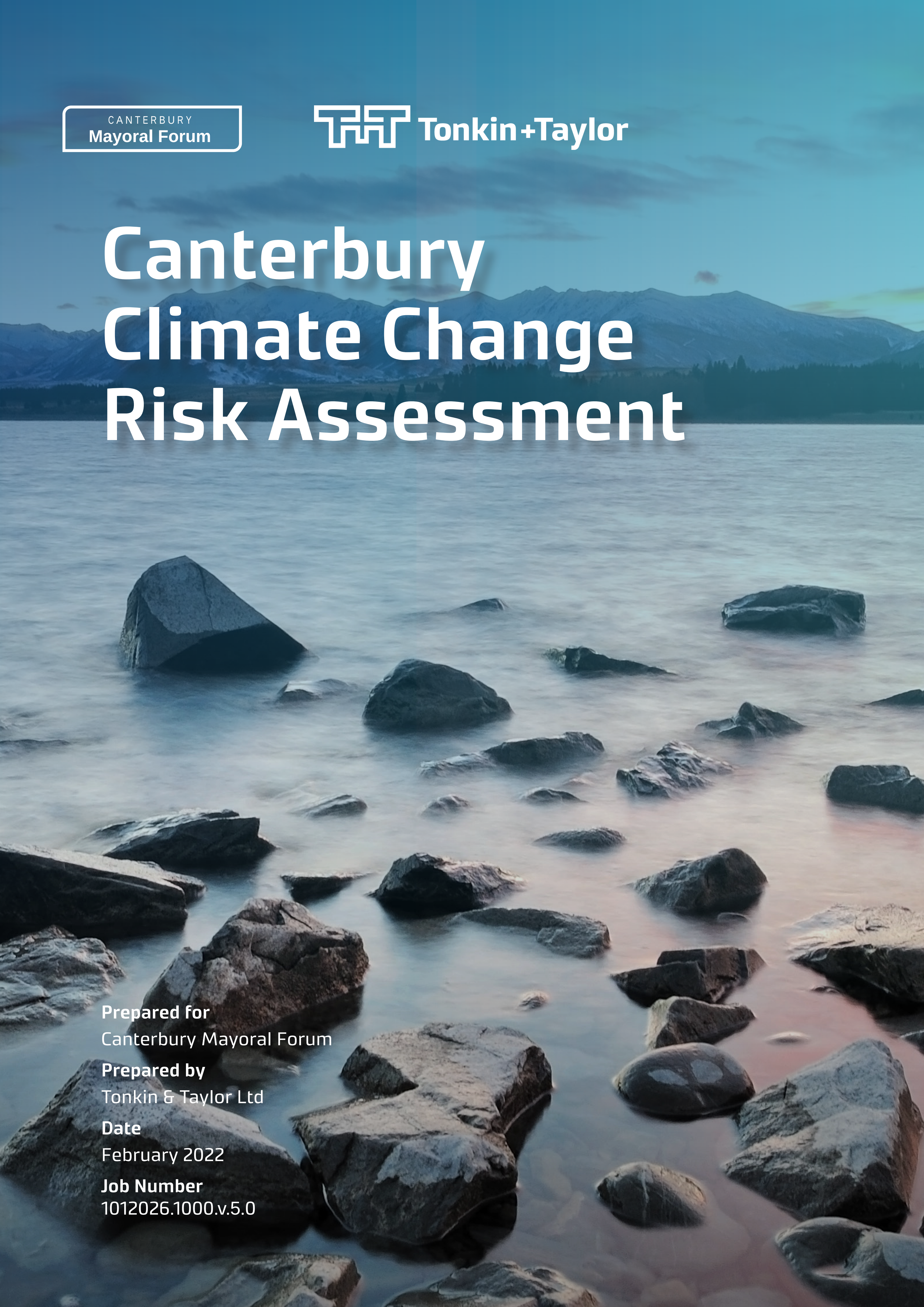

CANTERBURY
Mayoral Forum

Tonkin+Taylor

Canterbury Climate Change Risk Assessment

Prepared for
Canterbury Mayoral Forum

Prepared by
Tonkin & Taylor Ltd

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Canterbury Climate Change Risk Assessment

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This report was prepared in collaboration with Councils of the Canterbury Region and representatives from Ngāi Tahu.

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This report was prepared in collaboration with Council's of the Canterbury Region and representatives of Te Rūnanga o Ngāi Tahu.

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Table of contents

Kei a te pō te tīmatataka mai o te waiatataka mai o te atua

Nā Te Pō, ko Te Ao

Nā Te Ao, ko Te Ao Mārama

Nā Te Ao Mārama, ko Te Ao Tūroa

Nā Te Ao Tūroa, ko te Kore te whiwhia

Nā te Kore te whiwhia, ko te Kore te rāwea

Nā te Kore te rāwea, ko te Kore te tāmaua

Nā te Kore te tāmaua, ko te Korematua

Nā te Korematua, ko te Mākū Ka moe i a Māhoranuiātea, ka puta ko Raki

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Ko te aitaka o te takata

Ki te whai ao, ki te ao mārama

Ki te ao tūroa e tū nei

Tihei Mauriora!

- ‘Te Waiatatanga mai o te Atua: South Island Traditions’ original manuscript authored by Matiaha Tiramōrehu, 1849

1 Executive Summary

Climate change is the biggest environmental challenge of our time. It is already affecting us, and if left unchecked, will have broad and ongoing implications for all of New Zealand, across many generations. Even taking action to reduce emissions, science is now telling us that that some aspects, such as sea level rise, are locked in for the next century. Importantly, the specific impacts of climate change will be felt differently in different places, and the risks and opportunities that result from these impacts will also differ. As a result, there is an urgent need to understand these changes, and their associated risks, so that we can best plan for the future.

In 2019, a regional Climate Change Risk Screening assessment was undertaken by the Canterbury Climate Change Working Group, under the Canterbury Mayoral Forum (referred to as "the Working Group" throughout). This identified 180 climate-related risks that could have the greatest effect across the Canterbury Region, and included over 80 risks that were identified as priority risks. The results of this assessment fed into New Zealand's first National Climate Change Risk Assessment, commissioned by the Ministry for the Environment.

The priority risks identified in the 2019 assessment have now been used as the basis for this more detailed 2021 Canterbury Climate Change Risk Assessment (CCRA). This assessment provides detail about the highest risks[1] and opportunities associated with climate change, now and into the future. The project has involved collaboration with Papatipu Rūnanga representatives, Territorial Authorities and key stakeholder groups.

This report outlines the risks related to physical climate change that the Canterbury Region faces. The report centres around Te Tūtei o Te Hau (an integrated framework) aligned both with a Te Ao Māori worldview, and with the National Climate Change Risk Assessment (NCCRA) framework. It provides decision makers within relevant Councils with the technical information to enable prioritisation of the risks outlined, and to enable them to plan for action through development of strategic and long term plans.

Climate hazards for Canterbury

The global climate system is showing unprecedented changes, which can be attributed to the effects of increasing greenhouse gas emissions. Within this greater context, Canterbury's climate is also changing and these changes are projected to continue over long timescales. The severity and frequency of climate changes will depend on global efforts to curb greenhouse gas emissions. How climate hazards change in response to increasing levels of greenhouse gas emissions is uncertain, due to the complexity within the global climate system and interactions with socio-economic processes that drive emissions. This uncertainty is represented through the adoption of various scenarios that represent futures under different concentrations of greenhouse gases in the atmosphere (Representative Concentration Pathways, RCP). This assessment considers RCP 8.5 – which represents a 'high-end' emissions scenario with high future global greenhouse gas emissions.

Climate projections relating to this scenario are considered at 2050, and 2100. The National Institute of Water & Atmospheric Research (NIWA) have developed national and regional projections based on the IPCC Fifth Assessment Report (2014) which form the basis of this report (Macara et al., 2020).

In general, Canterbury is projected to see warmer temperatures, including an increasing number of hot days (defined as those hotter than 25°C), decreasing frosts, decreasing snow days, and increase in the daytime temperature range. Average annual rainfall shows small changes for most of the Region, but seasonal increases are likely in winter for most parts, and decreases in summer rainfall in some parts of Canterbury. Wind is generally likely to increase in speed. The frequency of extreme weather events is likely to increase (Carey-Smith et al., 2018). Drought potential is projected to

[1] Highest risks relate to those rated 'high' or 'extreme' during the 2020 Canterbury Climate Change Risk Assessment.

increase across most of the Region, and the sea level is projected to rise, with coastal hazards expected from additional influence from weather on storm surges and wave heights.

The projected changes that Canterbury is likely to see can contribute to risk directly by causing physical impacts, like wind damage or hotter temperatures creating heat stress, or by causing natural hazards, such as increasing flooding, landslides, drought, and wildfire.

Method

The risk assessment method is framed by the International Panel on Climate Change (IPCC), and is consistent with that used during the screening stage in 2020. This CCRA involved:

- Establishment of a Papatipu Rūnanga Project Steering Group (RPSG), to guide and advise on engagement and Te Ao Māori content.
- Co-development of the Te Tūtei o Te Hau (integrated framework) with the RPSG.
- Risk rating based on assessment of exposure and vulnerability.
- Refinement and description of human and governance related risks .
- A literature review, including gaps analysis, to build detailed understanding of priority risks.
- Risk aggregation, aligning risks to the new integrated framework, to allow for easier communication and reporting as part of this project.
- Stakeholder engagement, aligned to stakeholder and partner needs, including targeted subject matter workshops, focus groups, kānohi-ki-te-kānohi hui (face to face meetings), insights questionnaires (surveys), and targeted phone calls.
- Five case studies, chosen by participants, to explore interacting risks, recognising that the impacts of climate change will not occur in isolation, and risks will interact propagate through systems, creating multiple pressures across value areas.
- Identification of opportunities.

Summary of risks

The Canterbury Region faces a range of risks to all ngā pono (values) within te Ao Mārama (the safe place for humanity and the natural living world). These include direct physical risks from climate hazards to the natural and physical environment, such as those from climate hazards to many aspects within rerenga rauropi (biodiversity), wai (water), ngā waihanga (infrastructure services), hirihiri (energy), kāinga tūturu (historic heritage), and the natural resources that support ōhanga (prosperity). Climate change also poses direct risks to hauora (wellbeing), such as heat stress and injury from flooding.

From these direct risks, arise a range of indirect risks, as the physical impacts of climate change pose risks to the less tangible ngā pono of the Region. These include risks to hauora, and risks to ora rite (equity), hapori (sense of community), mātauranga (knowledge), and rangatiratanga (governance).

Across all ngā pono, risks from climate change are seen to increase with time. At the present day, the majority of risks are rated as insignificant or low, with 30% rated as moderate, 10% rated high, and 3% rated as extreme. These present-day highly rated risks (i.e. those rated as either 'high' or 'extreme') mainly include those to rerenga rauropi, wai (water), and ngā waihanga (infrastructure services). The present-day risks that are rated extreme include those relating to water supply and irrigation.

By late 21st century, risks within all ngā pono are rated as extreme, with the vast majority of all identified risks rated either high or extreme.

The challenges that climate change introduces will occur in different ways across the Region. The large land area and high geographic diversity of Canterbury means that some risks will be most relevant to certain areas. The environments of the Region can be characterised by its alpine/high country environments, montane/hill country, lowlands, coastal and marine habitats, freshwater systems and urban centres. An overview of these challenges is provided in Figure ES 1 below.

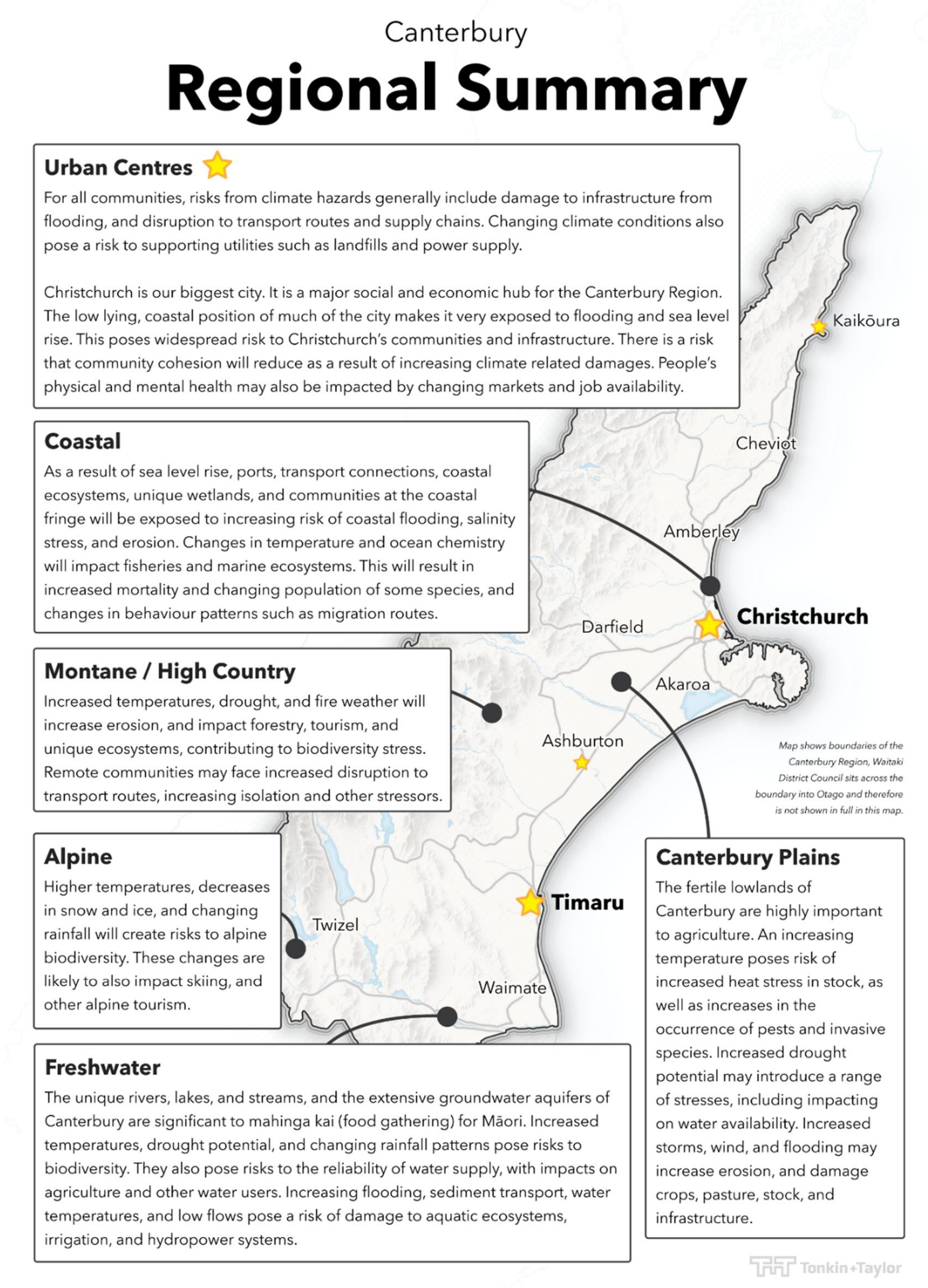


Figure ES 1: Regional summary of climate risks.

The alpine environment of Canterbury acts as an important water source to the Region's alpine rivers, supports unique biodiversity and generates tourism. Increased temperature, reduced snow and changing rainfall patterns pose some of the highest rated risks to these systems.

The Region's water sources play an important role in mātauranga Māori (Māori knowledge), as well as contributing to wider biodiversity and public amenity. They are also important sources of irrigation and stock water for agricultural activity, and support the water demands of towns and industry. Increased temperature and drought, as well as changing rainfall patterns, pose some of the highest rated risks to freshwater systems.

The montane/hill country and forested foothills support unique ecosystems and low-density farming and forestry. Increased temperature, fire weather, and changing rainfall patterns pose some of the highest rated risks to these systems.

The fertile lowlands of the plains are the agricultural powerhouse of the Region, supporting diverse farming activity and many farming communities. Increasing drought potential and related impacts on water availability and agriculture, as well as increased storms, winds, and flooding pose some of the highest rated risks to these systems.

The long coastline of the Region supports diverse ecosystems, including coastal wetlands and abundant marine species. Ports, transport connections, coastal ecosystems, unique wetlands, and communities along the coastal fringe, will all be exposed to increasing coastal flooding, salinity stress and erosion. Temperature and ocean chemistry changes will impact fisheries and marine ecosystems, resulting in changed behaviour patterns, such as migration routes and increased mortality, and changing the population of some species.

Ōtautahi/Christchurch, Canterbury's largest city, is a major social and economic hub for the Region. The low-lying coastal position of much of the city makes it very exposed to flooding and sea level rise, with widespread risks to its communities and infrastructure. Risks from climate hazards on all communities generally include damage to infrastructure from flooding, and reduced community cohesion from increasing climate related damages, disruption to transport routes and supply chains, impacts on physical and mental health and changing markets and job availability. Changing climate also poses risks to supporting utilities such as landfills, and power transmission.

Knowledge gaps and future research

Climate change presents a range of risks to the Region. However, uncertainty in the nature and severity of all aspects of climate risks is generally high. While assessment of these risks has been made using the best available information at the time, some gaps in knowledge can be clearly identified.

Some of the identified knowledge gaps may be filled through additional research into climate change and adaptation, which could build on the large body of established research. Extensive work is underway to gather data at local, national and international scales to further understand climate risks, and develop strategies to adapt to climate change. Research streams and data collection managed through Environment Canterbury, Universities and Crown Researchers, Sector representatives, and the National Science Challenges are of particular relevance to this regional climate risk assessment.

For the Canterbury Region, further assessment would be beneficial for those risks screened in 2019 but not prioritised. Assessing at a local or sector scale those risks which have been assessed at a regional scale, and conducting a detailed climate change risk assessment of built kāinga tūturu (historic heritage) would also be beneficial.

At a high level, these areas would benefit from further research:

- Transition risks – risks associated with a transition to a low-carbon economy, and those associated with equitable transition to climate adapted communities.
- Rerenga rauropi (biodiversity) – ecosystem and specific element responses to climate change.

- Wai (water) – at a regional level: surface water, groundwater, water availability, extreme events and flooding, and flood protection.
- Ngā waihanga (infrastructure services) – asset vulnerability in critical infrastructure sectors.
- Hirihiri (energy) – specific vulnerabilities relating to transmission and supply, beyond hydroelectricity.
- Ōhanga (prosperity) – financial implications and adaptations; sector vulnerability; impacts and interacting economic impacts, including modelling of global markets; sustainable agriculture; agricultural biosecurity; sustainable fisheries and opportunities.
- Hauora (physical health), hapori (sense of community) and ora rite (equity) – implications of gradual climate hazards on mental and physical health; mental wellbeing, equity, and community.
- Mātauranga (knowledge) – impacts and risks from climate change on mahinga kai and taonga.
- Rangatiratanga (governance), kawanatanga (governance) and mana whakahaere (autonomy) – crown and mana whenua (those with territorial rights to the land) relationships; policy, guidance, and coordination; lifeline utilities.

2 Te Timatanga

Kei a te pō te tīmatataka mai o te waiatataka mai o te atua

Nā Te Pō, ko Te Ao

Nā Te Ao, ko Te Ao Mārama

Nā Te Ao Mārama, ko Te Ao Tūroa

Nā Te Ao Tūroa, ko te Kore te whiwhia

Nā te Kore te whiwhia, ko te Kore te rāwea

Nā te Kore te rāwea, ko te Kore te tāmaua

Nā te Kore te tāmaua, ko te Korematua

Nā te Korematua, ko te Mākū Ka moe i a Māhoranuiātea, ka puta ko Raki

Ka moe i a Pokohārua te Pō Ka puta ko Aoraki, ko Rakamamao tāna ko Tāwhirimātea

Ko te aitaka o te takata

Ki te whai ao, ki te ao mārama

Ki te ao tūroa e tū nei

Tihei Mauriora!

Ngāi Tahu values and beliefs define all things from the time of nothingness – *Te Kore*, through the vast ages of darkness – *Te Pō*, to the first ever glimmer of light – *Te Ao*, to the longstanding light – *Te Aotūroa*, through to the emergence of moisture – *Te Mākū*.

This shared whakapapa, reinforces the tribal philosophy that all things are from the same origin. The welfare of any part of the environment determines the welfare of the people.

It is through whakapapa that all things are intricately linked, as well as having their individual place in the world. Ultimately, it is whakapapa that connects people to each other, to their ancestors, to the land and natural resources. For Ngāi Tahu, it is whakapapa that elucidate their descent from the gods of creation.

Ngāi Tahu lay claim to the same whakapapa as other iwi, through Rakinui and Papatūānuku and connection to their descendants. Whakapapa accounts for the way in which the earth, sky, oceans, rivers, elements, minerals, plants, animals, and people have been created. Whakapapa explains the very origins of everything, past and present, within the Māori world. It is the foundation upon which all things are built, the web that connects all things together, the anchor which holds all things in place and the vehicle by which all things link back to the beginning of time. Whakapapa binds Ngāi Tahu to the mountains, forests and waterways and life supported by them and the Taiao (environment). All things are considered to have a mauri (life force), to be living and to have a genealogical relationship with each other. People are therefore related to the natural world.

Sources:

Karakia based on '*Te Waiatatanga mai o te Atua: South Island Traditions'* original manuscript authored by Matiaha Tiramōrehu in 1849. Translated and edited by Manu Van Ballekom and Ray Harlow in 1987, and published by the University of Canterbury.

Te Maire Tau, Anake Goodall, David Palmer, and Rakiihia Tau (1990). *Te Whakatau kaupapa: Ngāi Tahu resource management strategy for the Canterbury Region*. (Aoraki Press, Wellington).

3 Introduction

Climate change affects communities now, but its full impacts will be felt across generations.

In 2019, the World Meteorological Organization (WMO) released the WMO Statement on the State of the Global Climate (WMO 2020). In it, UN Secretary-General Antonio Guterres commented that "climate change is the defining challenge of our time. Time is fast running out for us to avert the worst impacts of climate disruption and protect our societies from the inevitable impacts to come."

Since then, global concerns about the impact of climate change have only grown. In August 2021, the Intergovernmental Panel on Climate Change (IPCC) released its sixth assessment report, AR6 Climate Change 2021: The Physical Science Basis (IPCC 2021). The report states that "It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred." It goes on to discuss the increasing accumulation of evidence of human-induced climate change, that have become more apparent in the few short years since the fifth assessment report was released in 2014. This includes observed changes in extremes, such as heatwaves, heavy rainfall, droughts, and tropical cyclones, which can be attributed to human influence.

The specific impacts of climate change will be felt differently in different places. The risks and opportunities that result from of these impacts will also differ from place to place.

At a national level, the Ministry for the Environment (MfE) commissioned first National Climate Change Risk Assessment (NCCRA) for Aotearoa New Zealand in 2019 (MfE 2020). The NCCRA helps improve our understanding of the climate change risks and opportunities that New Zealand faces. The assessment covered all aspects of life in New Zealand, including our ecosystems, communities, infrastructure, and economics, and identified 43 priority risks associated with these. The risks were then grouped into five value domains: natural environment, human, economy, built environment, and governance.

At the time that the NCCRA was being developed, a regional Climate Change Risk Screening assessment was undertaken by the Canterbury Climate Change Working Group, under the Canterbury Mayoral Forum (referred to as "the Working Group" throughout). This assessment identified 180 climate-related risks that could have the greatest effect across the Canterbury Region was developed. Of these, over 80 (46%) were identified as priority risks, projected to have a big impact on the Region. A summary of these risks is included in Appendix A. Further detail on the priority risks, and the process undertaken to identify them, can be found in the Canterbury Climate Change Screening Report (2020). The outcomes of this project directly contributed to the development of the NCCRA.

These priority risks have now been taken forward from the screening as the basis for this more detailed 2021 Canterbury Climate Change Risk Assessment (CCRA). This assessment looks to provide detail about the highest risks[2] and opportunities associated with climate change, now and into the future. The project has involved collaboration with Papatipu Rūnanga representatives, Territorial Authorities and key stakeholder groups.

Key objectives in undertaking this Regional CCRA included:

- Alignment with the National Climate Change Risk Assessment (NCCRA) approach.
- Through the Working Group, ensuring project owners and sponsors, partners, stakeholders, communities and groups of people understand common objectives, and how to plan to achieve these.

[2] Highest risks relates to those rated 'high' or 'extreme' during the 2020 Canterbury Climate Change Risk Assessment.

- Co-design of rūnanga engagement with Ngāi Tahu, recognising their whakapapa and kaitiakitanga of Canterbury, to ensure meaningful participation in the project.
- Creation of an integrated approach for Te Ao Māori, that would incorporate Ngāi Tahu values and mātauranga, recognising the work that Ngāi Tahu have already undertaken in developing their *He Rautaki mō te huringa o te āhuarangi: climate change strategy.*
- Development of a cohesive report that will serve multiple purposes:
  - To provide information that will aid Canterbury councils' strategic and long-term planning.
  - To form the basis for any Canterbury Climate Strategy - that informs the Long Term Plan (LTP), 30 Year Infrastructure Strategy, Civil Defence Plans, and Regional and District Plans, Strategies and Policy Statements.
  - To act as an 'information toolbox', supporting local authorities in responding to requests from the Minister on effect of climate change risks.
  - To inform Greater Christchurch 2050, which is "setting a vision and plan for Greater Christchurch to achieve intergenerational wellbeing that also responds to climate change; and moving towards a zero-carbon economy...".
  - To support Canterbury engagement with Central Government on the National Adaptation Plan.
  - To inform councils' new climate reporting obligations to Government under the Zero Carbon Act.

Climate change has already changed the way many people think. Within Canterbury, different groups of people will be impacted in different ways. Engagement for this project was by necessity broad, to ensure diverse perspectives were captured.

Ngāi Tahu have already undertaken work to develop *He Rautaki mō te huringa o te āhuarangi: climate change strategy*, to provide direction around the challenges and opportunities that climate change brings and help ensure that their people will be sustained and even thrive in the generations to come.

As our youngest, rangitahi in particular will be particularly impacted by climate change. However, engagement with the Environment Canterbury Youth Rōpū highlights how much of an impact it is already having on them (see Figure 1.1 below).

Figure 3.1: Quotes from the Environment Canterbury Youth Rōpū engagement activities.

Climate change is here, and will continue to be exacerbated well into the future. Even taking action to reduce emissions, science is now telling us that that some aspects, such as sea level rise, are locked in for the next century. There is a need to understand these changes, and their associated risks, so that we can best plan for the future.

This CCRA outlines the risks related to physical climate change that the Canterbury Region faces. Waitaki District Council crosses the boundary between the Canterbury and Otago regions. Climate change does not stop at local government boundaries and its impacts will be felt across all of Waitaki, however the geographic scope of this risk assessment was the Canterbury region boundary, and so risks within the part of Waitaki district that are outside of the Canterbury region have not been assessed. The report encapsulates a holistic view, and is centred around Te Tūtei o Te Hau (an integrated framework) aligned to a Te Ao Māori worldview, and with the National Climate Change Risk Assessment (NCCRA) framework. It is hoped that the report will provide decision makers with the technical information to enable prioritisation of these risks, and subsequent actions. Climate change is here, now. We need strong ownership, today, to best prepare our communities for tomorrow.

4 Climate Hazards for Canterbury

The global climate system is showing unprecedented changes, which can be attributed to the effects of increasing greenhouse gas emissions. These changes are projected to continue over long timescales. The severity of climate changes will depend on global efforts to curb greenhouse gas emissions. Within this greater context, Canterbury's climate is also changing.

How climate responds to increasing levels of greenhouse gas emissions, and the timing of that response is uncertain. This uncertainty is shown through the adoption of various scenarios representing possible futures under different concentrations of greenhouse gases in the atmosphere (Representative Concentration Pathways, RCP). This assessment considers RCP 8.5, which represents a 'high-end' emissions scenario with high future global greenhouse gas emissions.

Climate projections relating to this scenario are considered at 2050, and 2100. The National Institute of Water & Atmospheric Research (NIWA) have developed national and regional projections based on the IPCC Fifth Assessment Report (2014). These assessments form the basis of climate change projections used within this report (Macara et al., 2020). Uncertainty in future projections creates ranges in potential climate changes.

In general, Canterbury is projected to see warmer temperatures, including an overall increase in the daytime temperature range, with an increase in the number of hot days (defined as those hotter than 25°C), decrease in the number of snow days and a decrease in frosts. Average annual rainfall shows small changes for most of the Region. However, seasonal increases are likely in winter for most parts, alongside decreases in summer rainfall in some parts of Canterbury. Drought potential is projected to increase across most of the Region. Wind is generally likely to increase in speed. The frequency of extreme weather events is likely to increase, and events with small annual exceedance probability (i.e. events with a low chance of occurring in any one year) are likewise projected to increase (Carey-Smith et al., 2018). The sea level is projected to rise by up to 0.8 m by 2100 for Canterbury (Macara et al., 2020), with an increase in coastal hazards expected as a result of the additional influence of weather on storm surges and wave heights. Unless otherwise stated, this is the sea level projection used for 2100 timeframe, as requested by Environment Canterbury.

Figure 4.1 provides an overview of climate change projections for the Canterbury Region. These projected changes contribute to risk in two ways:

- By acting as climate hazards to directly cause physical impacts, such as wind damage, increased temperature causing heat stress, sea level rise causing inundation.
- By causing effects that act as natural hazards, such as increased flooding and landslides, drought, coastal inundation and erosion, and increased instances of wildfire.

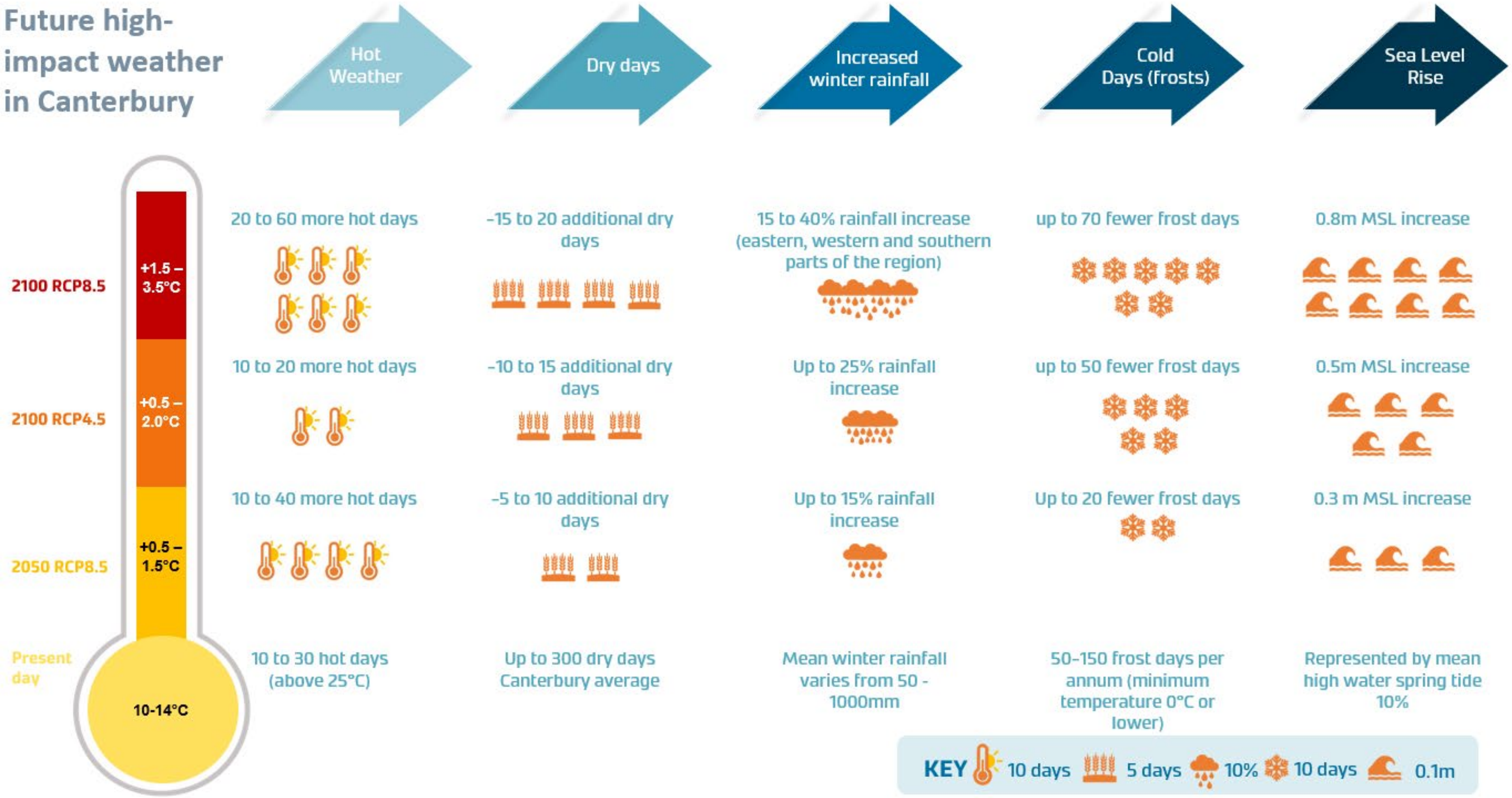


Figure 4.1: Summary of climate hazards in the Canterbury Region (Macara et al., 2020).

5 Te Tūtei o Te Hau: Surveillance of the Wind

5.1 The development of an integrated framework

We live in a highly complex and networked world, and as a consequence, there are multiple ways to consider climate risk. Environment Canterbury recognised that considering climate risk in a more holistic manner would provide a more nuanced understanding of priority risks and why these are important to the Region. It would also provide opportunity to better understand the priorities of our communities, and promote more positive interactions with them. To this end, development of the integrated framework used here not only sought alignment with the NCCRA framework, it also sought to centre around Te Ao Māori. It built upon research into existing central and local government frameworks for resilience and climate change, while also building upon established thinking on indigenous framing of sustainability (Bossa Dean, 2019), Māori holistic views on health expressed through Te Whare Tapawhā model(s) (Durie, 1984), and a kaupapa Māori framework for assessing resilience (Landcare, 2019).

From the project outset, a Rūnanga Project Steering Group (RPSG) was formed to advise on and help develop an integrated risk assessment framework. The collaboratively developed framework recognises and incorporates Te Ao Māori from the outset of the risk assessment process, includes kupu (words) and mātauranga (knowledge) from Ngāi Tahu papatipu rūnanga, and enables alignment with wider community and extracted values.

5.2 Te Tūtei o te Hau: Origins

Te Waiatatanga mai o te Atua is an appropriate allegory, which describes story forms, metaphor, and reference to themes such as the realm of Atua (gods), creation of people and the natural world.

When Ranginui (sky father) and Papatūānuku (earth mother) were separated, space was created in the world and Tane then supported other Atua to create the natural world, Te Taiao, the environment.

Tumatauenga and Rongo were envious and tried to desecrate, to destroy what Tane had created, therefore disassociating themselves from the environment. During his ascent to heaven to destroy Tane, Tumatauenga was defeated and weakened by a wind created by Tane forcing him back to Te Ao Mārama. Tumatauenga and Rongo then had to live in the desolation they created, whilst Tane lived in a place of abundance.

The story within has a deeper, hidden meaning, in reference to what happens when disassociation, or disconnection from the environment occurs, as well as intentional destruction. Climate change is the ‘utu’, the revenge for the maintenance of balance and harmony within society. It is like the great wind which usurped Tumatauenga and Rongo who couldn’t control the environment, making the natural world their own creation. The wind which was their undoing forced them to live in the desolation they had created.

In Te Ao Māori. The wind named ‘Te Tūtei o Te Hau: The surveillance of the wind’, is a guardian, an alert system, for the environment.

The name of the Framework has therefore been gifted as ‘Te Tūtei o Te Hau, Surveillance of the Wind’. When considering the effects of climate change, observations are collated and considered against this framework, our alert system, for understanding climate risk.

