus on agricultural greenhouse gas emissions reduction and limited adaptation-specific programmes. A review found that between 2007 and 2017 there were 22 papers published on agricultural adaptation in Aotearoa New Zealand, compared to 224 on mitigation.[703] There are currently no dedicated funds specifically for adaptation or considering mitigation and adaptation together, although building resilience is part of the purpose of the new Bioeconomy Sciences Institute. Effective research extension is also needed to facilitate adaptation. There are institutions that could drive adaptation action in their sectors (such as the levy bodies, or the Ministry for Primary Industries' On-Farm Support), but they may not be equipped to do so at scale.

Actions that advance iwi/Māori farming adaptation are also under-resourced. National initiatives include the Bioeconomy Science Institute's Land use transitions to enhance Māori communities programme,[704] and the Government's Māori Agribusiness Extension programme.[705] The recently concluded Deep South and Our Land and Water National Science Challenges wove principles from te ao Māori (the Māori world) and mātauranga Māori (historic and contemporary Māori knowledge) throughout, recognising how this can benefit all in adapting to climate change. Similarly, the Aotearoa Circle adaptation roadmap also borrowed a kaupapa Māori (Māori approach, Māori perspectives) framework to centre the work. It is not clear that any of these current or recent programmes will result in improved outcomes for iwi/Māori. Although sometimes located on less-than-ideal land due to historical patterns of land loss, contemporary Māori-owned farms may benefit from larger-scale and collective ownership models, which can be advantageous in terms of adaptive capacity.[694]

Although industry is continuing to undertake research aimed at building resilience into aspects of pastoral farming, there may still be a shortfall in action to ensure short-term actions are not maladaptive, to remove structural or institutional barriers, provide knowledge and support for adaptation actions for producers, and to link adaptation with public good outcomes.

Gaps for risk severity and policy

Robust and extensive research indicates that climate change will likely alter seasonal pasture growth patterns, increase variability in feed availability and exacerbate animal health and welfare issues due to heat stress. Modelling indicates both positive and negative impacts on pasture production. However, projected gains have not been realised, with current models not including all interacting variables and overestimating potential pasture production.[668] Expert consensus is that overall impacts are negative, emphasising the need for adaptation actions and strategies to reduce these risks. There is a gap in data regarding the overall level of climate change preparedness in agriculture.

Although the downscaled projections provide regional information at a 12 km resolution, localised data on the frequency and intensity of extreme events or changes in rainfall and temperature patterns are lacking.[15] This information would give farmers and advisors something to plan for that is specific for their situation. There are also gaps in understanding how heat stress affects different breeds and the potential trade-offs with productivity. Climate impacts on bees and pasture productivity and persistence are not known for this country. Generally, there is a major strategic knowledge gap regarding the state and resilience of the pasture system.[666]

There is a gap in policy relating to the gradual impacts of climate change on agriculture, with most policy relating to extreme events and disaster recovery. Similarly, there is a gap in policy to manage externalities and/or avoid maladaptive actions, a key role for policy.[706] Research and development is seen as an essential component of public policy for adaptation; however, there is a significant funding gap with no targeted investment in research and development for agricultural adaptation, and no public–private partnerships for adaptation, in contrast to Agri-zero for emissions reduction.

Summary

Pastoral farming is highly exposed to both ongoing, progressive effects and discrete events caused by climate change. Negative effects are experienced now, and these are likely to increase over the course of the century. Aspects of pastoral agriculture, such as pasture growth, agricultural soils, animal health and welfare, and farm infrastructure are sensitive to the effects of climate change. However, pastoral farming has traditionally exhibited a high degree of adaptability. Without strategic action, this resilience is likely to weaken in most parts of the country, farm profitability will reduce and some farms will become unviable, risking overall pastoral output. There are some limited opportunities for increased pasture or forage crop production, particularly in Southland, but these gains may be outweighed by the significant downside caused by extreme events and variability, in that region and others.

Although there is some evidence of pastoral sectors and individual farms taking action on climate change adaptation, those actions address current issues as they arise and are not typically forward looking. A coordinated approach across sectors, local and national government is generally lacking. The overall extent of climate change impact awareness is low and there is a lack of action beyond the immediate issues, which does not prepare the sector or country well for the future. Momentum towards adaptation action has stalled with reviews of climate and science policy and strategy.

The level of climate change risk to pastoral farming is likely to increase rapidly between now and mid-century. There is an opportunity in the next six years, before the next risk assessment, to address this shortfall and plan for transformational adaptation actions that facilitate economic growth and emissions reductions from agriculture. Action now can build pastoral farming resilience, and lead to greater land-use diversity and greater resilience for the overall national land-based economy.

Risk scorecard: Pastoral agriculture

Risks to pastoral productivity and animal health due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Farming systems are already affected by extreme temperatures, drought and extreme weather events with impacts on animals and feed. While some impacts may already be moderate (particularly for sheep and beef), national-level effects are still considered minor overall and the sector demonstrates high adaptive capacity, ability to recover and resilience.
2050	Major	Step change from reversible to irreversible impacts like soil erosion and coastal inundation. Feed supply becomes more vulnerable to precipitation changes. Increased frequency of extreme events shortens recovery periods. Adaptive capacity, though currently high, is unlikely to keep pace without sustained effort.
2090*	Major GWL 2 Major GWL 3–3.5	Systemic risks to animal farming intensify, with cascading effects on feed, land and infrastructure. Despite potential for adaptation (such as changing farming systems), the scale and persistence of impacts are expected to remain major under both low and high emissions scenarios.
Policy readiness		
Overall assessment	Significant gaps	Despite some sectoral and farm-level efforts, the lack of coordinated, forward-looking adaptation policy leaves the pastoral sector vulnerable to quickly accelerating climate impacts and unprepared for future risks.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium potential to address others in the assessment, including the risks to horticulture, freshwater ecosystems, indigenous biodiversity, physical health, social cohesion and cultural wellbeing.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Horticulture

Risks to horticulture productivity due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.

Climate change threatens the productivity of Aotearoa New Zealand's horticulture sector, which includes on-farm fruit and vegetable production for domestic and export markets. Climate impacts, such as altered growing conditions and exposure to drought, heatwaves, storms and pests, are expected to intensify. Horticulture was not identified as one of the two most significant risks in the *Economy* domain in the first national climate change risk assessment. This updated assessment incorporates new evidence on regional exposure and adaptation opportunities.

While this assessment found that risks to horticulture are minor for the current time period, due to the ability to recover from climate change impacts and to adapt management practices, they jump to major in 2050 (rather than moving first through moderate as tourism does) for mid-century. Risks to horticulture have been flagged as "ones to watch" in the Priorities for action report, along with agriculture. The effects of climate change are becoming more apparent in the sector, notably by various extreme weather events during the past few years, some of which have been partially attributable to climate change. Overall, at the national scale, the sector has demonstrated adaptive capacity to recover and continue producing with strong economic returns, but the severity of risk is expected to increase substantially by mid-century.

Risk overview

Aotearoa New Zealand's horticulture sector is increasingly exposed to climate-related hazards, including rising temperatures, shifting rainfall patterns, intensifying droughts and other extreme weather events, and expanding pest and disease pressures.[50] These hazards interact with regional exposure and infrastructure vulnerabilities, creating differentiated impacts across the country.

Regional projections affecting horticulture include increased extreme weather events and water demand

By the 2030s, drought frequency is projected to increase in Hawke's Bay and Canterbury, while Bay of Plenty is expected to face more frequent flooding and other extreme weather events, affecting horticultural productivity.[707-709] Longer-term projections suggest increasing irrigation demand and water-deficits across many regions of Aotearoa New Zealand by mid-century.[710] This will be driven by rising temperatures and changing rainfall patterns.[699] Research suggests that land-use transitions may become necessary where farming systems approach tolerance limits under climate stress.

Risks to horticultural productivity due to heat stress, reduced chilling hours, drought and rainfall changes

Climate impacts are already emerging. Heat stress is disrupting high-value crops such as grape, apple and kiwifruit production, with high temperatures reducing berry quality and accelerating ripening in grapes, and causing sunburn and declining fruit quality in apples and kiwifruit.[711-713] Warmer winters are reducing chilling hours required for flowering and fruit set in apples and kiwifruit, threatening yield reliability.[50] Although frost risk is expected to decline over time, late spring frosts remain a threat, prompting growers to invest in protection strategies.[714] Confidence in these trends, particularly rising temperatures and increasing drought frequency, is high.[715,716]

Drought and irrigation challenges are intensifying, particularly for growers reliant on rainfall or constrained water allocations. Smaller fruit size and reduced yields are noted by the horticulture sector in eastern regions, while growers are facing rising competition for water and high access/licence costs.[247] Coastal saltwater intrusion is also emerging as a potential long-term hazard accompanying sea-level rise (SLR), although horticulture-specific evidence remains limited.[50]

Soil degradation from erosion and sediment deposition is an increasing concern. This is particularly the case in sloped or flood-prone horticultural landscapes where extreme rainfall events are becoming more frequent.[717] Cyclones and other storm events have already caused significant land degradation. For example, after Cyclone Gabrielle in 2023 large areas of Hawke's Bay's productive land were smothered in silt, livelihoods disrupted and soil health compromised.[718,719] However, uncertainty persists around how nutrient cycling and soil functioning may respond to future climate stress.[9]

Thresholds may emerge when irrigation schemes reach capacity during consecutive dry years or when persistent heat and inadequate winter chill render crops commercially unviable. Infrastructure failures, such as breaches in flood protection, could trigger grower exit, land-use change and sector consolidation. Research findings show confidence in these directional trends is high, though uncertainties remain around local precipitation changes and the effect of multiple hazards occurring in quick succession (compound-event interactions).[9]

Risks to horticultural productivity due to pests and diseases as temperatures and weather patterns change

Pest and disease pressures are increasing across Aotearoa New Zealand horticulture. Warmer temperatures and changing humidity patterns are creating more favourable conditions for a wider range of pests and pathogens. See similar risks in the *Sectors relying on the natural environment* domain and *Indigenous biodiversity (from invasive species and pathogens)* risk analysis.

Climate-driven shifts in suitability are expected to enable several insect pests and diseases to expand into new regions, a trend supported by recent climate comparison and biosecurity modelling.[720,721] Confidence in the projected expansion of climatically suitable ranges for pests and diseases is generally high due to strong modelling consistency. In kiwifruit, *Pseudomonas syringae* pv. *actinidiae* (Psa) remains a key risk. Although resistance to control methods of Psa is closely monitored, current evidence indicates that resistance levels have remained in recent years.[722]

Cascading risks to horticulture may affect food security

Food security represents a cascading, system-level risk linked to horticultural disruption. Climate-driven variability in yields, increased biosecurity pressures and episodic extreme-weather events affecting transport networks can collectively reduce supply-chain reliability and contribute to price volatility.[723] Although these downstream impacts extend beyond the farm gate, they highlight the broader interlinkages influenced by climate change effects on horticultural production.

Iwi/Māori horticulture is vulnerable due to crop sensitivity and lower adaptive capacity

Iwi/Māori horticulture is particularly vulnerable due to intersecting environmental and structural factors. Traditional crops such as kūmara and rongoā (medicinal plant) species are sensitive to heat, drought and pest pressures, threatening maramataka-based (Māori lunar calendar) planting, māra kai (food garden) practices and intergenerational knowledge transmission. Iwi/Māori landowners often face adaptation barriers due to complex land tenure, limited access to capital and infrastructure gaps. Additionally, many Māori work in climate-exposed regions, with implications for employment and wellbeing.[65,724]

Adaptation options exist and the sector overall has demonstrated adaptive capacity

Despite the challenges it faces, the horticulture sector overall has demonstrated adaptive capacity. Growers are already investing in frost protection, irrigation upgrades and crop diversification. The Ministry for Primary Industries (MPI) and Plant & Food Research (now part of the Bioeconomy Research Institute) highlight that adapting to climate-driven change may involve switching to new cultivars, relocating crops and investing in water-storage capacity.[725]

Compounding and cascading factors

Compounding risks in horticulture arise when multiple climate hazards, such as drought, flooding and pest outbreaks occur simultaneously or in close succession, amplifying their combined impact. These physical stressors can be further intensified by socio-economic factors like limited infrastructure, financial constraints and workforce pressures, increasing the sector's overall adaptation burden.

Climate hazards in Aotearoa New Zealand increasingly occur in tandem, amplifying their impact. For example, multi-year droughts reduce water availability during critical crop stages, while intense rainfall events erode soils and overwhelm drainage systems, often within the same season.[50] Rising temperatures and altered seasonality are also enabling the spread of pests and diseases, with warmer conditions enabling the spread of subtropical weeds and insect vectors, particularly in northern regions.[88] These climatic stressors intersect with non-climatic risks like ageing irrigation infrastructure, limited cold-chain capacity and economic fragility among some smallholders. When hazards strike simultaneously or in quick succession, they can overwhelm systems designed for isolated events, leading to crop losses, disrupted supply chains and reduced market access.[726]

Socio-economic trends further compound climate-related risks. Iwi/Māori-owned horticultural businesses, which have expanded significantly, often lack access to robust irrigation or adaptation finance, making them more vulnerable to water stress and pest outbreaks.[65] Small- and medium-sized enterprises face rising costs for water, pest control and temperature management, with limited financial buffers to invest in resilience.[724]

Interaction with emissions reduction

Emissions reduction policies and land-use shifts are likely to both constrain and enable horticultural adaptation, depending on how they intersect with water and energy supply, and land systems. Changes to New Zealand Emissions Trading Scheme (NZ ETS) emissions costs can affect the operational costs for greenhouse growers using fossil-fuel-based process heat. Switching to alternative fuels (like biomass) has upfront costs, and there may be a case to consider targeted government support.[727,728] At the same time, innovation for emissions reduction, such as electrification of packhouses, low-emissions transport and renewable energy integration, could reduce long-term concerns about energy price volatility and support climate resilience.

Afforestation may compete with highly productive horticultural land, creating trade-offs for land-use in regions where crop suitability is shifting.[729] Conversely, climate hazards such as drought and pests may make emissions reduction harder to achieve by raising emissions from irrigation pumping, pest control and crop losses.

Policy readiness assessment

The national adaptation plan provides the main policy direction, aiming to strengthen climate information, support iwi/Māori partnership in food and fibre, improve water resilience and encourage innovation.[70] These actions indicate commitment, but many depend on future funding, voluntary uptake or sector-led implementation, meaning their impact is still emerging rather than fully realised.

In practice, several barriers slow adaptation. Long delays in approving new chemical and biological controls leave growers exposed to rapidly changing pest and disease pressures. Sivanto, for example, took four years to gain approval in Aotearoa New Zealand despite being widely used overseas.[730] From an industry perspective, the freshwater regulatory system has also made basic adaptation practices, such as crop rotation and on-farm water storage, difficult to implement, although recent proposals aim to simplify consenting.[731] Similarly, the biosecurity system's shared-cost model often disadvantages small or niche growers, as shown by the severe impacts of tomato potato psyllid (TPP) and *Candidatus* Liberibacter solanacearum on the tamarillo industry.[732]

There are strengths within the current system: MPI's On-Farm Support provides practical planning and readiness advice, some regional councils are completing climate-related risk assessments,[733] and collaborative programmes like A Lighter Touch are building longer-term resilience through agroecological research.[734] Industry groups contribute sector-specific planning, including Horticulture New Zealand's Action Plan and Zespri's adaptation strategy.[735] However, these initiatives are unevenly distributed across regions and crops, and readiness varies widely.