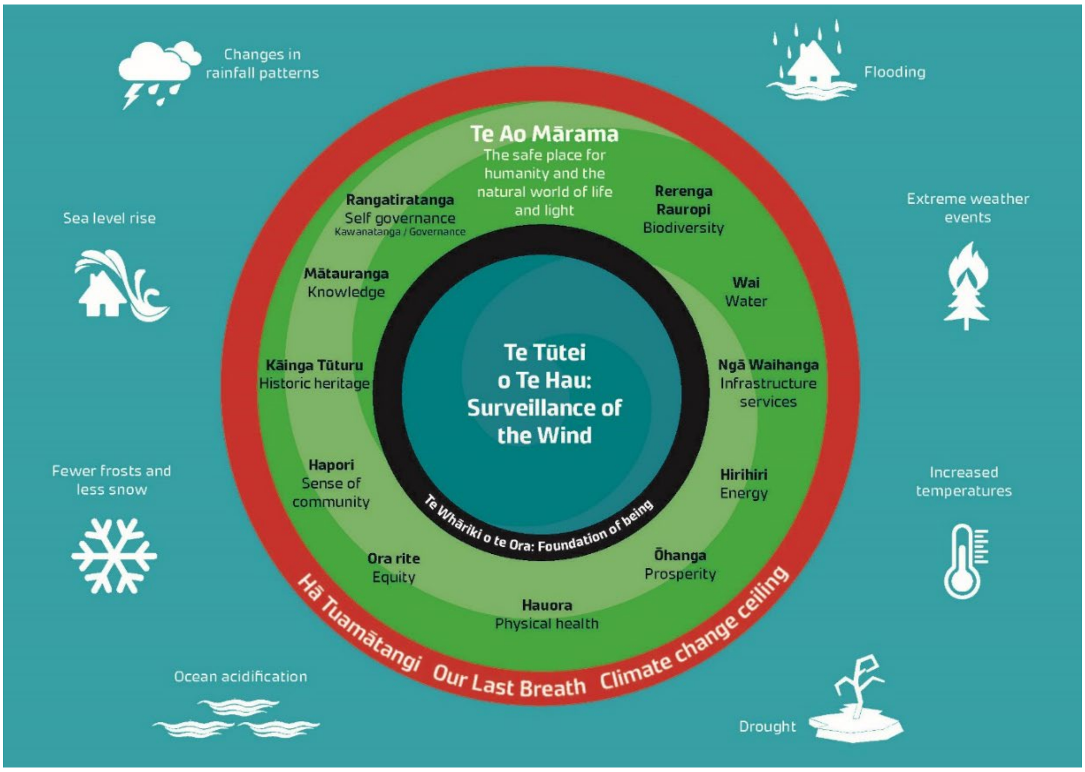


Figure 5.1: Integrated framework developed in collaboration with the Rūnanga Project Steering Group.

5.3 Understanding the diagram: Te Tūtei o Te Hau

The framework is presented as a series of circles, reflecting the circular nature of the world in which humans exist. At its core is the name gifted for the framework which draws on the whakapapa above.

The black circle, represents the inner boundary zone. This boundary zone represents the whakapapa, or genealogical connection, that extends from the spiritual realm to that of the human domain. It recognises that humans cannot exist without basic needs (environmental, economic, cultural) and a social foundation.

The green circle is the area within which humans can exist when we are functioning within the carrying capacity of our ecosystems. Ngā pono (the values) identified within this circle are those that are of critical importance to us to understand and respond to, when considering climate risk. They represent broad categories that are inherently interlinked through one central value. Ngā pono are individually explained within their own subsequent chapters.

The red circle represents the upper limit in which humans, environments and ecosystems can continue to exist. Beyond this boundary, it is no longer possible to respond proactively. This provides a transition to the outer components of the integrated framework, which are the climate variables that we face due to climate change. Te Tūtei o Te Hau recognises that in some instances (such as sea level rise) for some areas and communities, we may already be extending through the red circle into the outer extent of the framework. In these instances, more immediate action to respond to risks may be required.

When considered as a whole, Te Tūtei o Te Hau enables discussions that can span temporal, spatial and sectoral boundaries.

6 Method

Our risk assessment method is framed by the International Panel on Climate Change (IPCC), and uses the elements of hazard, exposure and vulnerability, with the overlap defining risk (see Figure 6.1). This is consistent with the method used during the screening stage in 2020 (refer 2020 Risk Screening Report).

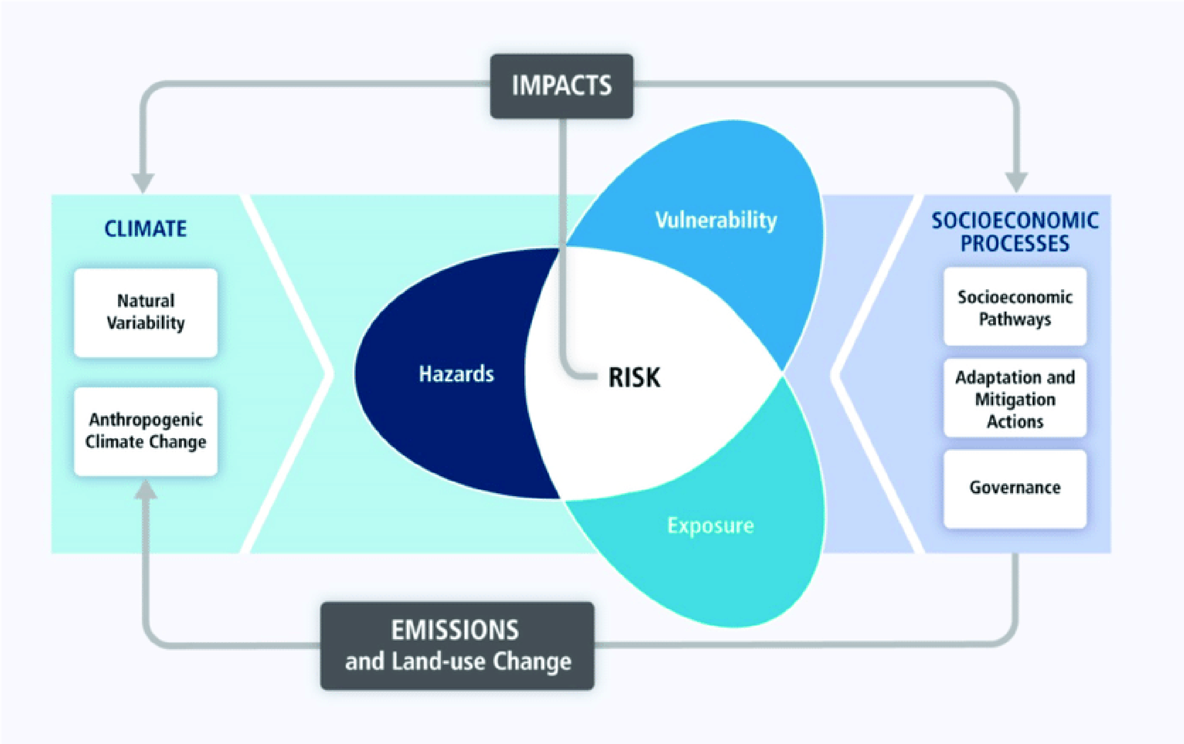


Figure 6.1: International Panel on Climate Change (IPCC) definition of risk.

The method enables a qualitative assessment for risk across specific criteria: exposure, sensitivity and adaptive capacity, discussed below. This allows for more focus on risk prioritisation, including consideration of interactions between differing risks, and any urgency of action that may be required to address specific risks.

6.1 Rating risk

Risk has been rated based on an assessment of exposure and vulnerability (relating to sensitivity and adaptive capacity). This is shown in Figure 6.2 below. Risks were assessed against agreed climate hazards for RCP8.5, for three time-horizons (current, 2050 and 2100). This ensured alignment to the NCCRA approach and subsequent report.

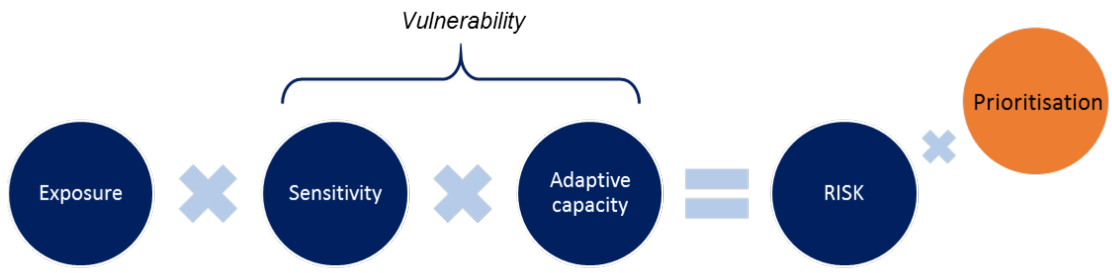


Figure 6.2: Risk equation based on exposure, sensitivity and adaptive capacity.

We recognise that some risks may not suit assessment and subsequent rating of exposure and vulnerability, such as those risks associated with governance matters. Rating human related risks has been undertaken following the above method where possible. Associated assumptions and limitations with both human and governance related risks are discussed below.

6.1.1 Human and Governance related risks

Applying a risk rating to human related risks is difficult due to the range of individual, organisational and universal values and perspectives. The effects resulting from climate change are on a scale. Even within a single event, not all people experiencing the event will necessarily be affected in the same way. For example, people in locations close to coastal areas will be more affected by sea level rise as this will impact their home (they may need to move or they may experience repeated flood or storm events). They may also have strong familial links to the area. By comparison, a person living 40 km inland is far less likely to be impacted by the loss of asset (house) and cultural connection (strong familial links). For them, the personal effect might be limited to access to coastal areas. This variability in lived experience makes quantification of exposure and vulnerability harder than risks within other domains. As seen in Vallance (2011), community involvement after a disaster is complicated by intensity, variety and scale of needs and by the range of those involved. Accounting for this complexity is difficult when looking into the future. It is made harder still by climate change increasing the volume of disasters that our communities are likely to face in future. This is a recognised limitation of projecting into the future, and one that is considered within human related risks.

Applying risk ratings to human risks in the Canterbury Region is challenging due to the diversity of values, complexity of our current society, geographic location, where people live, and the potential uneven distribution of impacts and hazards. Further, the ability to cope with and adapt to risk (adaptive capacity) is variable across individuals, groups, communities. However, broad trends can be teased out for individuals and communities, to provide some indication of the risks. The risks to those living in the Canterbury Region are a result of the settlement histories, demographic characteristics and spatial distribution of people and things of value in the landscape.

Exposure can be measured by a range of indicators, where availability of data is not necessarily sufficient to support a repeatable evaluation. Gaps have been identified in the body of research quantifying the health impacts of climate change for New Zealand, particularly relating to the interactions of climate change, demographic change and social change (RSNZ, 2017). Further consideration at a national scale would be beneficial to supporting qualitative evaluation of human risks at local and regional scales.

Similarly, for governance related risks, assessing risks by rating exposure and vulnerability is problematic. This is because of their nature of being indirect risks, that is, risks that are not directly impacted by physical changes in climate. As such, priority risks for governance that were identified during the Screening Project (2020) have been refined and described through stakeholder engagement and the literature review (discussed in section 7 below). They remain unrated, but are acknowledged as priority risks.

6.2 Prioritising beyond risk rating

Rating risks provides an initial method of prioritisation, with those risks that are rated 'high' and 'extreme' being of higher priority than those rated 'insignificant' or 'low' for example. Risk prioritisation beyond this is required to best inform decision making. This prioritisation is based on value judgements, which will be different for differing individuals, organisations, and groupings. Following the assessment of risk, further work can be undertaken to understand urgency and consequence, two ways to capture value judgements around risk.

How risks interact can also be considered when looking at prioritisation, with risks that have more interactions being of higher potential priority than those with limited interactions. Following detailed analysis of the priority risks, we explored the interrelationship between risks during stakeholder engagement, in order to assist prioritisation as described above. Participants were asked to connect priority risks to each other in a dot-to-dot exercise, identifying where they saw connections between risks. Given that most risks have some level of connection, participants were asked to focus on those connections they felt were most prominent, or noteworthy (i.e. worth paying attention to, interesting, or significant). This activity was undertaken using the priority risks, which were within the five value domains of the NCCRA Framework.

Beyond this, five case studies were taken forward to consider interactions across differing risks. These case study topics are reference points used to develop and document interactions, and may not denote risks in their own right. The five case studies are:

- Electricity outages.
- Community flooding.
- Mahinga kai.
- Tourism.
- Heat-stress related illnesses.

To assess interacting risks, a qualitative approach was used that involved stakeholder consultation and literature review. In the interacting risks engagement workshop, an activity was undertaken using bow-tie analysis principles. Bow-tie analysis allows for visualisation and depiction of direct 'upstream' and 'downstream' risks, often referred to as 'causes' and 'effects' respectively.

Based on the outputs of this session (bow-tie diagrams), a literature review was undertaken to:

a Investigate non-climate related risks which can compound the upstream climate risks.
b Investigate the values and frameworks which these direct effects impact.
c Consider the complex flow-on and feedback effects of the cascading risks.

The results of this analysis are captured within section 20.

6.2.1 Opportunities

Opportunities that result from physical changes in the climate for the Canterbury Region have been documented and agreed. A narrative has been provided to understand the impact of each identified opportunity for the Region. However, these opportunities have been neither rated in a quantitative way, nor assessed.

7 Approach

As discussed in the method section, priority risks formed the starting point to this CCRA, albeit recognising that the first phase, the 2020 Canterbury Climate Change Risk Assessment Project, was undertaken by a subset of stakeholder groups for the Canterbury Region (i.e. predominantly local government). On this basis, our approach for the method and engagement included:

- **A literature review:** to provide a robust evidence base to understand risks in greater detail and to identify any gaps from the first phase screening process.
- **Subject Matter Expert Engagement:** to elicit information specific to a particular value (e.g. rerenga rauropi – biodiversity, wai – water, ngā waihanga – infrastructure services, etc). See Appendix B for a list of stakeholders.
- **Ngāi Tahu ngā rūnanga Engagement:** to elicit information specific to Te Ao Māori and Ngāi Tahu values.

7.1 Literature review

A literature review was undertaken to build on the first phase screening process and inform a detailed understanding of each risk. To account for the narrower scope of stakeholder engagement in the 2020 Canterbury Climate Change Risk Assessment Project, we undertook a high-level gap analysis during the literature review stage. This was further complemented by the engagement activities undertaken during the 2021 domain workshops.

As part of the literature review, we also aggregated risks, as this provides easier communication of risks during engagement and subsequent reporting. The risk aggregation has been aligned to the new integrated framework, identified above in Figure 4.1.

7.2 Engagement overview

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

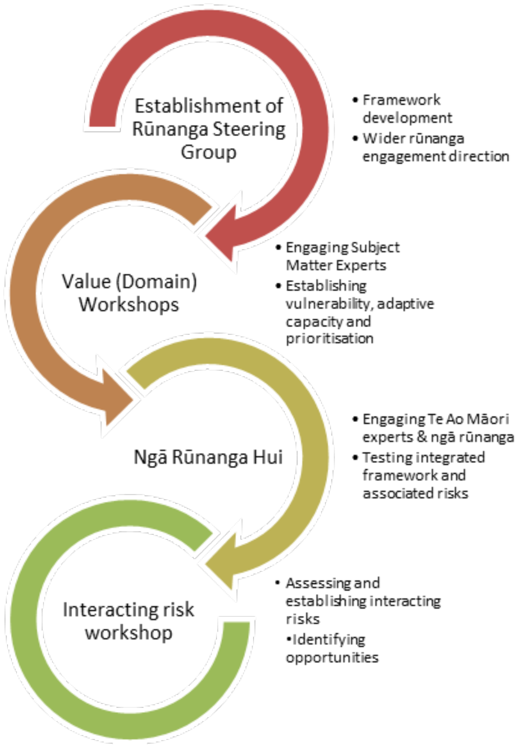
All engagement activities were underpinned by:

- Building awareness and understanding of the project amongst stakeholders so they would understand the final report and the process used to achieve it.
- Building an integrated approach for Te Ao Māori in understanding climate risk, and incorporating the values of Ngāi Tahu throughout.
- Providing a strong, broad, and representative evidence base to develop the CCRA report.
- Providing critical and informed input into the risk assessment, including risks, opportunities and gaps for further consideration.

7.2.1 Engagement method

Our engagement used a broad range of methods to achieve the project objectives and are aligned to stakeholder and partner needs. These are shown in the diagram to the right, detailed below, and include:

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



7.2.2 Rūnanga Project Steering Group

Our focus for rūnanga engagement has been to enable co-design of Ngāi Tahu engagement alongside rūnanga representatives, in order to test and validate the framework and engagement prior to implementation.

Establishment of the Papatipu Rūnanga Project Steering Group (RPSG) has been critical to this engagement. A mandated representative from each papatipu rūnanga was sought to act as an overarching interface for the project. We recognised that due to a combination of capacity and interest restrictions, many rūnanga indicated a preference to maintain a "for information only" watching brief of the project by way of receiving minutes and information and updates from the RPSG as appropriate. However, regular hui of the RPSG were held to develop the framework, with consistent representation from three rūnanga.

7.2.3 Wider Rūnanga Engagement

A series of three hui across the Region was considered to provide for greater representation across ngā rūnanga as part of the project. However, through critical enquiry by the RPSG it was determined that a targeted focus group hui would achieve a greater level of participation, as well as providing depth into the kōrero for understanding climate risks within Te Ao Māori. This hui occurred on 30 April 2021.

7.2.4 Domain focused workshops

The domain focused workshops sought a broader group of attendees than those of the 2020 Screening, reaching out to subject matter experts beyond local government, to best capture views within the Canterbury Region. See Appendix B for a list of stakeholders included in this project. These were undertaken throughout March 2021. The focus of these workshops was on risk prioritisation, including consideration of interactions between differing risks, and urgency of action required.

The key objectives for the domain focus workshops included:

- Increasing knowledge and understanding of participants about each priority risk within the Canterbury Region.

- Providing ratings for the individual criteria of risk (where possible).
- Further identifying information that could assist with prioritisation.

7.2.5 Interacting risks workshop

The interacting risks (also known as “cascading” risks) workshop sought to enable a cross-domain (cross-values) approach to understand the interacting risks. Understanding these risks is important given their foundational nature, as, left unaddressed, this could lead to maladaptation and lock in. Inclusion of interacting risks has not been undertaken as part of a climate change risk assessment in New Zealand before, therefore the key objectives for this workshop included:

- Increasing the knowledge and understanding of interacting risks in the Canterbury Region.
- Gaining specific examples for inclusion in the final report as case studies.
- Further identify information around prioritisation.

8 Summary of Risks

The Canterbury Region faces a range of risks to all ngā pono (values) within te Ao Mārama (the safe place for humanity and the natural living world). These include direct physical risks from climate hazards to the natural and physical environment, such as those from climate hazards to many aspects within rauropi (biodiversity), wai (water), ngā waihanga (infrastructure services), hirihiri (energy), kāinga tūturu (historic heritage), and the natural resources that support ōhanga (prosperity). Climate change also poses direct risks to hauora (physical health), such as heat stress and injury from flooding.

From these direct risks, arise a range of indirect risks, as the physical impacts of climate change pose risks to the less tangible ngā pono of the Region. These include risks to hauora (wellbeing), and risks to ora rite (equity), hapori (sense of community), mātauranga (knowledge), and rangatiratanga (governance).

Across all ngā pono, risks from climate change are seen to increase with time. At the present day, the majority of risks are rated as insignificant or low, with 30% rated as moderate, 10% rated high, and 3% rated as extreme. These present-day highly rated risks (i.e. those rated as either 'high' or 'extreme') mainly include those to rauropi (biodiversity), wai (water), and ngā waihanga (infrastructure services). The present-day risks that are rated extreme include those relating to water supply and irrigation.

By late century, risks within all ngā pono are rated as extreme, with the vast majority of all identified risks rated either high or extreme.

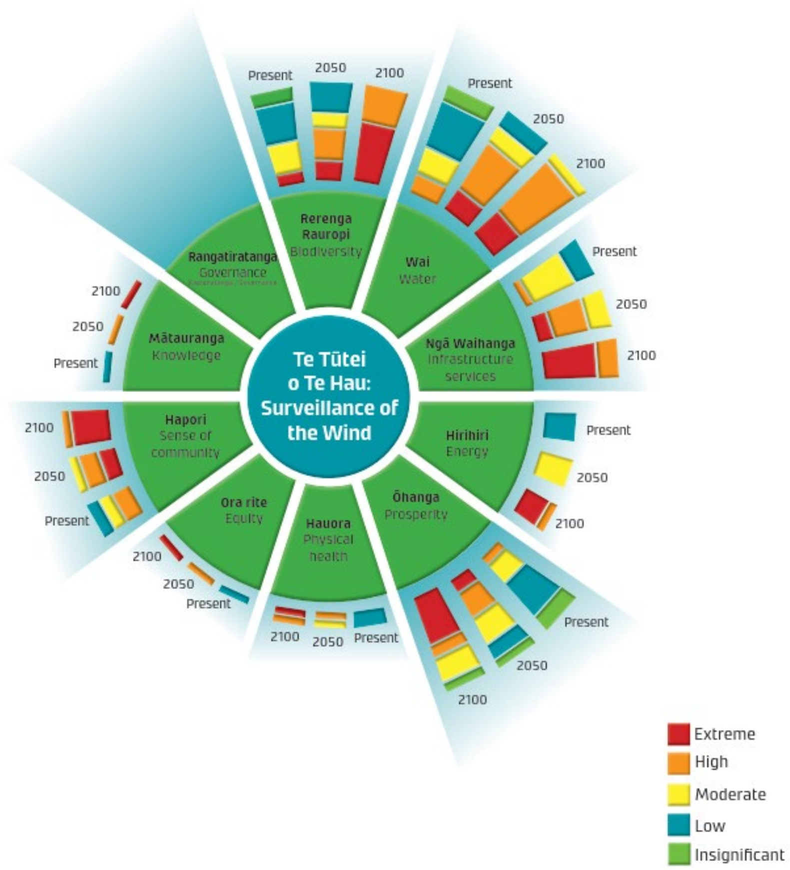


Figure 8.1: Summary of risk profiles for each of ngā pono (the values) across present, 2050 and 2100 timeframes, noting some risks are not rated, leading to blank values (e.g. rangatiratanga – governance, which, as an indirect risk is not directly impacted by physical changes in climate so cannot be rated using the same assessment of vulnerability, but nevertheless remains a priority risk).

The challenges that climate change introduces will occur in different ways across the Region. The large land area and high geographic diversity of Canterbury mean that some risks will be most relevant to certain areas. The environments of the Region can be broadly categorised into alpine/high country environments, montane/hill country, lowlands, coastal and marine habitats, freshwater systems and urban centres, as are summarised in Figure 8.2.

The alpine environment of Canterbury acts as an important water source to the Region's alpine rivers, supports unique biodiversity and generates tourism. Increased temperature, reduced snow and changing rainfall patterns pose some of the highest rated risks to these systems.

The Region's water sources play an important role in mātauranga Māori (Māori knowledge), as well as contributing to wider biodiversity and public amenity. They are also important sources of irrigation and stock water for agricultural activity, and support the water demands of towns and industry. Increased temperature and drought, as well as changing rainfall patterns, pose some of the highest rated risks to freshwater systems.

The montane/hill country and forested foothills support unique ecosystems and low-density farming and forestry. Increased temperature, fire weather, and changing rainfall patterns pose some of the highest rated risks to these systems.

The fertile lowlands of the plains are the agricultural powerhouse of the Region, supporting diverse farming activity and many farming communities. Increasing drought potential and related impacts on water availability and agriculture, as well as increased storms, winds, and flooding pose some of the highest rated risks to these systems.

The long coastline of the Region supports diverse ecosystems, including coastal wetlands and abundant marine species. Ports, transport connections, coastal ecosystems, unique wetlands, and communities along the coastal fringe, will all be exposed to increasing coastal flooding, salinity stress and erosion. Temperature and ocean chemistry changes will impact fisheries and marine ecosystems, resulting in changed behaviour patterns, such as migration routes and increased mortality, and changing the population of some species.

Ōtautahi/Christchurch, Canterbury's largest city, is a major social and economic hub for the Region. The low-lying coastal position of much of the city makes it very exposed to flooding and sea level rise, with widespread risks to its communities and infrastructure. Risks from climate hazards on all communities generally include damage to infrastructure from flooding, and reduced community cohesion from increasing climate related damages, disruption to transport routes and supply chains, impacts on physical and mental health and changing markets and job availability. Changing climate also poses risks to supporting utilities such as landfills, and power transmission.

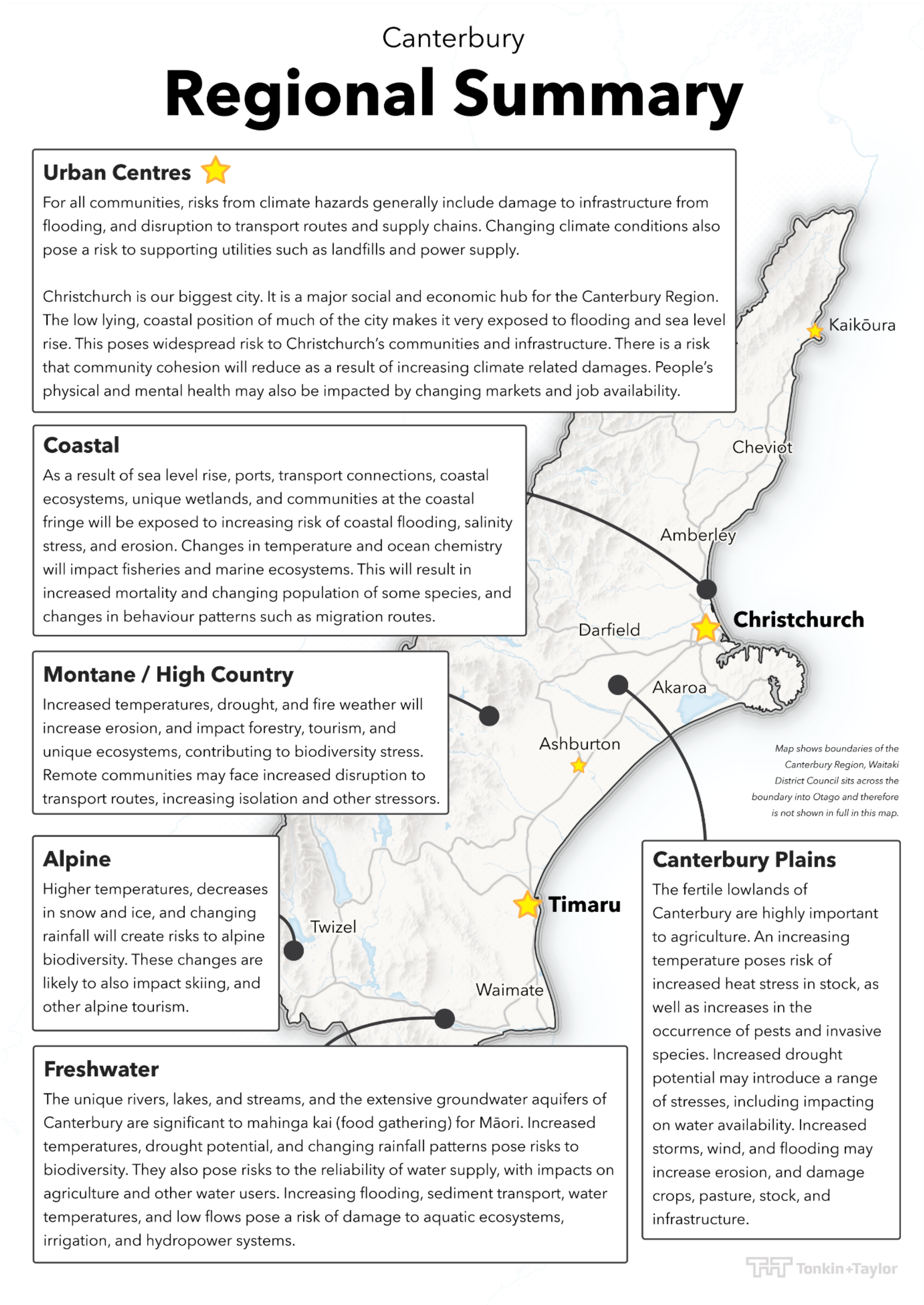


Figure 8.2: Regional summary of climate risks.

9 Rerenga Rauropi | Biodiversity

The biodiversity of Canterbury provides the life supporting systems that enable all organisms, including humans, to survive. It forms a fundamental part of the cultural identity and heritage of Ngāi Tahu, of subsequent settlers, and of the Canterbury community today.

The Region has many unique and precious ecosystems, from the majestic alpine slopes of the Main Divide to the vast and abundant Canterbury plains, as well as diverse and rugged coastal margins. Connecting all of these are the unique braided river systems – vital habitats and corridors that connect and nourish the land, ki Uta ki Tai (from the mountains to the sea). The biodiversity within these ecosystems includes taonga species, many of which are endemic to New Zealand and the Canterbury Region (Canterbury Biodiversity Strategy, 2008).

Protection of biodiversity values within Canterbury is the legal responsibility of the Department of Conservation, Environment Canterbury, and District Councils. Nationally 'Threatened' and ‘At Risk’ species within the Region are protected under the New Zealand Wildlife Act 1953. Many other organisations also work to protect local biodiversity, including the territorial authorities of the Region, iwi, and community and conservation groups.

Canterbury’s ecosystems are part of large interconnected systems, playing a central role in supporting biodiversity. They are intrinsically linked to many other aspects of social and ecological systems. Rauropi (biodiversity) links to many other ngā pono (values). Its link to wai (water) is particularly strong, for example where wetlands purify water, regulate flood flows and drought. Indigenous forests purify the air, and provide spaces that can be both peaceful and exhilarating for recreation. Canterbury’s fertile lands are fundamental to supporting the Region’s ōhanga (prosperity) through agriculture, fisheries and corridors that connect and nourish the land.

These diverse ecosystems are fundamental to hapori (sense of community) and kāinga tūturu (historic heritage), including through gathering mahinga kai (food). As the traditional Māori concept of gathering food, mahinga kai is related to the concepts of caring for the land and ecosystems that support and sustain life.

9.1 Summary of risks

The biodiversity of Canterbury is threatened by a changing climate. Towards the late 21st century, native terrestrial biodiversity faces extreme risk due to drought, increased fire weather and reduced snow and ice. Projected temperature increases for Canterbury indicate average warming of 1.5-3.5°C by 2100 under RCP8.5. This is likely to be accompanied by an increased annual range, with maximum summer temperature increases projected up to 5°C warmer than present, and minimum increases in (winter) temperatures around 1-2.5°C. Changes in annual average rainfall across Canterbury are expected to vary only by a small margin of +/- 5% by 2100 under RCP8.5. However, seasonal rainfall is projected to have higher variability. By 2100 increases of 15-40% in winter rainfall are projected for many eastern, western and southern parts of Canterbury, while small decreases up to 10-15% in inland/western Canterbury and about Banks Peninsula are projected for summer. These projections indicate increasing seasonality of annual rainfall, potentially with winter rainfall more strongly associated with storm events.

As per Environment Canterbury (2008), unique ecosystems/biomes particular to Canterbury include:

- Extensive alpine tussock-lands/herb-fields.
- Limestone areas in north and south Canterbury.
- Large tracts of beech.

- Pockets of mixed podocarp and podocarp/hardwood forests in the montane/hill country.

Terrestrial native species are generally grouped into altitudinal zones in the Canterbury Region, spanning the alpine zones of the western mountains, the inland and montane hill-country, and the lowlands, which include the Canterbury Plains and coastal margins.

Indigenous vegetation over the majority of Eastern Canterbury is threatened. Already, as at 2021, less than 10% has been retained from the northern Canterbury Plains to around Waimate, and less than 30% on Banks Peninsula. Pockets of higher vegetation cover remain around the Waitaki River, Lakes Pukaki and Tekapo, around the Seaward Kaikōura Range, and in the montane/hill and alpine/high country west of the frontal/eastern ranges.

In ecosystems that consist of fragmented pockets of habitat (as is the case in much of Canterbury, shown in Figure 9.1) there is less stability in individual habitat pockets. This leads to compounding losses of biodiversity across the Region. Sensitivity of native terrestrial biodiversity is linked to population sizes for key support species (i.e. the predominant habitat vegetation species), and the size and continuity of habitats. Areas where native habitats are highly fragmented have a high degree of sensitivity to both slow changes in climate and to event-type disturbances. Small/fragmented habitats can only support small populations of different species. This means that even where the biodiversity in a given ecosystem area is currently high, if there are small population sizes of many species, they have a high sensitivity to change. The loss of a small number of individuals or reduced reproductivity within these populations can have a proportionally larger impact on their success and overall survival.

Rerenga rauropi (biodiversity) is also important from a rūnanga perspective, as mahinga kai has significant value to Ngāi Tahu. The ability to collect mahinga kai contributes to physical, spiritual, social, and economic well-being. It is important for mahinga kai to be managed and gathered as was done by Ngāi Tahu ancestors. Mahinga kai enables the values of mana and manaakitanga (respect and hospitality) to be demonstrated, empowering Ngāi Tahu to thrive (Environment Canterbury, 2021). Mahinga kai or mahika kai (alternate local dialect term for mahinga kai) areas can include species (such as manu – birds, kai moana – seafood, rākau – plants, etc), natural habitats, materials and practices for harvesting food, and places where food or resources are, or were, gathered (Environment Canterbury, 2017).

Risks to he kura taiao (living treasures) are identified for each of the Canterbury environments (alpine/high, montane/hill, lowland, wetlands, freshwater and coastal), as well as a separate discussion on the threat to biosecurity from pests and diseases. The highest rated risk in each of the ecosystem and environment types is listed in Table 9.1.

Table 9.1: Summary of highest rated risks to biodiversity

	Higher mean temperatures			Change in mean annual rainfall			Drought			River and surface flooding			Coastal flooding		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Terrestrial, freshwater, and marine ecosystems from pests and diseases	M	E	E	M	H	E									
Natural coastal habitats (dunes, estuaries, rocky shores)															
Native marine biodiversity - flora & fauna															
Water quality in marine, estuary and harbour environments															
Native freshwater biodiversity - flora & fauna	I	M	E	I	L	H				L	L	H			
Native terrestrial biodiversity - flora & fauna															
Coastal wetlands										M	E	E			
Alpine / high country environments	L	M	H	I	L	H									
Lowland and coastal environments													L	L	H
Montane/hill country environments	I	L	H				L	L	H						

	Increased coastal erosion			Sea-level rise and salinity stresses			Storms and wind			Increased fire-weather			Increasing landslides and soil erosion		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Terrestrial, freshwater, and marine ecosystems from pests and diseases															
Natural coastal habitats (dunes, estuaries, rocky shores)															
Native marine biodiversity - flora & fauna															
Water quality in marine, estuary and harbour environments															
Native freshwater biodiversity - flora & fauna															
Native terrestrial biodiversity - flora & fauna															
Coastal wetlands	M	H	E	L	H	E									
Alpine / high country environments															
Lowland and coastal environments				L	M	E				M	H	E			
Montane/hill country environments							H	E	E	H	E	E			

	Extreme weather events			Reduced snow & ice			Ocean chemistry changes			Marine heatwaves			Climate change		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Terrestrial, freshwater, and marine ecosystems from pests and diseases				L	H	E									
Natural coastal habitats (dunes, estuaries, rocky shores)															
Native marine biodiversity - flora & fauna															
Water quality in marine, estuary and harbour environments															
Native freshwater biodiversity - flora & fauna															
Native terrestrial biodiversity - flora & fauna															
Coastal wetlands															
Alpine / high country environments				L	H	E									
Lowland and coastal environments															
Montane/hill country environments															

Key

I	Insignifcant
L	Low
M	Moderate
H	High
E	Extreme

P	Present day
M	Mid (2050)
L	Long (2100)

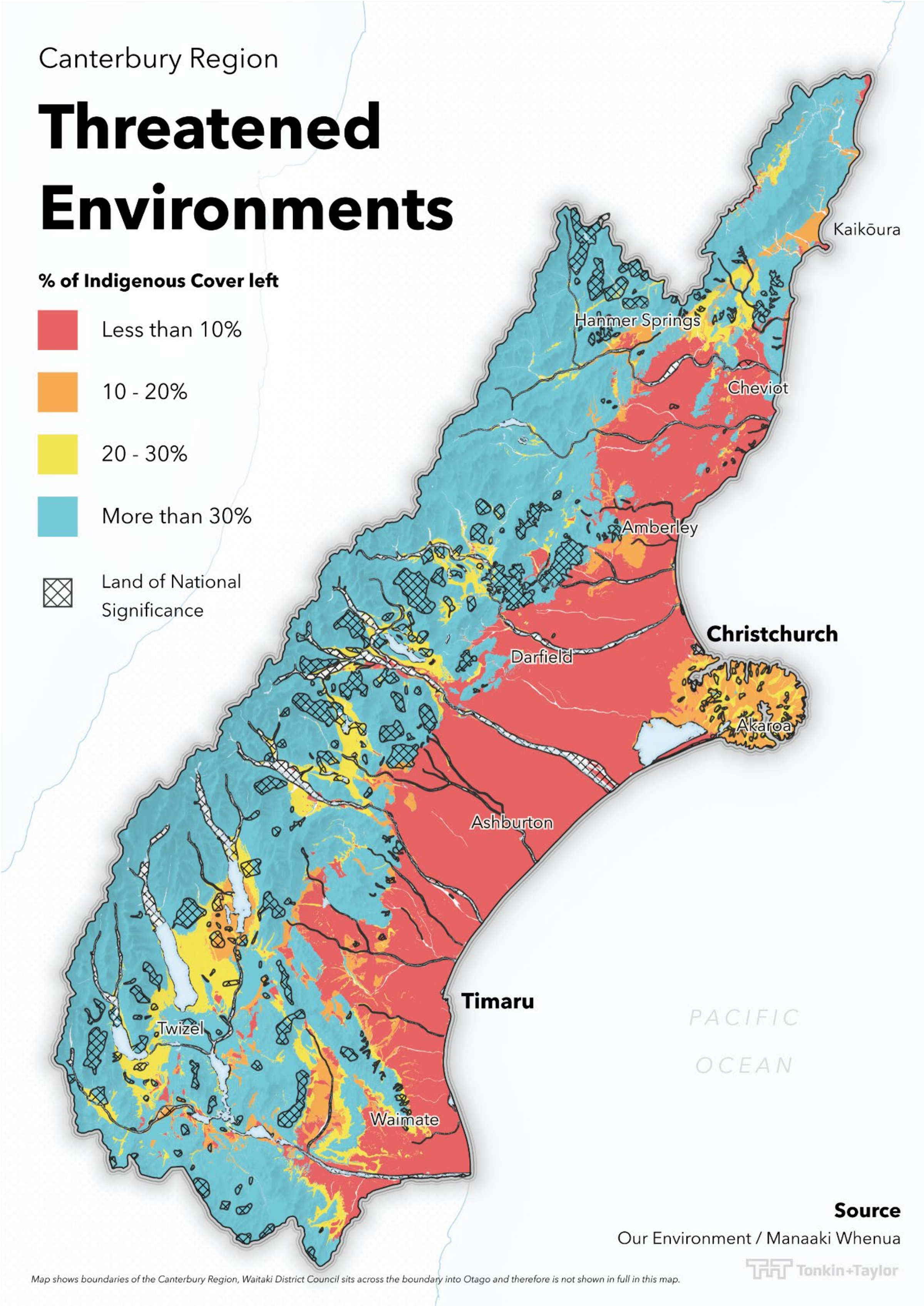


Figure 9.1: Threatened indigenous land cover and land of national significance in the Canterbury Region.

9.2 He Kura Taiao (living treasures) in alpine environments

The highest risks to flora and fauna in alpine environments from climate change include those from changes in snow and ice (both spatial and temporal extent), temperature rise, and changes in rainfall (Table 9.2). Reduced snow and ice combined with increased temperatures will reduce and fragment habitat suitable for alpine species. This, combined with increased competition from montane species, will lead to reduced alpine species population sizes and potential local extinction.

Table 9.2: Summary of risks to alpine environments

Risk statement	Risk				High level description
	Present	2050 (RCP8.5)	2100 (RCP4.5)	2100 (RCP8.5)	
Risk to alpine / high country environments due to reduced snow & ice	Low	High	Extreme	Extreme	Alpine and high country environments are projected to be exposed to reduced snow and ice as temperatures warm. Alpine ecosystems are likely to be adversely affected as alpine adapted flora and fauna change elevation tolerance, suffer from a reduction and loss of habitats and face increased competition from low-land species. Alpine adapted species often have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.
Risk to alpine / high country environments due to higher mean temperatures	Low	Moderate	High	High	Projected increases in mean temperature are likely to change the elevation tolerance of alpine species, cause reduction and loss of habitat, and cause increased competition from low-land species. Many alpine adapted species have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.
Risk to alpine / high country environments due to change in mean annual rainfall	Insignificant	Low	Moderate	High	Projected changes in rainfall patterns may cause increased dry periods and drought. This may lead to reduced water availability causing plant stress, leading to reduction or loss of alpine habitat and increased competition from species adapted to the lower altitudinal zones (e.g. montane), and possible changes of alpine ecosystems to montane ecosystems. Many alpine adapted species have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.

Alpine environments are located in western Canterbury in high-elevation areas above the treeline and below the permanent snow line along the Main Divide. The Seaward Kaikōura Ranges also support alpine environments outside of the Main Divide ranges. Most of these environments contain more than 30% native vegetation, and much of the land is included in public conservation land (Figure 9.1).

Alpine environments support ecosystems that comprise cold-adapted species characterised by tussock and herbfield species (Landcare Research, 2020). These areas support a wide range of highly specialised native plants including the native daisy (*Celmisia)*, speargrass *(Aciphylla)*, buttercup *(Ranunculus)*, and vegetable sheep *(*species of *Raoulia),* as well as native grasshoppers, lizard species (up to at least 1800-1900 m), invertebrates, and birds (such as kea, pipits, and rock wren) that are only found in these parts of New Zealand (Department of Conservation, 2021).

Alpine ecosystems support high biodiversity due to the large number of specialist species adapted to these environments. There is an inherent limit on the available habitat areas for alpine species due to the unique geographical nature of the alpine environment. Alpine species are directly exposed to projected decreasing snow and ice resulting from increasing temperatures, which directly impact their primary ranges. Water availability and seasonality are also likely to change as a result of reduced snow and ice and increasing temperatures. Although NIWA project a reduction in annual snow days, there is also a projected increase in winter rainfall. The implications of this for permanent snow fields and snow melt-run-off are uncertain (Macara et al., 2020).

Additionally to warming temperatures shifting alpine habitats to ever higher elevations, the elevation tolerance of more competitive low-land species will shift upwards (Halloy & Mark, 2003). This will likewise force alpine species into smaller geographic areas and may result in a tendency for alpine species to become “islanded” (Triantis & Matthews, 2020), leading to a slow loss of biodiversity in these ecosystems.

Many alpine plant species have slow reproductive rates and dispersal mechanisms, which contribute to a low adaptive capacity. Range limitations and geographic isolation of individual alpine terrestrial communities also contribute to a low adaptive capacity for many alpine species. This means that isolated pockets of alpine species are vulnerable to mortality/loss. For example, the Canterbury knobbled weevil (Figure 8.2) was assumed extinct, but was rediscovered in 2004 and is now considered one of New Zealand’s rarest species. Such species are specifically adapted to alpine environments, with limited adaptive capacity ,and are extremely sensitive to habitat degradation from fires and rodent predation (Hayward, 2018).

Figure 9.2: Canterbury knobbled weevil (left) and its natural habitat speargrass, Aciphylla aurea (right) (Source: New Zealand Conservation Authority, 2021, Shaun Barnett/Black Robin Photography, Wilderness Magazine, 2014).

9.3 He Kura Taiao (living treasures) in montane/hill country ecosystems

Risks to terrestrial montane/hill country ecosystems environments from climate change include those from drought, increased fire weather, storms, wind and higher mean temperatures. Exposure of montane/hill country to fire, storms and wind is rated to rise to extreme by late century. These hazards will contribute to erosion, damage to the ecosystem and species loss. The adaptive capacity of montane/hill country species is rated low due to slow recovery rates.

Table 9.3: Summary of risks to montane/hill country environments

Risk statement	Risk: Present	2050 (RCP8.5)	2100 (RCP4.5)	2100 (RCP8.5)	High level description
Risk to montane/hill country environments due to increased fire-weather	High	Extreme	Extreme	Extreme	Projected increases in wind, temperatures, and number of dry and hot days may increase the likelihood of wildfire in montane/hill country environments. Montane ecosystems within hill country environments are highly prone to species and habitat loss during fires. Wildfires can cause widespread mortality from which there can be long recovery times.
Risk to montane/hill country environments due to storms and wind	High	Extreme	Extreme	Extreme	Projected increases in storms and wind may damage montane/hill country environments. The erodible soils within these environments are particularly sensitive when bare. Depletion of native vegetation associated with grazing, pests and other hazards contributes further to erosion. These factors are likely to cause degradation of montane/hill country ecosystems.
Risk to montane/hill country environments due to drought	Low	Low	High	High	The occurrence of drought in montane/hill country environments is projected to increase over time. Ecosystems within these environments are currently relatively tolerant of hot dry conditions, however drought may cause water shortages stressing ecosystems, and contributing to species mortality. The slow recovery of ecosystems may lead to increasing establishment of exotic species.
Risk to montane/hill country environments due to higher mean temperatures	Insignificant	Low	High	High	Temperatures are projected to increase in montane/hill country environments over time. Ecosystems within these environments are currently relatively tolerant of hot dry conditions, however the adaptive capacity of species may reduce once temperature tolerance thresholds are reached.

Montane/hill country ecosystems occur in the hill country east of the Main Divide, including the high elevation basins such as the Mackenzie, Fairlie and Castle Hill basins. The foothills around the Seaward Kaikōura ranges and the inland Clarence River basin are also considered in the Montane/hill country group. In Canterbury these ecosystems are dominated by tussock and exotic grasslands and shrublands, with more than 30% native vegetation remaining. Rare species with habitats in these ecosystems include the great spotted kiwi, geckos, and skinks.

Climate projections indicate increasing drought by 2100, with projections of up to 15 more dry days per year, 60-85 more hot days and increases in accumulated potential evapotranspiration deficit (PED) across most of inland Canterbury. These changing climatic conditions will increase the frequency and severity of year-on-year droughts throughout the Region (Macara et al., 2020).

Montane/hill country ecosystems are currently relatively tolerant of hot dry conditions and have moderate adaptive capacity to changes such as temperature increases (Jentsch & Beierkuhnlein, 2008). As temperatures and the frequency of hot days and drought conditions increase, ecosystem sensitivity may increase over time as plants and animals suffer prolonged stress from decreased rainfall (Innes & Kelly, 1992). This is likely to lead to a lowering of the survival of montane/hill country species over time, ultimately reducing biodiversity which may reduce the adaptive capacity of the ecosystem.

Decreasing biodiversity (species loss) is likely to be observed following severe event scale disturbances such as fire and sustained/frequent/severe droughts. These types of events are expected to have a greater impact on ecosystems than gradual shifts in mean temperature and rainfall (Jentsch & Beierkuhnlein, 2008; Rogers et al., 2005). For event-type disturbances, native biodiversity can be considered to have a low adaptive capacity if sufficient individuals in the area affected by the event perish, and habitats are fragmented reducing the potential for seed distribution.

Native vegetation, particularly montane/hill-country ecosystems and some terrestrial plant species, typically have naturally slow self-recovery mechanisms following event type disturbances (Perry et al., 2014). In addition, some terrestrial animal species, such as some lizard and bird species, have naturally low reproductive output. Combined with small homing ranges and a reliance on the availability of specific and/or continuous habitat, this reduces their ability to recover from natural disturbances (Cree, 1994).

Without intervention by people, the populations of many native terrestrial species are likely to suffer from habitat loss and/or be displaced by exotic species during succession phases (e.g. native coloniser species are outcompeted by exotic coloniser species). This greatly prolongs – and in some cases even prohibits – the succession and recovery of native species, leading to potential species extinction.

There is likely to be an increase of effects resulting from increased exposure to seasonal extremes (wetter winters, severe storms, increased wind, and drier, hotter summers). For example, the Mackenzie Basin is a characteristic montane/hill-country ecosystem that is particularly susceptible to these extremes (Figure 9.3). Its sandy soil is susceptible to erosion, which is triggered by high wind and overland flow. This is most severe where bare soil is exposed, due to loss of vegetation associated with over grazing and damage from rabbits and other pest species (Basher and Webb, 1997).

Figure 9.3: The Mackenzie Country soils are prone to erosion, particularly when left bare due to fire or pest damage (Source – LINZ, 2021).

9.4 He Kura Taiao (living treasures) in lowland and coastal environments

Risks to lowland and coastal environments from climate change include those from sea level rise and salinity stress, fire weather, and flooding. Exposure of lowlands and coastal environments to fire and flooding is rated to rise to high by late century, and exposure to sea level rise is rated to rise to extreme. Coastal erosion may cause environments to become degraded or compressed if they cannot adjust and retreat inland in response to erosion. Flooding and fire will degrade habitats further, which may disrupt ecosystems.

Table 9.4: Summary of risks to lowland and coastal environments

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to lowland and coastal environments due to increased fire-weather	Moderate	High	Extreme	Extreme	Projected increases in wind, temperatures, and number of dry and hot days may increase the likelihood of wildfire. Lowland environments are sensitive to event type disturbances such as wildfire which may cause high rates of mortality and habitat destruction from which local ecosystems may not easily recover.
Risk to lowland and coastal environments due to sea-level rise and salinity stresses	Low	Moderate	High	Extreme	Projected sea level rise is likely to cause inundation, erosion and salinity stress. Sea level rise and erosion may compress or degrade coastal habitats, eventually leading to habitat or species loss. Coastal environments can adapt to sea level rise by shifting inland, however this is often limited by geographical constraints or existing land use.
Risk to lowland and coastal environments due to coastal flooding	Low	Low	High	High	Projected sea level rise is likely to contribute to increased coastal flooding which may cause erosion, salinization and degrade coastal habitats.

Lowland and coastal environments comprise the largest land area in Canterbury. They include the whole of the Canterbury Plains, Amuri Plains, Kaikōura, and Banks Peninsula, as well as the coastal margins along the east coast. These environments are typified by highly modified vegetation – less than 10% of native vegetation remains over most of this area. The lowland plains have the highest level of land-use intensification, and hence the lowest percentages of remaining indigenous vegetation. They consequently also have the lowest proportion of land in protected public conservation areas. Vegetation is dominated by exotic grassland or crops, with very small and fragmented pockets of native and exotic forests. There are very few connections between lowland refuges. Some larger forest remnants are present around hill margins such as Mt Peel and Mt Somers, the Mount Thomas forest, the Hundalees, and in the coastal hills to the south and north of Kaikōura.

Coastal environments will be exposed to a projected sea level rise of 0.8 m above the current level by the late century. The increasing mean sea level leads to large tides and greater inundation of coastal environments during storm events. It also creates higher salinity pressures on the coastal margin. Coastal margins naturally adapt to sea level rise and salinity stress by migration inland. There are generally physical barriers to this adaptation, in the form of geographic (e.g. sea cliffs) or man-made constraints (e.g. land development or coastal protection). In many cases, these prevent the inland migration of coastal dunes/marginal environments, causing these ecosystems to be compressed and therefore degraded. Eventually, this may lead to the complete loss of the coastal margin environment in these areas, and the associated loss of these ecosystems.

As intertidal habitats are reduced, the populations of many species traditionally relied upon for mahinga kai are likely to decline. Examples of these species include the threatened and declining population of kanakana/piharau (lamprey) that occupies freshwater and coastal habitats (Figure 9.4), as well as the dune vegetation pingao (golden sand sedge), and tororaro (wiggy wig) (Environment Canterbury, 2021, NIWA, 2021; New Zealand Plant Conservation Network, 2021).

Sea level rise will also likely lead to the loss and/or reduction of foraging and breeding habitat for some endemic coastal marine populations in the Canterbury Region. Those likely to be impacted include, but are not limited to, the pohowera (banded dotterel, *Charadrius bicinctus*), tōrea pango (variable oyster catcher, *Haematopus unicolor*), hoiho (yellow-eyed penguin – *Megadyptes antipodes*) and New Zealand fur seal (*Arctocephalus forsteri*).

High rates of erosion and sea level inundation will adversely affect near-shore marine environments as habitats are lost, and breeding areas for sea birds and marine mammals such as seals disrupted. River mouths, estuaries, and lagoons will also be inundated or eroded and degraded. This will impact the species inhabiting them, some of which include the world's rarest bird species, such as the tītī (Hutton's shearwater, *Puffinus huttoni),* black stilt (*Himantopus novaezelandiae)* and kororā (white-flippered penguin, *Eudyptula minor albosignata)*.

The increasing risk of fire weather relates to the projected increases in temperature and numbers of hot days in eastern Canterbury, alongside decreasing summer rainfall, particularly about Banks Peninsula. Lowland environments typically display tolerance to slow/ongoing changes in climate, but have a low tolerance for event type disturbances. Fires and floods causing high loss of individuals from local ecosystems lead to destabilisation of local habitats and subsequent collapse of these areas, unless human measures are taken to encourage regrowth/re-population following the events.

Figure 9.4: Kanakana/Piharau (lamprey) is an important mahinga kai resource and prized delicacy. It is a threatened species within Canterbury that is found in coastal and freshwater habitats that may be threatened further by loss of coastal margins (NIWA, 2021) (Source - Environment Canterbury 2021).

9.5 He Kura Taiao (living treasures) in wetland environments

Risks to wetland environments from climate change include those from sea level rise and salinity stress, coastal erosion, and flooding (refer Table 9.5). Inland wetlands are also exposed to increasing temperature, changes in rainfall and event type disturbances associated with flooding and fires. However, the screening of risks identified that coastal wetlands were a priority, and they are therefore the focus of this assessment. Exposure of coastal wetlands to erosion, sea level rise and flooding is rated to rise to extreme by late century. These systems are sensitive to salinity and sedimentation which can lead to changing species, and habitat loss.

Table 9.5: Summary of risks to coastal wetlands

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to coastal wetlands due to river and surface flooding	Moderate	Extreme	Extreme	Extreme	Projected increases in rainfall intensity is likely to increase the occurrence of flooding. This may cause sediment deposition within wetlands from upstream which can make wetlands shallower, smother habitats and carry additional nutrients or contaminants. Many wetland species are specifically adapted and may suffer from habitat degradation and loss.
Risk to coastal wetlands due to increasing coastal erosion	Moderate	High	Extreme	Extreme	Low-lying coastal wetlands are at risk from coastal erosion which may degrade habitats and cause sediment deposition.
Risk to coastal wetlands due to sea-level rise and salinity stresses	Low	High	High	Extreme	Sea level rise and coastal inundation are projected to increase, which will lead to increasing salinity stress to coastal wetlands. Species composition and biodiversity (species richness) is expected to change as a result of periodic or permanent salination of coastal wetlands. Mobile species (some plants and birds) can relocate however, many species of invertebrates, some species of plants, and fish species are specifically adapted to coastal wetland conditions and cannot tolerate large changes in salinity.

Wetlands comprise <10% of land area in Canterbury (Environment Canterbury staff personal communications, 2021). Consistent with other areas of New Zealand, they are drastically reduced relative to their extent pre-human settlement. A large number of current wetlands are found around inland lakes and post-glacial landscapes (e.g. in the Lake Coleridge area, and Upper Rangitata). Coastal wetlands make up a small proportion of current wetlands. In the Canterbury Region, these include those between Ōtautahi/Christchurch and Amberley, the Te Waihora/Lake Ellesmere wetlands, and minor marshes/wetlands south of Timaru and around Kaikōura.

Coastal wetlands naturally occur in the lowest coastal areas or in low-lying depressions. They are therefore particularly at risk to sea level rise and consequent salination. With projected late century increase in mean sea level of 0.8 m, coastal wetlands will be exposed to more frequent inundation from large tides and storm events and consequently flooding and erosion. Some wetlands may become more estuarine in nature as a result of sea level rise. Changes in wetland salinity have a large impact on the types of vegetation supported by coastal wetlands due to the tolerance of wetland species for these conditions. Species composition and biodiversity (species richness) is expected to change as a result of periodic or permanent salination of coastal wetlands.

Increased sedimentation in coastal wetlands is expected from coastal erosion, coastal flooding and surface water flooding. Sediment can smother habitats and carry additional nutrients or contaminants from nearby areas (depending on land uses). This not only has the potential to reduce the area of wetlands, but can also compound the effects of drought and increasing temperature if wetlands become shallower. Changing groundwater properties may also compound or alter the response of wetlands, as drought and reduced rainfall lower freshwater recharge, while sea level rise raises coastal groundwater levels and further contributes to salinisation (Department of Conservation, 2013).

Some types of wetland species (some plants and birds) are mobile and have a high tolerance to local changes in salinity and sedimentation. However, many species adapted to coastal wetland conditions are not mobile and cannot tolerate large changes in salinity or sediment volumes, these include invertebrates, some species of plants (e.g. the New Zealand mouse tail) and fish species such as the Canterbury kowaro (mudfish) (NZFOA, 2021). These species are likely to rapidly decline in coastal wetlands affected by these projected changes. Additionally, many species that are specifically adapted to wetlands, such as the Australasian Bittern (Figure 9.5), are rare and threatened and therefore have very little adaptive capacity (Environment Canterbury, 2021).

Figure 9.5: Australasian bittern (Environment Canterbury, 2021).

9.6 He Kura Taiao (living treasures) in native freshwater biodiversity

Risks to native freshwater biodiversity from climate change include those from higher mean temperatures, changes in mean annual rainfall, and fluvial and surface water flooding (refer Table 9.6). Freshwater ecosystems are rated to be highly exposed to raised temperatures, and changes in rainfall may result in both increased flooding and extended periods of low or no flow. While some species are highly adaptive, many others are specifically adapted to their environments, and have a low tolerance for change. Some aquatic species are sensitive to temperature increases, changes in water quality, and habitat loss associated with low flows.

Table 9.6: Risk to native freshwater biodiversity - flora & fauna

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to native freshwater biodiversity - flora & fauna due to higher mean temperatures	Insignificant	Moderate	Extreme	Extreme	Projected increases in temperatures are likely to raise the temperature of waterbodies, particularly shallower lakes and rivers and streams that are not fed by snowmelt. Many native species are sensitive to temperature increases and are adapted to a narrow range of water temperatures, while others are highly adaptive. Warmer temperatures can further alter water quality by contributing to algal blooms.
Risk to native freshwater biodiversity - flora & fauna due to fluvial and pluvial flooding	Low	Low	Moderate	High	Projected increases in high flows and extreme events may cause increasing disruption to river systems. High flows may cause erosion, sedimentation and damage from storm debris which can degrade habitats.
Risk to native freshwater biodiversity - flora & fauna due to change in mean annual rainfall	Insignificant	Low	Moderate	High	Projected increases in seasonal extremes are likely to stress freshwater ecosystems. Increased frequency of low flows can cause stress due to includes reduced flushing flows and can lead to the formation of stagnant pools and shallower waters which are more prone to temperature increases, which are harmful to aquatic ecosystems. The effect of reduced summertime rainfall in some river systems will be buffered by snowmelt.

Freshwater environments in Canterbury are characterised by large, braided rivers, alpine lakes and numerous hill-fed and lowland or spring-fed streams and rivers. Canterbury has the highest number of braided rivers in New Zealand, with 88 % of flow within the Region sourced from seven main alpine rivers (Clarence, Waiau, Hurunui, Waimakariri, Rakaia, Rangitata and Waitaki Rivers). Braided rivers are important biodiversity hotspots, providing habitat for many threatened or regionally endemic bird, fish, plant and invertebrate species (Environment Canterbury, 2011), some of which are important mahinga kai. The Region also holds more than 400 lakes throughout the coastal, lowland, and high-country environment. These lakes are a mixture of glacial, riverine, reservoirs and lagoons. Of note is Te Waihora (Lake Ellesmere), New Zealand's fifth largest lake and a unique coastal wetland/brackish lake environment (LAWA, 2021). Smaller streams and rivers throughout the Region provide important spawning habitat for species, including whitebait species (e.g. īnanga (*Galaxias maculatus*) at the tidal wedge river mouth etc).

Increasing temperatures mean that Canterbury's rivers and lakes will be exposed to wider temperature variations. High temperatures will be more common, and will particularly affect those rivers and lakes with low vegetation shading. Many of Canterbury's large alpine fed lakes will have a strong buffering capacity to moderate temperature increases due to their large volume and inflow, which is primarily sourced from snowmelt. Reduced rainfall and associated low lake volumes are likely to reduce this buffering. However, the effect of changing snow melt patterns is uncertain, as the lakes are typically fed by snowmelt during summer months (Kerr, 2013).

Many native aquatic species and their life history (e.g., spawning, migration periods) are particularly sensitive to changes in water temperature and have adaptations for a narrow range of water temperatures and flow regimes. Example species include, but are not limited to, the kāmana (Southern crested grebe) (Figure 9.6), Canterbury kowaro (mudfish), Southern kōura (*Paranephrops zealandicus*) and some non-migratory galaxiids such as Lowland longjaw galaxias, Canterbury galaxias, and alpine galaxias, as well as some migratory galaxiids such as Īnanga (*Galaxias maculatus*) (NZFOA, 2021).

Changes in water temperature can also alter water quality by contributing to algal blooms, which act as a contaminant. These can in turn impact aquatic ecosystems (Young, et al., 2013).

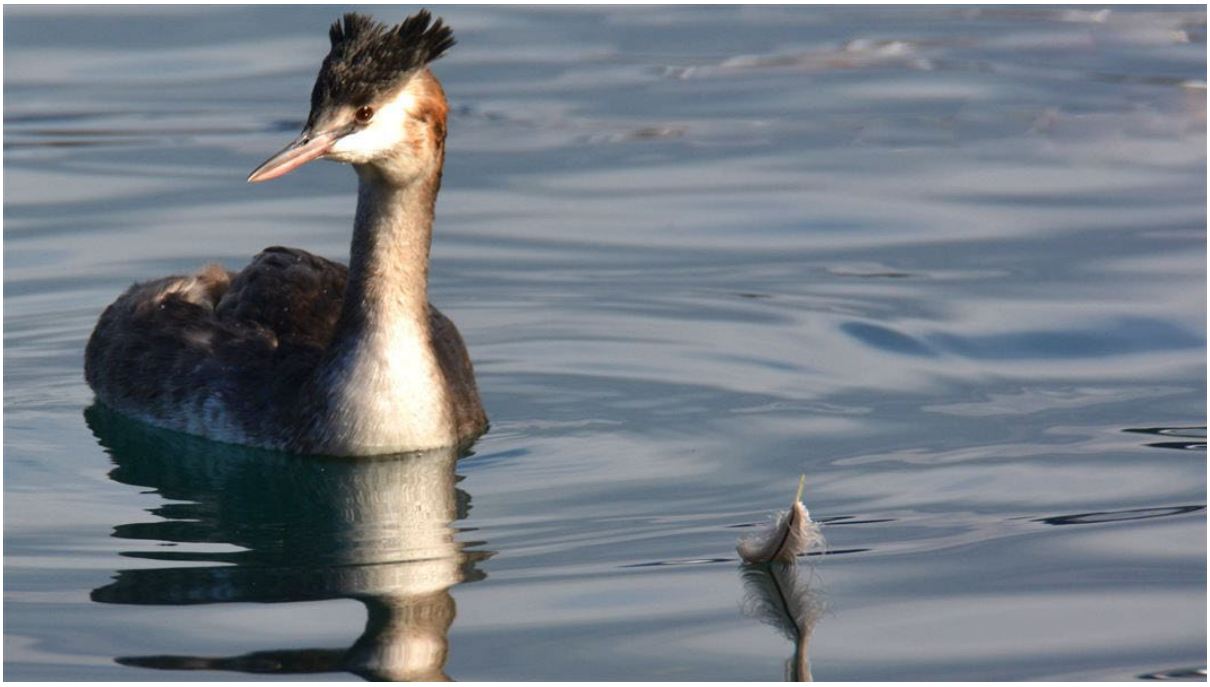


Figure 9.6: The kāmana (Southern crested grebe). The southern crested grebe is only found in New Zealand and Australia. Most breeding occurs in Canterbury and Otago, with breeding numbers observed to be increasing on the Canterbury Coast. Grebes thrive in rushes, sedges and reeds within wetlands and surrounding lakes. Their habitats are threatened and are sensitive to further degradation.

The projected increase in rainfall seasonality and storm-related flow changes in Canterbury rivers will increase the exposure of freshwater ecosystems to both high and low flows (floods and droughts).

Increased frequency of low flows can cause stress due to reduced flushing flows. They can lead to the formation of stagnant pools and shallower waters which are more prone to temperature increases, which are harmful to aquatic ecosystems (Jowett and Richardson, 1989). Summer flows in many of Canterbury’s major braided rivers may be buffered by snow melt. However, the shorter Rakahuri (Ashley), Waikirikiri (Selwyn) and Hakatere (Ashburton) rivers originate in the montane/hill country, and are projected to experienced reduced summer flows (Department of Conservation, 2013).

High flows can be damaging to river systems as they disrupt habitats and can carry debris which both clog and restructure habitats. Ecosystems must then recover and re-establish. An increase in intense rainfall events will increase erosion rates, as well as the rate of sedimentation into rivers and lakes. This will lead to an accumulation of nutrients which may contribute to eutrophication, or contribute to water bodies becoming shallower and ephemeral. It may also increase habitat disturbance, meaning that repopulation and recolonisation must occur over a shorter timescale. If this repopulation cannot occur species will be lost from the area (Kelly, 2010).

A loss of source populations due to increased mortality from temperature stress, habitat degradation and storm damage will also hamper recolonisation. This would affect the Canterbury mudfish, for example, which is the most threatened species of the five mudfish species found in New Zealand (Figure 9.7). It is found in a limited number of waterways, primarily between the Rakahuri (Ashley) River (in the north) and the Waitaki River (in the South). The Canterbury mudfish is also threatened by other factors, including habitat loss from bank erosion and drying out of pools (NZFOA, 2021).

Some freshwater species may have a moderate level of adaptability to changes in water temperatures and flow regimes depending on the degree of connection between suitable river reaches and lake habitats. For example, the tuna/hao (shortfin eel) is relatively tolerant to changing temperatures and can thrive in a range of environments (NIWA, 2021). Other species are already at the limits of their suitable ranges. These will have low tolerance to further changes in these climate related parameters. Examples include the threatened kēwai/waikōura (freshwater crayfish) and kākahi (freshwater mussel) (Environment Canterbury, 2021). Diadromous species occupy different habitats during different stages of their lifecycle and may be affected more strongly by the projected climate changes as habitats are altered during each stage of their life-cycle. Lifespan may also affect the adaptive capacity of species. Īnanga (*Galaxias maculatus*) generally only live for two years, so may have increased adaptive capacity, as it will take multiple generations to see effects from climate change. By contrast, eels can live for decades, and may be significantly affected during a single life-cycle (Ofori et al., 2016).

Figure 9.7: The kōwaro (Canterbury mudfish) is threatened, with a nationally critical status (Source- Department of Conservation, 2018).

9.7 He Kura Taiao (living treasures) in aquatic coastal and marine ecosystems

Risks to aquatic coastal and marine ecosystems from climate change include those from increased temperature and ocean chemistry changes. Exposure of aquatic marine ecosystems to ocean chemistry changes and temperature increases is rated to increase to high by late century. Aquatic species are highly sensitive to these changes, and species mortality and reduced condition is likely. The adaptive capacity of species is low, although migratory species may relocate to cooler waters.

Table 9.7: Risk to aquatic coastal and marine ecosystems

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to native marine biodiversity - flora & fauna due to marine heatwaves	Low	Low	High	High	Sea temperatures and marine heatwaves are projected to increase with climate change as sub-tropical currents penetrate further south. Marine species are sensitive to temperature changes which can cause physiological and behaviour changes, such as reduced phytoplankton abundance and alterations to species migration routes in fish, immobile species are likely to be particularly sensitive. Mobile species may adapt through migration to new habitats which may also see new species entering Canterbury's cooler waters.
Risk to native marine biodiversity - flora & fauna due to ocean chemistry changes	Low	Low	Moderate	High	Ocean acidification is occurring as oceans absorb excess CO2 from the atmosphere. These changes to ocean chemistry are projected to increase as atmospheric greenhouse gas concentrations rise. Ocean acidification may result in reduced availability of calcium carbonate, which impacts on the life cycle of calcifying organisms such as molluscs and echinoderms. Wider ecosystem disruption may result in increased mortality and population decline.

Sea temperatures are increasing (Sutton et al., 2019) and the frequency of marine heatwaves is increasing, resulting in instances of extremely high sea surface temperatures lasting for days to months (Ministry for the Environment & Statistics New Zealand, 2016). As global marine temperatures increase, the Canterbury marine environment is likely to experience increasing ocean temperatures through seasonal shifting of ocean currents (Boyd & Law, 2011). Over the next century sub-tropical currents will penetrate further south than the present bringing warmer ocean water along the Canterbury coast (Law et al., 2018). Marine species are generally very sensitive to temperature changes bringing about both physiological and behaviour changes, such as reduced phytoplankton abundance and alterations to species migration routes in fish (Ministry for the Environment & Statistics New Zealand, 2016; Dunn, et al., 2009).

Marine heatwaves are defined as warm water anomalies occurring for up to months in duration, that are thousands of kilometres in size (Hobday et al., 2018). They are becoming increasingly common and can impact the life history and overall health of immobile marine species (such as kelps – macroalgae and coralline algae, sponges, sea squirts and bivalves) (Boyd & Law, 2011). This could lead to a reduced abundance of such species within Canterbury waters. For example, macroalgae, which are primary producers and habitat formers in coastal ecosystems in Canterbury and throughout New Zealand, may be more vulnerable to increases in temperature. Recent research in Canterbury observed elimination of the bull kelp species *Durvillaea* during heatwaves in 2017/2018 in one bay in Lyttelton Harbour, with replacement by the invasive kelp *Undaria Pinnatifida* (Thomsen et al., 2019).

Ocean acidification is occurring as oceans absorb excess CO_2 from the atmosphere. This is expected to continue until atmospheric GHG concentrations stabilize (Ministry for the Environment & Statistics New Zealand, 2016). As the absorption happens, carbonic acid forms, contributing to a lower pH in oceans and a decreased availability of calcium carbonate. This fundamental shift in ocean chemistry may influence a variety of biotic, as well as abiotic, processes (Law et al., 2018). Reduced calcium carbonate is particularly detrimental for the early life history stages of calcifying organisms such as molluscs and echinoderms, calcifying algae/coralline algae (Tait et al., 2014), as well as coral species (not present within Canterbury). Species present within these groups are predicted to decline in response to these disrupted biotic processes (Hepburn et al., 2011) with flow on food web (Law et al., 2017) and economic (aquaculture) effects. For some non-calcifying phytoplankton and macroalgae, ocean acidification may provide benefits in the form of increased CO_2 for photosynthesis. However, for most marine species the resultant change in their acid-base balance will impact survival (mortality, reproduction, fitness), and condition (growth, biomass, fecundity). This has potential ramifications for foodwebs, ecosystem stability, services, and economic value (Doney et al. 2009) (refer to Section 13.4).

Marine foraging and breeding habitats and near-shore marine environments are also likely to be adversely affected or altered by the conjunction of changes in pH levels and sea temperatures with predicted increased rates of erosion and sea level rise from climate change.

The adaptive capacity for the marine and coastal environment is primarily dependent on the availability and utilisation of new habitats (Doney et al., 2012). As erosion and sea level rise occur and existing habitats are damaged or destroyed, other parts of the coast or river mouths are likely to become more favourable. For some species, south-wards range shifts are expected to occur as a result of climate change (Lundquist et al., 2011) as relatively high levels of coastal phytoplankton are observed in the inshore marine environment of Canterbury (Ministry for the Environment & Statistics New Zealand, 2019) and poleward shifts of flora and fauna species are observed internationally (Poloczanska et al., 2013). However, the availability of new habitat may not match the rate at which existing habitats are damaged, for example, there is a projected decline in coastal kelp forests and reduced intertidal zones. This would lead to a reduction in adaptive capacity over time for many species (Lundquist et al., 2011). This is likely to most strongly impact those species with long lives and slow reproductive rates (e.g., many of the most iconic native marine and coastal species such as pākirikiri (blue cod), moki (blue moki, *Latridopsis ciliaris*), tarakihi and hāpuku (groper)).

9.8 Biosecurity - safety from pests and diseases

Risks to terrestrial, freshwater, and marine ecosystems include those from increased pests and diseases resulting from a change in mean annual rainfall, increased temperature, and reduced snow and ice. As these prevail, the range and occurrence of pest species is likely to increase. Many exotic plant species have higher temperature tolerances than natives, and therefore may out-compete them where changed habitat conditions occur.

Table 9.8: Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to higher mean temperatures	Moderate	Extreme	Extreme	Extreme	Risks to biosecurity are likely to increase in response to projected rising temperatures. This may result in an increased range of invasive species, particularly where exotic species have higher temperature tolerance relative to indigenous species. Native species are often specifically adapted to the environment and climate, and may be out-competed by versatile invasives.
Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to change in mean annual rainfall	Moderate	High	High	Extreme	Risks to biosecurity are likely increase in response to projected changes in rainfall. Increasing peak flows in rivers may disturb habitats resulting in opportunities for exotic species to establish. Reduced rainfall or drought may further contribute to habitat loss and provide conditions for drought tolerant exotic species. Native species are often specifically adapted to the environment and climate, and may be out-competed by versatile invasives.
Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to reduced snow & ice	Low	High	High	Extreme	Risks to biosecurity are likely to increase in response to projected decreasing snow and ice. Reducing occurrence of frosts mean that frost sensitive invasive species may have an increased survival rate.

Due to its geographical isolation, New Zealand's unique biota and ecosystems are particularly vulnerable to the impact of non-indigenous pest species and diseases. The introduction of non-indigenous pest species and diseases has occurred only over the last ~300 years, through human activity. This has been either through intentional release (e.g. trout and possums) or accidental introduction (e.g. ship rats, mice, and numerous marine species). This has already resulted in the decline or displacement of many native plant and animal species.

The success of introduced species is largely attributed to their 'invasive' traits. These include their ability to tolerate varying abiotic conditions, high fecundity, multiple reproductive strategies, rapid growth potential, long-distance natural dispersal potential, wide environmental tolerances, and a tendency to be habitat generalists; they are often also opportunistic feeders. The absence of predators in their new regions also contributes to their success. As a result, many invasive species are better equipped than native species to survive in changing environmental conditions. Introduced species will often out-compete native species in stressed environments, and are likely to more rapidly occupy habitat left vacant by the mortality of native species. This threat has in part been reduced by conservation efforts to control pest populations in some areas of Canterbury (Department of Conservation, 2016).

There are over 100 native terrestrial and aquatic species (flora and fauna) categorised as "threatened" or "at risk" in the Canterbury Region (NZFOA, 2021). While loss of habitat due to human land-use changes is a major cause for the decline of many native species, competition and predation from pest plant and animal species is another important factor. The projected changes in temperature, drought, rainfall, and snow and ice extent across the Canterbury Region (discussed in

Section 9.2 above) are expected to increase the exposure of terrestrial, freshwater and marine ecosystems to pest plants and species.