For iwi/Māori, national policy recognises the importance of partnership and iwi/Māori-led adaptation, but practical resourcing and decision-making mechanisms remain limited.[70] Engagement is encouraged, but not consistently enabled.

Industry bodies such as Horticulture New Zealand have advocated for climate adaptation frameworks that reflect horticulture's unique risk profile and support community-led responses. They assert that reforms to agrichemical approval processes and freshwater rules could strengthen readiness, but, until implemented, growers remain vulnerable to climate-driven hazards.[736] They also emphasise long-term water security, arguing that reliable water access is fundamental for resilience in a warming, drier future.[737] Overall, current policies demonstrate intent but still fall short of fully addressing near-term climate-related risks for the horticulture sector.

Gaps for risk severity and policy

Evidence on climate-related risks to horticulture in Aotearoa New Zealand has improved since the first risk assessment, but key gaps remain in understanding the severity and spatial variability of compounding risks. While national assessments have documented trends in temperature, rainfall and extreme events, there is limited high-resolution data on how these hazards interact at the crop and catchment scale, particularly for multi-hazard scenarios like concurrent drought and flooding. There is also a lack of longitudinal data on the cumulative impacts of repeated climate shocks on yields, soil health and pest dynamics, which constrains the ability to model future risk trajectories and thresholds.[9]

While the national adaptation plan and sector strategies outline broad adaptation policy goals, there is limited available evidence on their implementation status, effectiveness or regional uptake. Progress on water resilience measures, pest monitoring systems and infrastructure upgrades is neither consistently tracked nor reported. There is also a lack of evaluation of how policies address the specific needs of iwi/Māori growers and the integration of ao Māori (Māori world) perspectives into adaptation planning.

Summary

Climate-related risks to horticulture in Aotearoa New Zealand are already significant and intensifying. Compounding hazards are increasing, placing stress on crops, infrastructure and supply chains. These risks are expected to worsen over the next two decades, with more frequent extreme events and shifting seasonal patterns reducing crop viability and increasing adaptation costs. Vulnerabilities are acute in regions with limited water infrastructure and among smallholders and some iwi/Māori growers, who face barriers to adaptation finance and planning.[50]

While national adaptation policies show intent, readiness remains moderate. The national adaptation plan and sector strategies outline key actions, but implementation is uneven, and critical gaps persist in infrastructure resilience, pest management and iwi/Māori participation. Without coordinated national action and targeted support, one or more regions could cross thresholds where current systems can no longer cope.[46,738]

Risk scorecard: Horticulture

Risks to horticulture productivity due to progressive and ongoing changes in temperature and precipitation, sea-level rise, extreme weather events, and associated impacts like enhanced spread of pests and diseases.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Horticulture is already affected by extreme temperatures, drought and extreme weather events, with impacts on yield, infrastructure and Māori food security and cultural practices. At present, the sector demonstrates high adaptive capacity, ability to recover and resilience.
2050	Major	Increased temperature extremes and pest pressure will quickly and seriously affect soil health, yields and intergenerational knowledge transfer. Māori communities face major cultural and social impacts. Recovery time for tree crops following extreme weather may result in unreliable yields. Adaptation is possible but uneven.
2090*	Major GWL 2 Major GWL 3–3.5	Long-term challenges include recovery time for tree crops and systemic risks to food security. Adaptive capacity and policy readiness will be critical but may not fully offset escalating climate pressures.
Policy readiness		
Overall assessment	Significant gaps	Existing policies and programmes provide a foundation, but lack the specificity, coordination and resourcing needed to fully address horticulture-related climate risks, leaving growers vulnerable in future.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it may do so as part of a package of related actions.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Tourism

Risks to the seasonality, accessibility and viability of the tourism sector due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Tourism is a cornerstone of Aotearoa New Zealand's economy, cultural identity and international reputation.[609,739] It is deeply connected to and heavily reliant on the country's unique natural environment, biodiversity, culture (including heritage and culinary experiences), access to landscapes, and functioning service, transport and utility infrastructure.[739-741]

Climate change presents escalating risks to tourism through both gradual environmental shifts to landscapes and ecosystems and acute disruptions from extreme weather events.[xliii,26,27,740,741] Climate change has effects on the assets that underpin visitor experiences: pristine environments, accessible natural attractions and reliable infrastructure influencing tourism experiences, operations and community wellbeing.[739-741] This includes the vulnerability of visitor destinations, regional tourism networks and communities reliant on income from tourism activities. Tourism in Aotearoa New Zealand relies heavily on both land and marine environments, many of which are exposed to climate-related hazards.[739-741] Climate-induced disruptions to lifeline infrastructure compound the vulnerability of remote tourism-dependent communities.[593,742]

The first national climate change risk assessment concluded tourism was vulnerable to both direct climate hazards (e.g. increased temperatures, flooding, erosion, wildfires) and indirect impacts (e.g. biodiversity loss, degraded landscapes, infrastructure disruption and changes in visitor behaviour).[26] Hence, "Risks to tourism from changes to landscapes and natural environment" was identified as a key socio-economic vulnerability, noting high exposure and sensitivity due to the concentration of tourism assets in hazard-prone locations and the reliance on international visitation patterns vulnerable to global climate impacts. Since then, increasing evidence points to the cumulative impacts of extreme weather events, infrastructure disruption and ecosystem decline on visitor experiences, local economies and community resilience.[593,740,741]

Risk overview

Tourism relies on the quality and accessibility of natural assets, but these face multiple climate hazards

Tourism in Aotearoa New Zealand relies heavily on the quality and accessibility of its natural assets – alpine regions, beaches, forests, glaciers, marine/freshwater environments and

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[xliii] An extreme weather event is one that is rare for a particular location or time of year (such as exceeding the 90th percentile of long-term observations).

cultural landscapes (including pastoral/viticultural landscapes). [739-741] These environments face multiple, interacting climate hazards – rising temperatures, altered precipitation, sea-level rise (SLR), and more frequent extreme events such as floods, landslides, increased storm intensity and frequency, coastal erosion, heatwaves, droughts and wildfires.[26,741] These affect both the natural attractions central to tourism and the supporting infrastructure. This manifests in gradual changes such as glacial retreat, biodiversity decline and reduced snow reliability.[594,595,741] Increased frequency of intense rainfall events damages key transport corridors, and SLR and storm surges threaten coastal tourism infrastructure, accommodation and attractions.[593,741,742] Coastal destinations are already experiencing erosion and inundation that threaten visitor facilities and scenic values, while inland regions face road closures from floods and landslides.[593,741,743]

Tourism's sensitivity arises from its dependence on natural landscapes, infrastructure and predictable weather patterns. Destinations built around fragile ecosystems (like geothermal or alpine zones) exhibit low tolerance for physical disturbance. Biodiversity loss has altered species distributions, and degradation of ecosystems – especially coastal dunes, estuaries and marine reserves – poses significant risks to nature-based and eco-tourism.[50,116] Warmer seas and marine heatwaves are already altering kelp cover and fish assemblages, with likely consequences for diving and fishing experiences.[116,134,135] See the *Coastal ecosystems, Marine ecosystems* and *Fisheries* risk analyses for more information.

Infrastructure and tourism assets are disproportionately concentrated in coastal and alpine regions.[741,744,745] For example, Te Taitokerau/Northland, Thames-Coromandel District (in the Waikato region), Bay of Plenty and Hawke's Bay already experience escalating coastal hazards.[50,270,741] Fiordland and the West Coast are especially vulnerable due to limited redundancy in transport infrastructure.[593,742,746] Climate hazards are projected to intensify by 2050 and 2090.[27] Damage to lifeline infrastructure – including state highways, airports, ports and wastewater systems – could isolate destinations and interrupt supply chains, reducing visitor confidence and regional resilience.[593,742] By 2090, some low-lying coastal tourism hubs (such as Coromandel, Kaikōura and parts of the Bay of Islands) could experience regular inundation from SLR and storm surges, threatening accommodation, transport routes and natural amenities.[27,50,741] For more information, See the *Built environment* domain.

Biodiversity and landscape degradation also pose growing risks to nature-based tourism, which accounts for a large share of visitor experiences. Coastal erosion and inundation threaten access to beaches, walking tracks and cultural sites.[593,741] Increased sediment and nutrient runoff (such as after a storm) affect water clarity and freshwater recreation.[27,50] Wildfire risk in forested reserves is rising, particularly in drier eastern regions.[39,615]

Tourism faces risks from changes in seasonality over the rest of the century

The seasonality of tourism is being reshaped.[741,747] Warmer temperatures may extend the summer season in some regions but reduce snow reliability for alpine tourism.[595,741,747]

Queenstown Lakes, Canterbury and Mackenzie regions face intensifying risks from glacial retreat, flooding and snow decline.[594,595,741] Mountain and alpine destinations face shortened winter seasons,[595,741] leading to reduced access and visitors, shifting the nature of tourism in these regions from adventure-based to scenic observation, and decreasing local employment opportunities.

By mid-century, continued glacial retreat is expected to reduce the accessibility and character of glacier-based attractions,[594] while weather-related transport closures are also projected to become more frequent.[741,742] Higher mean annual temperatures, increased heat stress and declining snow reliability are projected to reduce winter sports tourism and the length of ski seasons.[595,741] Regions such as Queenstown and Ruapehu are especially vulnerable due to both projected declines in snow reliability and weather extremes and their high economic reliance on climate-dependent tourism, with consequent flow-on impacts for hospitality and regional economies.[740] By late century, under high-emissions scenarios, climate impacts could make some alpine tourism infrastructure increasingly difficult or uneconomic to maintain.[741,747] Conversely, higher summer temperatures may shift visitor preferences but exacerbate pressure on water resources and ecosystems.

Iwi/Māori tourism faces risks of economic disruption and cultural loss

Impacts for iwi/Māori tourism are pronounced, given the strong cultural and economic ties to land and water, grounded in mātauranga Māori (historic and contemporary Māori knowledge), kaitiakitanga (guardianship, environmental stewardship) and relationships with specific places.[340,748,749] Climate change impacts on wāhi tūpuna (ancestral places), taonga species and ancestral coastal sites, posing dual risks of economic disruption and cultural loss. Flooding, coastal erosion and SLR can damage marae used for tourism and hosting, while biodiversity shifts threaten mahinga kai (food gathering places and practices).[152,153,340] The loss of access to taonga species and environmental damage undermines the visitor experience.[748] Some iwi/Māori are advancing climate adaptation strategies (for example Ngāi Tahu's Climate Action Plan or Te Arawa's Climate Strategy), yet sustained resourcing and meaningful inclusion in tourism and regional planning remain limited, constraining the ability of these strategies to fully support climate-resilient tourism development and community wellbeing.[65,176,340,750]

Climate thresholds may make some tourist destinations and activities unviable

Tourism assets face physical thresholds, such as erosion limits where land loss undermines structures, and temperature or precipitation thresholds beyond which key activities like skiing and tramping become unviable.[595,741,747] Cultural and social thresholds are emerging as communities face decisions about whether to defend, relocate or transform tourism-dependent settlements. Some locations, including Franz Josef, may approach points where repeated hazard exposure undermines the viability of maintaining existing tourism infrastructure.[593,741,747] Adaptive capacity varies significantly: regions with diversified attractions and robust infrastructure (like Canterbury and Otago) have resilience, whereas small, ecotourism-dependent communities are vulnerable.[741,747]

The confidence level is high for physical exposure and infrastructure disruption, and moderate for socio-economic responses and behavioural shifts.[741]

Compounding and cascading factors

Tourism risk is amplified by its interdependence with multiple other sectors – particularly transport, housing, energy and conservation management – and by its interaction with multiple climatic and socio-economic drivers. Compounding effects arise when climate-related hazards coincide or cascade. These may include heavy rainfall events triggering landslides that block access to visitor sites already under pressure from erosion or flooding, or flooding coinciding with storm surges, or heatwaves following drought. These can damage attractions, disrupt access and accelerate ecological decline.

Because extreme weather events such as storms and flooding are becoming more frequent and Aotearoa New Zealand's tourism demand is highly concentrated in the summer peak season, these hazards are increasingly occurring during periods of highest visitor activity, amplifying disruption and placing greater pressure on response capacity.[26,741] For example, damage to roads, airports and telecommunications disrupts visitor flows and constrains emergency responses.[593,742,751] Hence, tourism risk is intensified by infrastructure interdependencies. Economic shocks (as experienced from COVID-19) have demonstrated the sector's exposure to global volatility; climate hazards may amplify these stressors, threatening employment and community viability.

Tourism's exposure is heightened by infrastructure vulnerability.[593,742] Extreme rainfall events – such as those that damaged State Highway 6 along the West Coast and disrupted South Island access – demonstrate how a single weather event can isolate regions and cause cascading economic loss.[306,746] Similarly, disruptions to energy and water supplies can quickly impact transport and accommodation services. See the *Built environment* domain in this risk assessment.

In turn, tourism itself may compound environmental stress: high visitation accelerates erosion, pollution and carbon emissions, creating feedback loops that worsen local ecosystem decline.[740,752] The sector's high dependence on international visitation means it is sensitive to both global climate disruptions and shifting consumer behaviour toward low-carbon travel.[609,741,747]

Socio-economic trends, including continued growth in domestic tourism, changing visitor expectations (such as more sustainable, low-carbon and high-quality experiences, or eco-tourism) and evolving sustainability norms interact with climate change impacts. Many regions, such as the West Coast, Thames-Coromandel District (Waikato region) and Te Taitokerau/Northland, remain economically dependent on tourism, limiting diversification options and increasing vulnerability to climate shocks.[744,745,753,754] Visitor demand for nature-based coastal and alpine experiences, often coupled with expectations of comfort, accessibility and year-round services, increases exposure to climate hazards.[755,756] Housing pressures, insurance retreat, cost-of-living pressures and workforce shortages reduce community resilience to tourism-related shocks.[559,562]

Social compounding factors include population growth (leading to housing pressure) in major tourist hubs (as in Queenstown and Wānaka), straining infrastructure capacity.[757] Climate impacts exacerbate these pressures by affecting potable water availability, wastewater treatment and discharge, and energy security, creating tensions between residents and tourism operators.[50,758,759] Population growth and development in coastal settlements (such as Coromandel, Nelson and Tasman) further increase exposure of tourism assets and strain adaptation planning. Intensifying non-climate stressors, such as outdated infrastructure, housing shortages and labour market fluctuations, constrain the sector's adaptive capacity.