The tolerance of native species to both predation by and competition from invasive pest species is low. New Zealand native species are generally highly specialised, whereas pest species are typically more generalist. Further, the predation mechanisms of invasive mammals (e.g. scent hunters) are outside the biological adaptations to predation evolved by most native species, as the traditional predators were birds or other invertebrates (which do not hunt using scent). Likewise, mammal browsers were absent from terrestrial ecosystems until the last ~150 years, therefore native plant species (particularly young seedlings) have few defence mechanisms for these.

9.8.1 Terrestrial

Increasing temperatures will allow range expansion of many pest plant and animal species, such as wilding pines, into higher elevation areas with reduced snow and ice. Pests and diseases such as myrtle rust, which are presently limited to the North Island/northern South Island, are likewise projected to migrate their ranges further southward. Pest and weed species most likely to have greatest impact in Canterbury include increasing populations of established species such as rabbits moving into higher altitude regions as temperatures rise (Figure 9.8), as well as lowland and woodland species such as possums, mustelids, rats, goats, deer, tahr, chamois, pigs and wasp. These may all outcompete native species, and damage flora and habitats. Existing pest plants, including banana passionfruit, bell heather, boneseed, wilding conifers, Mexican daisy, grey willow, broom and gorse, are likely to continue to outcompete and smother native plants (Environment Canterbury et al., 2008). Frost sensitive species, such as Argentine ants and the passionfruit vine, may also become better established as frost days reduce (Ministry of Agriculture and Fisheries, 2010). Warmer temperatures can also support higher pest populations and influence complex biological systems such as the mast[3] response (McGlone & Walker, 2011) thus creating more pressure on native species.

9.8.2 Freshwater

Many types of invasive algae, invertebrates, and freshwater plants thrive in warmer water temperatures. When combined with the high sensitivity of many native species to warm temperatures, water stagnation during low flows and disturbed habitats during high flows, invasive species are likely to out-compete native species in freshwater environments. Weed invasion of riverbeds, animal pests predating on native fauna and invasive exotic species such as didymo (*Didymosphenia geminata*, or rock snot) are likely to continue to threaten native freshwater ecosystems (Environment Canterbury et al., 2008).

9.8.3 Marine

Regional port marine pest surveys for Canterbury are undertaken by Environment Canterbury (Palmer, 2021). An annual survey of Lyttelton Harbour is done as part of the Ministry for Primary Industries (MPI) Marine High Risk Site Surveillance programme (since 2002) (Woods et al., 2019). Across these areas, non-indigenous bivalve, sea squirt, crustacea, nudibranch and macroalgae species have been detected and reported. Many of these are range extensions from other New Zealand locations (Woods et al., 2019), but some are newly discovered invaders (Inglis et al., 2006). Surveys of Canterbury ports and harbours has identified Mediterranean fanworm (*Sabella spallanzanii*), the clubbed tunicate (*Styela Clava)* (Figure 9.8), and wakame Asian kelp (*Undaria Pinnatifida*) (Palmer, 2021; Woods et al., 2019). These are among invasive species listed on the MPI

[3] A mast response describes the tendency for trees across large areas to synchronously flower, causing abundant fruits and seeds. This increase in food availability can support increased breeding and population surges of native and non-native species.

unwanted marine organisms list. Being highly fecund, these invasive species can reach high densities in a short timeframe, resulting in an ability to outcompete or displace other species. They can also decrease the productivity of cultured species, and increase aquaculture processing and harvesting costs. As changes within the marine environment due to climate change take place, it is predicted that these and many other marine pests will be able to tolerate and, in some cases, thrive under new environmental conditions compared to their native predecessors. This leads to higher competitive strength within introduced marine pests, and potentially a depleted availability of resources and space for their native counterparts. For example, a study from Tauranga Harbour comparing the salinity and temperature tolerance of wakame Asian kelp (*Undaria Pinnatifida*) to two native kelp species (*Lessonia variegata*, *Ecklonia radiata*) showed that the introduced species had a broader tolerance to the experimental salinity and temperature conditions than the native species (Bollen et al., 2016).

Figure 9.8: Invasive species of Canterbury include the clubbed tunicate (Styela clava) – a type of invasive sea squirt (left, source – MPI, 2013), and rabbits (right).

10 Wai | Water

Wai (water) is important to communities for spiritual and cultural wellbeing, biodiversity and supporting human systems and industry. Water nurtures the growth of Canterbury's native fauna and flora, and gives life to the diverse agricultural activity of the Region. The Region's lakes and rivers are home to unique birds and aquatic life, they support recreation and are fundamental to the spectacular visual landscape of the Region. Wai holds cultural significance to Ngāi Tahu, where the mountains are connected through rivers, lakes, streams and springs, to the coast, and thereby the oceans, seas, and all things. The rivers of Canterbury act as corridors for the sediment and life within to migrate. Within te Ao Māori, each river and mountain is a living being, which has its own mana, where the small and the large streams that flow into one another are part of the whole. Upholding te mana o te wai (the health and wellbeing of water) is an important priority not only for Māori, but for the wider community. It is a fundamental concept of the National Policy Statement for Freshwater Management 2020 (New Zealand Government, 2020). Within this concept, the first obligation is to protect the health of water and its mauri, then to provide for essential human health needs such as drinking water, and finally to support other consumption, provided it does not affect the mauri of water.

Wai (water) is interconnected with many other aspects of the natural and physical world of Canterbury. Water is an integral part of the rerenga rauropi (biodiversity of the Region), as the life giver to all natural systems, and as habitat to the array of freshwater and marine aquatic species. The irrigation networks and other water supply systems are crucial elements in the ōhanga (prosperity of agriculture), and the supply of clean water supports the hauora (health and wellbeing) of Canterbury.

10.1 Water in Canterbury

The three main types of river within Canterbury are the alpine fed rivers, rain-fed foothill rivers, and spring-fed lowland streams. The alpine rivers have upper reaches in the Ka Tiritiri o te Moana (Southern Alps), which are snow-fed and alpine rain-fed, so have early summer peak flows. The rain-fed foothill rivers have winter peak flows. Finally, lowland streams are spring-fed from groundwater and therefore have depressed seasonal responses. The seven alpine rivers (Figure 10.2) contribute 88% of the flow from Canterbury's rivers, and are much greater in volume than its foothill rivers and lowland streams.

Canterbury also has an extensive groundwater system, with aquifer depths ranging from shallow surface level to over 300 metres (Figure 10.1). These aquifers are recharged from rainfall infiltration with contributions from the alpine and foothill rivers and from other surface water. They eventually discharge into surface water such as lowland springs, wetlands, streams, lakes or directly into the sea.

Canterbury has the country's largest amount of water-related infrastructure assets by asset value. This represents 30% of New Zealand's total water related asset value, which is double that of the next highest Region. Assets include flood control structures, pump stations, erosion protection structures, river structures and dams. New Zealand's flood protection was in the most part built between the 1930's and 1980's, and includes stopbanks, pump stations and river control works. The land that benefits from these systems has been fully utilised across much of New Zealand. Canterbury is no different, using areas of benefit for primary production or urban development (Giberson, 2019).

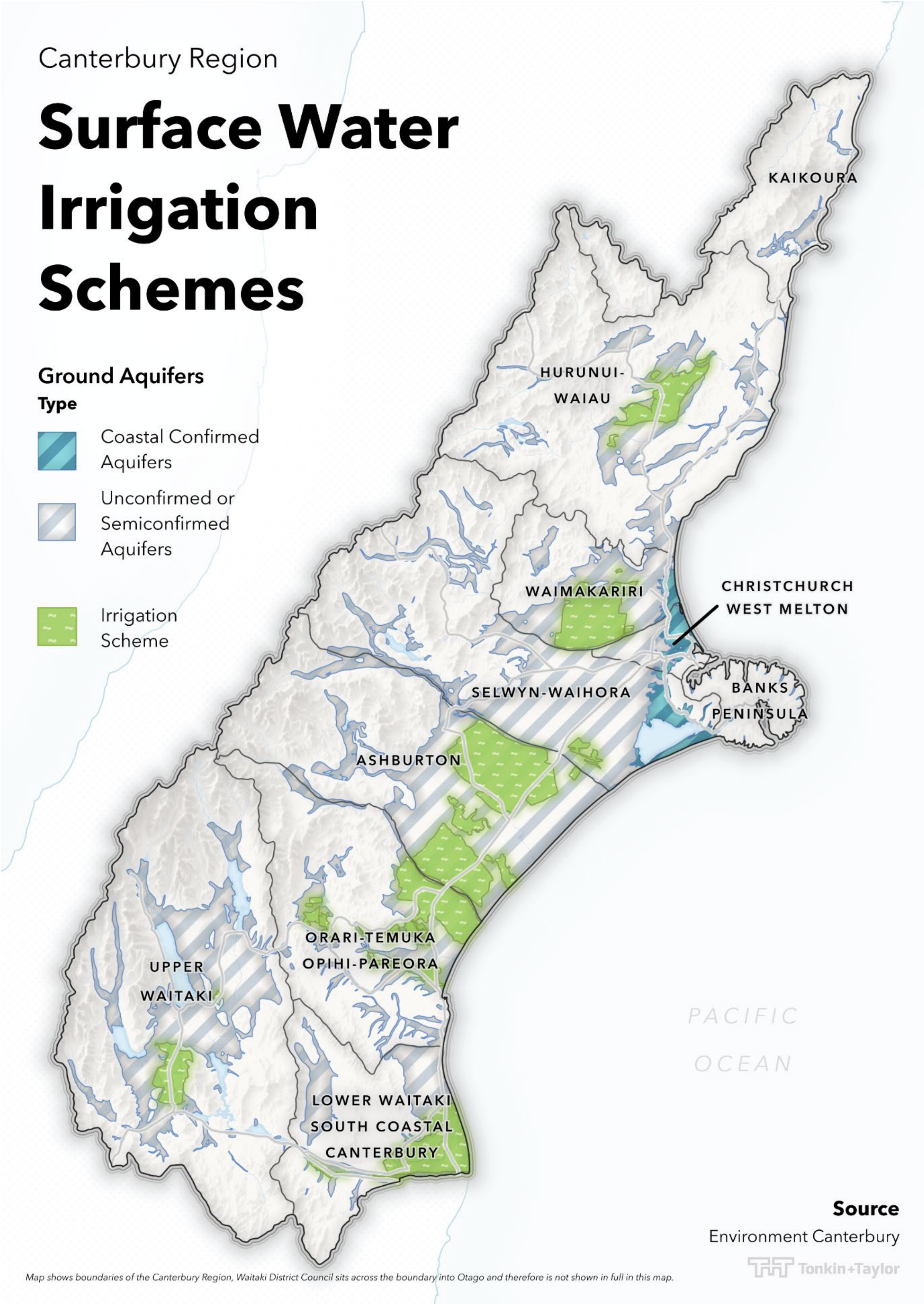


Figure 10.1: Canterbury water management zones (Environment Canterbury, 2009), irrigation schemes and aquifers.

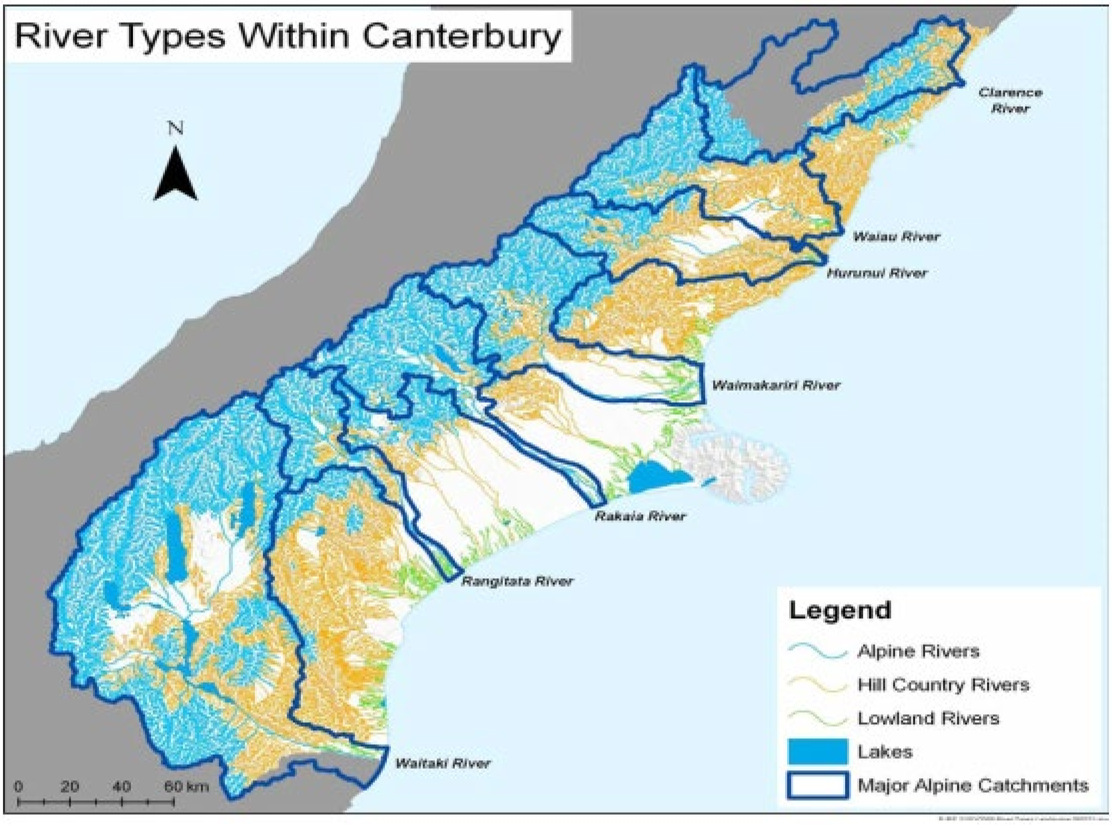


Figure 10.2: River types within Canterbury (Source ECAN, 2009).

10.2 Summary of risks

Risks to wai (water) are identified through consideration of surface water availability and quality, groundwater availability and quality, water supply infrastructure and flood defences. The highest rated risk relating to these aspects of water are listed in Table 10.1. These, and other highly rated risks, are presented below, with discussion of the main issues supporting the rating of the risks.

Table 10.1: Summary of highest risks to wai (water)

	Higher mean temperatures	Change in mean annual rainfall	Drought	River and surface flooding	Coastal flooding	Increased coastal erosion	Sea-level rise and salinity stresses	Storms and wind	Increased fire-weather	Increasing landslides and soil erosion	Extreme weather events	Reduced snow & ice	Ocean chemistry changes	Marine heatwaves	Climate change
Using RCP8.5	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L
Coastal barriers and sea walls					L H H	L H H	L H H	L H H							
Stopbanks and flood management schemes				M H E			L M M								
Groundwater - availability and quality		H E E	H E E				H E E								
Water quality (lakes and rivers)	L H E	I L H		L L H			I L H			M H H		I L H			
Stormwater assets				M H H											
Wastewater treatment plants						M H H	M H H								
Surface water availability and supply		M H H	H E E									L M H			
Water supply infrastructure				L M H				L M H							

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

10.3 Surface water quality in major lakes and rivers

The highest rated risks to surface water (lakes and rivers) availability and quality include those from changes in mean annual rainfall, snow and ice, flooding, erosion, sedimentation, higher mean temperatures and sea level rise/salinity stress.

Lakes and rivers will experience decreased water quality as the occurrence of low flows and warm temperatures increase. Water quality may also decrease as a result of sedimentation associated with increased peak flows and flooding.

Table 10.2: Summary of risks to surface water availability and supply

Risk statement	Risk: Present	Risk: 2050 *(RCP8.5)*	Risk: 2100 *(RCP4.5)*	Risk: 2100 *(RCP8.5)*	High level description
Risk to surface water availability and supply due to drought	High	Extreme	Extreme	Extreme	Projected increases in drought are likely to impact water availability and supply. Water supply is highly sensitive to drought due to extensive water abstraction. Reduced availability due to drought is likely to coincide with increasing demand. Strategies are currently in place to monitor and manage water sources to adapt to climate change. Further, measures to reduce demand may be adopted.
Risk to surface water availability and supply due to change in mean annual rainfall	Moderate	High	High	High	Projected changes in rainfall are likely to impact water availability and supply, with reductions in surface water availability in some parts of the region. Reduced availability due to low rainfall and river flows is likely to coincide with increased demand. Strategies are currently in place to monitor and manage water sources to adapt to climate change. Further, measures to reduce demand may be adopted.
Risk to surface water availability and supply due to reduced snow & ice	Low	Moderate	Moderate	High	Projections of reduced snow and ice are a component of complex hydrological changes that may contribute to reduced water availability. Reduced snow and ice may result in lower summer flows in the headwaters of many major Canterbury rivers.

Risk statement	Risk: Present	Risk: 2050 *(RCP8.5)*	Risk: 2100 *(RCP4.5)*	Risk: 2100 *(RCP8.5)*	High level description
Risk to water quality (lakes and rivers) due to river and surface flooding	Low	Low	High	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. Erosion and scour resulting from flooding may result in increased sediment in waterways, reducing water quality and disturbing habitats. Runoff entering rivers may also introduced increased nutrient and other contaminants. Modified rivers with constrained floodplains may be particularly sensitiveto degradation from flooding, and have limited adaptive capacity to adjust with changing flows.
Risk to water quality (lakes and rivers) due to change in mean annual rainfall	Insignificant	Low	Moderate	High	Projected changes in rainfall are likely to result in increased frequency of low flows in most rivers. Increased frequency of low flows may reduce flushing flows and compound the effects of warmer temperatures, promoting the growth of algae and macrophytes.
Risk to water quality (lakes and rivers) due to reduced snow & ice	Insignificant	Low	Moderate	High	Projected changes to snow and ice are likely to contribute to the increasing occurance of low flows. Increased frequency of low flows may reduce flushing flows and compound the effects of warmer temperatures, promoting the growth of algae and macrophytes.
Risk to water quality (lakes and rivers) due to higher mean temperatures	Low	High	Extreme	Extreme	Projected increases in temperature are likely to be detrimental to water quality in lakes and rivers. Warmer temperatures can be harmful to native frehwater biodiversity and promote the growth of algae and macrophytes. Smaller, shallow waterbodies, and those that are not snowmelt fed are likely to be most sensitive to warming temperatures.
Risk to water quality (lakes and rivers) due to increasing landslides and soil erosion	Moderate	High	High	High	Increased erosion and sediment from landslides may result in increased sediment in waterways, reducing water quality and disturbing habitats.
Risk to water quality (lakes and rivers) due to sea-level rise and salinity stresses	Insignificant	Low	High	High	Projected sea level rise may cause salinization and flooding or coastal rivers and lakes with increasing frequency. Saltwater intrusions have a profound impact on the water quality of lakes and rivers changing the types of ecological communities they can support.

Lakes and rivers will be exposed to projected increased intensity and frequency of storm events, leading to increased peak river flows and flooding. These events increase the risk of erosion and have the potential to change river and lake morphology.

Canterbury has many large, braided rivers which historically have large flood plains associated with them. Many flood plains have been developed and constrained for human land use and flood protection. Rivers with modified or constrained channels and flood plains are likely to be highly sensitive to projected climate changes, as there is limited capacity to convey increased flow. These are often also rivers with existing abstraction schemes providing water for drinking and/or irrigation. (refer to Section 10.5). Constraints on permanent riverbank morphology will limit the adaptive capacity of rivers to respond to changing flow conditions, and extreme weather events are likely to cause more damage to the river environment when the flood plain is cut off from the river. Conversely, those rivers with fewer (natural or anthropogenic) constraints may have a higher tolerance for changes, with new channels forming naturally. Increased erosion results in increased sediment in waterways, reducing water quality and disturbing habitats. The injection of sediment into rivers (and subsequently into lakes or into the sea) from large floods thus can mobilise large volumes of nutrients (and potential contaminants), affecting water quality in the receiving environment.

Increased projected low flow conditions in rivers contribute to warmer water temperatures due to reduced velocity and volume of water. The lack of flushing flows contribute to the build-up of sediment and nutrients (Jowett et al. 1990). Warm temperatures and reduced flushing flows favour the growth of algae and macrophytes, which lower water quality.

Projected temperature increases are likely to affect the water quality in lakes by increasing the likelihood of thermal stratification during summer months. Maximum temperatures are projected to rise by up to 6°C under RCP8.5 in inland areas. This strong summer warming will lead to higher water temperatures in lakes and rivers, particularly those in the low country with little or no shading of water bodies. Small or shallow lakes have a low tolerance of prolonged high summer temperatures. This increases the chance of prolonging thermal stratification. These types of lakes are likely to be sensitive to poor or reducing water quality measures earlier than larger/deeper lakes (Hamilton et al. 2013). Deeper lakes, and lakes in locations more exposed to the wind (such as some of the large hydro-lakes in inland Canterbury) will have a lower sensitivity to projected changes than shallow, sheltered lakes such as some of the inland lakes (e.g. Lake Lindon) and small shallow coastal lakes (Hamilton et al., 2013).

Coastal rivers and lakes are also likely to be exposed to rising sea level and subsequent salinisation through intrusion of saltwater. This is likely to be ephemeral at first but become more frequent towards the end of the Century as mean sea level increases, and storm events increase the inland intrusion of saltwater up rivers and into low-lying coastal lakes. Saltwater intrusions have a profound impact on the water quality of lakes and rivers changing the types of ecological communities they can support.

10.4 Groundwater availability and quality

The highest risks to groundwater availability and quality from climate change include those from changes in rainfall, drought, and salinity stress. Exposure of aquifers to reduced rainfall and drought may lower recharge rates, leading to reduced volume and potential water quality deterioration. Exposure of coastal aquifers to increasing sea levels may cause salinisation. Impacts on aquifer recharge rates and salinisation are not well understood, so are presented with a high level of uncertainty.

Table 10.3: Summary of risks to groundwater availability and quality

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to groundwater - availability and quality due to sea-level rise and salinity stresses	High	Extreme	Extreme	Extreme	Projected sea level rise may cause salinization of coastal aquifers which may be compounded where abstraction occurs near the coastal edge. The adaptive capacity of aquifers is considered low as most have reached the upper limit of the allowable allocation.
Risk to groundwater - availability and quality due to change in mean annual rainfall	High	Extreme	Extreme	Extreme	Changes in rainfall patterns are projected, with wetter winters and drier summers. Wetter winters may cause higher groundwater tables in winter, with dry summers and increasing evapotranspiration contributing to lower water tables in summer.
Risk to groundwater - availability and quality due to drought	High	Extreme	Extreme	Extreme	The occurrence of drought is projected to increase with climate change. This will lower water and reduce rates of recharge. Increased water demand is likely to coincide with extended dry periods and drought, placing further pressure on aquifers.

Large aquifers are present within the Canterbury Plains, particularly south of Timaru, the Amuri Plains, the Kaikōura Plains and the Mackenzie Basin. These aquifers are predominantly unconfined or semi-confined aquifer systems, located in the gravel outwash plains from the Ka Tiritiri o te Moana (Southern Alps) (Environment Canterbury, 2021). Coastal confined gravel aquifer systems have also been identified around Ōtautahi/Christchurch City. These extend from the Rakahuri (Ashley) River in the north to the surrounds of Te Waihora (Lake Ellesmere), and exclude most of Banks Peninsula. The impacts of climate change on aquifers, groundwater resources and dependent ecosystems have a high degree of uncertainty, due to the lack of detailed studies both in New Zealand and globally (Klove et al., 2014).

Groundwater availability in Canterbury will be exposed to increasing seasonality of rainfall, which can be characterised by wetter winters and drier summers. This will have consequential changes in river flows and lake levels. These hydrological changes, and increased evapotranspiration associated with warmer drier summers, are likely to result in higher water tables during winter, and lower water tables in summer (Unsal et al., 2014). Shallow aquifers, and those with naturally fast responses to rainfall, are likely to be most sensitive. Overall, reduced rates of recharge during summer months is likely, as the Canterbury plains experience lower rainfall and become drier (Painter, 2018).

Raised groundwater levels are likely to occur as a response to increased winter rainfall or rising sea level at the coast. Aquifers with a shallow groundwater table, such as those in the coastal aquifers and parts of Ōtautahi/Christchurch, will be most sensitive to these changes. This can increase flooding and liquefaction risk, cause infiltration into buried services and basements, contribute to buoyancy effects, or damage roading and landscaping .

For aquifers with significant volumes of summer abstraction, the increased drawdown during the time of least groundwater recharge may lead to a deterioration of water quality (as well as quantity), by increasing the rate at which water moves through the aquifer sediments (Klove et al., 2014). This effect will vary depending on the age of aquifers and the groundwater residence time.

Coastal aquifers may be sensitive to salinisation as sea level rises. This effect may be compounded by groundwater abstraction in coastal zones, which is also a significant contributor to salinisation (Ferguson, 2012). The degree to which these aquifers are prone is unknown and will likely depend on the nature of the aquifer sediments and the degree of aquifer confinement in coastal areas (Ingham et al., 2006).

In general, the adaptive capacity of groundwater aquifers (both coastal and inland) is based on the available volume, recharge rates, degree of interconnectivity between aquifers, and residence time of water in the aquifer systems. For coastal aquifers, the adaptive capacity is related to the extent that the aquifer extends inland, making it less prone to the effects of salination. For Canterbury aquifers, the adaptive capacity is considered low as most aquifers have reached the upper limit of the allowable allocation (Environment Canterbury, 2009). The Canterbury Region has a high dependency on groundwater to meet its water supply demands, limiting the ability of the region to manage any reduction in water availability.

10.5 Water availability and supply

The highest risks to water availability and supply from climate change includes those from changes to drought, flooding, and storms and wind (refer to Table 10.4).

Most parts of Canterbury are exposed to a high level of risk from drought, which will increase over time. Water supply systems, including irrigation schemes, are extremely sensitive to drought due to the compounding effects of both reduced water availability and the effects of warm temperatures causing increased demand. A degree of adaptive capacity is demonstrated through established water supply management practices within the Region. Strategies have been developed to manage water reliability, with consideration for the risks of climate change. A medium potential for adaptive capacity exists, particularly relating to town supply, where there is scope to reduce demand.

Table 10.4: Summary of risks to water supply and associated infrastructure

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to water supply infrastructure due to river and surface flooding	Low	Moderate	Moderate	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. High flows, sediment and debris may cause damage and disruption to water supply facilities, particularly above ground infrastructure such as intakes. Poor condition or ageing components may be upgraded to improve resilience. However, the potential to adapt water supply infrastructure may be limited by the need to draw water from exposed locations, and service existing communities.
Risk to water supply infrastructure due to storms and wind	Low	Moderate	Moderate	High	The frequency and intensity of storms are projected to increase over time. High flows, sediment and debris may cause damage and disruption to water supply facilities, particularly above ground infrastructure such as intakes. Poor condition or ageing components may be upgraded to improve resilience. However, the potential to adapt water supply infrastructure may be limited by the need to draw water from exposed locations, and service existing communities.

Canterbury's extensive braided alpine rivers provide the water to the groundwater aquifers that together provide fresh drinking and irrigation water to the Region's population and economy. (Environment Canterbury, 2021). Regulation of water supply within the Region is managed by Environment Canterbury. The management of water availability and quality is achieved through 10 water management zones, with boundaries reflecting the natural hydrological systems (Figure 10.1).

Throughout the Region, water is sourced from both groundwater and surface water, for both town supply (Figure 10.5), and irrigation (Figure 10.6). Most stock water is sourced from surface water, although this is dominated by the high volume of surface water consented in the Ashburton Zone (Figure 10.7). There are 34 irrigation schemes in Canterbury over 500 hectares (Figure 10.1). They are relatively small, and were established with the needs of particular catchments and localities in mind. Currently, all of the Region's surface water is fully allocated, and 94% of groundwater is allocated (Land Air Water Aotearoa, 2021).

Regionally, irrigation demands the highest water use, followed by stock water (Figure 10.3). These water uses translate to a high demand for water in rural areas, with consented water takes highest in the water management zones of Lower Waitaki South Coastal Canterbury, Ashburton and Selwyn-Waihora (Figure 10.4). Town water supply is a relatively small proportion of the regional water demand, with only 4% of the Region's consented water allocated to this use (Figure 10.3) (Land Air Water Aotearoa, 2021).

Surface water availability will be exposed to complex hydrological changes, including changing rainfall intensity, duration, and timing, and changing snowfall and snowmelt, as well as changing temperature, which impacts on evaporation and evapotranspiration, and complex groundwater interactions.[4] Projections show differing responses of surface water availability between inland and coastal areas (Macara et, al., 2020). Under RCP8.5, the mean annual discharge from rivers in eastern Canterbury is projected to increase by late century, while decreases are projected for rivers in inland areas. High flows are projected to increase in eastern areas by 50% by late century (RCP8.5), while decreases of 20% are projected for inland areas east of the main divide. This decrease in high flows within montane/hill country appears counter-intuitive when considering the significant increases in high flows in eastern (downstream) areas. These changes are thought to be associated with a projected decrease in the duration of large rainfall events, where although the rainfall intensity is increasing, the reduced rainfall duration results in a decrease in high flows (Macara et, al., 2020).

While some increases are projected for river flows in the alpine headwaters, flows are likely to become more seasonal due to a reduction in snow and ice. Snowmelt-fed rivers are sourced from alpine snow and ice that is stored through winter and released as spring and summer snowmelt. Ongoing reductions in the extent of snow and ice will reduce spring and summer snowmelt volumes, leading to lower summer flows in the headwaters of many major Canterbury rivers and their tributaries.

Mean annual low flows are projected to decrease across most of Canterbury under RCP 8.5 by late century, with reductions of over 20% in many parts of the Region. The notable exception is the south-eastern catchments, along the Waimate and southern Timaru coast. These are projected to see a 20% increase in low flows. In the montane/hill country, low flows typically occur during winter months. There is some uncertainty relating to how these low flows will be affected, where projected increases in winter rainfall could reasonably be expected to increase low flows during this time. However current models suggest that this is not the case, and that flows will remain unchanged (Macara, et al., 2020).

[4] Hydrological modelling using a water balance model provides an indication of surface water availability in Canterbury (Macara et al., 2020). This projection of surface water availability considers projections of rainfall, temperature, and other weather elements where available. The model simulates storage in the snowpack, plant canopy, rooting zone, shallow subsurface, lakes and rivers, taking into account approximate land cover and land use.

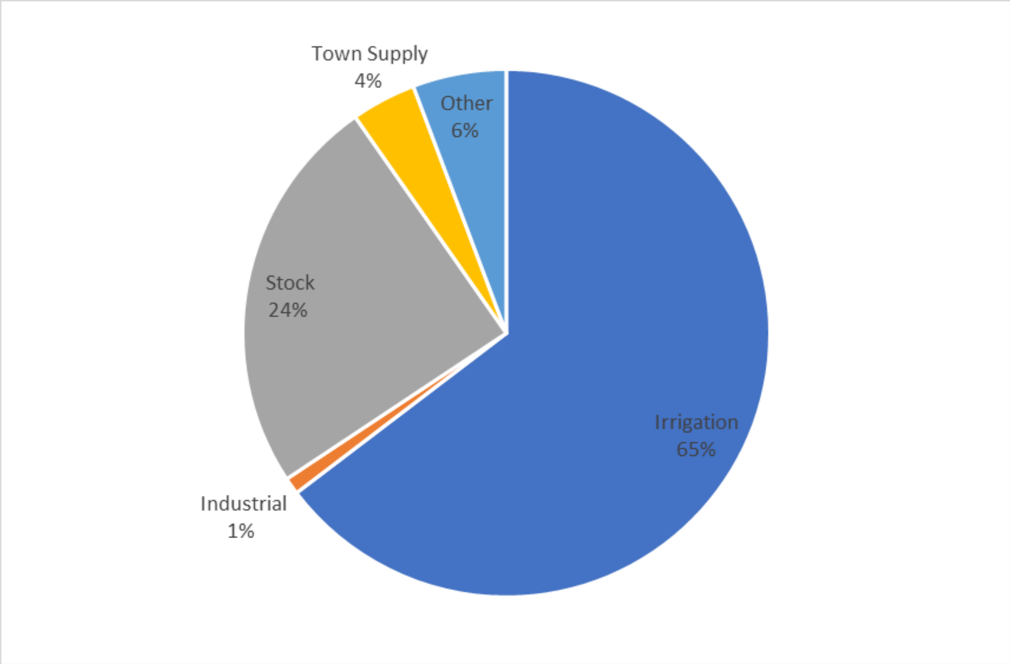


Figure 10.3: Consented water demand by type of use in Canterbury (Land Air Water Aotearoa, 2021).

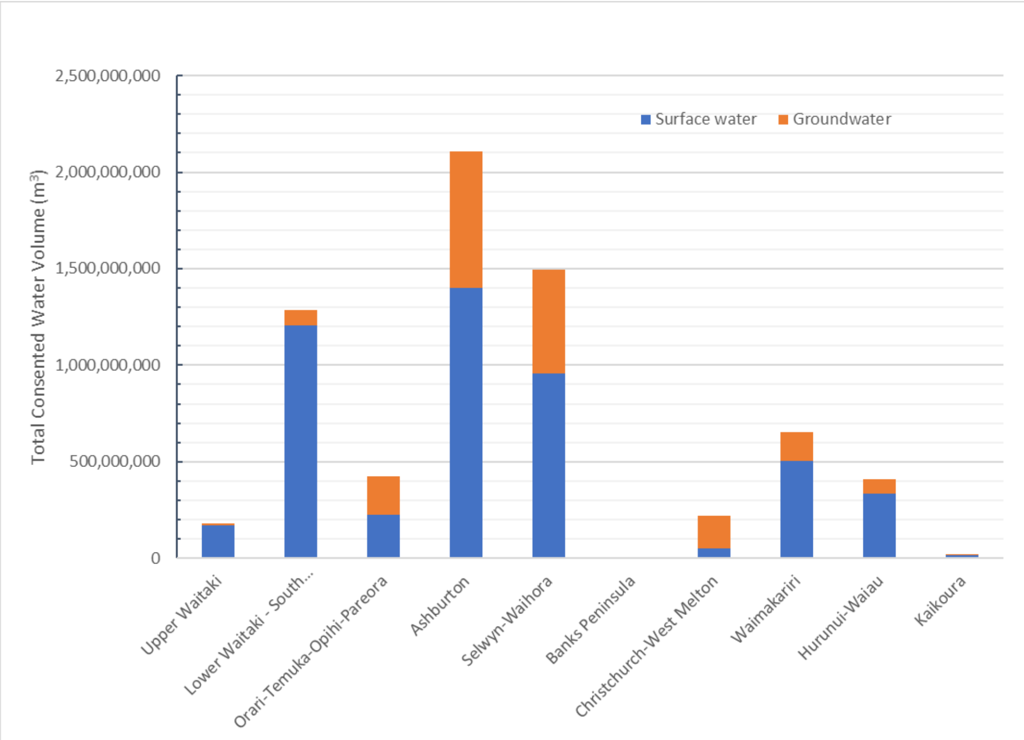


Figure 10.4: Consented water volume according to source by water management zone in Canterbury (Land Air Water Aotearoa, 2021).

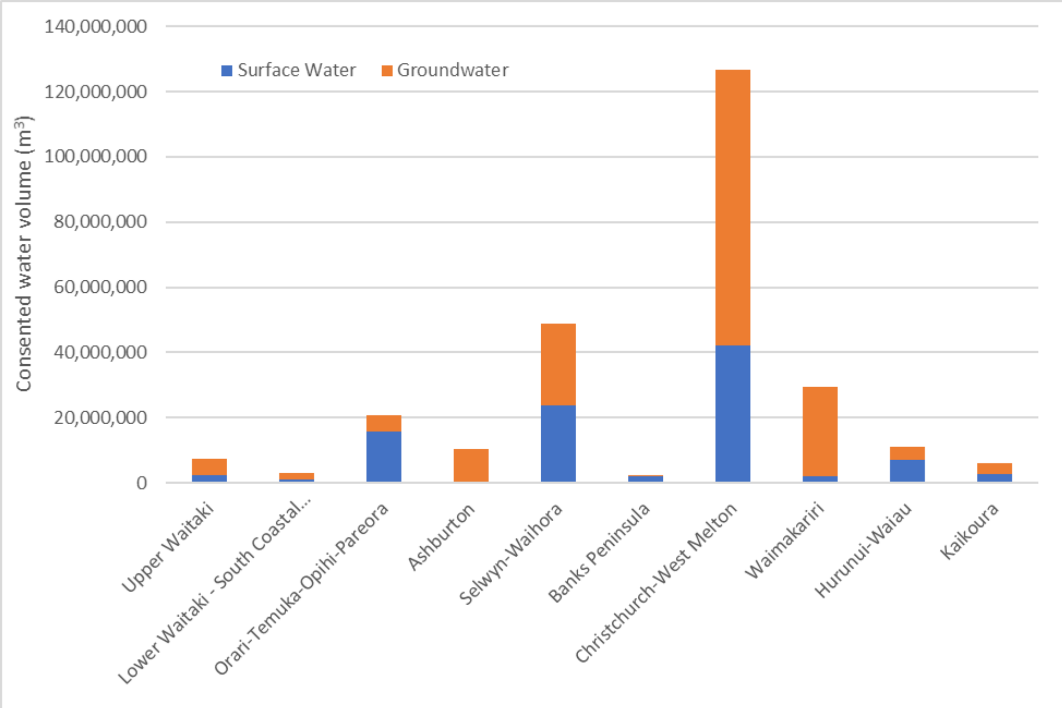


Figure 10.5: Consented water volume, by source and district, for use in town supply (Land Air Water Aotearoa, 2021).