Interaction with emissions reduction

Tourism contributes approximately 5–7% of Aotearoa New Zealand's total greenhouse gas emissions (varying by methodology and year).[760,761] Within the tourism footprint, air transport accounts for most of those emissions, around 74% of tourism-related emissions in 2023 (including only domestic aviation and international flights by New Zealand carriers), with the balance made up by road and other transport and other tourism activity sectors.[760,761] Regional and local tourism strategies are increasingly prioritising low-emissions mobility, sustainable operations and conservation-led tourism.[762,763] Expansion of renewable energy and electrification of vehicle fleets not only supports emissions reduction but can also enhance tourism resilience, for example by diversifying energy sources and reducing reliance on fossil fuel supply chains and centralised infrastructure. Distributed and renewable generation with local storage (e.g. solar plus batteries) can maintain critical services and mobility during extreme weather events or network outages. This is a key resilience benefit for remote or off-grid tourism destinations.[764,765] Climate-resilient infrastructure, including resilient electric vehicle (EV) charging networks and decentralised energy systems, is also essential to support these transitions.

Climate mitigation initiatives in the tourism sector can also support adaptation when they are designed to strengthen environmental and infrastructure resilience. The International Visitor Conservation and Tourism Levy (IVL)[766] provides an example of this alignment by generating revenue from international visitors that can be reinvested in conservation projects and tourism infrastructure. When strategically directed toward climate-exposed ecosystems, visitor management and resilient infrastructure, such funding can both reduce environmental pressures and strengthen the sector's capacity to adapt to climate impacts. The Tourism Industry Transformation Plan (ITP) sought to embed sustainability and resilience into tourism planning, but momentum reduced after changes in government priorities.[410,767,768] Carbon offset schemes and visitor education initiatives may complement adaptation efforts, but long-term resilience will likely depend on broader structural changes in how tourism develops and operates.

At the same time, tourism growth can intensify environmental pressures that interact with climate-related risks. Increasing visitor numbers contribute to emissions from international travel and place additional strain on ecosystems, infrastructure and local communities. The IVL provides a mechanism for visitors to contribute to addressing these pressures by funding conservation and tourism system improvements, helping to ensure that the costs of maintaining natural and tourism assets are not borne solely by local communities.[769] However, the effectiveness of this mechanism depends on how consistently and strategically funds are directed toward protecting climate-exposed ecosystems and strengthening resilient infrastructure.

Nature-based tourism and conservation partnerships offer dual benefits for adaptation and mitigation through reforestation and ecosystem restoration. Conversely, rebuilding damaged infrastructure without climate-proofing risks locks in emissions-intensive pathways.[770]

Policy readiness assessment

Adaptation planning is fragmented, lacking enforceable mechanisms and funding

The tourism sector's adaptation planning remains fragmented, with strong local initiatives but limited national coordination.[593,768,771] The Department of Conservation (DOC), Tourism New Zealand and regional tourism organisations (RTOs) are all integrating climate considerations into destination management plans. However, national tourism policy has historically prioritised growth rather than resilience: National tourism planning, as exemplified by the Government's Tourism Growth Roadmap, centres on increasing international visitors and tourism export value, illustrating an ongoing policy emphasis on volume and economic growth.[771] National adaptation initiatives relevant to tourism are dispersed (such as the national adaptation plan 2022[270] and Regional Economic Development frameworks).[597] They provide direction on sustainable and climate-resilient tourism but lack enforceable mechanisms or dedicated resourcing.

The ITP provided a valuable platform for embedding climate adaptation, regenerative tourism principles and mātauranga Māori frameworks.[593,768] However, this work has been halted, reducing continuity in coordinated adaptation planning.[410,768] While its discontinuation limits national coordination, its conceptual groundwork – emphasising regenerative tourism, low-carbon operations and partnership with iwi/Māori – remains influential in regional strategies. The IVL provides a key funding stream to support tourism sustainability and conservation projects.[766] However, current funding is unlikely to meet all adaptation needs, especially for adaptation of infrastructure and protection of nature-based tourism assets.[766,769]

The IVL and DOC initiatives contribute modestly to resilience through conservation and infrastructure maintenance. DOC's Climate Change Adaptation Action Plan, Regional Destination Management Plans and the IVL-funded initiatives collectively enhance resilience, but their implementation remains uneven across regions.[44,772] Local governments often lack dedicated funding and technical capacity for tourism-specific adaptation projects, particularly in small or remote communities. Key agencies that coordinate nationwide infrastructure and conservation planning do not operate under a unified climate-related risk framework for tourism.[270,593,771]

Local government and iwi/Māori adaptation planning is emerging, but requires expertise and resources

Local government plans and RTOs increasingly integrate climate adaptation into destination management plans (such as Northland and Queenstown Lakes), but guidance is limited and implementation capacity varies. Smaller councils often lack the technical expertise and long-term funding needed for hazard modelling, infrastructure resilience upgrades and ecosystem restoration.[772] The DOC Climate Change Adaptation Action Plan[78,773] supports nature-based tourism resilience, while regional councils manage coastal hazard planning.[163] Iwi/Māori decision-making and participation in climate adaptation are limited in tourism adaptation policy.[176,340,749] There are emerging examples of iwi-led initiatives integrating mātauranga Māori and kaitiakitanga into tourism planning.[340,749,774,775]

Barriers include lack of coordination

Key barriers include policy and institutional fragmentation, limited financial resources and reliance on discretionary levies (such as the IVL), short-term economic incentives, inconsistent incorporation of climate projections into regional planning, short budgetary cycles misaligned with long-term adaptation horizons, and lack of cross-sectoral coordination (e.g. by a central agency/system). Industry awareness of climate-related risks has improved. However, adaptation actions (such as seasonal diversification, infrastructure relocation or nature-based solutions) are unevenly implemented and often constrained by fragmented policy and coordination mechanisms across sectors and levels of decision-making.[37,593]

Without renewed national coordination and sustained adaptation investment, the sector is constrained by fragmented responsibilities and insufficient dedicated funding.[593,771,772] There is potential for irreversible degradation of natural assets and loss of key tourism assets. Integrating climate resilience criteria into regional tourism funding and national strategy updates would help to prevent further vulnerability.

Gaps for risk severity and policy

Data on visitor exposure mapping, infrastructure vulnerability and economic loss attribution remain sparse, with tourism vulnerability research still lacking comprehensive destination-scale vulnerability indices and long-term empirical economic impact data.[593,752,776] Longitudinal data on the economic impacts of climate hazards on tourism remain limited, as do ecosystem service valuations linking biodiversity loss to tourism revenue.[593,776] Monitoring of visitor perceptions and behavioural responses to degraded environments are limited, hindering demand forecasting.[776] Few studies quantify the cumulative effects of multiple hazards or include the value of cultural assets in risk assessments.[144,593,776] A policy gap persists in translating local adaptation trials into national frameworks.

Policy evidence gaps include a lack of comprehensive, standardised metrics for assessing tourism's adaptive capacity and evaluating adaptation effectiveness across regions, as well as incomplete integration of climate-related risk into tourism infrastructure planning and funding mechanisms.[26] There is minimal evaluation of existing adaptation measures, limited assessment of iwi/Māori tourism vulnerability and the costs of damage to culturally significant environments and heritage, and no comprehensive approach (following the discontinuation of the ITP).[26,410,768]

Data gaps persist in measuring tourism exposure to cascading climate hazards, particularly for lifeline infrastructure dependencies and the vulnerability of small and iwi/Māori tourism enterprises. Economic modelling often underestimates indirect losses from climate effects.

More systematic monitoring is needed to understand visitor behaviour under changing climate conditions (such as temperature comfort or seasonal preferences) and to integrate that understanding into resilience planning and investment decisions.

Summary

Tourism in Aotearoa New Zealand faces increasing climate-related risk due to its dependence on vulnerable landscapes, ecosystems and infrastructure.

While policy frameworks are evolving, adaptation remains fragmented, with limited national coordination and significant data gaps for tourism.[593,771,772] Addressing these risks requires national coordination, ecosystem-based adaptation and partnership with iwi/Māori to safeguard both livelihoods and cultural landscapes. National coordination is needed to align tourism strategy, infrastructure investment and conservation policy with climate projections.[593,771,773] Without decisive adaptation measures, impacts will intensify by mid-century, undermining the sector's economic, cultural and social foundations.

Proactive adaptation can safeguard Aotearoa New Zealand's international reputation as a sustainable destination and preserve the integrity of the natural and cultural landscapes upon which tourism depends.

Risk scorecard: Tourism

Risks to the seasonality, accessibility and viability of the tourism sector due to progressive and ongoing changes in temperature and precipitation, sea-level rise and extreme weather events.

Not identified as one of the most significant risks.

	Score	Rationale
Risk severity		
Now	Minor	Overall, risks to tourism are expected to be present but relatively low, with impacts generally manageable and recoverable. However, adaptation is uneven, awareness remains limited, access to finance varies and coordination is inconsistent.
2050	Moderate	Climate impacts increase, including extreme weather events disrupting mobility, infrastructure, loss of operating days and productivity; heat and drought affecting visitor experience; glacial retreat (tipping points may be reached); and reduced snow cover affecting ski season. Opportunities for tourism to adapt in response.
2090*	Moderate GWL 2	
	Major GWL 3–3.5	Tourism affected by increase in extreme weather events and the potential cut-off of lifeline services. Māori tourism particularly vulnerable due to impacts on cultural sites and kaitiakitanga practices and obligations.
Policy readiness		
Overall assessment	Moderate gaps	While foundational strategies and funding mechanisms exist, tourism adaptation remains fragile due to limited/fragmented statutory support, weak strategic coherence and gaps in long-term resilience planning and environmental safeguarding.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it has a strong connection to the risks in the built environment and natural environment.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

DOMAIN: Governance

This domain covers the systems and frameworks that guide how decisions are made, shaping how people, communities and institutions plan, act, adapt and are supported in a changing climate.

As set out throughout this risk assessment, adaptation presents complex challenges and choices affecting the systems Aotearoa New Zealand relies on for economic, social, cultural and environmental wellbeing. This includes roles and responsibilities, powers and duties, funding and financing arrangements, and the systems for monitoring, enforcement and oversight.

This section looks at the ability of governance systems and processes to support those choices and enable action to address those challenges. Governance enhances or reduces the ability to address other risks: good governance helps avoid sharp shocks from forced actions made reactively, and supports investor confidence.

The risks in this domain were identified as one of the most significant in the assessment. Together, they present high potential for adverse consequences by 2050, and acting now provides an opportunity to get ahead of future impacts and address several risks at once. For more, see the Priorities for action report.

Governance is central to adaptation because it influences every other domain. It determines how quickly decisions are taken, how resources are prioritised, and whether the actions that are taken are equitable and effective. As climate change intensifies, the decisions required from Aotearoa New Zealand's governance systems will become more frequent, complex and contested.

Te Tiriti o Waitangi/The Treaty of Waitangi (Te Tiriti/The Treaty) is central to this domain, as it establishes the constitutional relationship between the Crown and iwi/Māori. Te Tiriti/The Treaty also sets obligations about authority, participation and accountability that shape decision-making, including about the climate.

The first national climate change risk assessment laid out significant issues related to governance. This 2026 risk assessment also highlights that governance is an area where improving readiness for climate change would make a significant difference and have nationwide impact.

What makes this domain unique?

Governance is a cross-cutting domain that is both a driver of increased risk and is itself exposed to risk

Governance sits across all the risk assessment domains, shaping how risks are identified, prioritised, funded and managed. Climate change amplifies pressures on governance systems through more frequent extreme events to plan for and respond to, greater fiscal demands and heightened public expectations. Governance risks are therefore barriers and enablers to taking action on adaptation.

Te Tiriti/The Treaty obligations also sit at the heart of governance, requiring the Crown to uphold Te Tiriti/The Treaty in decision-making, planning and resource allocation. These obligations derive from and are clarified in both the general principles of Te Tiriti/The Treaty, as well as in specific settlements between the Crown and iwi.

Existing system limitations will intensify as climate change accelerates

Aotearoa New Zealand has many strong governance features, by international standards. For example, the country has well established institutions, free and fair elections, and an independent judiciary underpinning the rule of law. However, many of the features of how Aotearoa New Zealand is governed were not developed to address the scale and complexity of climate change, and are increasingly under pressure.

Climate change exposes and deepens existing governance limitations. Inequities in exposure and vulnerability, gaps in statutory tools, unclear mandates, fragmented responsibilities, limited capability, inconsistent funding arrangements and variable oversight challenge effective climate decision-making. Climate hazards heighten these challenges by increasing the complexity, urgency and frequency of such decisions. Gaps in Te Tiriti/The Treaty implementation and statutory support for iwi/Māori governance capability may further constrain effective adaptation and reinforce existing inequities.

Governance risks are distinct but interconnected, creating reinforcing cycles

Each governance risk concerns a separate system component (such as mandates, funding, monitoring, capability or Te Tiriti/The Treaty implementation), but these components are tightly interdependent. Role clarity is necessary for efficient coordination, implementation relies on resourcing, monitoring is important for accountability, and Te Tiriti/The Treaty mechanisms can support trust and participation. These interactions create reinforcing feedback loops that amplify system-wide impacts and determine the effectiveness and legitimacy of adaptation.

Effective governance reduces long-term costs and supports wider economic, social and environmental systems

If governance systems overall are not adequate for the scale and complexity of climate-related risk, decisions may be delayed, inconsistent or inequitable. This increases long-term fiscal pressures, heightens exposure for the most vulnerable, and creates risks for economic stability, environmental management and infrastructure resilience. The compounding and cascading effects of climate change further intensify these fiscal pressures, underscoring the need for new approaches to funding adaptation.

Weak governance also threatens institutional legitimacy: people may begin losing confidence in the organisations that are relied on to manage climate change impacts. This can further slow adaptation and undermine collective action.

How does this domain interact with other domains?

Governance shapes all other domains

Governance provides the enabling conditions for adaptation across all domains by shaping the mandates, processes and resources through which risks are managed. Strong and clear climate governance can increase investment confidence, enable coordinated infrastructure planning, support environmental outcomes and lead to more equitable social impacts. On the other hand, capacity and capability constraints across central and local government exacerbate these challenges.

Because the Crown–Māori relationship extends across every sector and region, Te Tiriti/The Treaty-related climate governance arrangements can also have impacts in other domains. This affects environmental management, social wellbeing, economic resilience and the legitimacy of adaptation actions.

Māori perspective

Te Tiriti o Waitangi/The Treaty of Waitangi sets the constitutional foundations for Aotearoa New Zealand

Te Tiriti/The Treaty is integral to the governance domain because it sets the constitutional foundations for how authority is exercised and shared in Aotearoa New Zealand.

Te Tiriti/The Treaty obligations shape how climate decisions are made, including who participates, how accountability is maintained and how adaptation responsibilities are distributed. Mechanisms exist that can give effect to tino rangatiratanga (self-determination), enable iwi/Māori governance authority or integrate mātauranga Māori (historic and contemporary Māori knowledge) into adaptation decision-making, but these mechanisms are not consistent across statutory and regulatory frameworks.

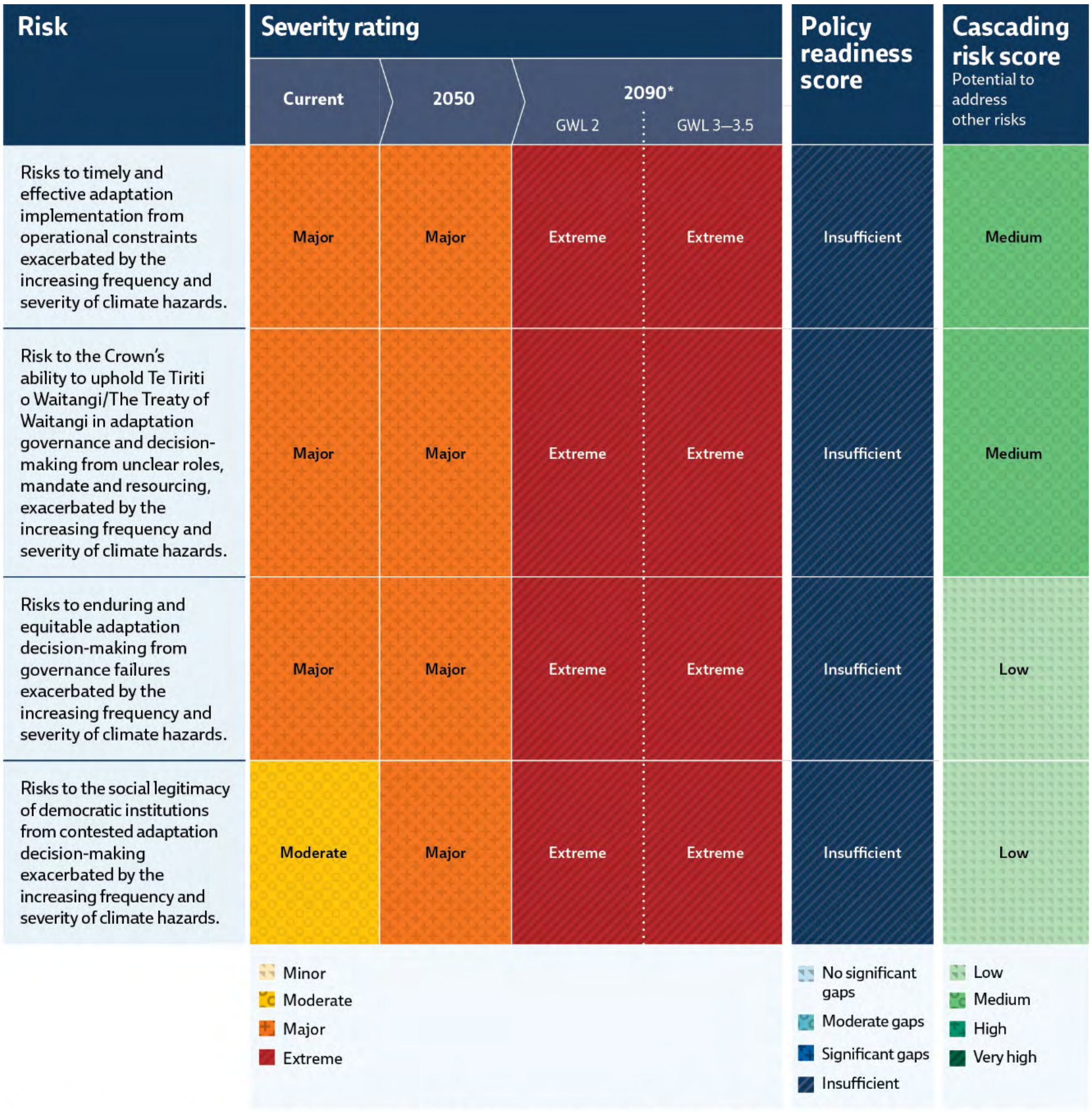
Iwi/Māori are often providing leadership in adaptation action and support after extreme weather events. However, many iwi/Māori organisations lack focused and adequate resourcing to participate effectively in climate governance processes, while they face disproportionate climate exposure linked to historical land confiscations and constraints on developing whenua Māori. Limited statutory pathways for iwi/Māori-led decision-making and culturally informed risk management weaken equitable adaptation and affect the Crown’s ability to meet its Te Tiriti/The Treaty obligations under increasing climate pressures.

Systemic policy issues

There is ongoing reform across key policy areas including resource management and local government. Reform of these systems, alongside and in alignment with the development of the National Adaptation Framework, has the potential to strengthen governance in Aotearoa New Zealand, setting up for effective adaptation-related decision-making. At this stage, it is too early to assess how these reforms will support adaptation. While these reforms are ongoing there is uncertainty that can delay implementation, and the resources of relevant institutions and organisations are focused on the reforms themselves rather than implementation.

A coherent and enduring approach to adaptation governance will reduce barriers to action and enable effective and efficient policy choices.

Table 3.7: Risk ratings for Governance



Risk	Severity rating				Policy readiness score	Cascading risk score Potential to address other risks
	Current	2050	2090*			
			GWL 2	GWL 3–3.5		
Risks to timely and effective adaptation implementation from operational constraints exacerbated by the increasing frequency and severity of climate hazards.	Major	Major	Extreme	Extreme	Insufficient	Medium
Risk to the Crown's ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and decision-making from unclear roles, mandate and resourcing, exacerbated by the increasing frequency and severity of climate hazards.	Major	Major	Extreme	Extreme	Insufficient	Medium
Risks to enduring and equitable adaptation decision-making from governance failures exacerbated by the increasing frequency and severity of climate hazards.	Major	Major	Extreme	Extreme	Insufficient	Low
Risks to the social legitimacy of democratic institutions from contested adaptation decision-making exacerbated by the increasing frequency and severity of climate hazards.	Moderate	Major	Extreme	Extreme	Insufficient	Low

Severity rating	Policy readiness score	Cascading risk score
Minor	No significant gaps	Low
Moderate	Moderate gaps	Medium
Major	Significant gaps	High
Extreme	Insufficient	Very high

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0-3.5°C by 2090 (GWL 3-3.5).

RISK: Effective adaptation implementation

Risks to timely and effective adaptation implementation from operational constraints exacerbated by the increasing frequency and severity of climate hazards.

This risk is about the capacity of communities, organisations and systems to take action, and how this capacity can be affected by climate hazards.

Timely and effective adaptation actions are critical to safeguarding and reducing risk to Aotearoa New Zealand's people, assets and ecosystems from intensifying and increasing climate hazards. Flooding, coastal inundation, sea-level rise (SLR), drought and wildfire are already resulting in increasing social, economic and cultural losses.[165,777] These impacts are projected to accelerate, yet the capacity of the system to implement adaptation measures remains limited.

This risk arises from the challenges converting adaptation intent into sustained implementation. Drivers of this risk include inconsistencies across sectors and unclear accountabilities,[46,778] as well as persistent workforce shortages and coordination gaps.[415,779] This is distinct from governance durability issues, which are addressed in the enduring governance risk.

Climate change hazards magnify these constraints, as each major event redirects resource and effort towards emergency recovery, delaying attention to and investment in long-term risk reduction.[11] This self-reinforcing cycle leaves communities more exposed to future hazards and erodes institutional capacity to adapt.

This was identified as one of the most significant risks as part of the combined governance risk

Three of the four governance risks were rated at major severity in the present day, and the other was at major by 2050. All four governance risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to governance together satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050 and, because of the very low base of current readiness, significant lead time is required to prepare for them. More detail about these risks is contained in the Priorities for action report.

Risk overview

Local government lacks options for funding and financing and capacity for delivery

Local government's roles in relation to land-use planning, infrastructure, community services and emergency response mean that local government is vital to adaptation. Currently, local government's ability to deliver adaptation action is constrained.[46] The scale of adaptation, upgrading infrastructure, enabling managed retreat and planning resilient development, exceeds available resourcing in terms of both financial resource and technical capacity.[779]

Central government coordination can help increase efficiencies across local government entities, as can the coordinating functions of organisations like Local Government New Zealand and Te Uru Kahika. Without coordination, councils may duplicate work and develop contradictory approaches, which is likely to increase costs and slow implementation.

Some councils have begun important work understanding climate hazards in their areas and working with communities and infrastructure providers to increase resilience. Larger councils, such as Auckland, have more resources available to do this, while many small and rural councils experience skill shortages and fiscal stress, often relying on consultants whose expertise is not retained in-house, while staff turnover after major events further erodes continuity and learning.[415,436]

Small and rural councils are under most pressure

Some smaller, rates-constrained councils such as those in the West Coast, Southland and Te Taitokerau/Northland face disproportionately high hazard exposure while having few staff working on climate adaptation and limited resourcing to plan and implement adaptation measures. Nevertheless, some small councils have made great progress, such as that highlighted in the Commission’s Northland case study. Often such actions have been achieved with central government funding contributions.

All councils face challenges funding the maintenance of existing infrastructure, and this is often harder in councils with a smaller rating base. Upgrading infrastructure can be expensive, but is important for resilience: see the *Built environment* chapters. Smaller councils may encounter operational limits sooner as hazard frequency increases and infrastructure renewal demand accelerates (for example, as assets reach end-of-life and repeated weather events put further pressure on budgets).

Durable funding and financing options and capability pathways would assist with reducing the gaps between smaller and larger councils.

Short-term funding does not support long-term decision-making

Most adaptation activity relies on short-term appropriations or contestable grants; this approach constrains longer-term resilience planning and investment.[777,778] With a cost-sharing framework between central government, councils and communities signalled but not yet developed, difficult adaptation decisions, such as managed retreat, are repeatedly deferred, producing a form of institutional paralysis.[415] Over time, this deferred decision-making risks triggering step-change consequences like the inability to insure, stranded assets or sudden policy shifts, once hazards or financial stress exceed local capacity to respond. Overcoming these challenges would underpin adaptation action that is timely and smoother.

Implications of this risk for iwi/Māori include short-term and unstable funding, and delays to adaptation measures

Iwi/Māori play critical roles in adaptation governance and delivery, but under-resourcing of operational capacity (including technical staff, specialist expertise and project management) and a lack of sustained funding for capability building limit their capacity to act. Iwi/Māori are often expected to participate in consultation without equitable funding or access to technical support.[155] Short-term engagement models and project-based grants or unstable funding[176] do not support the development of long-term adaptation capability, while gaps in statutory direction for adaptation on whenua Māori can constrain the ability of owners and trustees to manage risk effectively.[444,516]

Compounding and cascading factors

Hazards affect budgets and workforce capability, while expenditure is reactive not long term

Repeated hazard events divert resource and effort toward recovery, reducing the capacity for proactive adaptation.[11] Over time, this produces attrition, institutional fatigue and erosion of expertise.[11,436,444] Reactive expenditure also reduces the fiscal space for long-term adaptation investment.[777] When adaptation projects are delayed or unevenly implemented, community trust and investor confidence can decline, amplifying social and economic vulnerability.[778] If confidence erodes faster than public systems can demonstrate delivery improvement, market actors may rapidly shift investment patterns before adaptation governance catches up, causing shocks. This could create an inflection point where public governance systems lose influence over decisions about how to adapt, and accountability to the public becomes less clear.

Interaction with emissions reduction

Workforce and funding constraints that limit adaptation delivery also hinder progress on emissions reduction. When adaptation is reactive, through rapid rebuilds or carbon-intensive infrastructure, it can inadvertently increase emissions.[48]

Policy readiness assessment

Current policies offer operational support, but lack implementation capacity and coordination strategies

The system’s current policy and legislative architecture provide limited operational support for adaptation delivery. The national adaptation plan (2022) sets out objectives and actions across government. However, it does not include actions focused on key aspects of adaptation delivery, including a workforce development strategy, dedicated funding streams and financing tools, and coordination structures with authority to direct resources or resolve bottlenecks.

The Climate Change Response Act 2002 establishes monitoring and reporting obligations but does not create delivery mechanisms, fund implementation capacity or establish coordination authority. The Climate Change Interdepartmental Executive Board provides oversight and tracking of policy implementation.

The National Adaptation Framework (2025) (NAF) is a non-statutory policy framework that sets out the Government's long-term direction for adaptation. However, the framework does not directly address delivery and operational capacity constraints. The extent to which the NAF helps to address these constraints will depend on whether the NAF is paired with resourced delivery mechanisms including workforce development programmes, dedicated technical support (especially for small councils) and operational coordination with authority to resolve implementation barriers.

For example, the Government has announced that local government will be required to develop adaptation plans in priority areas. Addressing the workforce and resourcing constraints already faced by local government will be important for ensuring councils can effectively deliver on that requirement. Guidance and nationwide standardisation on the process for developing and implementing plans will be important for consistency, and to support efficiencies across local government entities.

Adaptation implementation requires workforce planning, technical support and regional and iwi/Māori expertise

Adaptation implementation requires sufficient workforce capability, operational coordination and sustained investment. Current evidence shows all three are inadequate.[415,780] Councils face skill shortages and high staff turnover. Contributing to this, professional pathways for climate adaptation specialists are not well developed, while technical support for complex tasks (for example, climate modelling, retreat planning, infrastructure design) is concentrated in large centres, leaving small and rural councils dependent on expensive external consultants.[415]

Many iwi/Māori organisations similarly lack access to dedicated technical support or training programmes to build in-house adaptation capability. These capacity constraints require sustained investment in workforce planning and development, technical support and coordination systems.

Long-term adaptation measures are constrained by short-term funding

Local authorities are often reluctant to commit ratepayer funds to major adaptation initiatives (managed retreat, infrastructure upgrades) without assurance of Crown co-investment, while central government agencies lack mechanisms to allocate funding directly to delivery.[415,444] This can result in a coordination failure where even parties that do have resources choose not to deploy them without assurance of matched investment from others.

Gaps for risk severity and policy

While multiple inquiries and surveys consistently report fragmented mandates, volatile funding and capability shortages, the evidence base for how and where delivery constraints materially affect adaptation outcomes is incomplete. There is no national baseline on operational capacity across councils and iwi/Māori organisations; nor has there been systemic tracking of specific indicators focused on coordination, funding settings or tools since the first risk assessment.

On policy readiness, there are reforms and actions that could enable effective adaptation decision-making, but limited evidence of implementation of adaptation solutions on the ground. The Government reports on delivery of adaptation actions through the Interdepartmental Executive Board and the Commission reports on the implementation of policies and effectiveness of the Government's plan. However, there is no systemic monitoring and reporting on funding for Māori-led initiatives. The absence of outcome-level evidence means readiness remains evaluated largely from policy design than demonstrated action.

Summary

The risk to adaptation delivery and implementation reflects significant challenges to the system's ability to implement at the speed and scale required by climate change. It is driven by operational capacity constraints such as workforce shortages, fragmented coordination structures, inadequate technical support and unsuitable or lack of funding and financing mechanisms. Climate hazards expose and intensify these issues, diverting resources and effort into emergency recovery, at the expense of investment in proactive adaptation that could reduce future impacts. Overcoming these challenges would make broader adaptation responses smoother.

Risk scorecard: Effective adaptation implementation

Risks to timely and effective adaptation implementation from operational constraints exacerbated by the increasing frequency and severity of climate hazards.

Identified as one of the most significant risks as part of the combined governance risk.