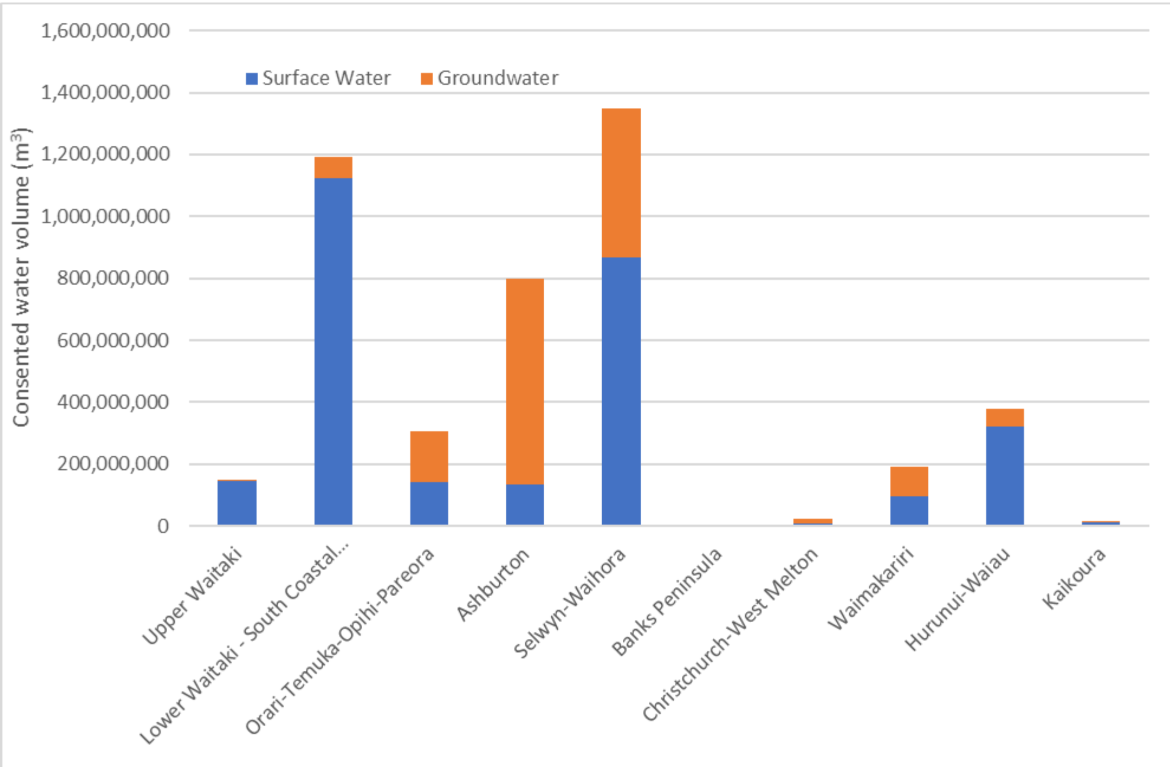


Figure 10.6: Consented water volume, by source and district, for use in irrigation (Land Air Water Aotearoa, 2021).

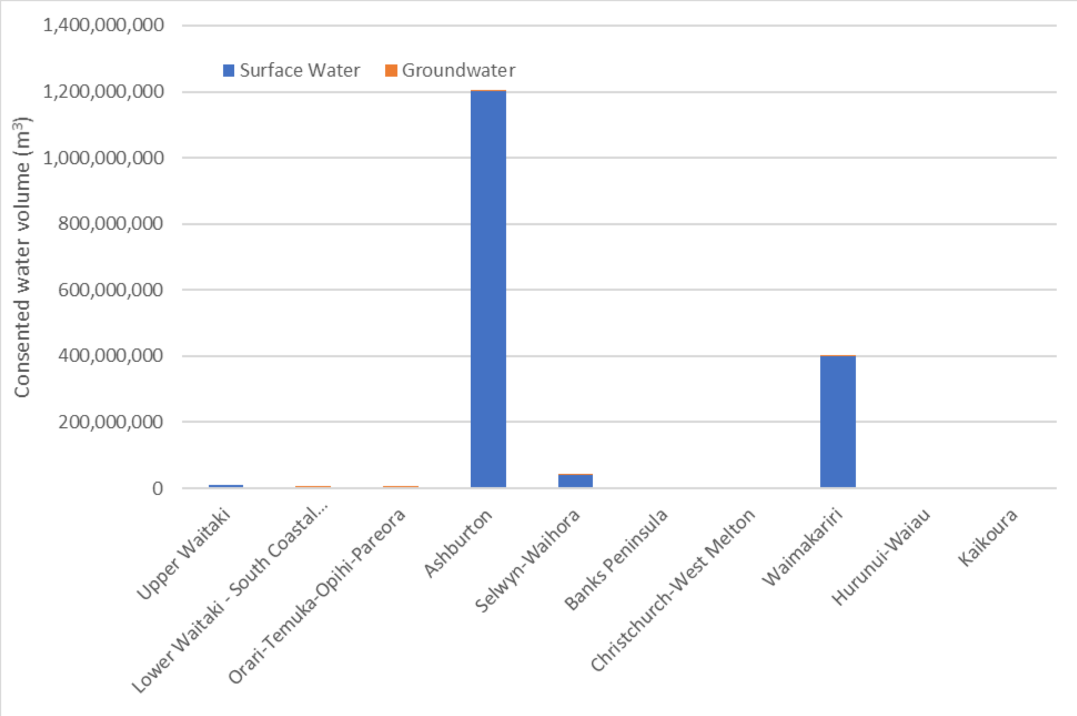


Figure 10.7: Consented water volume, by source and district, for use in stock water (Land Air Water Aotearoa, 2021).

10.5.1 Irrigation and stock water supply

Climate change will place pressure on surface water and groundwater sources. This is due to a range of projected changes, particularly, changing rainfall patterns, decreases in summertime low flows, decreases in mean annual flows in inland areas, and increasing drought potential. These are likely to reduce irrigation water supply reliability, with potential for a reduced ability to support the current level of supply. Reduced availability is likely to coincide with increased demand for irrigation, as high temperatures or increased drought potential may impact optimum pasture growth. Further increased water demand is likely to be required to cope with heat impacts on stock (Environment Canterbury, 2009).

Sensitivity of the Region to drought is currently rated as extreme. The 2016 droughts in Canterbury were the worst since those of the 1980s, with 86% of water bores across the Region affected. This caused unreliable water supply to farmers, with a range of impacts for agriculture. Until recent regulation changes, increasing numbers of wells were being sunk for irrigation purposes in the upper parts of the Canterbury catchments, because of the unreliability of flows in the foothill rivers. This type of groundwater abstraction reduces the flow of water through the groundwater system down to aquifers in lowland areas. This in turn reduces flows into spring-fed streams in lowland areas, a problem which is then further compounded by surface water abstraction in lowland areas.

In recent years, improved coordination of water consents and a shift toward water storage has been established through the Canterbury Water Management Strategy (CWMS). Use of stored water instead of groundwater for irrigation purposes in the upper part of the catchment supports the restoration of healthy flows in lowland streams (Environment Canterbury, 2009).

For over a decade, Environment Canterbury has been aware of, and actively addressing, the risks from climate change to the Region's water supply. The CWMS was established in 2009. A major consideration in the formation of this approach was ensuring reliability of water supply under climate change. The strategy's integrated management approach, combined with the reform of water use regulations, was intended to address ongoing water availability and quality issues that were expected to worsen with climate change. Management of the 10 zones established under the CWMS includes a collaborative community-led approach to sustainable water resources management (Environment Canterbury, 2009).

10.5.2 Town supply

Town supply water demand generally increases during periods of warmer temperatures when water availability is at its lowest. Summer peaks in demand often occur due to increased shower use, outdoor watering, and increased demand in fire fighter services (Stakeholder Engagement, 2021).

At a regional scale, current sensitivity of town supply is low. Most districts report that their residential water demand is well within current allocations. For example, Christchurch City Council is allocated 82 billion litres of water each year for household supply and to keep parks and gardens green. It currently uses about 70 percent of that allocation. However, water supply in some locations is very restricted. For example, Banks Peninsula is supplied by surface water from small local streams and is therefore very drought sensitive. Relative to the demand for irrigation and stock water, the volume of water required for town supply is extremely low. In this regard, water availability for town supply is likely to be less sensitive to the pressures that drought and increasing seasonality introduce, as the volumes required to meet demand are a small fraction of regional water availability.

Measures to reduce water consumption in urban areas may be more easily achieved, by improving efficiency through fixing leaks, and applying typical water saving measures, such as metering, water charges, and education, and other demand management initiatives. These may be particularly effective in areas with high water usage. Current average daily residential water usage for Ashburton and Ōtautahi/Christchurch is slightly below the national average of approximately 280 litres/person/day. All other districts have relatively high consumption rates, with over double the national average in Mackenzie (Figure 10.8), and therefore these districts may have a higher capacity to adapt.

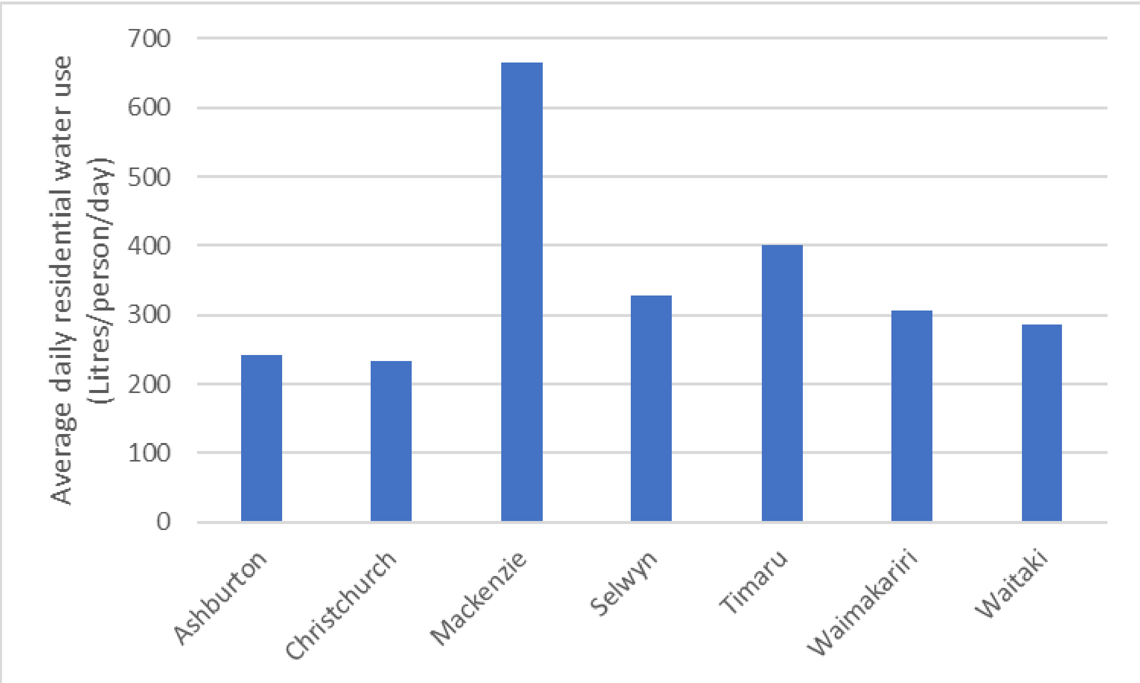


Figure 10.8: Average daily residential water use by district in Canterbury, 2019 (no data available for Hurunui, Waimate, and Kaikōura) (Water New Zealand, 2020).

10.6 Risks to water supply infrastructure

The highest risks to water supply and infrastructure from climate change includes those from changes to storms and flooding.

Exposure of water supply infrastructure to coastal, fluvial and surface water flooding is rated as extreme, particularly in Ōtautahi/Christchurch City where a large proportion of the water supply network is exposed to flooding. The sensitivity of these systems is influenced by the condition, age and type of water supply infrastructure. In particular, treatment facilities and other exposed infrastructure are at risk of damage from erosion and flood water ingress. The adaptive capacity of infrastructure is rated as medium, as components of these systems can be upgraded to improve resilience, but the capacity to relocate is usually limited.

Local councils are responsible for the supply, distribution, and treatment of safe drinking water. Most districts manage numerous small water supply schemes to deliver water to urban and rural communities (Figure 10.9). As the city with the highest population, Ōtautahi/Christchurch has the largest town supply demand, and the largest network of supporting infrastructure (

Table 10.5). Water supply to Ōtautahi/Christchurch City serves close to two thirds of the Region's population, through 160,000 connections. As such, quality and security of supply is critical for the health and wellbeing of a large proportion of the Region's population. Collectively, Councils manage over 10,000 km of water supply pipe, along with associated supply, treatment and distribution facilities. Water supply is sourced through the means of river intakes, infiltration galleries, storage reservoirs, dams, and bores. Facilities to distribute water include water treatment plants, storage reservoirs, tanks and pump stations.

Table 10.5: Urban water and rural water supply and distribution infrastructure

District	Number of on-demand water scheme	Connections	Water supply pipe (mains) (km)
Ashburton	12	9685	371
Ōtautahi/Christchurch	7 urban and 6 rural	160000	>3000
Hurunui	7 urban and 12 rural	7000	2,145
Kaikōura	5	less than 4000	210
Mackenzie	6	2580	242
Selwyn	30	17,394	1,300
Timaru	12 (6 urban, 4 rural drinking and stockwater, 2 stockwater)	17570	1853
Waimakariri	7 on demand, 3 semi restricted and 5 fully restricted	19,215	935
Waimate	7	6000	914
Waitaki	15	1,689	11,103

Source: WaterNZ, 2020; Ashburton District Council, 2018; Christchurch City Council, 2021; Hurunui District Council, 2021; Kaikōura District Council, 2021; Mackenzie District Council, 2018; Selwyn District Council, 2018; Waimakariri District Council, 2021; Waimate District Council, 2018; Waitaki District Council, 2021.

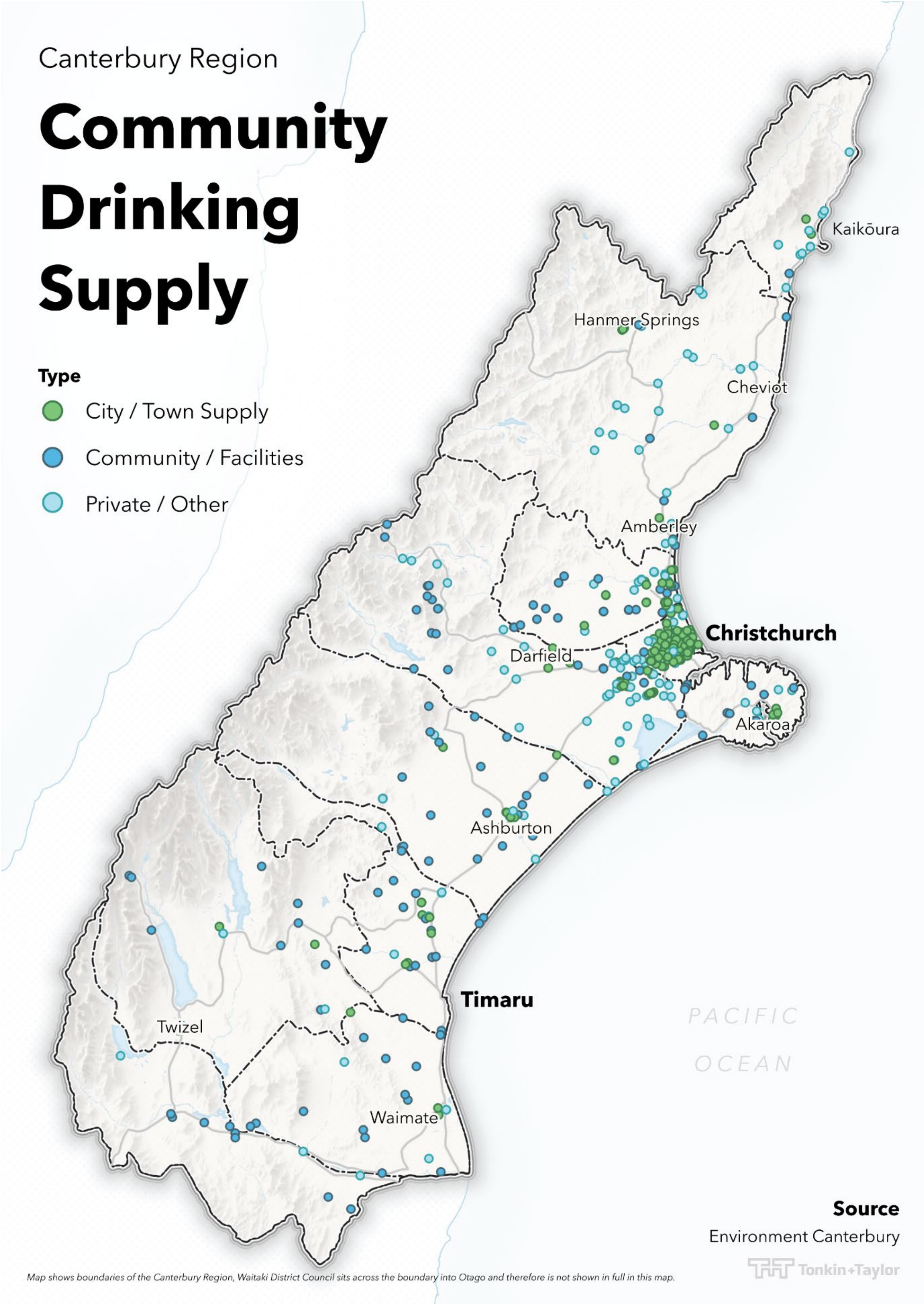


Figure 10.9: Water supply bores and community drinking water supply points.

Water supply infrastructure within Canterbury is highly exposed to coastal, fluvial and surface water flooding in New Zealand. This is primarily due to populous areas within Ōtautahi/Christchurch City residing in both coastal and low-lying areas. A total of 2,204 km of water supply pipe is exposed to inland flooding in the Canterbury Region, with nearly 80% of that located in the Ōtautahi/Christchurch district alone (totalling 1,742 km). Lower flood exposure occurs outside of Ōtautahi/Christchurch, with 105 km of water supply pipe exposed in the Waimate District and 80 km in the Hurunui district (Figure 10.10) (Paulik, Craig, & Collins, 2019).

Approximately 285 km of water supply pipe is exposed to coastal flooding related to extreme weather at 1% Annual Exceedance Probability (AEP) + 0.0 m sea level rise. This increases to 378 km of exposed water supply pipe with 0.3 m sea level rise, and 543 km with 0.8 m sea level rise. The largest proportion of this exposure is in Ōtautahi/Christchurch, with 256 km at 0.0 m sea level rise, 343 km at 0.3 m sea level rise and 499 km at 0.8 m sea level rise. The district with the next highest exposure is Timaru with around 15 km of pipe exposed at 0.0m sea level rise (Figure 10.11) (Paulik, et al., 2019).

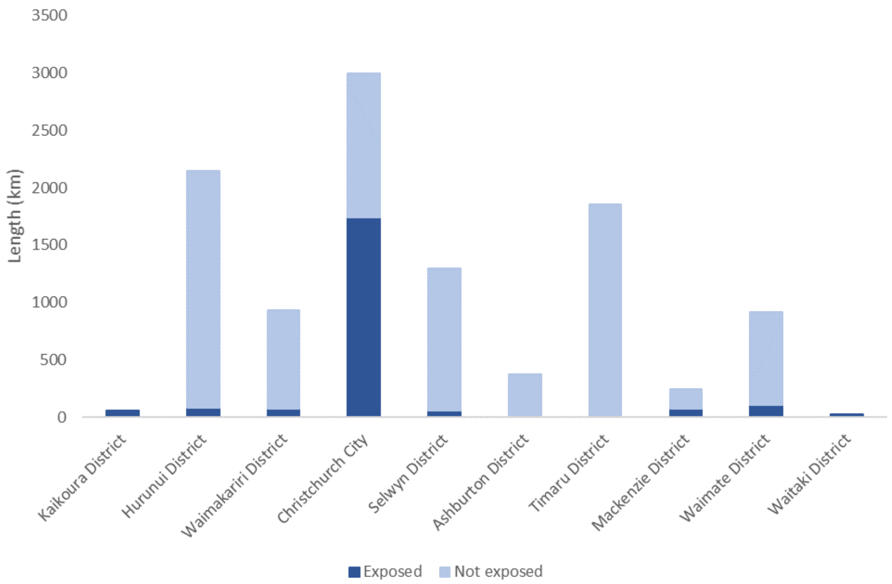


Figure 10.10: Exposure of water supply pipes to present day river and surface water flooding by district (Paulik et al., 2019).

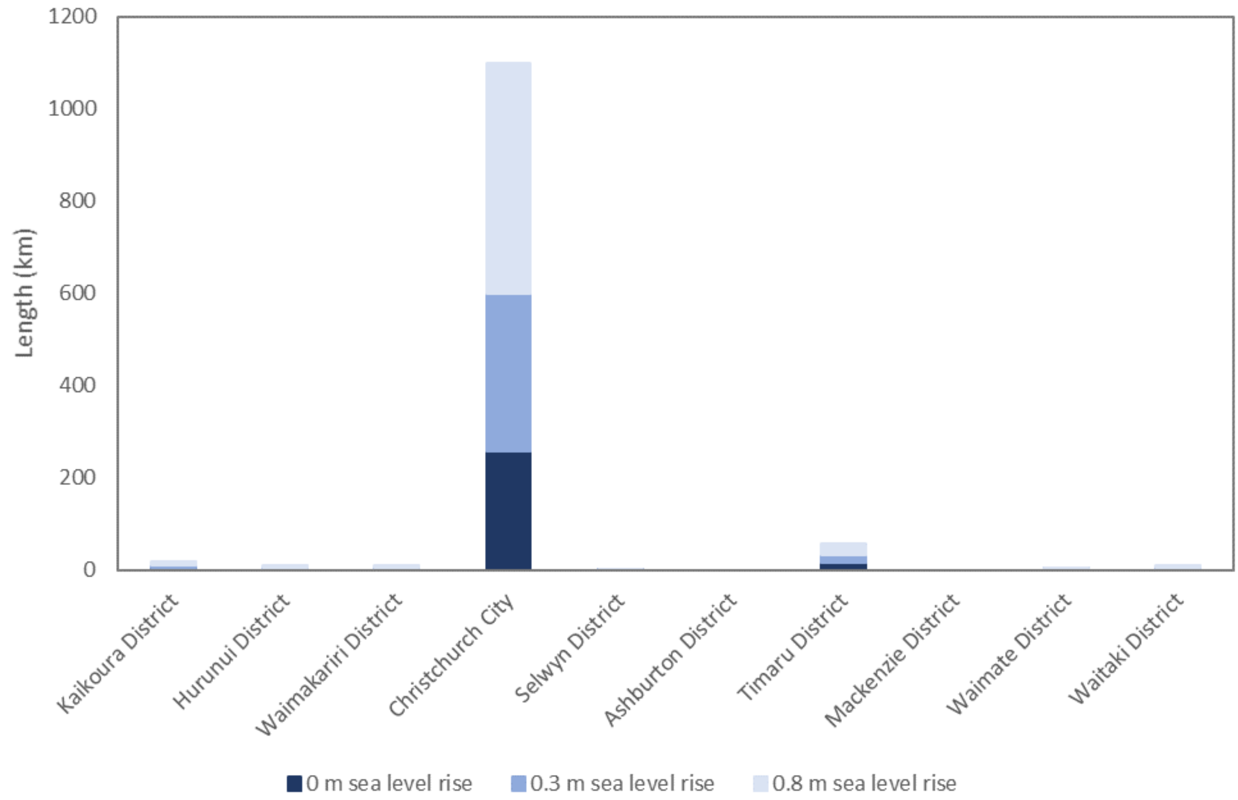


Figure 10.11: Exposure of water supply pipes to present day coastal flooding and incremental sea level rise by district (Paulik et al., 2019).

Flooding and extreme events can cause damage and disruption to water supply facilities, particularly above ground infrastructure such as intakes. Water supply intakes must be located within the water body, therefore those that are located within rivers are highly exposed to storms and flooding. This can cause damage from high flows, debris, scour and high sediment loads (CDEM, 2021). Water supply treatment facilities are often located near intakes, so may be exposed to damage, or ingress of flood water. Water supplies may be compromised due to ingress of flood water, resulting in a need for boil water notices, or broader community disruption (Environment Canterbury, 2021). Some of Canterbury's water supply systems are sourced from secure groundwater systems, so are not treated (Kaikōura District Council, 2021). This can introduce a level of risk in relation to contamination, particularly during flooding events where sediment, debris and contaminants can enter systems.

Pipe networks are rated to have a low sensitivity to storms and flooding. Water supply pipe networks are generally buried and sealed, so are protected from surface flooding. Shallow or exposed components of the water supply system may be prone to erosion or storm damage. Many of the Region's networks have a high proportion of aged infrastructure, which may have a higher sensitivity to damage from flooding. However, some parts of the water supply infrastructure in Ōtautahi/Christchurch and Waimakariri have been extensively replaced following the Canterbury Earthquake Sequence (commenced 2010). This may provide an increased resilience in these parts of the system.

The ability to upgrade components of the system provides some adaptive capacity. However, many components, such as intakes and urban networks, are limited in their capacity to relocate away from flood exposure as they must remain in place.

10.7 Stormwater and wastewater infrastructure

The highest rated risks to stormwater and wastewater infrastructure include those due to sea level rise, coastal erosion, and river and surface water flooding. Stormwater and wastewater systems are discussed together, as assets within these systems face many similar impacts from climate change.

The risk to both stormwater and wastewater assets due to coastal, river, and surface water flooding, sea level rise and salinity stress is rated as extreme by late century. This is due to the high and increasing exposure of stormwater and wastewater assets to coastal and river flooding, a high sensitivity to a range of impacts from flooding, and a low adaptive capacity.

Table 10.6: Summary of risks to stormwater and wastewater infrastructure

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to stormwater assets due to river and surface flooding	Moderate	High	High	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. Overloading of stormwater systems are likely to cause flooding of surrounding communiites, damage to components of the stormwater network, and have consequences for the water quality of recieving waterbodies. Older systems are likely to be particularly sensitive as these are often in poorer condition with smaller capacities.
Risk to wastewater treatment plants due to sea-level rise and salinity stresses	Moderate	High	High	High	Projected sea level rise may cause erosion damage, and increased occurance of inundation resulting in overflows. Rising groundwater may introduce flotation of buried components, and increased infiltration to wastewater pipelines, causing increased loading on pumping stations. Salinization of wastewater may cause corrosivity and have implications for wastewater treatment plant operations.
Risk to wastewater treatment plants due to increasing coastal erosion	Moderate	High	High	High	Projected sea level rise may cause erosion damage to components of the wastewater system that are located near the coastal edge. Wastewater assets can be expensive to upgrade, and options to relocate are limited as these systems perform best when located at the downstream point of the network.

10.7.1 Wastewater infrastructure

Wastewater assets within Canterbury include piped networks (including gravity, pressure and vacuum), treatment plant pumps, on-site systems, and a range of treatment and disposal systems. Most small-scale systems provide treatment to wastewater using oxidation ponds, with larger centres providing UV disinfection. Final disposal of effluent is typically by way of soakage trenches, and basins to land, or irrigation to land. The largest centres (Ōtautahi/Christchurch and Ashburton) manage tertiary wastewater treatment plants, with treated wastewater discharging to the coast (Table 10.7).

The scale of service provided by districts reflects their populations. Ōtautahi/Christchurch, Ashburton and Waimakariri operate the highest number of connections. As the largest system, Ōtautahi/Christchurch wastewater infrastructure includes eight treatment plants, 2,679 km of public wastewater pipes, 30,817 manholes, and 239 pumping, lift, and vacuum stations. The flat, low-lying topography of Christchurch contributes to wastewater network challenges, with flat grades and significant pumping requirements. Where grades are flat and flows lower (for example during times of drought), it is sometimes necessary to flush extra water down the line to prevent blockages.

Table 10.7: Wastewater infrastructure

District	Towns serviced	Connections (population)	Sewerage Pipe length (km)
Ashburton	3 (Ashburton (including Lake Hood), Methven Rakaia)	8,993	171
Ōtautahi/ Christchurch	9 (Ōtautahi/Christchurch, Lyttelton, Diamond Harbour, Governors Bay, Akaroa, Duvauchelle, Tikao Bay and Wainui	160,000	1,622 (gravity) 253 (pressure) 61 (vacuum)
Hurunui	7 (Amberley, Amberley Beach, Leithfield, Leithfield Beach, Greta Valley, Motunau, Cheviot, Waikari, Hawarden and Hanmer Springs)	no data	141
Kaikōura	2 (Kaikōura and Ocean Ridge)	approximately 3,000 (winter) - 4500 (summer)	61
Mackenzie	4 (Fairlie, Tekapo, Twizel (and Burkes Pass))	2,786	78
Selwyn	14	63% of population	300
Timaru	4 (Timaru, Geraldine, Pleasant Point and Temuka)	30,000	354
Waimakariri	12	17,083	240
Waimate	1 (Waimate)	1,730	67
Waitaki*	4 (in Region) Lake Ohau, Omarama, Otematata, Kurow	(785)	27

* For Waitaki, table 10.7 shows only the infrastructure located in the Canterbury region. Infrastructure in the Otago region will be under similar climate stress, and this should be factored-in during future climate change response activities.

Source: Ashburton District Council, 2018; Christchurch City Council, 2021; Hurunui District Council, 2021; Kaikōura District Council, 2021; Mackenzie District Council, 2018; Selwyn District Council, 2018; Waimakariri District Council, 2021; Waimate District Council, 2018; Waitaki District Council, 2021; Timaru District Council, 2021.

In Canterbury, wastewater networks are highly exposed to coastal, surface water and river flooding. Wastewater networks are prone to exposure from coastal and river flooding because the discharge points of these assets are generally at the lowest elevation of a populated area (White, et al., 2017). Over 1,000 km of wastewater pipe in Canterbury crosses flood-prone land (Figure 10.12) (Paulik, et al., 2019). Exposure of wastewater assets to coastal flooding (including 0.8 m sea level rise) may affect around 345 km of pipe. Of this, 297 km is located within Ōtautahi/Christchurch City and 32 km in Timaru (Figure 10.13) (Paulik, et al., 2019).

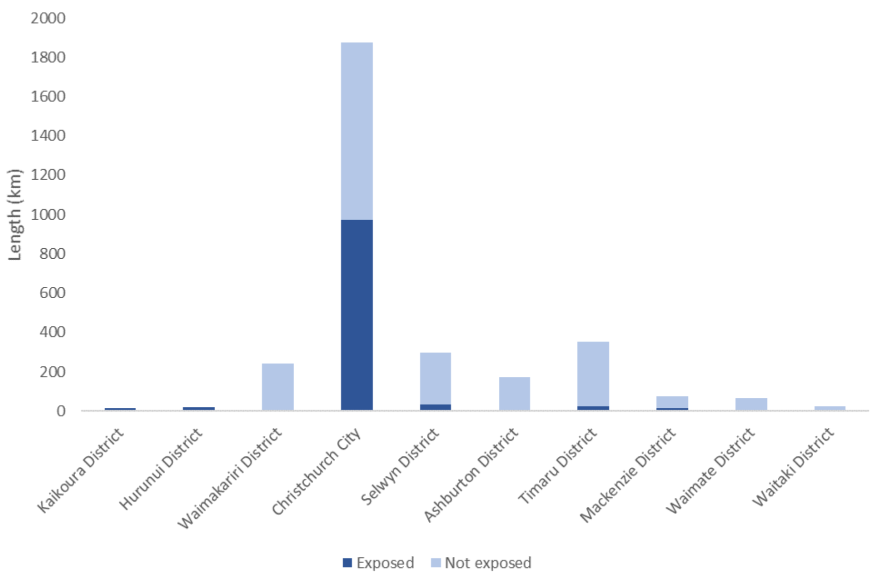


Figure 10.12: Exposure of wastewater pipes to present day river and surface water flooding by district (Paulik et al., 2019).

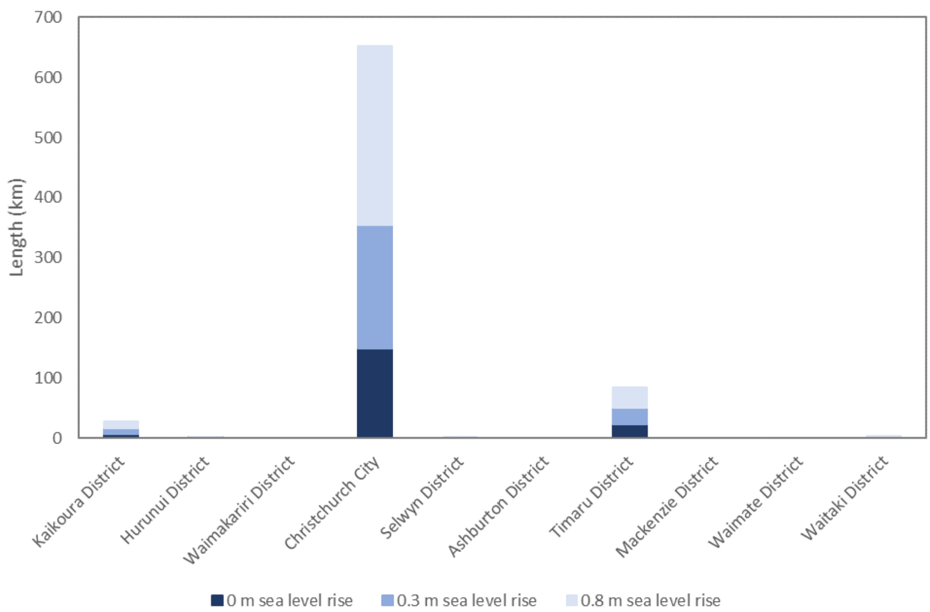


Figure 10.13: Exposure of wastewater pipes to present day coastal flooding and incremental sea level rise by district (Paulik et al., 2019).

Wastewater networks are sensitive to flooding due to a range of impacts (Hughes, et al., 2019):

- Sea level rise may lead to the stranding of some services or communities, particularly in the low-lying areas of Ōtautahi/Christchurch.
- Infiltration from floodwater into wastewater pipelines can cause blockages and damage, or overload pump stations and wastewater treatment plants. This can cause uncontrolled discharges to waterways, with consequential water quality implications.
- Infiltration of sea water can increase salinity of wastewater flows, altering treatment plant processes, or it can contribute to deterioration of pipe condition. It can also have negative

consequences for the mechanical and biological integrity of these systems and higher operating and maintenance costs. (Flood & Cahoon, 2011).

- Higher groundwater tables can further increase infiltration, introduce issues relating to flotation, or reduce the performance of land disposal (Hughes, et al., 2019).

The design, age, and location of the wastewater system can influence the sensitivity of a wastewater network. Many older systems are not designed to accommodate increased flows that may occur from flooding, and therefore will lack capacity, having potential to overflow more frequently (White, et al., 2017). They may also be in worse condition, so will be more susceptible to corrosion or damage from erosion. Newer assets, such as those replaced following the Canterbury Earthquake Sequence (commenced 2010), may have reduced sensitivity to these types of damages.

Wastewater treatment plants and assets have a low adaptive capacity because they are generally constrained by the network they serve. The systems are generally complex in nature and are designed for permanent serviceability. The potential replacement of wastewater assets provides some adaptive capacity, as these can be designed to consider future climate conditions. Wastewater infrastructure is, however, expensive to upgrade. It is hard to relocate into areas that are not exposed to climate related hazards, as this type of infrastructure performs best when located at the downstream point of the network (Stakeholder Engagement, 2021).

10.7.2 Stormwater infrastructure

Stormwater systems include piped networks, manholes, inlets, outfalls, pumping stations, soakage pits, wetlands, bioretention devices and detention dams. Additionally, there is an extensive network of rural drains, swales, and channels, some of which are serviced as part of the road network. As with the wastewater network, the scale of stormwater assets reflects the size of the town or city. The vast majority of stormwater assets are located in Ōtautahi/Christchurch City (Table 10.8).

Table 10.8: Stormwater infrastructure

District	Towns serviced	System length (km)
Ashburton	3	42.2
Ōtautahi/Christchurch		935
Hurunui	22	12
Kaikōura	2	17
Mackenzie	3	18
Selwyn	21	80
Timaru	4	145
Waimakariri	5	107
Waimate	1	13.5
Waitaki*	4 (in Region)	5

* For Waitaki, table 10.8 shows only the infrastructure located in the Canterbury region. Infrastructure in the Otago region will be under similar climate stress, and this should be factored-in during future climate change response activities.

Source: Ashburton District Council, 2018; Christchurch City Council, 2021; Hurunui District Council, 2021; Kaikōura District Council, 2021; Mackenzie District Council, 2018; Selwyn District Council, 2018; Waimakariri District Council, 2021; Waimate District Council, 2018; Waitaki District Council, 2021.

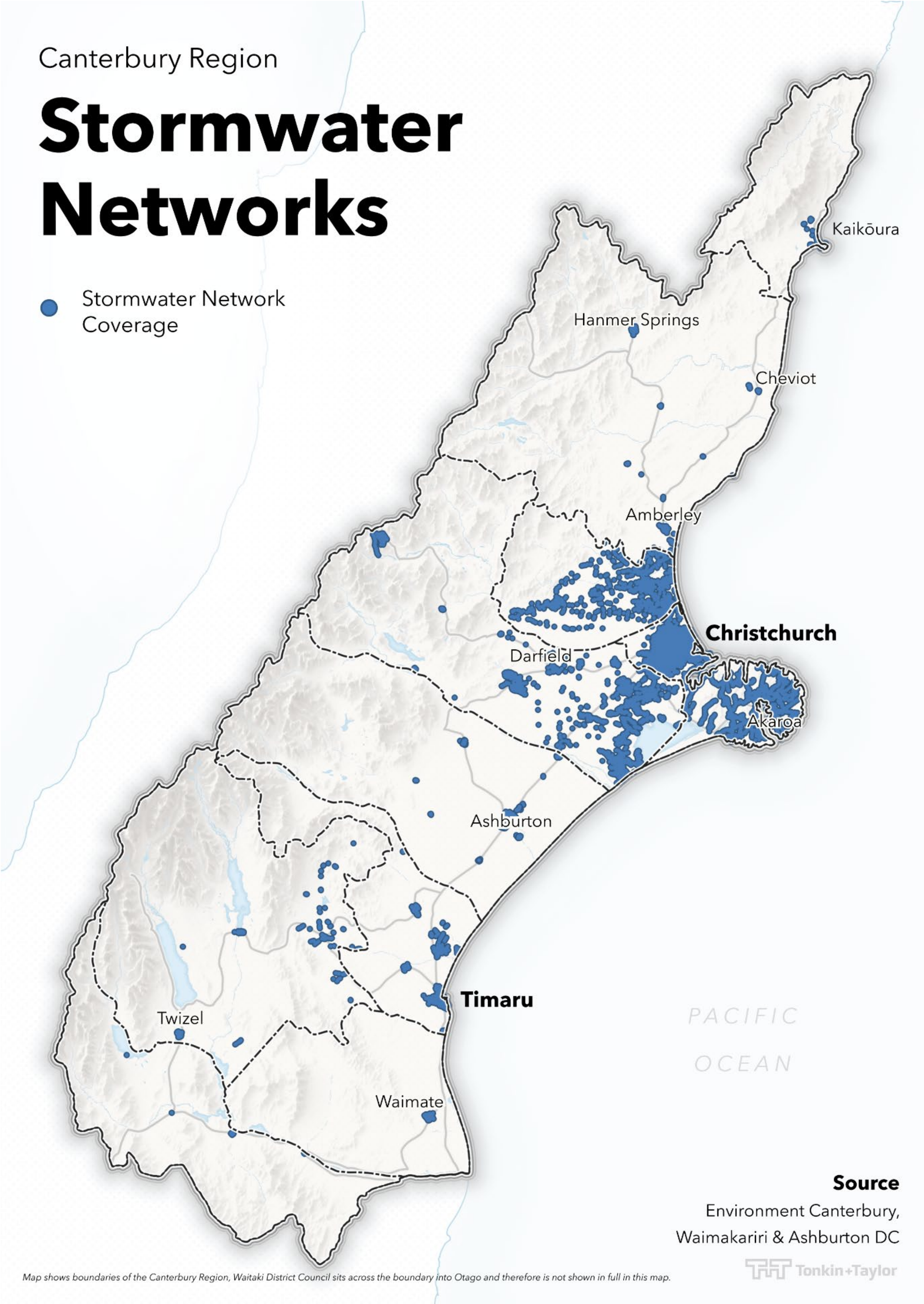


Figure 10.14: Stormwater networks in the Canterbury Region.

In Canterbury, stormwater systems are highly exposed to coastal, surface water, and river flooding. Ōtautahi/Christchurch City has more than 700 km of stormwater pipelines situated within floodplains (Figure 10.15). A further 207 km of stormwater pipelines will be exposed to coastal flooding under RCP8.5 with 0.8 m sea level rise (Figure 10.16) (Paulik, et al., 2019).

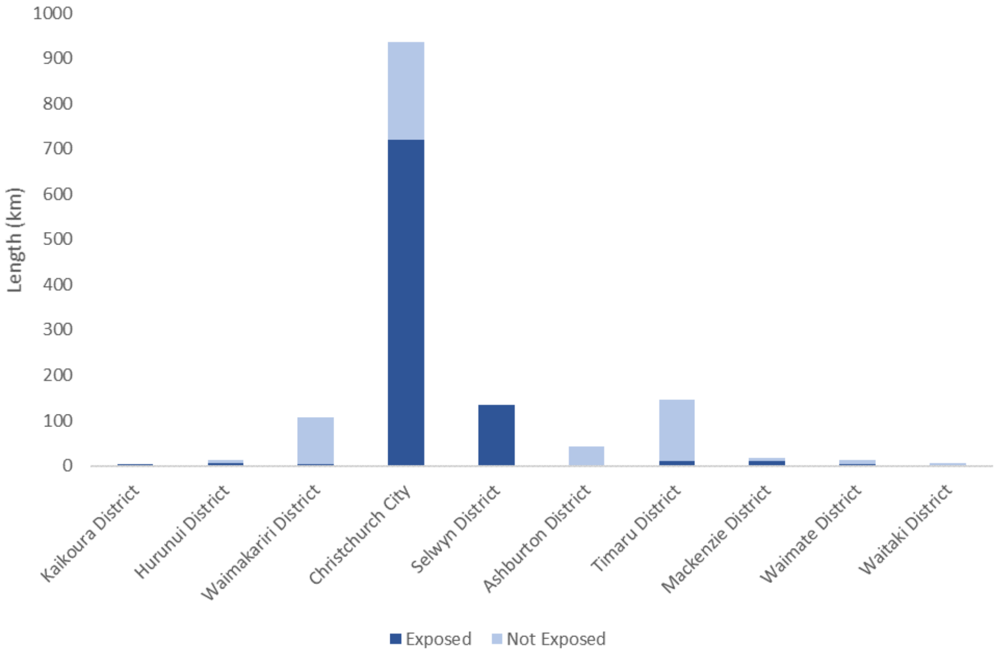


Figure 10.15: Exposure of stormwater pipes to present day river and surface water flooding by district (Paulik et al., 2019).

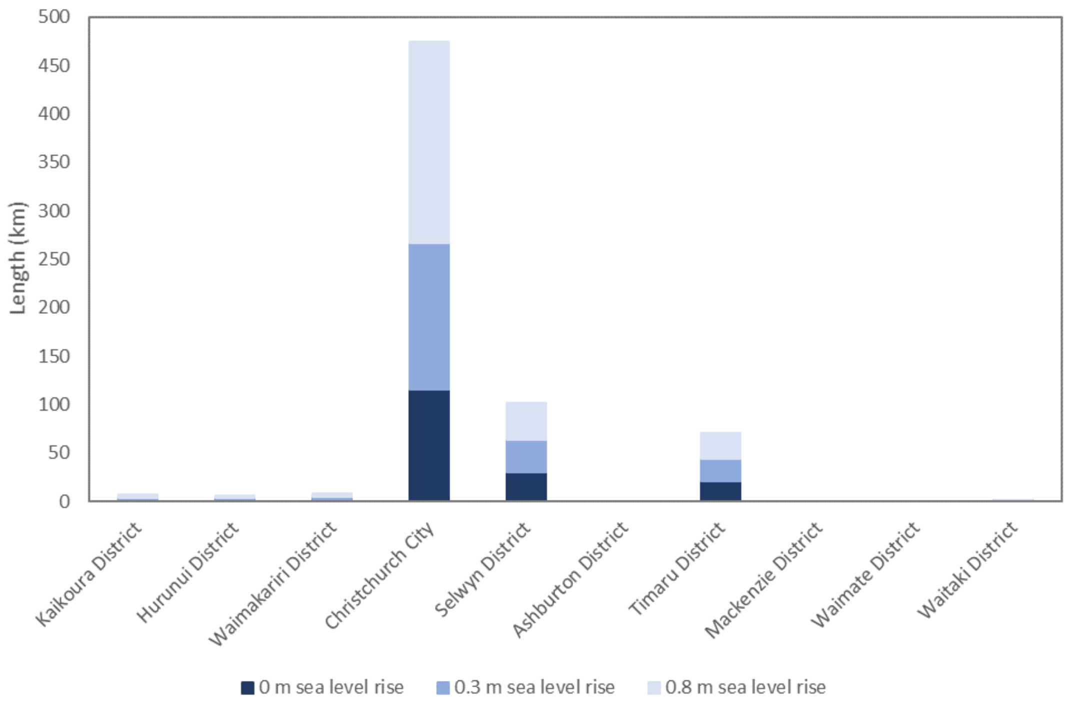


Figure 10.16: Exposure of stormwater pipes to present day coastal flooding and incremental sea level rise by district (Paulik et al., 2019).

Stormwater systems are sensitive to flooding and due to a range of impacts (Hughes, et al., 2019):

- Coastal and river flooding is likely to result in erosion. This can damage outfall structures located near rivers or the coast.
- High water levels (due to flooding) at outfall locations are likely to reduce the capacity for drainage, which may compound surface flooding in urban areas.
- Flooding may overload stormwater systems, causing inflows to combined wastewater systems, with consequential water quality implications.
- Raised groundwater levels may contribute to infiltration, further reducing the capacity of the network, or introducing issues relating to flotation, particularly in pump stations.

Many of these issues also contribute to water quality issues within the receiving waterways.

As with wastewater networks, ageing infrastructure has increased sensitivity to many of these impacts. Most councils have identified that their stormwater infrastructure is ageing, and so are taking action to upgrade the network. Some areas of new infrastructure within Ōtautahi/Christchurch may have increased resilience to some of these issues, as councils require that new stormwater infrastructure must be designed to accommodate climate change. Areas within Kaikōura have recently benefited from seismic uplift, providing benefits for drainage that are likely to reduce the exposure of the town to flooding.

Stormwater systems have a low adaptive capacity because they are generally constrained by the connection to the broader network, and rely on gravity to convey flows.

10.8 Flood defences

The highest rated risks to flood defences are those due to sea level rise, coastal erosion, and flooding.

Coastal flood defences and stopbanks near the coast will be exposed to increasing sea level rise and coastal erosion. River flood protection schemes will be exposed to increased magnitude and frequency of extreme rainfall, which may contribute to increased erosion and scour, overtopping or failure. Older stopbanks generally have lower levels of protection, and those in poor condition will have the highest sensitivity to erosion. The adaptive capacity of stopbanks is limited by high costs and limited land availability.

Table 10.9: Summary of risks to stopbanks and flood management schemes

Risk statement	Risk: Present	Risk: 2050 *(RCP8.5)*	Risk: 2100 *(RCP4.5)*	Risk: 2100 *(RCP8.5)*	High level description
Risk to stopbanks and flood management schemes due to river and surface flooding	Moderate	High	Extreme	Extreme	Projected increases in the size and frequency of flood events may effectively lower the level of service currently provided by stop banks and increase the occurrence of overtopping or flood damage. Although the structures are designed to convey floods, exceeding the design capacity or frequent exposure to high flows may cause damage or failure. is exceeded, or increasing damage may occur with high flows. Options to adapt or upgrade may be limited by high construction costs and limited land availability.
Risk to stopbanks and flood management schemes due to sea-level rise and salinity stresses	Low	Moderate	Moderate	Moderate	Projected increases in sea-level rise will increase the exposure of stopbanks located near the coastal edge to related flooding and erosion damage. A relatively small portion of schemes may be exposed to coastal hazards relative to fluvial flooding, with sensitivity, to damage influenced by the condition and age of the structure. Options to adapt or upgrade may be limited by high construction costs and limited land availability.

Table 10.10: Summary of risks to coastal barriers and sea walls

Risk statement	Risk Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	High level description
Risk to coastal barriers and sea walls due to increasing coastal erosion	Low	High	High	High	High exposure is rated at present day due to location along coastal edge, increasing to extreme by late century. Moderate sensitivity as structures are designed to protect against coastal hazard, but design capacity may be exceeded, or increasing damage may occur with increasing exposure. Medium adaptive capacity reflects the ability to upgrade, which is limited by high costs and limited land availability.
Risk to coastal barriers and sea walls due to coastal flooding	Low	High	High	High	Projected increases in sea-level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.
Risk to coastal barriers and sea walls due to storms and wind	Low	High	High	High	Projected increases in sea level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.
Risk to coastal barriers and sea walls due to sea-level rise and salinity stresses	Low	High	High	High	Projected increases in sea level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.

For the purpose of this assessment, flood defences are defined as stopbanks and sea walls. Environment Canterbury manages 59 river control and drainage schemes from Kaikōura to Waitaki (shown in Figure 10.17), protecting a total asset value of $691 million. A drainage bylaw is in place to manage, regulate, and protect these assets from inappropriate modification, damage or destruction (Environment Canterbury, 2021b).

Across Canterbury, flood protection and drainage works are carried out in dedicated rating districts. Management of rating districts is split over three geographical engineering areas: Northern, Central and Southern Canterbury (Environment Canterbury, 2021b). The Northern District covers the Waimakariri-Eyre-Cust Scheme to the Kaikōura Rivers and Kaikōura Drainage Schemes. The Central

District covers the Halswell Drainage and Te Waihora to Ashburton Hinds Drainage Scheme. The Southern District covers the Rangitata River to the Lower Waitaki River (Figure 10.17).

The level of service provided in each flood protection scheme varies across the 59 schemes. Currently, levels of protection are agreed with the benefitting community through a public meeting process. A flood protection and drainage bylaw is established to manage, regulate, and protect flood protection assets from damage, and to support monitoring of maintenance requirements (Environment Canterbury, 2021).

Twenty-five of the largest flood protection schemes have representative river rating district liaison committees. These committees are the voluntary eyes and ears on the ground for their local river flood and erosion protection and drainage works, and influence the overall direction of flood and erosion protection and drainage works.


Canterbury Region
Transport
Road
Rail
Airport
Aerodrome
Kaikōura
Hanmer Springs
Cheviot
Amberley
Christchurch (CHC)
Lyttelton Port
Darfield
Akaroa
Ashburton
Mt Cook (MON)
Timaru (TIU)
Timaru Port
Twizel
Waimate
PACIFIC OCEAN
1
7
73
75
77
79
80
8
83
Source
Waka Kotahi / KiwiRail / LINZ
Tonkin+Taylor
Map shows boundaries of the Canterbury Region, Waitaki District Council sits across the boundary into Otago and therefore is not shown in full in this map.

Figure 10.17: Flood defences in the Canterbury Region.

Stopbanks in Canterbury will be exposed to increasing size and frequency of flood events. This is due to projected increase in rainfall events with small annual exceedance probabilities throughout the country (Carey-Smith et al., 2018). As a result, flood flows are likely to increase in magnitude and frequency, effectively lowering the level of service currently provided by stopbanks. This may increase the occurrence of overtopping and cause flooding. Overtopping or flows that exceed the design capacity can lead to stop bank failure (Stakeholder Engagement, 2021).

The condition of stopbanks influences their sensitivity to climate change impacts. Older stopbanks generally offer a lower level of protection, as modern design standards account for changes in flows due to climate change (Stakeholder Engagement, 2021). Schemes that are in poorer condition may have an increased likelihood of scour or breach (Environment Agency, 2006). In these cases, failure threshold may be less than design standards, meaning that breach of the stopbank could occur before overtopping. Discussion with Environment Canterbury Flood Engineers suggest that this is likely the case for many of the stopbanks across Canterbury (Stakeholder Engagement, 2021).

Vegetation alongside flood defences is integral to design. It takes a long time to establish and grow back if damaged by fire weather or flooding. Depending on the type of vegetation, these can also act as a fire starter/enabler.

The majority of flood schemes in Canterbury (including but not limited to: Waitaki, Waihao, Otaio, Pareroa, Opihi, Orari and Waimakariri), contain sections located within close proximity to the coast. These schemes will have increasing exposure to sea level rise, coastal erosion and coastal inundation.

Stopbanks have a limited adaptive capacity due to the permanent nature of these assets. Earth stopbanks can be upgraded, but land availability for significant increases in size and extent of protection is often limited. Resistance from communities to having infrastructure in their back yard can be a further barrier to upgrades (Stakeholder Engagement, 2021). The cost of stopbank upgrades can be high. For example, cost of upgrades to the Waimakariri Flood Protection Scheme was $40 million. This project was implemented to reduce the risk of flooding in Ōtautahi/Christchurch City, Waimakariri, and Selwyn districts, by increasing the overall scheme capacity to 6,500 m^3/s. It included repair of earthquake damage, and added strength and resilience to the flood protection system already in place, as well as significantly lowering the risk of break-out during major flood events (Environment Canterbury, 2021).

As sea level rise and coastal hazards increase, coastal defences will be exposed to increasing damage and erosion, and the level of protection they provide will reduce. Integrated flood management planning uses both hard and soft approaches, which can provide some adaptive capacity. Ensuring both hard and soft defences (such as coastal wetlands) are designed for future climate conditions supports adaptation, which is important for continued community protection (Stakeholder Engagement, 2021). In some areas of Canterbury, an adaptive approach to coastal defences has been applied. For example, in Caroline Bay dunes have been created to protect communities and assets from coastal flooding. Dune restoration has also occurred throughout the Region, following erosion after large storms hitting the coast, particularly in Pegasus Bay (Orchard, 2014). Dunes and coastal wetlands are exposed to coastal storms, and subsequent flooding due to their location along the coast. These factors are likely to cause increasing erosion.

11 Ngā Waihanga | Infrastructure Services

Our communities rely on the infrastructure that serves them. Ngā waihanga (infrastructure services) describes these critical services. Our roads, rail, ports, and airports allow our people to connect with each other physically. They also provide critical corridors for our supply chains and services. Solid waste management keeps our communities functioning safely by protecting them from contaminated land and waste. Some infrastructure services are discussed in other sections, including three waters infrastructure within Section 8 Wai (Water).

Canterbury is the largest of New Zealand's Regions by area, spanning a significant length of the South Island. Many critical transport routes cross the Region, which is also home to the country's second largest airport and two major ports (Figure 11.1).

Ngā waihanga (infrastructure services) is interconnected with many other aspects of the natural and physical world of Canterbury. These critical aspects of our infrastructure are integral to hapori (sense of community). By managing our solid waste carefully, we can contribute to protecting wai (water), rerenga rauropi (biodiversity), and hauora (physical health).

11.1 Summary of risks

Risks to ngā waihanga (infrastructure services) are identified through consideration of transportation routes, ports and airports, as well as solid waste and energy supply and transmission. The rated risks relating to these aspects of ngā waihanga (infrastructure services) are identified in Table 11.1 below.

Table 11.1: Risks to Ngā waihanga (infrastructure services)

	Higher mean temperatures	Change in mean annual rainfall	Drought	River and surface flooding	Coastal flooding	Increased coastal erosion	Sea-level rise and salinity stresses	Storms and wind	Increased fire-weather	Increasing landslides and soil erosion	Extreme weather events	Reduced snow & ice	Ocean chemistry changes	Marine heatwaves	Climate change
Using RCP8.5	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L
Airports				M H E											
Marine facilities							L M H	M H E							
Rail	L M H					H H E	L M H			M H E					
Roads and bridges				L H E		M H E	L M H								
Solid waste management and contamination sites				M M H		M E E	M E E								

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

11.2 Linear transport

Risk to linear transport includes risks to roads, bridges, and rail networks. The highest rated risks from climate change include those due to changes in rainfall and sea level rise, with associated flooding, and coastal erosion.

Risk to linear transport due to inland flooding and erosion is rated to increase to extreme by late century. This is because exposure to flooding is projected to increase, and is also due to the high sensitivity of these assets to erosion. There is currently a moderate sensitivity to flooding, which is likely to increase to high over time. Linear transport generally has a medium adaptive capacity to flooding. There is a low rated adaptive capacity of linear transport to coastal erosion, with retreat or abandonment of assets being the likely feasible options. Linear transport is also at risk from increased temperature as pavements can melt, rails can warp, and maintenance of unsealed roads made more difficult at high temperatures. Specific assets have differing levels of adaptive capacity. For rail, risk resulting from increased temperatures and landslides is rated as extreme by the end of the century. This is due to its extreme exposure and extreme sensitivity to these hazards at 2100. However, the adaptive capacity for rail assets is rated as moderate, as increased maintenance is likely to decrease the risk. Bridges are rated to have a low adaptive capacity to risk, due to their permanent nature and the high cost of replacement

Table 11.2: Summary of risks to linear transport

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to rail due to increasing coastal erosion	High	High	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increasing storminess. Sections of rail are exposed to coastal erosion, particularly along the Kaikoura Coast. Coastal erosion may damage tracks severely, and cause disruption to services. Some coastal routes have limited options for alternative inland routes, and are required to continue to serve existing communities.
Risk to rail due to increasing landslides and soil erosion	Moderate	High	Extreme	Extreme	A large section of the Kaikoura rail line is located adjacent to coastal cliffs. Coastal erosion may erode or destroy the track causing disruptions and damage. There is potential for strengthening of these sections of cliff face or improved coastal defences.
Risk to rail due to higher mean temperatures	Low	Moderate	High	High	Projected increasing temperatures may increase the occurrence of buckling of tracks. Maintenance can be done to avoid buckling i.e. destressing
Risk to rail due to sea-level rise and salinity stresses	Low	Moderate	High	High	Projected sea level rise may cause inundation and increase salinity stress for coastal rail routes such as those along the Kaikoura Coast. This may cause coastal erosion, disruption to services and increase corrosion due to salt water intrusion. Some coastal routes have limited options for alternative inland routes, and are required to continue to serve existing communities.
Risk to roads and bridges due to increasing coastal erosion	Moderate	High	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increased storminess. Coastal roads and bridges may be exposed to erosion which can damage bridge footings, road foundations, and erode surfaces. Options to adapt include retreat or abandonment.
Risk to roads and bridges due to river and surface flooding	Low	High	Extreme	Extreme	Projected increases in extreme rainfall events are likely to result in increased surface and riverine flooding. Bridges exposed to flooding may be damaged through erosion, debris strike or washout. Flooding can cause disruption and damage to roads, which is influenced by material, type of structure, condition and age. Improved resilience can be achieved though maintenance and provision of alternative routes.
Risk to roads and bridges due to sea-level rise and salinity stresses	Low	Moderate	High	High	Projected sea level rise is likely to increase exposure of roads to inundation and salinity stress. Roads exposed to inundation may be damaged and travel routes disrupted.

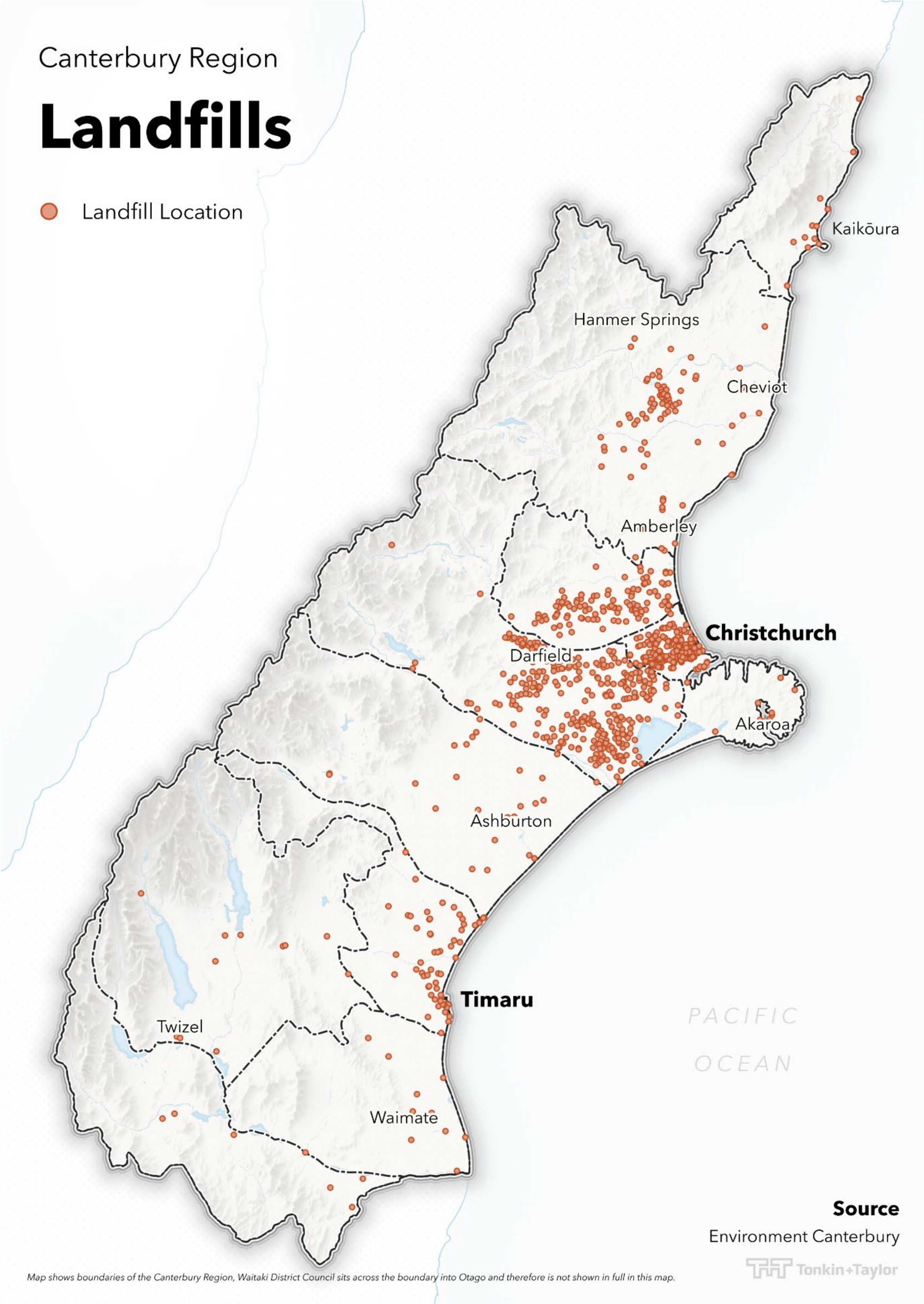

Canterbury Region
Landfills
Landfill Location
Kaikōura
Hanmer Springs
Cheviot
Amberley
Christchurch
Darfield
Akaroa
Ashburton
Timaru
Twizel
Waimate
PACIFIC
OCEAN
Source
Environment Canterbury
Map shows boundaries of the Canterbury Region, Waitaki District Council sits across the boundary into Otago and therefore is not shown in full in this map.

Figure 11.1: Major transport routes in the Canterbury Region.

The Canterbury Region has 9,904 km of sealed road and 6,218 km of unsealed roads. Of the total 16,122 km of road, 13,188 km is categorised as rural, and 2,916 km as urban (Figure NZ, 2021). Ashburton and Selwyn have the longest networks of rural roads, and Ōtautahi/Christchurch the greatest length of urban roads (Table 11.3).

Table 11.3: Length of road and bridges within each district (Figure NZ, 2021)

District	Rural roads (km)	Urban roads (km)	Bridges (number)
Ashburton	2410	202	181
Christchurch	731	1677	353
Hurunui	1361	80	280
Kaikōura	157	27	47
Mackenzie	677	62	95
Selwyn	2296	303	no data
Timaru	1481	240	280
Waimakariri	1312	267	288
Waimate	1286	52	185
Waitaki*	1627	171	121

* For Waitaki, table 11.3 shows only the infrastructure located in the Canterbury region. Infrastructure in the Otago region will be under similar climate stress, and this should be factored-in during future climate change response activities.

Canterbury has the second largest rail route length in New Zealand at 611 km (2017 data, Figure NZ).

The rail route and State Highway 1 (SH1) provide an important connection along the length of the Region. State highways provide an important connection to many of the communities in the Region. In some cases, the State highway is the main, or even the only, connection serving the town. Both rail and State highway routes are generally located in the flat lowlands along the coastal fringe of the Canterbury plains, in some cases adjacent to the coastline. The Region's many rivers cross these routes (Figure 11.1). The damage to SH1 sustained during the Kaikōura Earthquake (2016), along with more recent flooding during May and June 2021, highlighted the importance of state highways in connecting communities.

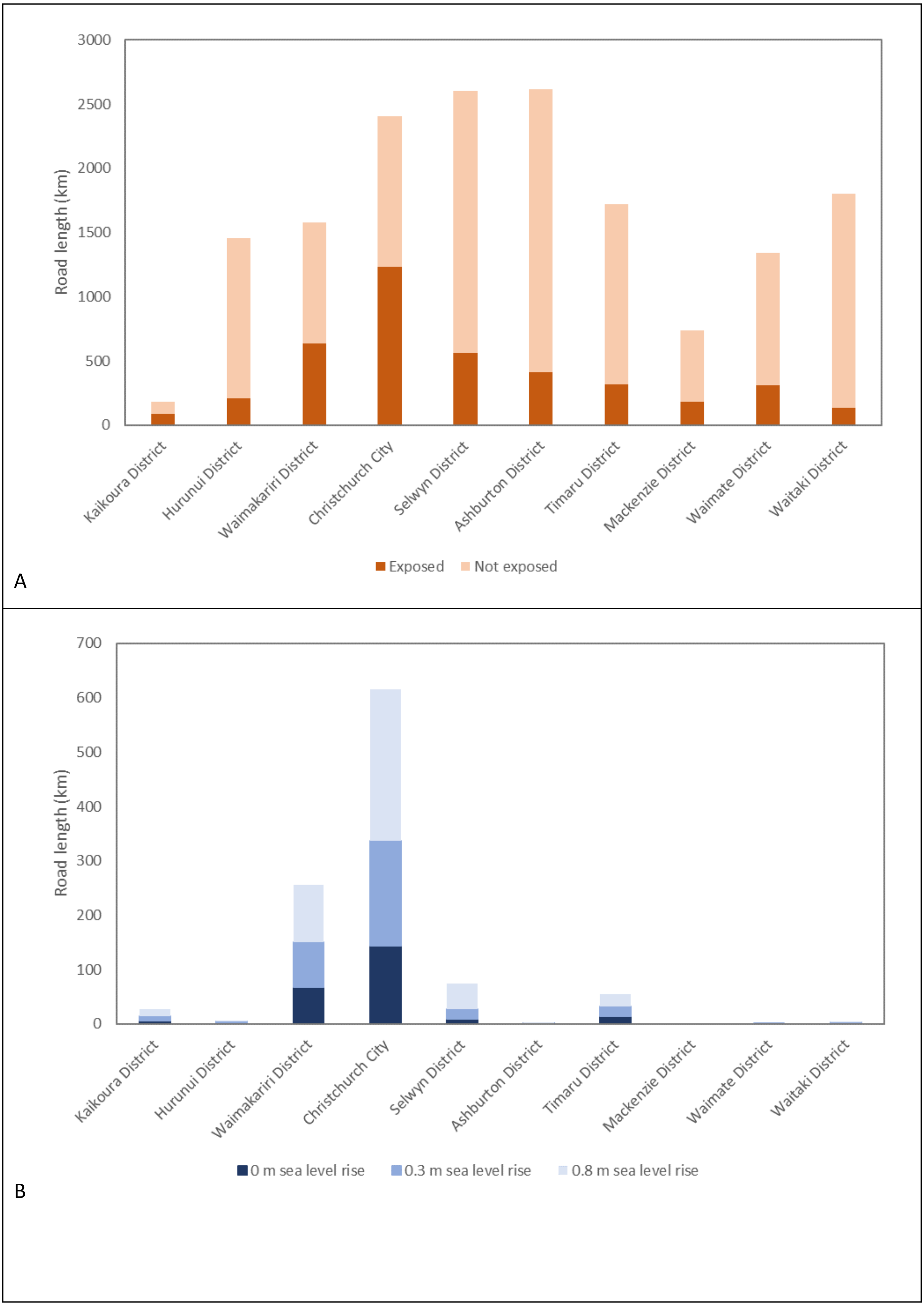
Canterbury's roads and rail have high exposure to surface water flooding, with 3,947 km of road, and 156 km of railway exposed. Of the exposed roads, 1,232 km are located within Ōtautahi/Christchurch City, followed by 637 km in the Waimakariri District and 415 km in the Ashburton District (Figure 11.2). Of the rail lines exposed, 28 km are located within the Waimakariri District, 25 km are located within Selwyn, and Waimate and Ōtautahi/Christchurch each have 22 km exposed (Figure 11.2).

Canterbury's roads have extensive exposure to coastal flooding. There is 243 km of road exposed to at the 1% AEP + 0.0 m sea level rise. This increases to 321 km with 0.3 m sea level rise, and 469 km with 0.8 m sea level rise. Of those roads exposed at 0.0 m sea level rise, 144 km are located in Ōtautahi/Christchurch City, 67 km are located within the Waimakariri District and 14 km are located within Timaru. This increases to 279 km, 104 km and 23 km with 0.8 m sea level rise for Ōtautahi/Christchurch, Waimakariri and Timaru Districts respectively (Figure 11.2).

There is 8 km of rail exposed at the 1% AEP + 0.0 m sea level rise within the Canterbury Region. This increases to 10 km with 0.3 m sea level rise and 17 km with 0.8 m sea level rise[5]. Of the rail exposed

[5] Sea level rise is projected to be up to 0.8 m under RCP 8.5. Exposure data relative to 0.9 m sea level rise is included in this assessment as this is the available information.

at the 1% AEP + 0.0 m sea level rise scenario, 3 km is located within each of the Waimakariri and Kaikōura Districts (Figure 11.2) (Paulik, et al., 2019).



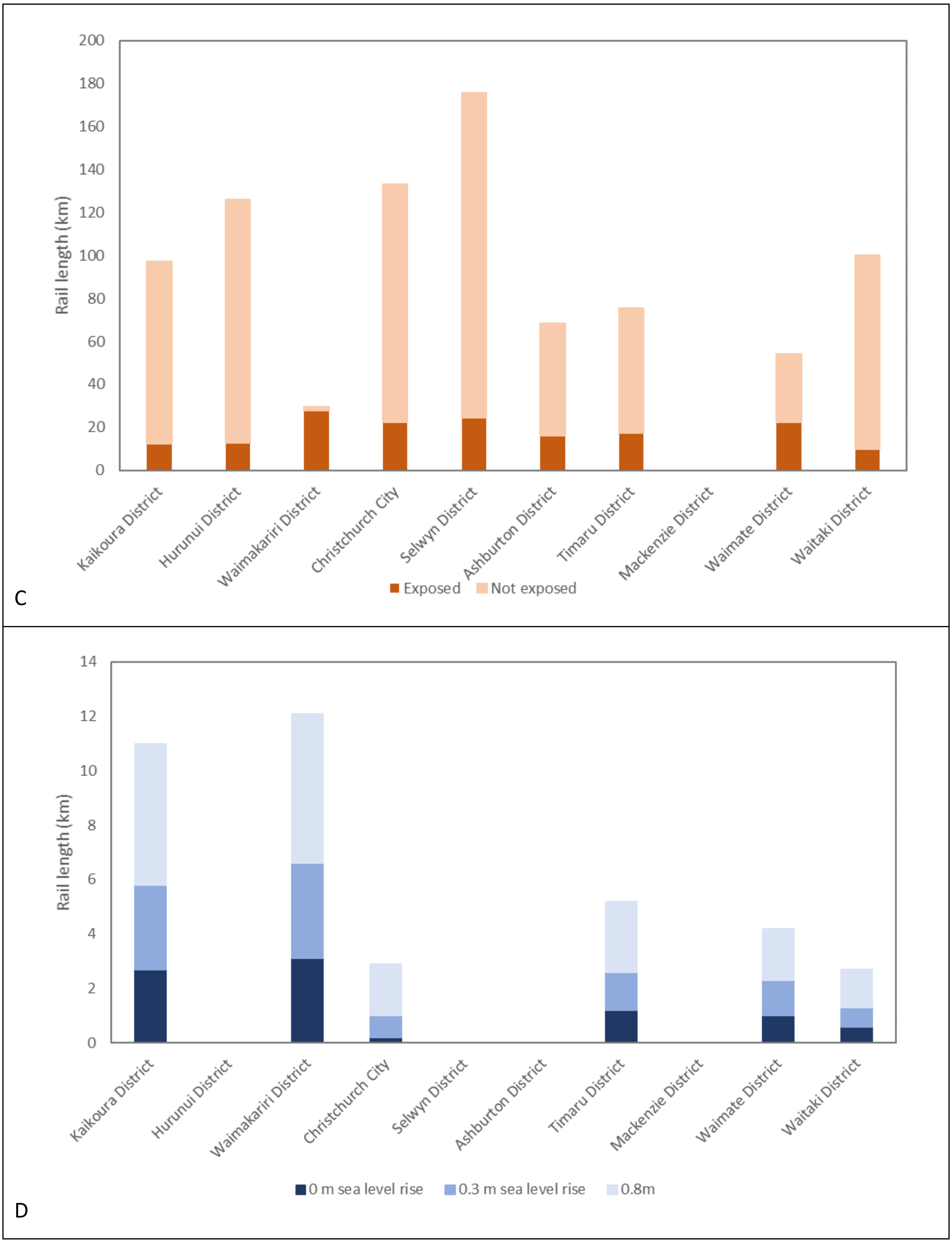


Figure 11.2: Exposure of roads and rail to present day flooding (A and C respectively) and coastal flooding (B and D) by district in Canterbury (Paulik et al., 2019).