	Score	Rationale
Risk severity		
Now	Major	Adaptation implementation capacity is patchy and uncoordinated around the country. Councils and iwi/Māori leading adaptation action face long lead times, siloed operations and limited funding. Workforce shortages and unclear accountabilities worsen these constraints.
2050	Major	Delivery is likely to be increasingly hampered by unclear roles and uncoordinated funding as climate hazards intensify, unless these issues are addressed.
2090*	Extreme GWL 2	Capability and funding gaps are likely to widen further in the face of growing need for widespread adaptation. Without sufficient coordination and funding, poorly targeted and/or under-resourced interventions could create a high probability of maladaptation.
	Extreme GWL 3–3.5	Governance systems are likely to face repeated, cascading events that overwhelm already-stretched capacity.
Policy readiness		
Overall assessment	Insufficient	Current policy and legislative architecture provide limited operational support for adaptation delivery. Policy lacks implementation mechanisms, including a workforce development strategy, dedicated funding streams and coordination structures with authority to direct resources or resolve bottlenecks.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium overall potential to address others in the assessment, including all the others in the *Governance* domain.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation

Risk to the Crown's ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and decision-making from unclear roles, mandate and resourcing, exacerbated by the increasing frequency and severity of climate hazards.

Climate change presents a growing risk to the Crown's ability to uphold its obligations to Māori, established by Te Tiriti o Waitangi/The Treaty of Waitangi (Te Tiriti/The Treaty), within adaptation governance. As climate hazards intensify, strains on Māori–Crown relationships are likely to face further pressures. Adaptation efforts are likely to be more effective if they enable iwi/Māori to adapt their communities in ways that are consistent with their tikanga and priorities.

The Climate Change Response Act 2002 requires the Commission to have regard to "the Crown–Māori relationship, te ao Māori, and specific effects on iwi and Māori". The Crown's actions and abilities to uphold Te Tiriti/The Treaty in adaptation governance are relevant to that, but it is not the role of the Commission to assess directly whether the Crown has upheld Te Tiriti/The Treaty.

Iwi/Māori often exercise rangatiratanga and leadership in responding to climate hazards. The Government Inquiry into the Response to the North Island Severe Weather Events [11] and the Ministerial Inquiry into Land Use in Tairāwhiti and Wairoa (2023)[531] both recommend Te Tiriti/The Treaty consistent governance with stronger Māori decision-making roles. The Expert Working Group on Managed Retreat (2023)[516] sets out tikanga-informed pathways.

Recent Crown actions in broader environmental policy areas that may be perceived to reduce the roles of iwi/Māori in decision-making, alongside decisions to reduce some funding streams for Māori climate adaptation, may increase the likelihood that iwi/Māori continue to be disproportionately affected by climate change, and that government policies further affect the ability of iwi/Māori to deal with the impacts of climate change.

As the Crown comes under increasing pressure generally from more frequent and severe climate hazards, these are likely to place further pressures on the Crown–Māori relationship. This in turn could reduce the effectiveness of Aotearoa New Zealand's adaptation system's collective adaptation efforts in the coming decades.

This was identified as one of the most significant risks as part of the combined governance risk

Three of the four governance risks were rated at major severity in the present day, and the other was at major by 2050. All four governance risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to governance together satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050, and, because of the very low base of current readiness, significant lead time is required to prepare for them. More detail about these risks is contained in the Priorities for action report.

Risk overview

The Crown's broader actions provide the context for climate-related Te Tiriti/The Treaty risks

There is a specific risk to the Crown arising from Te Tiriti/The Treaty and any potential breaches, and there is also a broader, fundamental risk for sustainable adaptation efforts. When Te Tiriti/The Treaty responsibilities are not adequately understood or upheld, the result is usually an erosion of the Crown–Māori relationship.

Given the many points of pressure currently affecting the Crown–Māori relationship across a wide range of issues and concerns, it is crucial that adaptation efforts not only meet legal obligations but also actively strengthen the partnership. This includes demonstrating integrity in Te Tiriti/The Treaty commitments, maintaining meaningful and ongoing engagement with Māori, and ensuring Māori perspectives, rights and decision-making authority are embedded throughout adaptation planning and implementation.

Adapting in a way that reflects genuine partnership offers an opportunity to reinforce the relationship and support more equitable and resilient outcomes for both Māori and the Crown. Conversely, failing to do so would risk compounding existing grievances, undermining trust, and reducing the effectiveness, legitimacy and long-term durability of adaptation strategies.

Consistent guidance supports shared understanding

Central and local government agencies operate without consistent guidance on how to implement Te Tiriti/The Treaty in adaptation. Each council implements its own approach, leading to an inconsistent approach nationally. This could lead to divergent climate impacts for iwi/Māori.

Meanwhile, iwi/Māori participation in adaptation governance remains largely consultative and constrained with available resourcing. As a result, iwi and hapū are often required to engage in multiple Crown- or council-led processes without the authority or investment to shape decisions. This places additional pressure on iwi/Māori, who are often already being asked to interact with the Crown across a range of other reforms and issues.

Hazards are already damaging taonga (treasures)

Hazards are already damaging taonga unevenly across regions, with Te Taitokerau/Northland, Bay of Plenty, Hawke's Bay and the East Coast experiencing disproportionate impacts due to the overlap of high climate exposure (coastal erosion, flooding, sea-level rise (SLR)) and high concentrations of whenua Māori, marae, urupā (burial ground) and mahinga kai (food gathering practices and places).[157] Adaptation planning and frameworks rarely integrate or value local mātauranga Māori (historic and contemporary Māori knowledge) or uphold rangatiratanga (authority, autonomy).[46] As climate change increases and intensifies over time these hazards will place further pressure on local and central government, in turn placing pressure on the relationships with iwi/Māori, which could accelerate governance failures.

Implications of this risk for iwi/Māori include impacts on self-determination

Failure to uphold Te Tiriti/The Treaty in adaptation governance would have severe and compounding effects for iwi, hapū and whānau. Intensifying hazards threaten marae, urupā (burial grounds), whenua Māori, mahinga kai (food gathering practices and places) and taonga species; exclusion from decision-making over how these hazards are addressed limits the ability of iwi and hapori Māori (Māori communities) to determine how their communities are protected or, in some cases, potentially relocated.[781]

Compounding and cascading factors

Broader tensions in the Crown–Māori relationship affect climate adaptation

Climate change interacts with other issues affecting the Crown–Māori relationship and the decisions the Crown makes with regard to Te Tiriti/The Treaty. Climate adaptation is viewed as part of the broader Crown–Māori relationship. There are longstanding structural factors such as land tenure constraints, housing quality and health conditions that interact with climate change. This means there are relationships between all aspects of the Crown–Māori relationship and the Crown's more specific abilities to uphold Te Tiriti/The Treaty obligations that relate to climate change.

For example, loss of access to whenua (land), waterways and taonga sites weakens cultural continuity, disrupts mātauranga Māori and collective wellbeing, contributing to intergenerational harm.[444] This may contribute to existing socio-economic inequities. At the system level, fragmented governance and persistent exclusion limit adaptive capacity, increasing the likelihood of maladaptation across housing, health and natural systems – increasing exposure to climate-related hazards.

Policy changes are already affecting iwi/Māori communities

The Crown's decision to reduce funding for the Māori Climate Action Platform without announcing any new funding past the end of the current funding cycle, and to not introduce legislated partnership mechanisms, reduces the means to exercise rangatiratanga or integrate mātauranga Māori into adaptation responses.[176]

When adaptation funding, managed retreat, land management or resilience decisions proceed without Te Tiriti/The Treaty partnerships, whenua Māori, housing and infrastructure are more likely to be lost or devalued. This is likely to result in deepening inequities and place further strain on the Crown–Māori relationship.[155]

Interaction with emissions reduction

Through the New Zealand Emissions Trading Scheme (NZ ETS), forestry has played an important role in Aotearoa New Zealand's approach to emissions reduction under successive governments. Many iwi/Māori landowners have registered exotic pine forestry in the NZ ETS. The design of the NZ ETS creates barriers to changing the use of this land (as well as for iwi/Māori landowners of pre-1990 exotic forests).[782]

The *Forestry* risk in this report outlines risks arising from climate change that are relevant to Māori foresters: iwi/Māori will be affected by the risks climate change pose to the forestry sector, including extreme rainfall, windthrow, wildfire and drought. Actions to address risks to forestry as climate hazards intensify are an opportunity for the Crown to demonstrate its commitment to Te Tiriti/The Treaty.

Policy assessment

Te Tiriti/The Treaty references are inconsistent across adaptation frameworks

Some legislation that is central to climate adaptation includes Te Tiriti/The Treaty. This includes the Climate Change Response Act 2002 and the Local Government Act 2002, although neither establishes enforceable Māori governance roles or resourcing. No long-term national Māori adaptation policy framework or resourcing exists.

The 2025 National Adaptation Framework (NAF) sets out that central government establishes standards, regulations and institutional settings while local government leads local responses. The NAF is intended to clarify roles and cost-sharing but it is unclear if or how this will relate to iwi/Māori as the NAF does not include references to iwi/Māori or Te Tiriti/The Treaty.[176] Recent policy changes have removed or reduced targeted funding streams, including those that supported Māori-led adaptation under the 2022 national adaptation plan.

Partnership approaches are discretionary when they don't have legislative foundations

Partnership approaches to adaptation exist in many parts of Aotearoa New Zealand, often driven by decisions and commitments at a local level. However, nationwide, current policies and structures do not ensure the Crown upholds Te Tiriti/The Treaty in adaptation; this can have effects on the Crown–Māori relationship and national capacity to adapt to the effects of climate change. This is in part due to an inconsistent approach to roles and responsibilities split across multiple agencies at both a local and central level, and a lack of clarity regarding the roles of the Crown and Māori in climate adaptation. The current approach lacks strong foundations, such as a legislated mandate for shared decision-making, enduring resourcing for iwi and hapū participation, and accountability mechanisms that drive the positive outcomes that could be realised through the Crown–Māori relationship. Partnership is often discretionary – dependent on local goodwill rather than embedded in law or funding design.

Engagement and consultation are inconsistent

Inconsistent consultation with iwi/Māori arises from capability gaps across both Crown institutions and local government as well as system design issues. The Crown retains centralised control of adaptation policy while devolving delivery to local authorities that often lack Te Tiriti/The Treaty capability and clear guidance. Engagement with iwi/Māori is often ad hoc and uneven, reliant on local government capacity and political will.[154,155] Consultation is often transactional, which can lead to participation fatigue for iwi and hapū who have a range of pressing issues that the Crown seeks to engage on, with varied influence over outcomes. Fragmented reforms across resource management and emergency management could create inconsistent obligations and limited accountability. Although some regional partnerships (such as Mana-to-Mana in Otago and Maketū Iwi Collective) demonstrate good practice, these are often because of individual champions rather than system design.[154,155]

Gaps for risk severity and policy

The Crown does not appear to systematically monitor or evaluate how adaptation decisions uphold the Te Tiriti/The Treaty, meaning visibility of performance and outcomes can be unclear. Where the Crown has removed Te Tiriti/The Treaty obligations from policy frameworks and reduced Māori adaptation funding, these actions appear likely to reduce the Crown's ability to uphold Te Tiriti/The Treaty. They are also likely to affect the Māori–Crown relationship.

Summary

The Crown's ability to uphold Te Tiriti/The Treaty in relation to adaptation governance is at risk. While some local initiatives demonstrate what Te Tiriti/The Treaty-consistent adaptation can achieve, progress remains fragmented and dependent on individual leadership. The Commission has a legislated role to consider the Crown–Māori relationship but does not evaluate or assess potential or alleged breaches of Te Tiriti/the Treaty.

It is unclear if or how the National Adaptation Framework and associated reforms will clarify the role of iwi/Māori or the Crown–Māori relationship in adaptation, or set out enduring resourcing or mechanisms for Māori-defined adaptation initiatives. Without these structural foundations, the governance system is likely to remain reactive and inequitable, reproducing and potentially exacerbating the vulnerabilities it seeks to reduce.

Taking action now to strengthen the foundations of the Māori–Crown relationship, and the Crown's abilities to uphold its Te Tiriti/The Treaty responsibilities, will help ensure that as climate change intensifies and governance systems generally come under increasing and competing pressures, appropriate systems and frameworks are in place to support Te Tiriti/The Treaty to be upheld.

Risk scorecard: Ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation

Risk to the Crown's ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and decision-making from unclear roles, mandate and resourcing, exacerbated by the increasing frequency and severity of climate hazards.

Identified as one of the most significant risks as part of the combined governance risk.

	Score	Rationale
Risk severity		
Now	Major	Uneven approach often reliant on local actions. Māori-led adaptation strategies and inclusion are often under-resourced. Treaty partnership roles are not embedded. Lack of statutory mechanisms leads to inequities in adaptation decision-making and resourcing.
2050	Major	Pressures on iwi/Māori likely to intensify if repeated, unfunded consultation requirements increase. Growing implications for the Crown–Māori relationship.
2090*	Extreme GWL 2 Extreme GWL 3–3.5	Treaty obligations highly likely to be unmet across adaptation systems. High risk of breakdowns in Crown–Māori relationships.
Policy readiness		
Overall assessment	Insufficient	Legislation and policy responses are insufficient, with major gaps in funding, capability and inclusion of iwi/Māori perspectives and leadership in adaptation governance.
Cascading risk		
Overall assessment	Medium	Addressing this risk has medium overall potential to address others in the assessment, including all the others in the Governance domain.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Enduring adaptation governance

Risks to enduring and equitable adaptation decision-making from governance failures exacerbated by the increasing frequency and severity of climate hazards.

Climate adaptation requires institutional commitments that endure across time. There is general widespread agreement in favour of durable policy frameworks and mechanisms that support long-term decision-making, but Aotearoa New Zealand's governance system has so far produced limited outcomes.[46,415,779] This risk is separate from delivery constraints such as workforce and funding gaps, which are addressed in the *Effective adaptation implementation* risk.

Some legislative frameworks have been put in place, such as the one under which this risk assessment is produced. However, ongoing and varied institutional reform proposals have produced governance discontinuity rather than substantive change over the past decade. Major reforms to resource management and climate adaptation legislation have been announced, repealed or superseded before being implemented, affecting the ability of local government and other implementation agencies to plan confidently for the 20–50-year horizons necessary.

With increasing frequency and severity of climate hazards, decision-makers face incentives to take immediate actions in response. It is important to respond to events, but without enduring frameworks, immediate responses can direct energy and resources away from long-term resilience planning.

Short-term incentives for undertaking visible actions appear to have outweighed those for reducing long-term risk, leaving the system exposed to escalating hazard losses and institutional fatigue.[783] Continuous proposals, reviews and revisions create the appearance of progress, while the underlying mandates and incentives remain largely unchanged.

Climate hazards intensify these governance weaknesses, exposing institutions, iwi/Māori and communities to higher physical and fiscal risks when reforms delay or reverse investment in adaptation.[784,785] Without institutional mechanisms that support continuity, adaptation frameworks remain vulnerable to change and delay, contributing to fiscal exposure, regulatory uncertainty and fragmented delivery.