The numerous rivers and coastal routes within Canterbury mean that many of the Region's transport connections are exposed to flooding and erosion. Many bridges also serve as critical connections, as was highlighted during recent Canterbury floods, during which flooding and debris caused damage to the Ashburton Bridge on SH1. The bridge provides a critical connection, disruption of which impacted the supply chain, affecting the lower South Island (Stakeholder Engagement, 2020).

The sensitivity of roads and bridges to flood damage such as erosion is influenced by both road condition and material type. Rural roads and unsealed roads are often in poorer condition than urban roads, as they have less frequent maintenance. Increased rainfall and flooding events can cause washouts of roads, leading to extensive disruption and a high cost for repair. For example, the April 1951 flooding in Canterbury caused $7.7 million (measured in equivalent 2009 dollars) in damage to roads. Slips and washouts blocked major railway lines, with several slips on the line between Craigieburn and Avoca, and Darfield and Springfield. Three major washouts occurred between Hanmer and Lewis Pass, with heavy surface flooding in many locations. (New Zealand Historic Weather Events Catalogue, 2021). The South Canterbury floods in 1986 caused $30 million (measured in equivalent 1991 dollars) in rail and road damage, with floods, slips, washouts and surface flooding occurring. Many roads were scoured out. (New Zealand Historic Weather Events Catalogue, 2021)

Coastal erosion, increased rainfall, and flooding can all cause scouring of bridge foundations, which can lead to foundation failure. Sea level rise can cause saline incursion, increasing the rate of material deterioration. (Gardiner, et al., 2009a)

Rail sensitivity to flood and heavy rainfall is influenced by ballast material and construction. Ballast can be susceptible to washout during flood events, causing delays and reducing speeds. (Network Rail, 2020).

The adaptive capacity for State highways and main trunk lines is generally limited due to their permanent nature, need to connect to the communities that they serve, and limited alternative geographic corridors. However, some actions can be taken, through increased maintenance or strategic planning, to reduce impact from climate related hazards. These include:

- Raising road and rail levels, and increasing redundancy within the network (Byett, et al., 2019).
- Destressing tracks to ensure buckling does not occur in increased temperatures.
- Managed retreat.
- Technical and operational solutions, e.g. change in design standards to ensure alignment with flood risk strategies. (Gardiner, et al., 2009b).

11.3 Marine facilities and airports

The highest rated risks to marine facilities from climate change include those from sea level rise, increased storms and wind, and flooding. Marine facilities will be exposed to sea level rise and increasing severity of storms and wind.

Risk to marine facilities due to extreme weather events is rated as extreme by late century, with the risk due to sea level rise increasing to high by the end of the century. Sensitivity of marine facilities to both hazards is high, and they have a limited capacity to adapt through relocation.

Additional risks were raised during the 2021 Stakeholder Engagement, however these have not been rated or assessed as they were not identified during the 2020 Screening stage. One risk is that, as with other pavements, airport runways are also at risk from increased temperature as pavements can melt. Another identified risk is that reduced air density associated with warmer temperatures can lead to a need for longer take-offs, requiring longer runways, and reduced passenger capacity (Coffel et al., 2017).

Table 11.4: Summary of risks to marine facilities and airports for differing hazards

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to marine facilities due to storms and wind	Moderate	High	Extreme	Extreme	Sea level rise and increased storminess is projected to increase with climate change. This may cause disruption to port operations as storm surge and severe weather prevents normal operation and increases the risk of damage to cranes. The capacity for ports to adapt is limited by the need to remain at coastal locations, however these facilities can be upgraded to provide improved protection to sensitive equipment
Risk to marine facilities due to sea-level rise and salinity stresses	Low	Moderate	High	High	Sea level rise is projected to increase with climate change and may cause inundation of some facilities. The capacity for ports to adapt is limited by the need to remain at coastal locations, however low lying and sensitive parts of these facilities may be upgraded or raised.

There are four harbours within the Canterbury Region, including the two large commercial ports of Lyttleton and Timaru, as well as Akaroa and Kaikōura Harbours (which each have some commercial activities). Commercial vessels include all cargo vessels, cruise ships, fishing vessels, ferries and tourism operators throughout the Region (Environment Canterbury, Commercial Shipping, 2021). There are 31 airfields within the Canterbury Region, with one main international airport- Ōtautahi/Christchurch.

There is low exposure of airports to coastal flooding and sea level rise. After 1.4 m of sea level rise, only one airport will be exposed (Paulik, et al., 2019). Two airports, located in Ōtautahi/Christchurch City and Mackenzie District, are exposed to flooding. The nature of port facilities requires that they are located at the coastline, therefore all port facilities in the Region will be exposed to increasing sea level rise and coastal hazards.

Sea level rise and increased coastal flooding and storms have the potential to impact port facilities. Facilities will have increased risk of damage to surfaces, buildings, and electrical equipment as flooding increases. Disruption to operations will occur more regularly as storm surge and severe weather prevents normal operation and increases the risk of damage to cranes. The capacity for ports to adapt is limited by the need to remain at coastal locations. However, these facilities can be upgraded to provide improved protection to sensitive equipment.

Airports are sensitive to increased rainfall and flooding, which can cause damage to airport buildings, runways, and underground infrastructure. Increased rainfall can also require increased separation between planes during take off and landing, where airports with limited space will have a greater sensitivity (Burbidge, 2016). Increasing northwest wind events may increase runway usage, leading to an increase in upgrades and maintenance of assets. Increasing extreme weather events may change operational aspects of airports, impacting on planning. It may also drive an increased need for north-west runways and flight patterns, leading to an impact on noise contours (Stakeholder Engagement, 2021). Smaller airports have a moderate capacity to adapt, as they may be able to relocate or reconfigure runways. Christchurch Airport has limited capacity to relocate or reconfigure, due to the high costs and permanence of the facilities. Remodelling of the Waimakariri river is critical for understanding surface water flooding effects for the Christchurch International Airport, and will support mitigation measures.

11.4 Landfills and contaminated sites

The highest rated risks to solid waste management infrastructure include those from coastal erosion, sea level rise, and river and surface water flooding.

Risk to landfills and contaminated sites due to coastal erosion and sea level rise is presently rated moderate, increasing to extreme by late century. This is due to both increasing exposure over time from high to extreme, combined with a high sensitivity and low adaptive capacity. Risk to landfills and contaminated sites due to flooding is lower relative to erosion and sea level rise, due to a greater capacity for protective works to be effective against riverine erosion.

Table 11.5: Risks to solid waste management and contamination

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to solid waste management and contamination sites due to increasing coastal erosion	Moderate	Extreme	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increased storminess, which may expose some coastal landfills to erosion. Old landfills are particularly sensitivity to erosion due to often poor lining and capping protection. Increased leachate my be produced, or the integrity of landfill may be compromised. Landfills have a low adaptive capacity as they are permanent features that are expensive and complex to remove. Remedial works may increase protection against erosion and leachate.
Risk to solid waste management and contamination sites due to sea-level rise and salinity stresses	Moderate	Extreme	Extreme	Extreme	Projected sea level rise may expose some coastal landfills to salinity stress and inundation. Old landfills have high sensitivity due to likely poor lining and capping protection. Water ingress may cause Increased leachate to be produced, which may be a contaminant if the integrity of the landfill is compromised. Landfills are permanent features that are expensive and complex to remove, however remedial works may increase protection against erosion and leachate.
Risk to solid waste management and contamination sites due to river and surface flooding	Moderate	Moderate	High	High	Projected increases in extreme rainfall events are likely to increase riverine and surface flooding, increasing the number and frequency of landfills that are exposed. Flooding can cause erosion and cause floodwater to enter the cap. This is of particular concern for old landfills due to the often poor lining and capping protection. Landfills have a low adaptive capacity as they are permanent features that are expensive and complex to remove. Remedial works may increase protection against erosion and leachate.

For the purpose of this assessment, solid waste management infrastructure includes landfills (open and closed), and contaminated sites. A high-level risk screening identified 902 landfills located throughout the Canterbury Region (Figure 11.3) (Tonkin & Taylor, 2020).

The main active landfill within the Region is Kate Valley Regional Landfill. Smaller landfills are located at Redruth, and the Municipal landfill at Kaikōura Resource Recovery Centre. Districts operate numerous waste management facilities, including water transfer centres and resource recovery centres. With the exception of Kaikōura, where a trial on kerbside collection was established to minimise waste (Kaikōura District Council, 2020), districts typically offer urban kerbside collection. The extent of disposal of waste on private farms is unknown but acknowledged to be likely in some districts (Mackenzie District Council, 2018). Councils are still managing the legacy of historic landfills (waste dumps). Since 1991, 52 dumps in Canterbury have been closed, with the Kate Valley Landfill established to manage regional waste (Transwaste Canterbury, 2021).

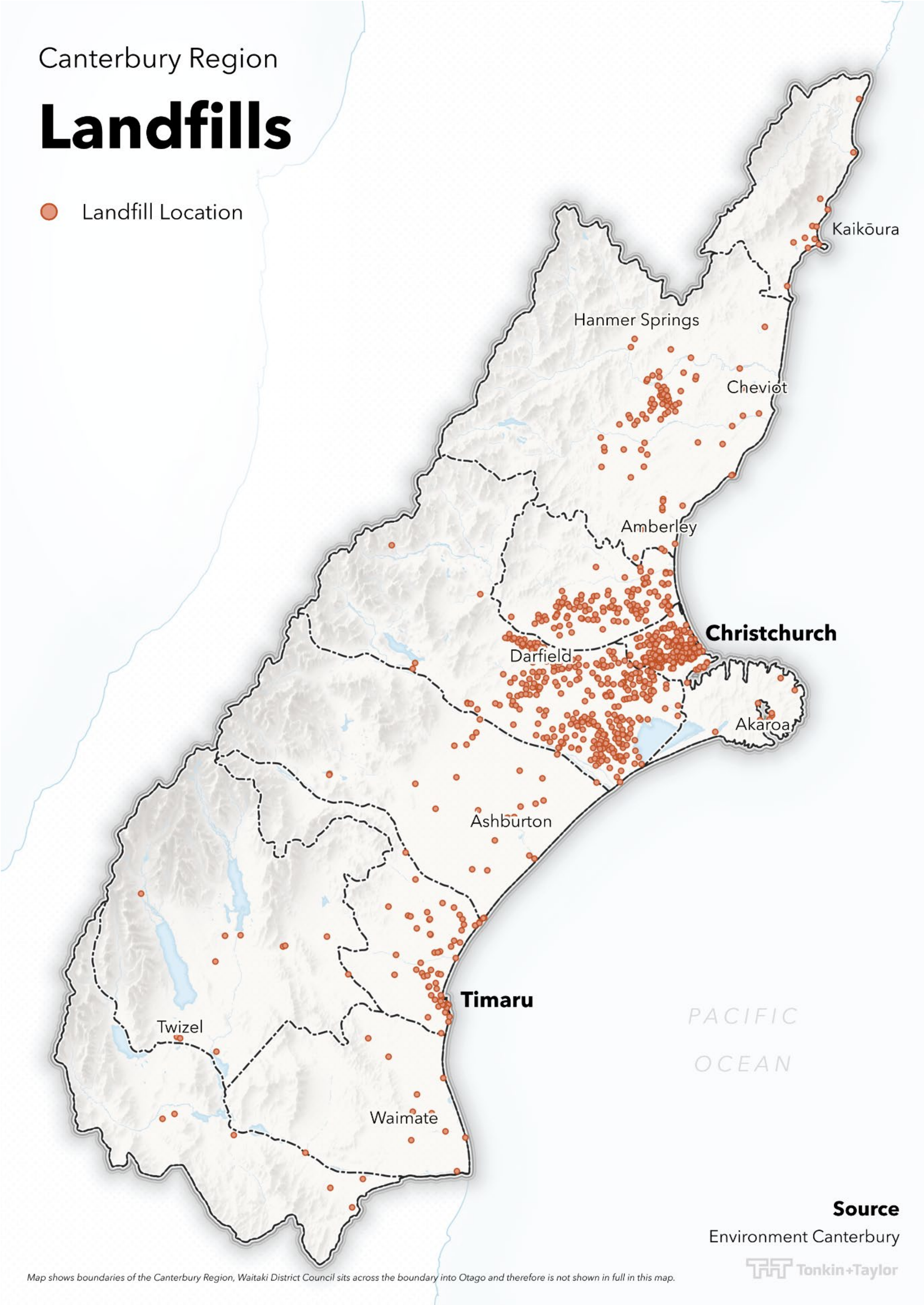


Figure 11.3: Location of landfills in Canterbury.

Of the 902 landfills within the Canterbury Region, 38 are exposed to river flooding. A further 34 are located within 150 m of the coast, meaning they are likely to be exposed to coastal erosion. There are 68 landfills exposed to the 1% AEP + 0.0 m sea level rise event, increasing to 77 with 0.3 m sea level rise, and 91 with 0.9 m sea level rise (Figure 11.4) (Tonkin & Taylor, 2020).[6]

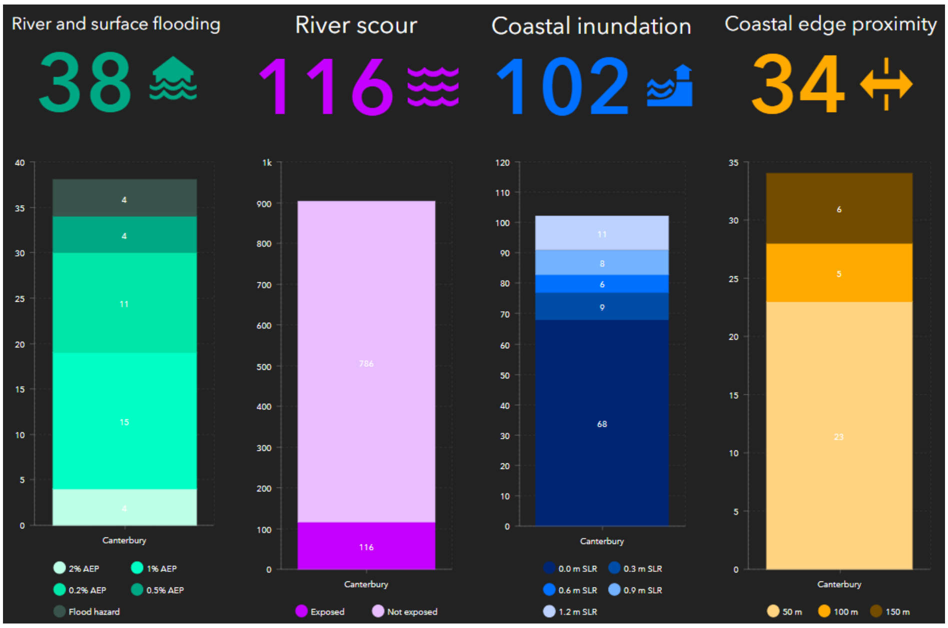


Figure 11.4: Exposure of landfills in Canterbury to flooding, scour and coastal inundation (Tonkin & Taylor, 2020).

Design characteristics can influence a landfill or contaminated site's sensitivity to climate related hazards. Characteristics such as a liner, cap, thickness of the cap, and whether there are any known issues with the landfill site can all influence its sensitivity to climate related hazards. Landfills with no liners have a greater sensitivity to sea level rise and coastal flooding, as water can cause leachate to escape and the mobilisation of contaminants (Beaven, et al., 2020). This is typically more common in older landfills that were not designed to modern standards. Many old landfills were formed from unlined old quarries, shingle pits, or areas that needed to be filled such as gullies or depressions. Many have been abandoned or capped, so are hard to detect. The full extent of landfills in Canterbury is unknown, as these include private dumping, farm waste sites, and historical capped pits, for which there are no records (Environment Canterbury, n.d).

Landfills with known issues have increased sensitivity due to the likelihood of their integrity failing. Open landfills have a greater sensitivity to flooding as materials can be mobilised more easily. They are also more sensitive to increased rainfall as storm water infiltration increases leachate generation, which has consequences for the receiving environment.

Landfills are permanent features, therefore adaptive capacity is relatively limited, as relocation is generally very costly. Closed landfills located away from river and coastal flooding are generally at lower risk from climate change. Those that are exposed to flooding and coastal inundation have increased risk of erosion, as older landfills were often not designed with suitable lining to protect against erosion. Canterbury Region is actively working to identify and manage the risk of climate change to landfills in the Region. District councils are also working to reduce risks to landfills, for example through improved capping or erosion protection (Timaru District Council, 2018).

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[6] A measurement of 0.9 m sea level rise is used here for 2100 timeframe as per the Canterbury Landfills project (Tonkin & Taylor 2020).

12 Hirihiri | Energy

Hirihiri (energy) is a lifeline service supporting the economy and wellbeing of all communities within Canterbury. The Region provides a significant contribution to the national electricity grid through its major power schemes in and around the Waitaki River (Figure 12.1), creating a relatively high proportion of renewable energy for the nation. Current energy usage also relies on sources outside the electricity grid. These are mainly non-renewables, such as petrol, diesel, and other fossil fuels. Typically, 33% of energy consumption in Ōtautahi/Christchurch is sourced from renewable energy (Greater Christchurch Partnership, 2021).

Hirihiri (energy) is interconnected with many other aspects of the natural and physical world of Canterbury. It is fundamentally integrated into the way communities operate. It supports hauora (physical health), through powering healthcare facilities and homes. It supports ōhanga (prosperity) by powering businesses, machines, supply chains and many aspects of our food supply. It supports hapori (sense of community) and ngā waihanga (infrastructure services) by powering much of the infrastructure that our communities rely on to function, including transport and waste management systems, as well as powering systems that deliver water supply, and wastewater systems designed to protect our wai (water).

12.1 Summary of risks

Risks to Hirihiri (Energy) are summarised by energy generation and energy transmission infrastructure.

	Higher mean temperatures			Change in mean annual rainfall			Drought			River and surface flooding			Coastal flooding			Increased coastal erosion			Sea-level rise and salinity stresses			Storms and wind			Increased fire-weather			Increasing landslides and soil erosion			Extreme weather events			Reduced snow & ice			Ocean chemistry changes			Marine heatwaves			Climate change		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Energy generation							L	M	H																																				
Energy transmission										L	M	E	L	M	E																L	M	E												

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

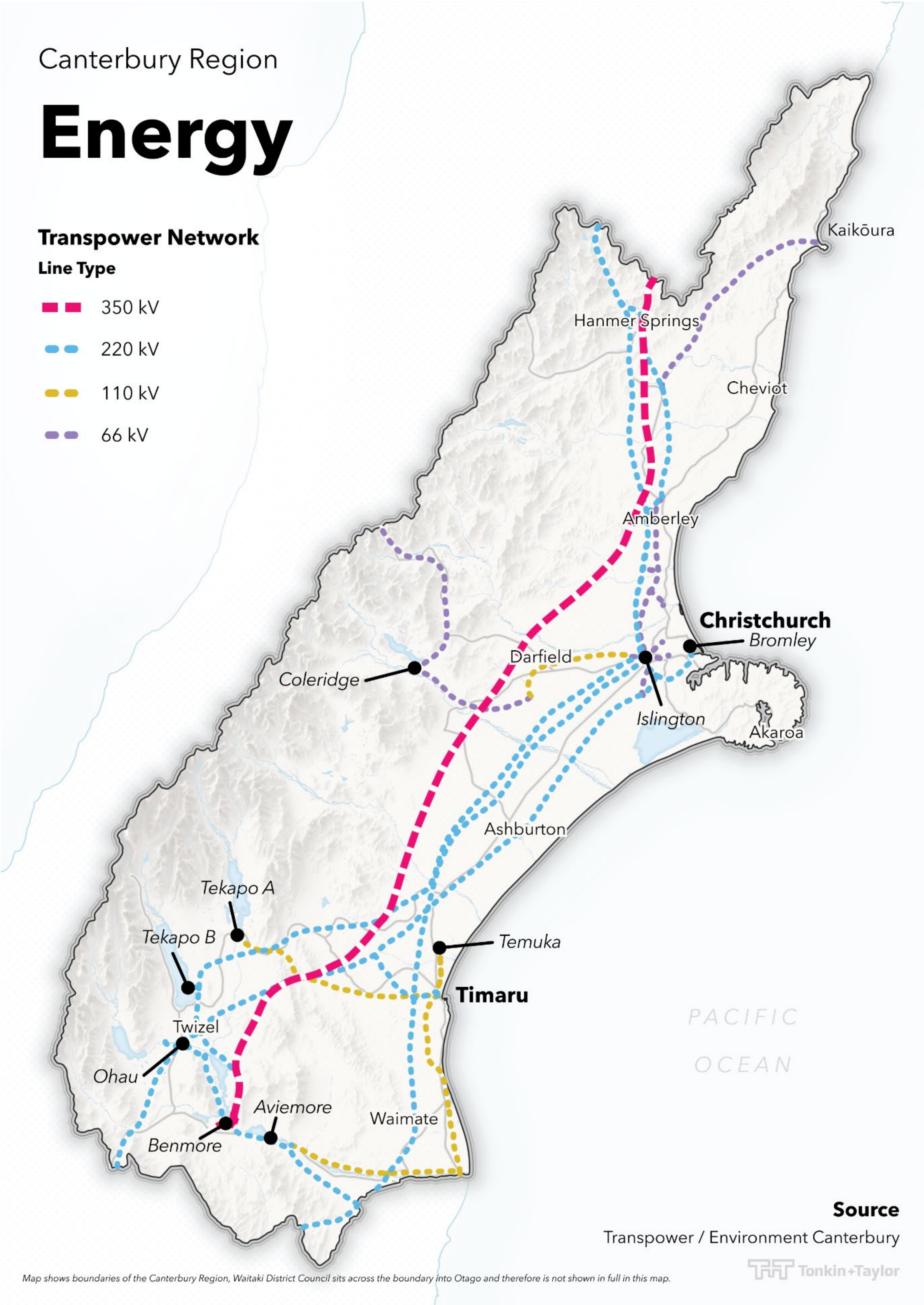


Figure 12.1: Energy and power distribution networks in the Canterbury Region.

12.2 Energy generation and transmission infrastructure

The highest rated risks to energy generation and transmission infrastructure include those from fire, drought, extreme weather events, and river, surface, and coastal flooding.

Energy generation in Canterbury is primarily sourced from hydropower schemes. The risk from drought to hydropower generation is rated to increase to high by late century, as exposure to increasing drought potential rises. Hydro power generation has high sensitivity to reduced water availability, as water is the primary resource from which energy is generated. Existing schemes have low capacity to adapt, but as a sector, there is a moderate adaptive capacity due to the potential for development of diverse renewable energy sources.

The risk to energy generation from other extreme events is rated to increase to extreme by late century. This is due to present low exposure levels increasing to extreme by late century, alongside high sensitivity of lines and structures to damage from winds and flooding, and a medium adaptive capacity limited primarily by cost.

The risk to power transmission from fire is likely to increase, conversely, power transmission can also contribute to fire. These risks were acknowledged in the Stakeholder Engagement (2021), however as they were not identified as priority risks in the 2020 Screening stage, they have not been fully assessed.

Table 12.1: Risks to energy generation and transmission infrastructure

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to energy generation due to drought	Low	Moderate	High	High	The potential for drought is projected to increase over time, which may impact water availability. Hydropower generation is the dominant source of energy generation in region, and is highly dependent on water availability. The adaptive capacity of hydropower generation is low for existing schemes, however there is potential for increased establishment and uptake of diverse energy sources regionally and nationally.
Risk to energy transmission due to river and surface flooding	Low	Moderate	Extreme	Extreme	Extreme weather events are projected to increase, with increasing exposure of transmission lines to wind, rainfall and flooding. Overhead transmission lines are particularly sensitive to damage from wind and flooding. Measures to reduce exposure of transmission lines include burying lines, however this can be prohibitively expensive for existing infrastructure.

Hydropower in Canterbury generates over 1,800 MW, providing over one third of the national hydro generation capacity. This contributes around 55-60% of the national energy supply. Canterbury's generation sites include major power stations at Benmore (540 MW) and the Upper Waitaki Scheme (848 MW), both operated by Meridian Energy. The majority of regional electricity generation occurs in these schemes, which are located on the Waitaki River and its tributaries (Tekapo, Pukaki, and Ohau) (Figure 12.2).

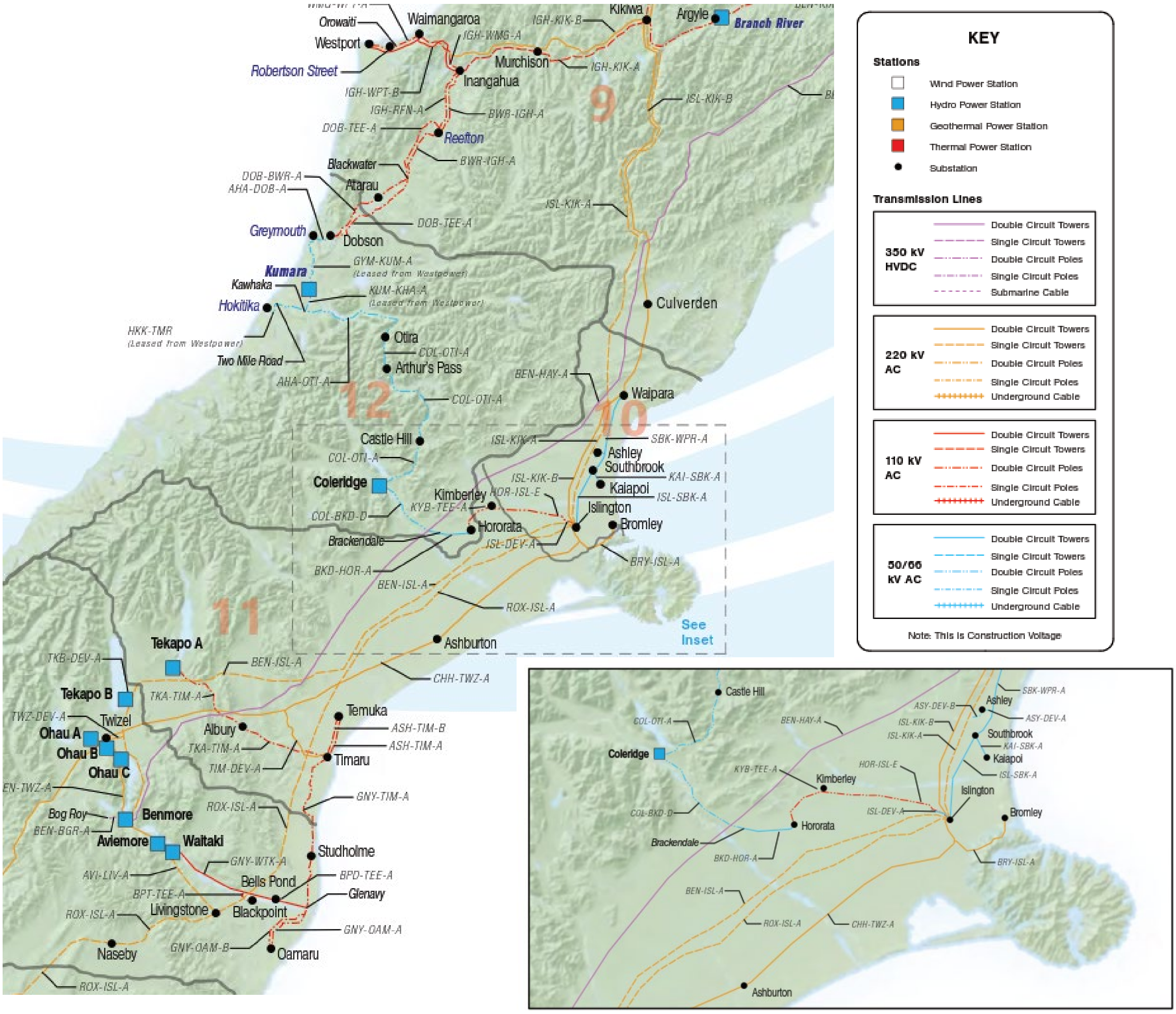


Figure 12.2: Substation and transmission locations (Adapted from Transpower (2020)).

12.2.1 Energy Generation

Within Canterbury, 8.35 billion m³/year of water is consented for hydro-electricity. This makes up 55% of the total water volume consented in the Region (LAWA, 2021). Exposure to drought throughout the Region is projected to increase, as warming temperatures and changing rainfall patterns increase drought potential. While mean discharge of river flows in the Region are generally projected to decrease, increases are projected for many headwaters of the hydro lakes under RCP8.5. Low flows across the Region are projected to decline, however inflows to the Waitaki catchment may be less affected. Hydrology of the inflows to alpine lakes is complex due to changing snow and rainfall patterns. The full effect of climate change on hydropower generation warrants further research (Caruso et al., 2017).

The majority of energy generation within the Region is sourced from the hydropower schemes, particularly those in the Waitaki catchment. Hydropower generation is dependent on water availability, and is therefore highly sensitive to drought and reduced water availability. Increased drought and reduced low flows are likely to impact the reliability of water availability for water generation (Caruso et al., 2017). Increasing mean flows in the Waitaki catchment may benefit power generation in the short term, and storage of this increased water availability may support increased resilience to low flows on an annual cycle. However, the capacity of the lakes to achieve longer term storage and provide some resilience to drought may not be sufficient. Increased inflows may present challenges relating to flooding and management of the lakes (Caruso et al., 2017).

Changing regulatory and consumer demands are likely to occur as New Zealand transitions to a lower carbon economy. The importance of hydropower generation within a national context is likely to increase as a result of these changes. Transition risks are not addressed within this assessment, but it is likely that these changes will increase demand for hydroelectric power generation, in addition to developing alternative energy sources.

Changing climate variables are also likely to alter existing demand patterns. For example, warmer temperatures are likely to increase summer electricity demands for cooling. Increased wet days may drive demand for clothes dryers, however, this may be balanced by a reduction in winter heating needs due to warmer winters. The importance of hydro-electric power generation to the national electricity supply makes it extremely sensitive to reduced reliability of water availability.

The adaptive capacity of power generation is considered moderate. Existing hydro-electric power schemes have limited capacity to improve drought resilience. There is capacity for the sector to develop diverse generation sources, and uptake of distributed private generation such as solar is increasing. Increased adoption of distributed energy generation increases resilience by diversifying energy sources, reducing reliance on major transmission lines. Security of energy supply is managed at a national scale, with potential for diverse generation options throughout the country.

12.2.2 Transmission infrastructure

Transmission through Canterbury is critical to wider national energy supply, as the national ‘grid backbone’ passes through the Region. This supplies all major load centres in New Zealand through the HVAC transmission network, and consists of:

- A ‘grid backbone’ of 220 kV transmission lines stretching nearly the full length of each Island.
- A network of 110 kV lines running roughly parallel to the 220 kV system.

The HVDC Inter-Island link transmission line originates at Benmore Power Station, continues north, and crosses the Cook Straight to connect the North and South Islands. Power typically flows northwards from the South Island to the North Island, but during dry periods with low hydro generation can flow from north to south (Transpower, 2020).

Transpower manage and operate the National Grid within the Region, supplying electricity to three main distribution companies. These are shown in Table 12.2, along with their asset distribution and supply.

Table 12.2: Distribution companies in the Canterbury Region and their asset distribution

Distribution company	Customer supply	Network
Orion	207,500 customers in Ōtautahi/Christchurch and Selwyn	Approximately 11,350 km of lines and cables
MainPower	41,000 customers in Hurunui, Waimakariri, Kaikōura	Approximately 5,100 km of lines and cables
Alpine Energy	33,500 customers in Timaru, Mackenzie and Waimate Districts	Approximately 3,900 km of lines and cables

Sourced from (Orion, 2021; MainPower, 2018; Alpine Energy 2020).

Exposure of transmission lines to severe weather is projected to increase with climate change. By late century, mean spring and winter wind speed is projected to increase by 5-15%, and up to 25% north of Rangiora (Macara et al., 2020).

Winter rainfall is projected to increase across most parts of the Region, with the intensity and frequency of extreme rainfall events projected to increase. This is likely to increase the occurrence of flooding (Carey-Smith et al., 2018). There are currently over 800 km of Transpower transmission lines, with over 1400 structures, and 10 sites located on land that is exposed to inland flooding in the Canterbury Region (Paulik et al., 2019). Of these, Waimate has the highest exposure at 18%, while Kaikōura is not recorded as having any (Figure 12.3) (Paulik et al., 2019).

Exposure of transmission lines to coastal flooding and sea level rise in Canterbury is among the highest within the country. Canterbury has approximately 13 km of transmission lines exposed to present day coastal flooding, rising to 19 km under 0.8 m sea level rise. The Region has 28 sites exposed at present day, rising to 39 sites by late century. Exposure of lines is spread across Ōtautahi/

Ōtautahi/Christchurch City, Waimakariri, Waimate and Waitaki Districts (noting that some of Waitaki exposure is within the Otago Region). Timaru District is also exposed to a lesser extent (Figure 12.4) (Paulik et al., 2019).

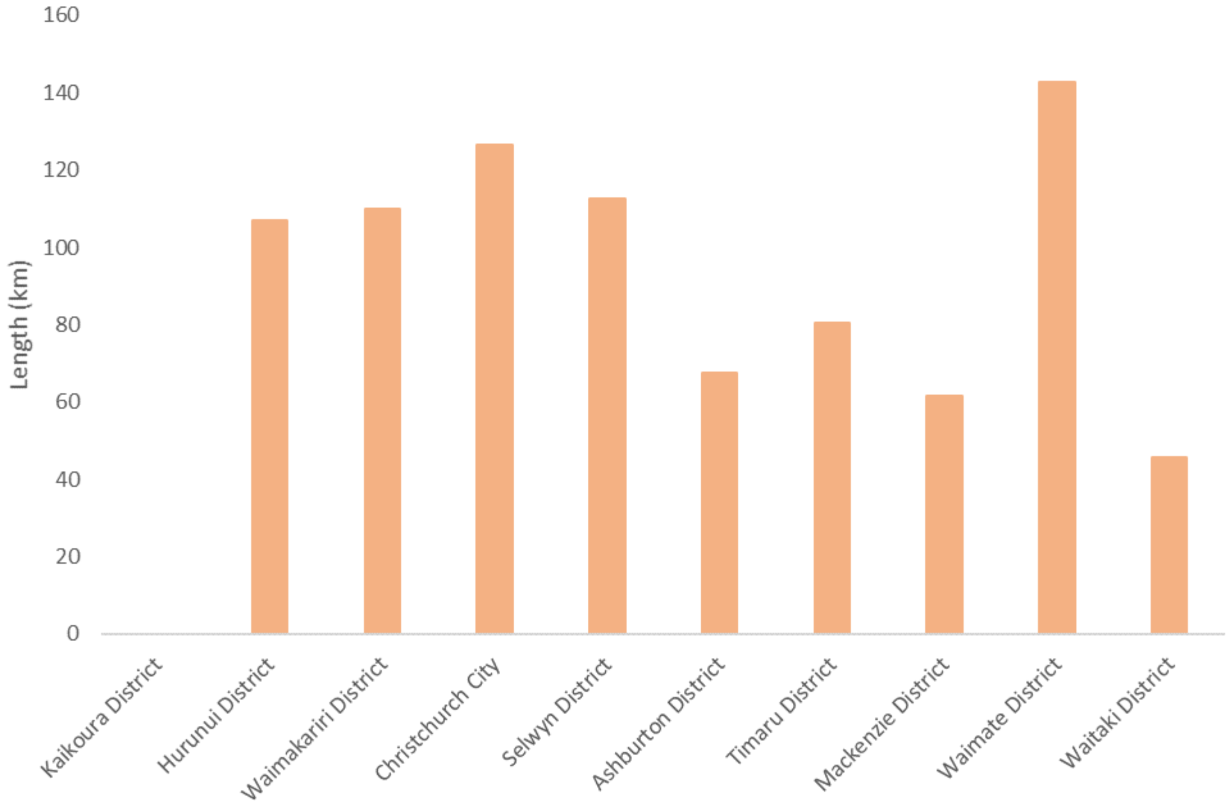


Figure 12.3: Exposure of electricity transmission lines to present day river and surface water flooding by district (Paulik et al., 2019).