This was identified as one of the most significant risks as part of the combined governance risk

Three of the four governance risks were rated at major severity in the present day, and the other was at major by 2050. All four governance risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to governance together satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050, and, because of the very low base of current readiness, significant lead time is required to prepare for them. More detail about these risks is contained in the Priorities for action report.

Risk overview

Institutional design features are needed to support stable adaptation policy as hazards intensify

Effective climate adaptation depends on governance systems capable of sustaining long-term commitments, alongside immediate responses to climate hazards when they occur.[785] This requires institutional design features such as bipartisan agreements, independent oversight bodies, protected funding and financing streams and statutory mechanisms that reduce the liklihood of reversal. Currently, Aotearoa New Zealand's adaptation governance system lacks some of these protective features, and tends towards repeating reforms and reactive responses.

Over the past decade, overlapping reforms and changing mandates have led to institutional volatility that prevents policy maturation and institutional learning. This has meant that governments have developed and announced adaptation policies, councils and implementation agencies have begun planning in response, then the policy frameworks have been revised or repealed before they have been implemented or evaluated.[46,165,415,444] This has created a pattern of reform and an implementation gap where resources are repeatedly redirected toward designing new systems rather than operating existing ones.

Uncertainty affects infrastructure investment decisions

The consequences of this pattern extend beyond administrative inefficiency. Councils report that policy uncertainty constrains their ability to make long-term infrastructure investments, adopt district plan provisions or commit to managed retreat pathways .[786] Private investors similarly defer decisions when regulatory settings are not perceived to be durable.

Legislated Treaty of Waitangi settlements can provide durable iwi/Māori partnerships

Where Te Tiriti o Waitangi/The Treaty of Waitangi settlements have created legislative partnership arrangements, the conditions for durable governance arrangements have often been strengthened. National policy instruments acknowledge mātauranga Māori (historic and contemporary Māori knowledge), yet stop short of creating Te Tiriti/The Treaty-based mandates or statutory pathways for hapū-led planning.

On the other hand, some mechanisms for Māori–Crown partnerships are susceptible to disestablishment or uncertain resourcing, which can create reluctance to invest in processes that may not endure. Māori-led adaptation demonstrates leadership through iwi consultancies, post-settlement governance entities and regional partnerships.[154] These often depend on discretionary arrangements rather than statutory mechanisms.[165,415,787] This can delay the evolution of Te Tiriti/The Treaty-based partnerships into stable institutional arrangements.[155,415,788]

Compounding and cascading factors

Frequent changes in legislative arrangements and adaptation policy frameworks create a pattern that hinders effective implementation of adaptation actions.[402,434] This can compound fiscal, institutional and social vulnerabilities.

Major events trigger reactive reform cycles

Major events such as Cyclone Gabrielle trigger reactive reform announcements rather than consolidation or progress of existing commitments.[11,165] Furthermore, recovery decisions have often been made case-by-case in the absence of durable frameworks, reinforcing policy uncertainty. As a result, councils can be faced with unclear choices and potentially stranded investments, discouraging proactive adaptation.[415]

Lack of implementation can erode public trust

Repeated reform cycles without implementation can undermine public confidence in the Government's ability to manage long-term risks. For example, communities facing adaptation decisions (such as how or where to rebuild damaged infrastructure) will benefit from institutional stability and clarity, without which they may lose trust in institutional commitments and the value of cooperation.[444] If this creates barriers to agreeing a common way forward, political willingness to make difficult adaptation decisions may be reduced, creating a self-reinforcing cycle of delayed action.

Policy discontinuity compounds fiscal risk, but proactive investment could reduce this

The fiscal consequences of policy changes compound over time. Post-disaster costs absorbed by the Crown are projected to rise from NZ$0.7 billion in 2020 to NZ$3.3 billion in 2050.[789] However, policy discontinuity hinders the proactive adaptation investments that could reduce these future liabilities. Without durable frameworks, reactive expenditure cycles continue.[516,778]

Interaction with emissions reduction

Investors take confidence from stable policy direction: institutional instability and policy discontinuity can undermine emissions reduction efforts by disrupting investment signals. Frequent policy changes also weaken opportunities for joint mitigation-adaptation design, by incentivising quick, short-term choices. Policy durability is required to commit capital and capability to long-term adaptation planning.[790]

Policy readiness assessment

Broad national frameworks exist

The Climate Change Response Act 2002 sets out a broad national framework to guide national adaptation policies – including the preparation of risk assessments like this one every six years, national adaptation planning in response and regular monitoring of national adaptation plans. This cycle is intended to support enduring decision-making, while allowing for flexibility in response to changing priorities. The Commission will publish a progress assessment of the first national adaptation plan later in 2026, and this risk assessment will inform the second plan in 2028.

Existing statutes such as the Resource Management Act 1991, Local Government Act 2002 and Civil Defence Emergency Management Act 2002 provide adaptation levers but are themselves subject to continuous reform, reducing the institutional stability that would support long-term implementation.

In December 2025, a new National Policy Statement for Natural Hazards 2025 (NPS-NH) came into effect. This requires local authorities to assess and manage natural hazard risks in a consistent way, with a focus on avoiding very high risk, using the best available information. The NPS-NH sets a national baseline but allows for local flexibility, including more conservative provisions. The NPS-NH is a transitional measure while the broader reforms to the resource management system are being developed and implemented.

Enduring frameworks balance stability with flexibility, underpinned by accountability

Without statutory direction or protected funding, adaptation initiatives are subject to shifting priorities, annual budget decisions and individual champions – all vulnerable to change. Dispersed responsibilities across central and local government, combined with the absence of a statutory coordination mandate, enable accountability shifting rather than coordinated and sustained action.

Funding and financing arrangements remain fragmented, with cost-sharing principles between central and local government for adaptation planning and action unresolved.[784] Governments preserve fiscal optionality through discretionary annual appropriations rather than committed multi-year funding. However, this creates investment uncertainty for councils, iwi/Māori and other potential investors who wish to plan major adaptation initiatives with assured funding and financing pathways.[415,786,791]

Gaps for risk severity and policy

Evidence gaps constrain assessment of both risk severity and policy effectiveness. Data on iwi/Māori participation and capability are incomplete, and local government capacity is not consistently tracked.

Summary

Without stronger long-term adaptation frameworks with widespread support to provide stability and clear accountabilities to drive implementation, short-term and reactive responses could undermine effective long-term decision making and increase costs.

Governance and policy discontinuity, the pattern of reform without implementation, is a fundamental constraint on adaptation, distinct from operational delivery challenges. The system lacks mechanisms to protect adaptation commitments from disruption, enabling policy changes before outcomes can be realised or evaluated.

This creates compounding effects where frameworks are reversed before implementation. It prevents institutional learning, while councils, iwi/Māori and investors defer decisions due to uncertainty. Repeated reform cycles can erode public confidence. Climate events trigger further reactive reform rather than continuation and consolidation. This escalates fiscal exposure as the Crown absorbs growing post-event costs, reducing capacity to invest in resilience.

Risk scorecard: Enduring adaptation governance		
Risks to enduring and equitable adaptation decision-making from governance failures exacerbated by the increasing frequency and severity of climate hazards.		
Identified as one of the most significant risks as part of the combined governance risk.		
	Score	Rationale
Risk severity		
Now	Major	Unclear and inadequate legislation and frameworks are creating widespread difficulties in planning for adaptation. Councils and iwi/Māori are actively calling for greater statutory direction. Regulatory uncertainty constrains adaptation planning and weakens system effectiveness.
2050	Major	Increasing chances that long-term adaptation planning and investment become unviable if mandates and funding remain uncertain.
2090*	Extreme GWL 2 Extreme GWL 3–3.5	Significant threat that a coordinated climate response becomes unviable. As a result, state institutions may struggle to coordinate or function more generally.
Policy readiness		
Overall assessment	Insufficient	The system lacks mechanisms to protect adaptation commitments from disruption, enabling policy reversal before frameworks can mature or be evaluated.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it has strong connections to the risks to the legitimacy of democratic institutions and the ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

RISK: Legitimacy of democratic institutions (from contested climate decision-making)

Risks to the social legitimacy of democratic institutions from contested adaptation decision-making exacerbated by the increasing frequency and severity of climate hazards.

Climate adaptation raises complex issues for affected communities, governance systems and decision-makers. Working through disagreements to arrive at agreed ways forward is a core function of effective governance systems and democratic institutions. If the systems to resolve disagreements aren't working well, people can lose faith in the whole system. Taking action to strengthen democratic institutions is a foundational way to create the conditions in which Aotearoa New Zealand is enabled to make complex decisions about climate adaptation.

As climate impacts intensify, adaptation decisions will become more contested, requiring institutions to balance competing values in an uncertain environment. In the context of adaptation, legitimacy is built both through the processes used, such as engagement, consultation and recognition of Te Tiriti o Waitangi/the Treaty of Waitangi (Te Tiriti/The Treaty) and through the perceived fairness and consistency of the outcomes delivered.

Climate change will increase the frequency and severity of events that test institutional performance, while also amplifying other social and political tensions. Decisions on who bears the costs of adaptation (such as through managed retreat, funding allocation or infrastructure withdrawal) raise issues of distributive justice, procedural fairness and trust in authority.[516] If adaptation processes are perceived as opaque, inconsistent or exclusionary, public confidence is likely to erode.[415,444,792]

This was identified as one of the most significant risks as part of the combined governance risk

Three of the four governance risks were rated at major severity in the present day, and the other (this risk to the legitimacy of democratic institutions) was rated moderate in the present day but was at major by 2050. All four governance risks were assessed as insufficient (the lowest score) for readiness. We combined these risks as one of the most significant because they are similar in scope, they can be addressed by similar actions and combining them would support action. The combined risk to governance together satisfied the first two principles of our review for significance: they present high potential for adverse consequences now, with little in place to address them, warranting immediate focus. They will also present high potential for adverse consequences by 2050, and, because of the very low base of current readiness, significant lead time is required to prepare for them. More detail about these risks is contained in the Priorities for action report.

Risk overview

Trust in institutions is supported when decisions are clear, fair and well explained

The social legitimacy of democratic institutions is exposed and vulnerable to the pressures of climate adaptation.[415] Local Government New Zealand reports that intensifying hazards, changes in policy and uneven delivery are straining people's trust in government, particularly at the local level where adaptation decisions are most tangible.[793] A 2023 General Social Survey found declining trust in Aotearoa New Zealand institutions since 2021, with trust in Parliament showing the sharpest drop.[794] Organisation for Economic Co-operation and Development surveys similarly identify variable levels of trust across the public system in other countries.[795]

The risk is driven by procedural and delivery issues. Procedurally, engagement, transparency and application of Te Tiriti/The Treaty obligations are important factors contributing to fairness and accountability. In delivery, different expectations, equitable outcomes and policy continuity can all influence confidence that institutions can and will follow through on commitments.

These patterns are visible in contentious adaptation contexts such as managed retreat, where unclear roles, mandates and compensation frameworks have generated local conflict and legal challenge.[787,796] Recent adaptation processes, such as on the Kāpiti Coast, demonstrate how unclear roles, community fragmentation, scientific disagreement and process uncertainty can translate into procedural conflict, legal challenge and stalled decision-making, illustrating how climate impacts become legitimacy issues rather than solely planning issues. In contrast, South Dunedin residents report that opportunities to participate in adaptation decision-making and community-led processes have contributed to increased confidence in governance processes.[427]

Some communities feel the effects of weak institutional trust more strongly

Exposure to this risk is uneven across communities and regions. Trust in institutions in relation to climate adaptation is related to underlying trust in institutions regarding other issues. Trust tends to be lower among communities experiencing deprivation, low education levels or historical marginalisation.[797] Iwi/Māori, low-income and rural communities are particularly affected, often facing both higher physical climate-related risks and weaker institutional recognition or support.[155,781] Where iwi/Māori are treated as stakeholders rather than Te Tiriti/The Treaty partners, engagement processes may not meet associated legal and cultural requirements and expectations.[798] These pressures become visible where hazard-prone land, local infrastructure withdrawal or zoning decisions disproportionately affect communities, creating heightened expectations for fairness and partnership that institutions often struggle to meet.

Unclear roles and frequent policy changes make institutions harder to trust

Frequent reform cycles, inconsistent or weak mandates and short-term political incentives erode institutional coherence and blur accountabilities.[799] A lack of national direction on adaptation roles and funding leaves councils to navigate politically sensitive decisions without adequate support.[793] Under a high climate impact scenario, legitimacy risks are projected to intensify alongside socio-political polarisations.[800]

Low trust can lead to conflict, slower decisions and reduced cooperation

Aotearoa New Zealand's experience with contested retreat planning shows how climate decisions can stall when institutions lack perceived legitimacy, with conflicts and delays becoming governance outcomes in themselves. The consequences of reduced social legitimacy in democratic institutions include maladaptation, stalled action, escalating contestation and legal challenges, and declining public cooperation with adaptation measures. Over time, these dynamics risk fuelling wider disillusionment with government and weakening overall democratic resilience.[801]

Iwi/Māori may experience greater loss of trust

Iwi/Māori are disproportionately affected by legitimacy risks due to historical exclusion from decision-making and limited capacity to engage across multiple processes.[165,415,444] Adaptation decisions that do not actively seek to strengthen the Crown–Māori relationship or integrate mātauranga Māori (historic and contemporary Māori knowledge), for example for whenua Māori and managed retreat, can erode both fairness and institutional credibility.[46,154] Without iwi-led and Te Tiriti/The Treaty-based approaches, adaptation processes risk continuing historical injustices.[443] See also the *Ability to uphold Te Tiriti o Waitangi/The Treaty of Waitangi in adaptation governance and implementation* section of this report.

When climate pressures outpace trust, institutions risk losing legitimacy

Exposure to legitimacy risk is already visible where adaptation decisions such as managed retreat produce conflict, contestation or litigation because roles, funding criteria and fairness expectations are unclear. Increasing frequency and severity of climate hazards will heighten the value of having credible participation structures in place, without which current gaps may become entrenched. Under a high climate impact scenario, exposure may escalate further as sociopolitical issues, declining trust in science and uneven delivery amplify polarisation and reduce institutional resilience.

Repeated procedural failures, unmet expectations or mis-managed high-stakes decisions erode cooperation. Communities may withdraw from planning processes, resort to litigation or lose confidence in expert advice. A poorly managed disaster, a highly contested retreat programme or a Te Tiriti/The Treaty-based legal precedent could trigger sudden shifts in public confidence and decision authority.

Compounding and cascading factors

Social legitimacy underpins public cooperation and adaptive capacity, so it is connected to the effectiveness of governance across all domains. Credible, transparent and inclusive decision-making can help to prevent democratic institutions becoming both the cause and the consequence of compounding climate and social pressures, where hazard impacts are interpreted as institutional failure rather than environmental stress.

Multiple pressures building at once can deepen mistrust and reduce resilience over time

This risk interacts with and amplifies other governance and adaptation risks. Climate hazards and high-stakes adaptation decisions act as stress tests for institutions. For example, managed retreat processes have already generated local conflict and legal challenge where mandates, roles and perceived unfairness have become legitimacy issues. Declining trust reduces cooperation with adaptation policies, weakens support for funding and reform, and increases vulnerability to misinformation during crises, particularly when communities experience repeated climate shocks or infrastructure failures.

Adaptation decisions that involve relocation, land-use change or redistribution of resources are inherently sensitive. When accountability is unclear or consultation is inadequate, these processes can trigger contestation, protest or non-compliance, further delaying adaptation. Over time, procedural failures and unmet expectations feed back into declining trust, creating self-reinforcing cycles of disengagement and institutional fragility.[795,798,802]

Interaction with emissions reduction

Fair and visible climate action can build trust

Adaptation actions that have widespread support can also increase people’s willingness to choose emissions-reducing behaviours, linking credible adaptation processes with stronger public engagement in emissions reduction.[803] Where emissions reduction policies are perceived as opaque or inequitable, trust in institutions may decline, particularly among communities already under adaptation stress.[802,804]

Policy readiness assessment

Current policies recognise the issue but don’t yet ensure fair or consistent practice

Existing frameworks provide partial coverage of the institutional legitimacy risk but lack enforceable mechanisms for fairness, accountability and Te Tiriti/The Treaty partnership. The Climate Change Response Act 2002 establishes national planning, monitoring and reporting. The National Adaptation Framework seeks to clarify local government requirements for adaptation planning, legislating clearer roles and responsibilities, improving national risk information and cost-sharing principles and mandating adaptation plans in priority areas.

While good practice examples exist at the local level (such as the South Dunedin Futures programme and regional iwi–council partnerships), these are uneven nationwide. Without system-wide standards or accountability mechanisms, institutional legitimacy will continue to depend on discretionary leadership and trust built through individual relationships rather than enduring structures.

Limited capacity and unclear accountability make it hard to maintain or build trust

Implementation is constrained by fragmented mandates, resourcing challenges and limited institutional capability. Councils face capacity pressures, litigation risk and inconsistent national guidance.[796,798] Engagement remains piecemeal and often reactive, shaped by short-term consultations rather than enduring relationships or shared decision-making.[796,798] Under-resourcing is a major constraint, with many councils operating with small, overstretched policy teams and limited communication capacity, constraining their ability to engage deeply or maintain clear communication around climate-related risk.[415] This can be compounded if decision-makers – either by choice or because of limited resources and capacity – prioritise immediate service delivery over long-term adaptation planning, and by the perception within some councils that climate change is too complex or intractable to address.[796] The result is uneven engagement quality and widening gaps in public understanding and trust.[778,795]

If these issues are not addressed soon, trust may decline further as climate impacts grow

As more communities face increasing climate hazards, procedural and institutional gaps in adaptation governance could become entrenched, with fragmented responsibilities and precedent-driven decision-making that are difficult to reverse. The National Adaptation Framework could create an important structural base: its effectiveness depends on matching role clarity with resourced delivery pathways, iwi/Māori participation and transparent support for trade-offs. Statutory foundations, sustained investment and monitoring of procedural integrity will help adaptation choices resolve contestation and strengthen legitimacy as climate pressure intensifies.

Gaps for risk severity and policy

There is a lack of good data on how fair, inclusive and consistent current processes are

Limited monitoring and evidence, particularly around engagement quality, accountability and Te Tiriti/The Treaty partnership practice, complicate assessment of this risk. However, submissions, evaluations and recent inquiries consistently identify recurring issues of unclear mandates, uneven resourcing, eroding confidence and increasing contestation in adaptation governance.

Summary

The legitimacy of Aotearoa New Zealand's democratic institutions underpins the credibility and success of climate adaptation. There are moderate risks to this in the present day but potential for these risks to grow to major by 2050. Embedding participatory, Te Tiriti/The Treaty-based and transparent governance will be critical to maintaining trust, fairness and responsiveness as adaptation decisions become more complex and contested. Some communities, councils and iwi/hapū are demonstrating how strong participatory processes and transparent decision-making can achieve widely supported outcomes – this is needed nationwide.

Risk scorecard: Legitimacy of democratic institutions (from contested climate decision-making)

Risks to the social legitimacy of democratic institutions from contested adaptation decision-making exacerbated by the increasing frequency and severity of climate hazards.

Identified as one of the most significant risks as part of the combined governance risk.

	Score	Rationale
Risk severity		
Now	Moderate	Gaps in mandates and perceptions of failure to act are already affecting confidence in government institutions. There is a moderate risk of declining legitimacy, where unclear responsibilities and contested narratives reduce public confidence in adaptation governance.
2050	Major	Councils and communities are likely to face escalating adaptation needs. Increased chances that trust in accountability and fairness will be eroded if institutions fail to respond, cost-sharing processes are not transparent and impacts are felt unequally.
2090*	Extreme GWL 2	Institutional accountability and mandate gaps will likely persist in a context of escalating climate pressures. There is a threat of systemic governance breakdown if institutions lose credibility and can no longer function effectively.
	Extreme GWL 3–3.5	
Policy readiness		
Overall assessment	Insufficient	Existing frameworks provide partial coverage of the institutional legitimacy risk, but lack enforceable mechanisms for fairness, accountability and Te Tiriti/ Treaty partnership.
Cascading risk		
Overall assessment	Low	Addressing this risk has low overall potential to address others in the assessment, though it has strong connections to the risks to enduring adaptation governance.

*Global warming levels for 2090 indicate lower and higher climate impact scenarios. The low climate impact scenario is based on global warming of 2.0°C by 2090 (GWL 2). The high climate impact scenario is based on global warming of 3.0–3.5°C by 2090 (GWL 3–3.5).

Appendix 1

Climate change scenarios used in this risk assessment

Different sets of climate change scenarios have been produced over time, and these scenarios are framed in different ways. The IPCC Fifth Assessment Report (AR5) used Representative Concentration Pathways (RCPs),[14] whereas the Sixth Assessment Report (AR6) used Shared Socioeconomic Pathways (SSPs).[12] Climate projections can also be framed as global warming levels (GWLs). A brief explanation of each is below.

- **Representative Concentration Pathways (RCPs):** The RCPs describe a range of potential greenhouse gas and aerosol concentration pathways. Four RCPs were examined in the IPCC Fifth Assessment Report: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. They are named according to the indicative radiative forcing[1] produced by the end of the century compared to 1750; for example, RCP2.6 assumes a radiative forcing of 2.6 W m^{-2} in 2100. Each RCP assumes CO_2 concentrations based on different emissions scenarios (i.e. mitigation with low levels of emissions (RCP 2.6), stabilisation (RCP 4.5 and RCP 6) or very high emissions (RCP 8.5).[14,16]
- **Shared Socioeconomic Pathways (SSPs):** The emissions scenarios developed for AR6 are based on a wide range of socio-economic drivers, including population growth, technological development and economic development. The resulting emissions scenarios represent different narratives for energy use, air pollution control, land use and greenhouse gas emissions. The SSPs are labelled SSP1 to SSP5, and describe a range of plausible trends in how society may evolve over the 21st century: sustainability' (SSP1), 'middle of the road' (SSP2), 'regional rivalry' (SSP3), 'inequality' (SSP4) and 'fossil-fuel intensive development' (SSP5).[17,16] In AR6, the SSPs were combined with the RCPs to produce five scenarios that cover a range of plausible societal and climatic futures: SSP1–1.9, SSP1–2.6, SSP2–4.5, SSP3–7.0 and SSP5–8.5.[16] In the SSP labels, the first number refers to the Shared Socioeconomic Pathway (ranging from 1 to 5), and the second number refers to RCP scenarios, indicating the approximate global effective radiative forcing in 2100.[12]
- **Global warming levels (GWLs):** Climate projections based on GWLs describe the expected impacts that will be experienced when the world reaches particular levels of warming compared to the pre-industrial era (1850–1900). GWLs are used to integrate the assessment of climate change and related impacts and risks since patterns of changes for many climate variables at a given GWL are common to all emissions scenarios considered and are independent of the timing when that level of warming is reached.[2]

Table A1.1 shows how the global warming levels correspond to RCPs and SSPs.

The **assessments** of risk outlined in this report are based on information sources that use any of the climate change scenarios outlined above. Risks were assessed under both a low climate impact scenario and a high climate impact scenario. Where possible, risks were assessed using evidence that aligned with global warming equivalent to approximately 1.5°C by 2050 and 2°C by the end of the century for a low climate impact scenario, and using evidence that aligned with approximately 2–2.5°C by 2050 and 3–3.5°C by the end of the century for a high climate impact scenario. Note the emissions trajectories in RCP8.5 are now generally considered to be unlikely given global efforts. However, the scenario is still sometimes used to help consider the possible range of some impacts where there are uncertainties in the models. For more information, refer to the Summary of method report published alongside this report.

For the **projections** of changes in climate hazards outlined in this report, we have referred to the SSPs from AR6, as these were the scenarios downscaled for Aotearoa New Zealand.[18] SSP1–2.6 is used for the low climate impact scenario, and SSP3–7.0 is used for the high climate impact scenario. See section 3.2 of the separate Summary of method report for more information on the Commission's selection of climate change scenarios.

Table A1.1: Correspondence between global warming levels and SSP and RCP emissions scenarios for the two time periods used in the risk assessment, relative to 1850–1900 baseline

Time horizon	Global warming	SSP	RCP
2050	1.5°C (low impact)	SSP1–2.6 (low emissions): projected warming of 1.7°C (range 1.3 to 2.2 °C)[19]	RCP2.6 (projected warming of 1.6°C, range 1 to 2.2°C) (low emissions)[14]
	2–2.5°C (high impact)	SSP3–7.0 (high emissions): projected warming of 2.1°C (range 1.7 to 2.6°C)	RCP6.0 (projected warming of 1.9°C, range 1.4 to 2.4°C) and RCP8.5 (projected warming of 2.6°C, range 2 to 3.2°C) (high emissions)
2090	2°C (low impact)	SSP1–2.6 (low emissions): projected warming of 1.8°C (range 1.3 to 2.4°C)	RCP2.6 (projected warming of 1.6°C, range 0.9 to 2.3°C) and RCP4.5 (projected warming of 2.4°C, range 1.7 to 3.2°C) (low emissions)[14]
	3–3.5°C (high impact)	SSP3–7.0 (high emissions): projected warming of 3.6°C (range 2.8 to 4.6°C)	RCP6.0 (projected warming of 2.8°C, range 2.0 to 3.7 degrees) and RCP8.5 (projected warming of 4.3°C, range 3.2 to 5.4°C) (high emissions)

Source: Derived from Ministry for the Environment and Intergovernmental Panel on Climate Change (IPCC)

Technical glossary

Note there is a reo Māori glossary provided at the end of *Ngā mea hirahira o te ao Māori*, which provides English contextual translation of kupu Māori used in that section.

1% AEP flood event	A 1% annual exceedance probability (AEP) flood has a 1% chance (or 1 in 100 chance) of happening in any given year – it does not mean it will only occur once in 100 years. See 'Annual exceedance probability'.
adaptation	The process of adjusting to the actual or expected changes brought about by climate change. For people, and the systems people create, this means making changes to try to avoid or minimise the harm or damage from climate change and its effects – or to benefit from opportunities climate change might provide. These could be changes, for example, to laws, policies, practices, processes, as well as to physical structures and the built environment. In nature, and within natural systems, adaptation can happen by itself through ecological and evolutionary processes, or with human assistance, by helping those systems adjust to climate change and its effects.
adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences from climate impacts.
algal blooms	Algae are aquatic plants, which range in size from tiny single-celled phytoplankton to large seaweeds. Under some conditions, algae can reproduce in large numbers, causing algal 'blooms' which often appear as coloured patches (usually red or brown) in the water.
annual exceedance probability	Annual exceedance probability (AEP) is the chance that a flood of a specific size will occur or be exceeded in any given year.
anthropogenic	Resulting from or produced by human activities.
benthic organisms	Organisms that live on or in the ocean floor, either attached to or burrowing into it.
biodiversity	The variability among living organisms from all sources including, among other things, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.
bioeconomy	An economy based on use of biological resources and processes to produce products and services, such as food, fibre and recreation.

blue carbon processes	Biologically driven carbon fluxes and storage in marine systems that are amenable to management. Coastal blue carbon focuses on rooted vegetation in the coastal zone, such as tidal marshes, mangroves and seagrasses. These ecosystems have high carbon burial rates on a per unit area basis and accumulate carbon in their soils and sediments. They provide many non-climatic benefits and can contribute to ecosystem-based adaptation. If degraded or lost, coastal blue carbon ecosystems are likely to release most of their carbon back to the atmosphere. There is current debate regarding the application of the blue carbon concept to other coastal and non-coastal processes and ecosystems, including the open ocean.
bryozoan thickets	Bryozoan (also known as lace coral) thickets are a rare habitat type composed of bryozoan – a sessile, filter-feeding, colonial animal which occur, from tropical to polar latitudes.
carbon dioxide	A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, and of land-use changes and industrial processes. It is the principal greenhouse gas that affects the Earth's atmosphere. See 'greenhouse gases'.
carbon sequestration	The process of capturing and storing carbon dioxide to reduce its concentrations in the atmosphere. It involves capturing, securing and storing carbon dioxide from the atmosphere to stabilise carbon in solid and dissolved forms so that it does not cause the atmosphere to warm.
cascading impacts	These occur when a climate-related risk or hazard generates a sequence of secondary events in natural and human systems that results in physical, natural, social or economic disruption – the resulting impact is often significantly larger than the initial impact.
Climate Change Response Act 2002	The Act that establishes the Climate Change Commission and contains the framework for the 2050 emissions reduction target and emissions budgets. It also provides a legal framework to enable Aotearoa New Zealand to meet its international obligations under the United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Paris Agreement; and provides for the implementation of the New Zealand Emissions Trading Scheme (NZ ETS) and the synthetic greenhouse gas levy.
climate resilience	The ability to prepare for, respond to and cope with the impacts of changing climate without losing essential functioning and identity, including those progressive and ongoing changes that can be anticipated and those that occur as extreme events.
climate stressor	Events and trends that have an important effect on the system exposed and can increase vulnerability to climate-related risk.

coastal edge proximity	A proxy for susceptibility to coastal erosion. It can be used to describe the distance between a place and the coast. High coastal proximity, for example, is very close to the shoreline. See ‘coastal erosion’.
coastal erosion	The loss of land due to coastal processes such as waves and tidal currents wearing land away over time. Occurs when a net loss of sediment or bedrock from the shoreline results in landward movement of the high-tide mark.
coastal inundation	Flooding of coastal land due to extreme sea levels driven by tides, storm surge, wave processes, or sea-level rise.
coastal squeeze	Intertidal habitat loss which arises due to the high-water mark being fixed by a defence, such as a seawall, and the low-water mark migrating landwards in response to sea-level rise.
co-benefit	A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment.
compounding impacts	Arise from the interaction of hazards, which may be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors.
confidence intervals	The robustness of a finding based on the type, amount, quality and consistency of *evidence* (e.g. mechanistic understanding, theory, data, models, expert judgement) and on the degree of *agreement* across multiple lines of evidence. In this report, confidence is expressed qualitatively.
cultivars	An organism – especially one of an agricultural or horticultural variety or strain, originating and persistent under cultivation.
cyanobacteria	Bacteria that are aquatic (live in the water) and photosynthetic (can manufacture their own food).
displacement	The involuntary movement, individually or collectively, of persons or other species from their home or community.
domain	The second national climate change risk assessment is framed around seven ‘value domains’ – groupings of tangible and intangible values, assets and taonga that are important to Aotearoa New Zealand. The seven domains are: Natural environment; Sectors relying on the natural environment; People, health and communities; Built environment; Economy and finance; Ngā mea hirahira o te ao Māori (things of importance in the Māori world); and Governance.
drought	Drought is an exceptional period of water shortage for existing ecosystems and the human population (due to low rainfall, high temperature and/or wind). See ‘dry spell’.

dry spell	Dry spells are periods of abnormally reduced water availability, but shorter and not as severe as a drought.
ecosystem	A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases, they are relatively sharp, while in others they are diffuse. In the current era, most ecosystems either contain people as key organisms or are influenced by the effects of human activities in their environment.
ecosystem services	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as: 1. **supporting** services such as productivity or biodiversity maintenance 2. **provisioning** services such as food or fibre 3. **regulating** services such as climate regulation or carbon sequestration 4. **cultural** services such as tourism or spiritual and aesthetic appreciation.
effective adaptation	Effective adaptation reduces climate risk, anticipates and accounts for complexities, anticipates and accounts for the uncertain nature of climate change risks and impacts, and aims to avoid maladaptation.
emissions	Greenhouse gases released into the atmosphere. The Climate Change Response Act 2002 covers the following greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.
endemic	Plants and animals that are only found in one geographic region.
equity	The principle of being fair and impartial, and a basis for understanding how the impacts and responses to climate change, including costs and benefits, are distributed in and by society in more or less equal ways.
eutrophication	Over-enrichment of water by nutrients such as nitrogen and phosphorus. It is one of the leading causes of water quality impairment. The two most acute symptoms of eutrophication are *hypoxia* (or oxygen depletion) and harmful algal blooms.
exotic production forests	Plantation forests made up of tree species that are not indigenous to Aotearoa New Zealand and that are intentionally planted and managed primarily for commercial means.
exotic forestry	Forests that are mainly made up of exotic tree species (e.g. radiata pine).
exposure	How much of value is present in the face of a particular hazard – the people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

extreme weather event	An event that is rare at a particular place and time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as, or rarer than, the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense.
fire weather	Fire weather refers to weather conditions conducive to triggering and sustaining wildfires. Fire weather does not include the presence or absence of fuel load. See 'wildfire'.
fluvial flooding	This occurs when rivers and streams overflow. Flooded rivers and streams may break their banks causing water flows on to adjacent low-lying areas. See also 'pluvial flooding'.
forest ecosystem	A vegetation type dominated by trees consisting of living organisms, their non-living environment and the interactions within and between them. Many definitions of the term 'forest' are in use throughout the world, reflecting wide environmental, social, and economic differences.
global warming levels (GWLs)	Global warming levels (GWLs) offer a relatively new way to look at and communicate future climate change. In this approach, the regional climate change response is shown relative to the average global warming (e.g. 0.5°C, 1.0°C, 1.5°C, 2.0°C) above a specified baseline period, typically pre-industrial (1850–1900).
greenhouse gases (GHGs)	Atmospheric gases that trap heat and contribute to climate change. The gases covered by the Climate Change Response Act 2002 are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
greywater	Greywater is lightly used water from showers, bathtubs, sinks, and washing machines in the home.
gross domestic product (GDP)	GDP measures the value of a country's economic activity, and is Aotearoa New Zealand's official measure of economic growth.
gyre	A circular or spiral form. Specifically, in this context, a large circular ocean current defined by the IPCC as a basin-scale ocean horizontal circulation pattern with slow flow circulating around the ocean basin, closed by a strong and narrow (100 to 200 km wide) boundary current on the western side. The subtropical gyres in each ocean are associated with high pressure in the centre of the gyres; the subpolar gyres are associated with low pressure.
hazard	In this assessment, we refer to hazards as physical events or trends caused by climate change. Climate hazards can be progressive and ongoing changes (such as sea-level rise, warming temperatures, and changing seasonal weather patterns) or extreme events (such as cyclones, droughts and wildfires). While climate change does not necessarily cause extreme events, it makes them more frequent and severe.

heatwave	Heatwaves are periods of abnormally hot weather, often defined with reference to a relative temperature threshold, lasting from two days to months.
herpetofauna	Amphibians and reptiles.
high impact climate scenario	In this assessment, we assessed risks using two climate impact scenarios (based on different levels of global warming, as compared to pre-industrial levels). The high climate impact scenario was based on global warming of 3.0–3.5°C by 2090.
hydrodynamics	A branch of physics that deals with the motion of fluids and the forces acting on solid bodies immersed in fluids and in motion relative to them.
impact	The consequences of realised risks on natural and human systems, which result from the interactions of climate-related hazards (including extreme weather events), exposure and vulnerability. Impacts in this assessment are generally effects on human lives, livelihoods, health and wellbeing; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. They can be harmful or beneficial. Also known as consequences or outcomes.
indicator	A sign or signal that shows something exists and its level of progress.
indigenous forest	Forests that are completely or predominantly made up of indigenous tree species. In addition to natural forests, this would include a forest whose tree crown consists of, for example, 90% tall mature tōtara trees (an indigenous species) and 10% pine trees (exotic species) spread throughout the forest.
indigenous species	Indigenous species, also known as native species, of plants and animals are species: 1. that were present 85 million years ago and are still present, or 2. that descend from those present 85 million years ago, or 3. have arrived since but without human assistance and have survived.
indirect risk	An indirect climate risk can emerge as a secondary consequence of a climate hazard, for example when extreme weather damages power lines, causing a power cut.
insurance retreat	When the cost of insuring for a particular hazard gets so great an insurer may withdraw insurance for a home or asset altogether.
Intergovernmental Panel on Climate Change (IPCC)	Intergovernmental panel under the United Nations, which prepares comprehensive Assessment Reports about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

inundation	The condition of being flooded – for example, coastal inundation refers to flooding from the sea.
landslides	The movement of rock, soil and vegetation down a slope. Landslides occur when the strength of a slope is overwhelmed by stresses imposed on that slope which can be sudden (earthquake or heavy rain) or gradual.
leachate treatment facilities	Facilities which foster the removal of contaminants from the liquid that drains from a landfill or waste pile. This liquid, known as leachate, contains high concentrations of organic matter, heavy metals, and various chemical pollutants.
lifeline utility	Entities that provide essential infrastructure services to the community – including water, wastewater, transport, energy and telecommunications.
lead time	This reflects the period between the recognition of an issue, and effective management of that issue. This can be because of delays in response, and also because the response decided on takes time to set up – for instance to train a workforce to new requirements.
lock in	A situation in which the future development of a system, including infrastructure, technologies, investments, institutions and behavioural norms, is determined or constrained ('locked in') by historical developments.
loss	Damage to, and/or destruction of, homes, natural and constructed assets, property and livelihoods by climate-related hazards.
low climate impact scenario	In this assessment, we assessed risks using two climate impact scenarios (based on different levels of global warming, as compared to pre-industrial levels). The low climate impact scenario was based on global warming of 2.0°C by 2090.
maladaptation	When negative outcomes result from adaptation actions. This could include, for example, actions that may lead to increased risk of adverse climate-related outcomes, including increased greenhouse gas emissions, increased vulnerability to climate change impacts and/or reduced welfare, now or in the future. Maladaptation is usually an unintended consequence.
managed forests	Forests subject to human interventions (notably silvicultural management such as planting, pruning, thinning), timber and fuelwood harvest, protection (fire suppression, insect suppression) and management for amenity values or conservation, with defined geographical boundaries.
managed retreat	An approach to reduce or eliminate exposure to intolerable risk, by enabling the relocation of assets, activities and sites of cultural significance away from areas at risk from climate change and natural hazards.

marine heatwave	A period during which water temperature is abnormally warm for the time of the year relative to historical temperatures, with that extreme warmth persisting for days to months. The phenomenon can manifest in any place in the ocean and at scales of up to thousands of kilometres.
marine stratification	The formation of two distinct layers in the sea due to differences in temperature (warm layer overlying a cooler layer), salinity (fresh water overlying saltier water), or both. The interface between the two layers is very efficient at limiting the exchange of water and its properties (such as nutrients).
mean high water springs (MHWS)	The average of the level of each successive high waters, during a period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest (spring range).
mitigation	Human actions to reduce emissions by sources or enhance removals by sinks of greenhouse gases. Examples of reducing emissions by sources include walking instead of driving or replacing a coal boiler with a renewable electric powered one. Examples of enhancing removals by sinks include growing new trees to absorb carbon, or industrial carbon capture and storage activities.
model, modelled	Representation of an idea, object, process, or system to describe or explain phenomena that cannot be experienced directly, to discover features of and ascertain facts about a system and its behaviour.
natural forest	Primary or regenerated forest recovering from previous land use. Natural forests possess many or most of the characteristics (species composition, structure, ecological function) of a forest indigenous (or native) to the given site. While natural forests can be managed (such as for selective harvest, forest products or cultivation within the forest), they are not the same as tree plantations.
nature-based solution	Approaches to addressing societal challenges, such as climate change, by integrating, protecting, sustainably managing, and restoring natural ecosystems. For example, using vegetation (e.g. street trees or green roofs) or water elements (e.g. rivers or water treatment facilities) can help reduce heat in urban areas or support stormwater and flood management.
North Island Severe Weather Events	A collective term for the Cyclone Hale (January 2023), Auckland Anniversary heavy rainfall (January 2023) and Cyclone Gabrielle (February 2023) extreme weather events. The term was specifically used for the 2023 Government Inquiry into the Response to the North Island Severe Weather Events.
nutrient cycling	Processes through which essential nutrients, such as nitrogen, phosphorus, and other elements, are captured and made available for use by organisms, including corals. This cycling is crucial for maintaining cultural health and promoting primary productivity in ecosystems.

ocean acidification	Ocean acidification is the process through which, as concentrations of carbon dioxide in the atmosphere increase, more is absorbed into oceans, making them more acidic. See also ‘ocean warming’.
ocean warming	Ocean warming demonstrates the uptake of heat by the global ocean, which increases as global surface temperature increases.
pluvial flooding	Occurs when the amount of rainfall exceeds the capacity of storm water drainage systems, or the ground, to absorb it. Excess water flows overland, ponding in hollows and low-lying areas, or behind obstructions. See also ‘fluvial flooding’.
policy readiness	Consideration of how prepared Aotearoa New Zealand is to address each risk, based on an analysis of current and planned policies, plans and actions. Each risk has been given an overall policy readiness rating from ‘no significant gaps’ to ‘insufficient.’
primary productivity (biological)	The rate of growth of plants and algae, where they convert nutrients and minerals into biomass through photosynthesis, powered by energy from the sun.
projections, projected	Estimated value of a future quantity (such as emissions levels) based on a prescribed set of assumptions.
recruitment	Recruitment in ecology refers to the process by which new individuals are added to a population, through birth, reaching maturity or immigration, and is a key factor in population and ecosystem dynamics.
Representative Concentration Pathway (RCP)	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover.
residual risk	The level of risk related to climate change impacts that remains after adaptation, and after efforts have been made to mitigate risk.
resilience	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.
risk (climate risk/ climate-related risk)	The potential for adverse consequences, for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Adverse consequences may affect human lives, livelihoods, health and wellbeing; economic, social and cultural assets and investments; infrastructure; services (including ecosystem services); and ecosystems and species. See ‘hazard’, ‘exposure’, and ‘vulnerability’.

risk assessment	The scientific estimation of risks, which may be either quantitative or qualitative.
risk management	The process of making plans, actions, strategies or policies to reduce the likelihood and/or scale of potential adverse consequences, based on assessed or perceived risks.
risk of isolation	Risk of communities, households or people being cut off from essential services like emergency services, supermarkets, education, work, and cultural sites of significance (such as marae) if transport networks are damaged.
river and surface flooding	The overflowing of the normal confines of a water body or the accumulation of water over areas that are not normally submerged. Floods can be caused by unusually heavy rain, for example, during storms and cyclones. See 'fluvial flooding' and 'pluvial flooding'.
salinity	Dissolved salt content of a body of water or soil. Salts are highly soluble in surface and groundwater and can be transported with water movement.
scenario	A plausible set of assumptions about economic and social development, and technological and behavioural changes.
sea-level rise (SLR)	Increases in the height of sea levels over time, which may occur globally or locally.
sedimentation	The deposition of rock fragments, soil, organic matter, or dissolved material that has been eroded – that is, has been transported by water, wind, ice or gravity.
sensitivity	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change.
severity	Severity considers the nature and scale of potential consequences Aotearoa New Zealand faces from each risk. This gives an indication of how serious the impacts of climate risks may be for each affected sector or system, and for the country as a whole.
Shared Socioeconomic Pathway	IPCC's 6th Assessment Report (2021–22) shifted to a new core set of future representative scenarios, based on Shared Socioeconomic Pathways (SSPs). These comprise different socioeconomic assumptions that drive future greenhouse gas emissions. The scenarios span a wide range of plausible societal and climatic futures, based on greenhouse gas emissions, that result in the stabilisation of global warming at 1.5°C to over 4°C warming by 2100.
shoreline change	Shoreline change refers to alterations in the shoreline – in the climate risk context it is closely related to coastal erosion. See 'coastal erosion'.

slash	Tree waste left behind after commercial forestry activities.
social cohesion	This describes the sense of belonging, connection and solidarity among groups in society. The social cohesion risk analysis considers both the impacts on those who move away and the impacts on the community left behind.
speciation	The process by which new types of living things are thought to develop from existing ones during evolution.
taxa	A biological classification to represent a group of organisms that share common characteristics and are classified together within a hierarchical system.
Te Tiriti o Waitangi/ The Treaty of Waitangi (Te Tiriti/The Treaty)	Aotearoa New Zealand's founding document, signed between Māori and representatives of the British Crown in a series of signing events beginning 6 February 1840. See Schedule 1 of the Treaty of Waitangi Act 1975.
thermal squeeze	An ecological phenomenon in which rising temperatures force species, especially cold-adapted or predator-vulnerable species, into progressively smaller, cooler habitat zones, typically at higher elevations.
thresholds	There are points when change can reach a level where a species, for instance, or a community or part of a human system, cannot absorb further change, and is no longer resilient. Where that threshold lies is not always clear, and can often only be confirmed in hindsight. Climate change increases the likelihood of breaching such thresholds. See also 'tipping points'.
tipping point	A critical threshold beyond which a system reorganises, often abruptly and/or irreversibly.
trophic level	An organism's position in a food chain or food web.
vulnerability	The conditions that determine how climate change impacts may affect an area, system or community – it includes sensitivity to harm, and the ability to cope and adapt (see 'adaptive capacity').
wildfires	Wildfires are a type of fire which burns strongly and out of control on an area of grass, bush or forest. As the climate changes, wildfires are becoming more frequent.
windthrow	Damage to trees, caused by storms and high wind that can result in trees falling or becoming lodged on other trees.

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