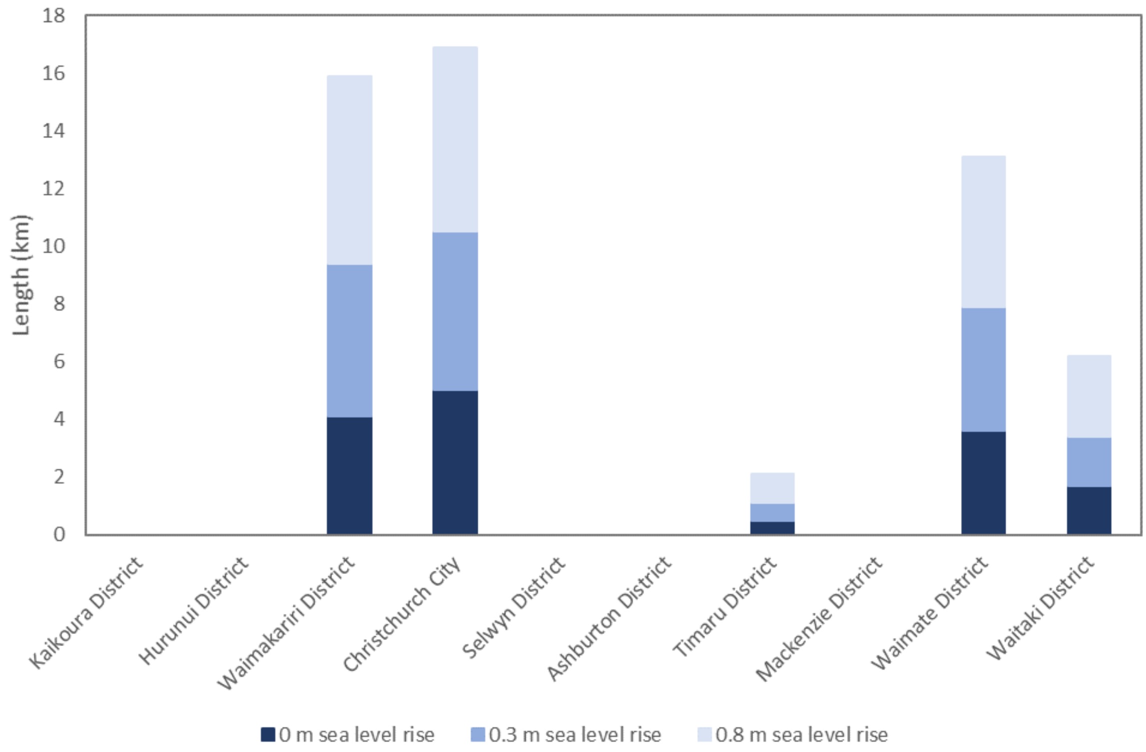


Figure 12.4: Exposure of electricity transmission lines to present day coastal flooding and incremental sea level rise by district (Paulik et al., 2019).

Transmission and distribution infrastructure are highly sensitive to weather extremes, including strong wind, heavy rain, flooding, snow and lightning. Performance reporting from Orion indicates that weather extremes are a common cause of faults by incident (Figure 12.5, Top), and are the highest contributing factor to power outages by minutes of power supply lost (Figure 12.5, bottom) (Orion, 2021). Factors affecting sensitivity to severe weather include:

- Presence of surrounding vegetation: This can contribute to wind damage, as falling trees or branches may damage lines during extreme events. Vegetation also contributes to fire risk.
- Age and condition: Older assets and those in poorer condition are more likely to sustain damage. For example, the reliability performance of the Orion network worsened after the Canterbury earthquake sequence (commenced 2010). Since then, unplanned interruptions have increased, with weather and asset failure the biggest contributors. The large horizontal ground movement and ongoing shaking from the earthquakes put some equipment under stress, causing increased sensitivity to damage.
- Overhead versus underground cables: Overhead cables typically suffer more faults than underground cables because they are exposed to weather, tree, and animal related damage and other interference such as traffic accidents. However, when underground cables do have a fault, repairs can take much longer. Lower customer density in rural areas make installation of underground wires uneconomical, hence outages are often higher in rural areas (Orion, 2021).
- Wind damage beyond design loading: Transpower's transmission towers, poles, and lines are designed to 200 km/hr winds and can typically withstand higher wind speeds. Local distribution networks are typically designed for around 900-1200 Pa or 160 km/hr (Hexamer, 2018). Outages due to wind were uncommonly frequent during the 2014 financial year, due to four wind storms (occurring during July 2013, September 2013 and March 2014).

- Flood damage: Flooding can cause severe damage to assets, including direct flood and debris damage, scour and erosion, and damage to electrical equipment. For example, during the December 2019 Rangitata floods, a Transpower 22kV tower collapsed, two power poles were damaged, one transformer submerged under water and an underground cable was exposed in a washout (Alpine Energy, 2020). These damages hampered emergency management, and were a potential health and safety risk.

Transmission and distribution infrastructure can both contribute to fire risk (acting as a cause of fire), and be severely damaged by wildfire. Areas of high vegetation cover, such as scrub and forestry, in locations with transmission and distribution lines, will generally be of highest risk.

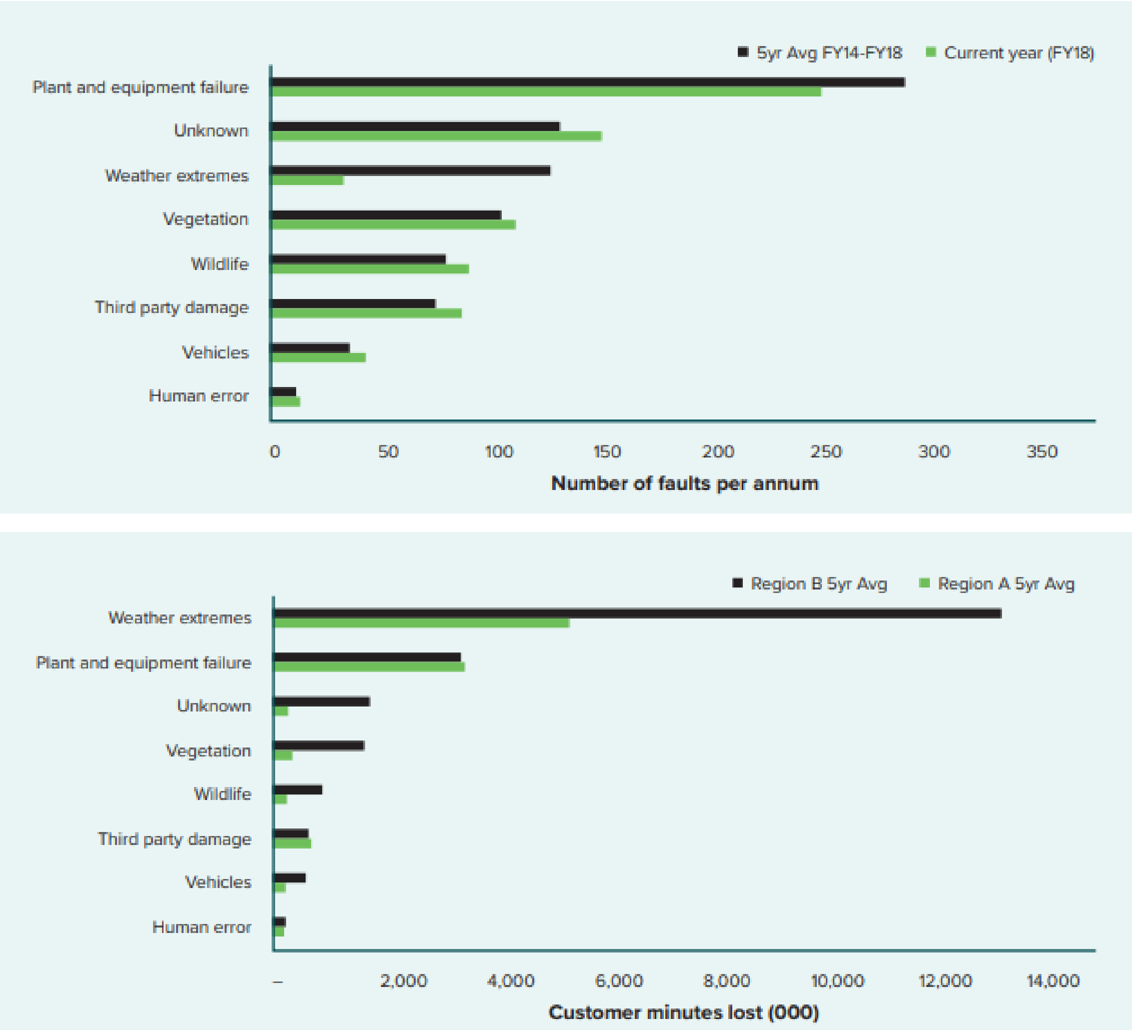


Figure 12.5: Orion number of faults by cause (top). Causes of unplanned interruptions for urban (Region A) and rural (Region B) customers (Financial Year 14 – Financial Year [FY] 18 only) (bottom) (source Orion, 2021).

The adaptive capacity of existing distribution infrastructure is considered medium. Opportunities exist to relocate lines away from areas prone to flooding, or to underground lines that are currently overhead. However, these options are often prohibitively expensive. Increased maintenance is an effective strategy to minimise sensitivity to damage. This has been demonstrated by Orion, with fewer outages reported following their improved maintenance routine. Changing legislation and other increasing drivers to reduce carbon emissions are likely to support the growth of renewable energy demand and innovation. Increased use of distributed energy sources such as solar and wind can increase resilience by adding alternative sources and transmission, providing redundancy within the system.

13 Ōhanga | Prosperity

The ōhanga (prosperity) of Canterbury is important to livelihoods within the communities of the Region. Prosperity allows communities to thrive, and is an important contributor to the quality of living. Canterbury employs 13% of the national workforce, contributing 13% of the national Gross Domestic Product (GDP).

Canterbury has many natural advantages supporting a strong, innovative economy that contributes to building resilient, connected communities. Its economy includes significant industry in agriculture, forestry and fishing, and manufacturing, and a diverse range of trades and services as shown in Figure 13.1 (Infometrics 2020). The extensive fertile soils of the Canterbury Plains support a diverse agricultural activity, while its abundant coastal and offshore waters support a thriving fishery. The stunning natural beauty and resources of Canterbury supports the country's second largest tourism industry. Containing over half the Region's population, Ōtautahi/Christchurch City is a major economic driver for the Region. Its services, university, and industries generate 71% of the Region's GDP (MBIE 2020).

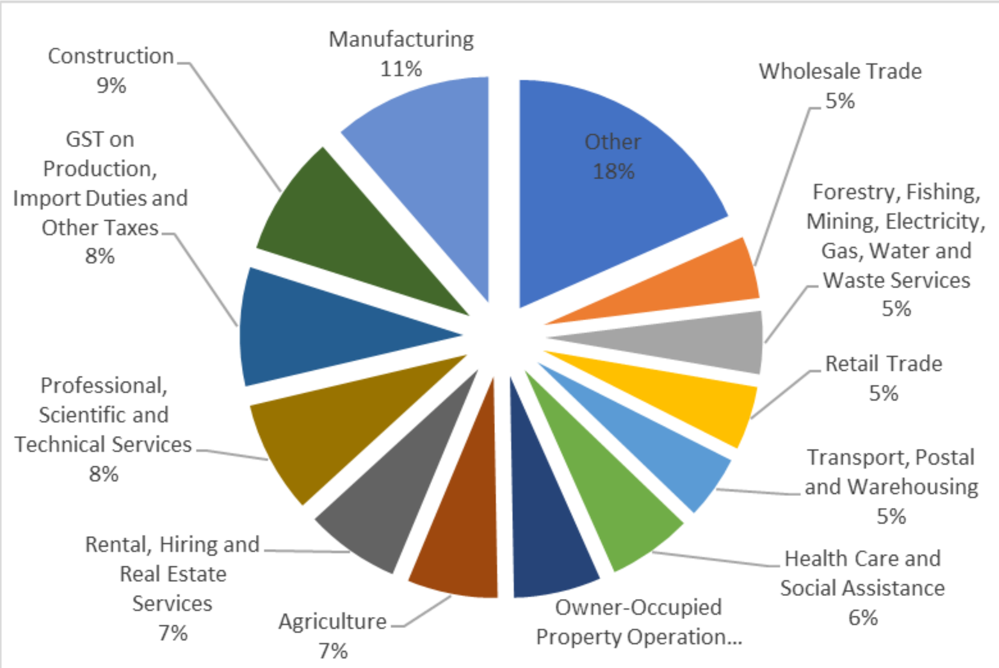


Figure 13.1: Economic profile of Canterbury 2018. Tourism is not represented as a standalone industry in this figure. Tourism accounts for 16% of GDP, and is spread across many industries (Infometrics, 2020, MBIE, 2021).

The prosperity of the Region is influenced by numerous industry and governance groups. Initiatives such as The Canterbury Mayoral Forum and Christchurch NZ provide valuable direction, development and resources to the economy. Industry associations such as Dairy NZ, Horticulture New Zealand, and NZ Winegrowers provide advocacy, and support to help businesses thrive.

Canterbury's prosperity is an integral part of the region's natural and social systems. The wai (water) and rauropi (biodiversity) of the Region contributes to much nature-based tourism, and is the foundation upon which the agriculture, fisheries and forestry industries are built. These primary industries contribute to the wider prosperity of the Region through value-chain flow on to industries such as manufacturing, transport and services. From these industries, income to workers contributes to ora rite (equity), by providing income to workers and communities, and building hapori (sense of community). Supporting the businesses of Canterbury is the built infrastructure including hirihiri (energy), the roads and connections (ngā waihanga – infrastructure services) and buildings (kāinga tūturu – historic heritage).

13.1 Summary of risks

The prosperity of Canterbury is at risk from climate change. The sectors that derive income from land-based activity such as agriculture, forestry, fisheries and tourism will primarily face direct impacts from climate change. Insurance, business and the cost of living will face a range of impacts from climate change. Many of these are indirect, and stem from climate impacts on the people and environment of Canterbury.

The risks presented in Table 13.1. are rated based on the projected climate hazards, known sensitivities, and adaptive capacity of these systems as they presently exist. The effects of a transition to a low carbon economy and climate resilient community are not assessed as part of this assessment. It is acknowledged that investment and innovation is likely to occur as a product of this transition, and that this may lower sensitivity to these risks.

Risks to ōhanga (prosperity) are identified for the agriculture, forestry, fisheries and aquaculture, and tourism sectors. More general risks to insurance, business and the cost of living are also identified. The highest rated risk in each of the identified sectors are listed in Table 13.1. These, and other highly rated risks, are presented in the sections that follow, with discussion of the main issues supporting the rating of the risks.

Table 13.1: Summary of risks to ōhanga from differing hazards

	Higher mean temperatures	Change in mean annual rainfall	Drought	River and surface flooding	Coastal flooding	Increased coastal erosion	Sea-level rise and salinity stresses	Storms and wind	Increased fire-weather	Increasing landslides and soil erosion	Extreme weather events	Reduced snow & ice	Ocean chemistry changes	Marine heatwaves	Climate change
Using RCP8.5	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L
Crops	I L M		H E E					M M H							
Livestock	I L M		H E E												
The cost of business								L M E							
Supply chains										L L M					
Insurance							L H E								
Climate exposed debt															
Residential insurance															
Fisheries and aquaculture								L M M					M E E	L H E	
Exotic forestry	I I L							L M H	M H E						
Tourism sector				L H E								M H E			

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

13.2 Agriculture (crops and livestock)

The highest identified climate change risks to agriculture include risks to livestock farming due to higher temperatures and drought, and risks to crops due to higher temperatures, drought, storms and wind. The exposure of agricultural land to drought and warmer temperatures will increase over time. Livestock farming is extremely sensitive to the reduction in water availability that is likely to be associated with drought. Livestock are sensitive to temperature increases, as these can cause heat stress.

The adaptive capacity of livestock to increased drought is rated as low. However, agriculture is rated as having a higher adaptive capacity to increased temperatures, as farmers have the potential to change stock breed or adjust farm management practices (e.g., shade) to suit a changing climate.

Crops are sensitive to damage from storms, wind, flooding and increased pests, and are extremely dependant on water availability. The potential to change crop cycles and adjust timing or varieties will provide some adaptive capacity.

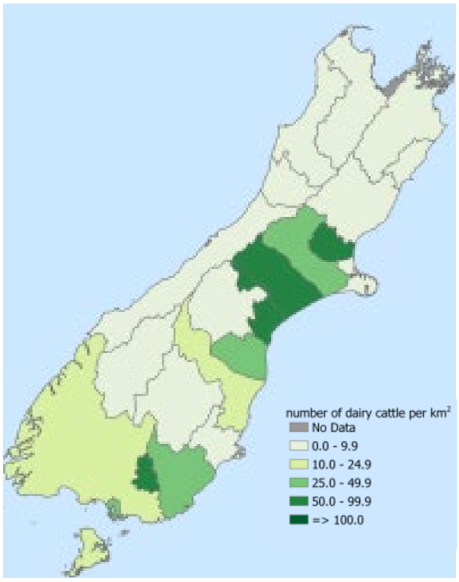
Table 13.2: Summary of risks to agriculture

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to crops due to drought	High	Extreme	Extreme	Extreme	Projected increase in drought potential is likely to impact crops. Crops are extremely dependent on water availability for irrigation.
Risk to crops due to storms and wind	Moderate	Moderate	High	High	Projected increases in storms and wind will increase exposure of crops to flooding, wind and storm damage. Crops are highly sensitive to damage from flooding and storms which can destroy crops. Change of crop cycle, timing or varieties may provide some adaptive capacity, also changing management measures such as wind shelter breaks
Risk to crops due to higher mean temperatures	Insignificant	Low	Moderate	Moderate	Projected increase in temperatures may increase pests and irrigation demand. Change of crop cycle, timing or varieties may provide some adaptive capacity or increased use of pesticides.
Risk to livestock due to drought	High	Extreme	Extreme	Extreme	Projected increase in drought potential is likely to impact livestock farming. Livestock farming is extremely dependent on water availability to sustain optimum grass growth and for stock drinking water. Relocation of stock or feed supplementation may reduce impacts of drought on stock.
Risk to livestock due to higher mean temperatures	Insignificant	Low	Moderate	Moderate	Projected increase in temperature are likely to impact livestock farming. Livestock are moderately sensitive to temperature, which can lead to heat stress and lower milk production. The impacts of temperature on herds may be reduced through breeding for temperature resilience.

Canterbury's expansive fertile soils support an extremely active agricultural sector (Figure 13.3). Agricultural activity (measured by GPD) is highest in Ashburton and Selwyn districts. Relative to the district population and percentage of total GDP, Waimate, Hurunui, and Mackenzie are strong agricultural producers (Figure 13.4, Table 13.3) (MBIE 2020). Canterbury is the largest producer of vegetables in New Zealand, with the country's largest production of peas, carrots and potatoes, and significant production of most other vegetables (Fresh Facts, 2017). Fruit production is also strong in Canterbury, with wine grapes and berryfruit the dominant fruit crops grown (Fresh Facts, 2017). The Region has some of the highest density cattle farming within New Zealand, particularly within the Waimakariri, Selwyn, Ashburton and Timaru Districts (Figure 13.2) (EHINZ, 2017).

Table 13.3: Agricultural GDP in Canterbury, 2018 (MBIE 2020)

Area	GDP($m)	GDP per capita($)	% of district Total GDP
Canterbury	2,392	3,841	7%
Ashburton District	642	18,548	29%
Ōtautahi/Christchurch City	247	642	1%
Hurunui District	236	18,214	36%
Kaikōura District	20	4,994	14%
Mackenzie District	63	12,344	27%
Selwyn District	489	7,722	22%
Timaru District	226	4,757	8%
Waimakariri District	165	2,692	10%
Waimate District	175	21,608	51%



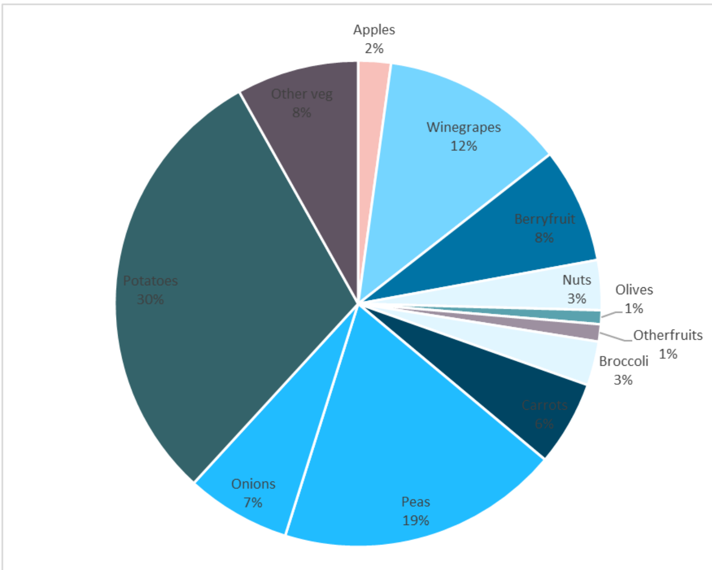


Figure 13.2: Density of dairy cattle by territorial authority in the South Island of New Zealand, 2012 - Left (EHINZ, 2017). Fruit and vegetables grown in Canterbury, % by planted area, 2017 – Right (Fresh Facts, 2017).

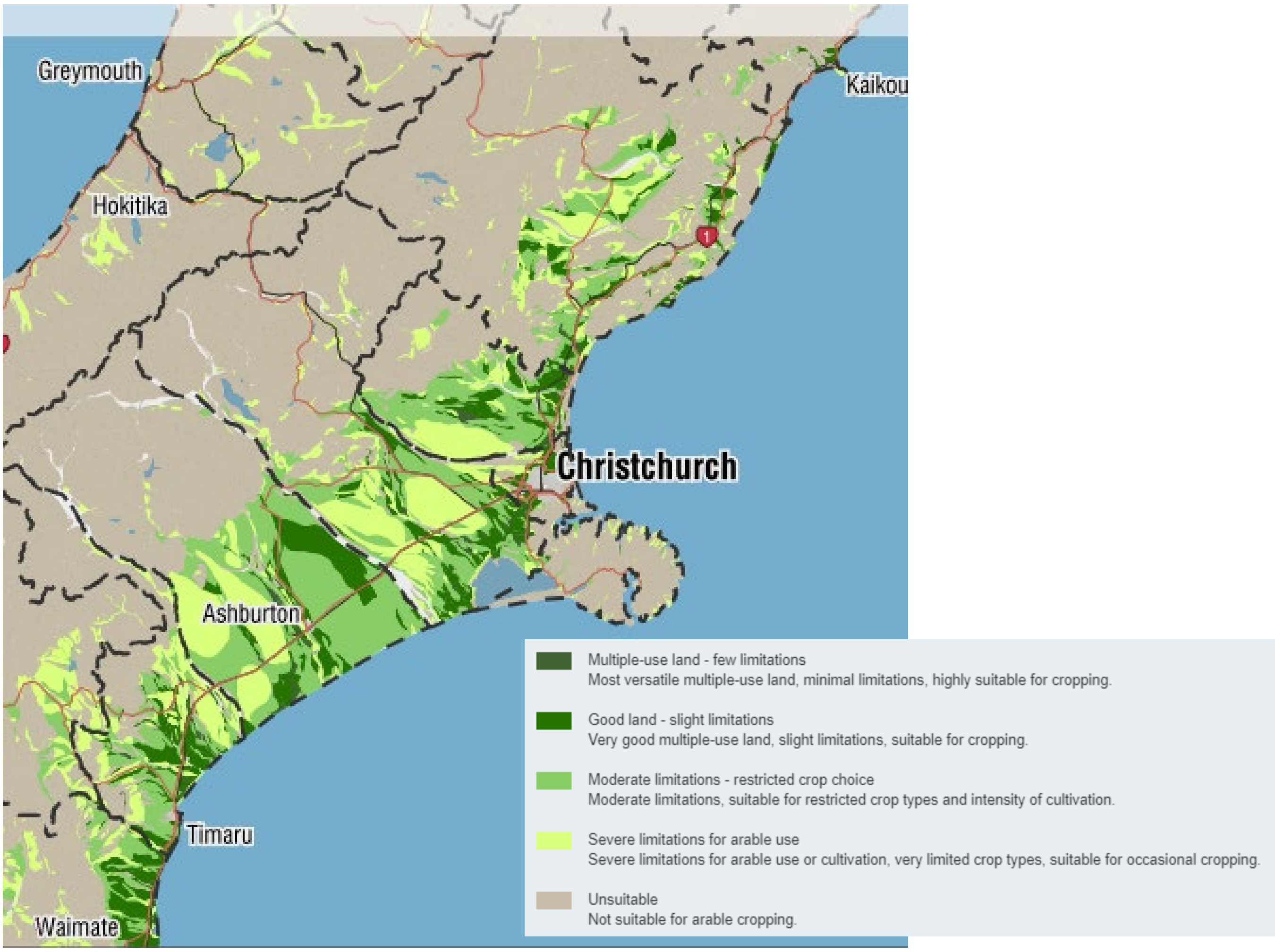


Figure 13.3: Land suitability for arable cropping in the Canterbury Region (Landcare Research 2021).

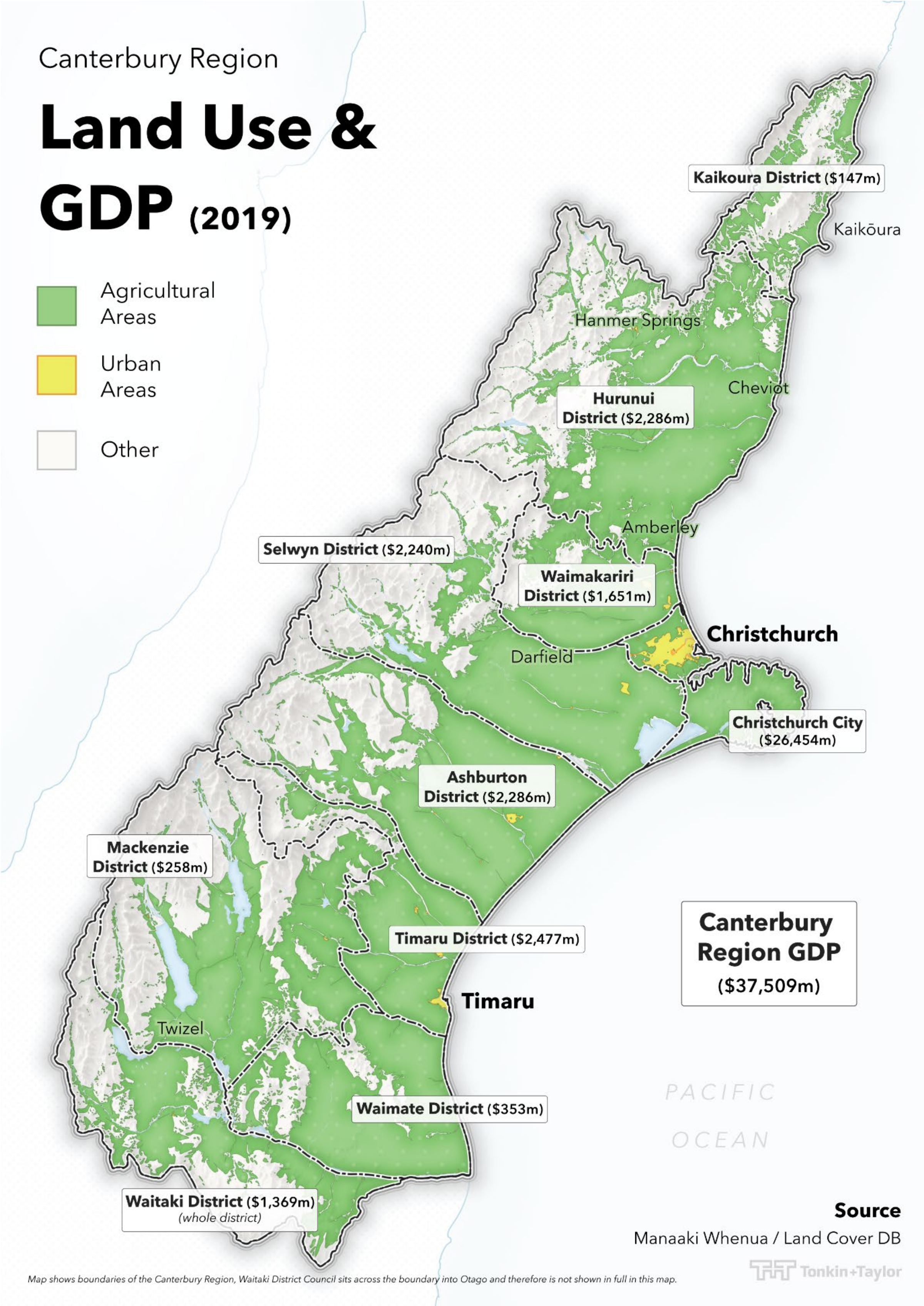


Figure 13.4: Land use in the Canterbury Region showing GPD by District (2019).

The Canterbury Region contains multiple large braided rivers, notably those in the plains such as Waitaki, Opihi, Rangitata, Hakatere (Ashburton) River, Rakaia, Waimakariri, Rakahuri (Ashley), and their tributaries. Those in the northern catchments include Kowai, Waipara, Hurunui, and Waiau Uwha. Land use surrounding these rivers is predominantly agricultural, with large areas of short-rotation crop land, orchards and other perennial crops (Landcare Research, 2020). Livestock and horticultural farming are largely based within the cropland and exotic grasslands within the Canterbury Plains, mainly around river valleys and lower plains, and also along the coastal fringe (Landcare Research, 2020).

The main agricultural areas of Canterbury are projected to be exposed to increasing temperature and reduced frosts. Annual hot days (>25 ^{o}C) are projected to increase by 20-60 days for much of Canterbury, and up to 85 days in some inland areas under RCP8.5. Over the same timescale, reduction in frosts of 10-30 days across much of the Canterbury Plains are projected, with decreases of up to 50 days in inland areas under RCP 8.5. Temperatures at present typically include 10-40 hot days and 10-50 frost days per year in the Canterbury Plains (Macara et al., 2020).

The potential for drought is projected to increase across most of Canterbury as the accumulated Potential Evapotranspiration Deficit (PED) increases by 100-200 mm per year by late century under RCP8.5. As the growing season advances, the amount of water lost from the soil through evapotranspiration typically exceeds rainfall, giving rise to an increase in soil moisture deficit. As soil moisture decreases, pasture production becomes moisture constrained (Macara et al., 2020).

Water availability is likely to become more variable across most of the Canterbury Plains. Winter rainfall is projected up to 40% in coastal southern areas by late century under RCP8.5. Summer rainfall is projected to increase by up to 20% in inland Canterbury Plains, while gradually reducing towards coastal areas, with up to 5-15% deficit in projected summer rainfall surrounding Ōtautahi/Christchurch. Although there is likely to be increasing rainfall in some areas, climate change is projected to reduce water availability across most rivers in Canterbury, through reductions in mean annual discharge and low flow in many areas (Macara 2020). Further impacts on groundwater will also contribute to the decreased reliability of water supply for irrigation, as discussed further in Section 8 Wai | Water.

Flooding is expected in Canterbury, with projected increases in mean annual flood flows as winter rainfall is projected to increase considerably in many eastern, western and southern parts of the Region. Existing flood exposure of productive land is extremely high, with close to one quarter of all productive land in Ōtautahi/Christchurch and Waimakariri exposed to flooding, and higher areas (over 500 km^2) exposed in Selwyn and Ashburton Districts (Figure 13.5) (Paulik et al., 2019). Increases in floodplain depth and extent are likely to result from the increasing intensity of extreme rainfall events across the Region (Macara, 2020; Trevor Carey-Smith, 2018). Farms on the coastal fringe are also likely to be exposed to increasing coastal flooding, with many already at current risk of coastal erosion (Figure 13.6). Flood and related damages pose significant risk to buildings, access roads, assets and livestock, which would result in significant financial losses to farmers.

Flooding and other sudden extreme events pose a risk of disruption to supply chains through disruption to transport routes (refer to Section 11.2). The dairy industry is particularly vulnerable to disruption in the supply chain, as dairy cows typically require regular twice daily milking, and stored milk must be transported within 1-2 days for processing (Welth & Marshall, 2017).

Pasture and vegetable crops are sensitive to changes in temperature, rainfall, and sunshine hours. Livestock wellbeing and productivity is dependant primarily on sufficient water availability, pasture, and locally grown feed crops (Morris, 2013). Increased temperatures and rainfall will have both positive and negative impacts on agriculture. Warmer winters are likely to benefit survival rates of lambs, and improve growth rates of pasture (MPI, 2014). However, the changing temperatures and increasing drought potential may influence optimum pasture varieties suitable to the Region.

Changing rainfall, temperature, and drought are likely to drive increasing growth rate variability of pasture, which may contribute to increased feed deficit as well as higher surpluses (MPI, 2014).

Livestock are highly sensitive to temperature and suffer from heat stress. Increased temperatures may pose a risk to animal health, particularly in parts of Canterbury where stock are already at risk due to regular exposure to high summer temperatures, (Ausseil et al., 2020). Livestock are known to respond to heat stress by reducing their feed intake, with consequences for animal condition and milk production (Verkerk et al., 2007). Increasing temperatures may shift the timing of fruit setting, or drive a change in harvest and planting dates (Clark et al., 2012). A range of other potential impacts from increased temperature and drought identified at a high level may apply to Canterbury, including changes to wool quality and higher potential for spoilage during supply chain logistics (Frame et, al. 2018).

Pests and diseases are likely to increase with temperature, drought, and reduced frosts. The incidence of existing diseases in Canterbury, for example the grapevine downy mildew, is expected to increase with increasing temperature and rainfall (Beresford & McKay, 2012). Temperature increases may also aggravate stock related illness such as mycotoxins, and prevalence of flies (Verkerk et al., 2007). Disruption to complex natural systems, for example, the mast response, are likely to further contribute to pest populations. The range of many exotic pests, weeds and diseases will likely gain an advantage under projected climate changes (McGlone & Walker, 2011). Existing control measures may be less effective, as climate change may impact upon the ecology of existing biological control agents used in New Zealand to supress pests and weeds. The decreased occurrence of frosts may further raise the potential for pests (McGlone & Walker, 2011; MPI, 2019)

Warmer temperatures and drought are likely to result in increased water demand. This includes increased irrigation to compensate for soil moisture loss through evapotranspiration, and increased stock water for thirsty stock under increased temperature. Irrigation is widespread in Canterbury, and many farmers will be affected by further pressure on water storage, water regulation, water storage access and irrigation availability (Stakeholder 2021). Reduced availability will contribute to the significant existing regulation challenges that farmers face in Canterbury (Kalaugher, 2015).

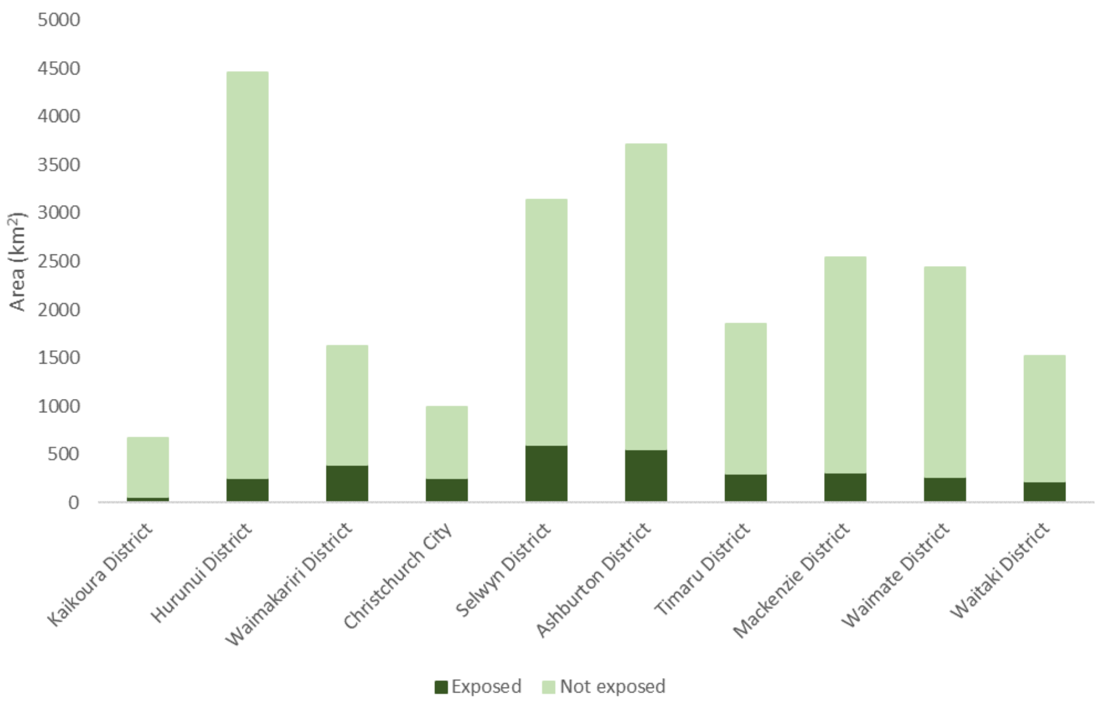


Figure 13.5: Exposure of productive land to river flooding relative to total productive land area by district (Paulik et al., 2019).

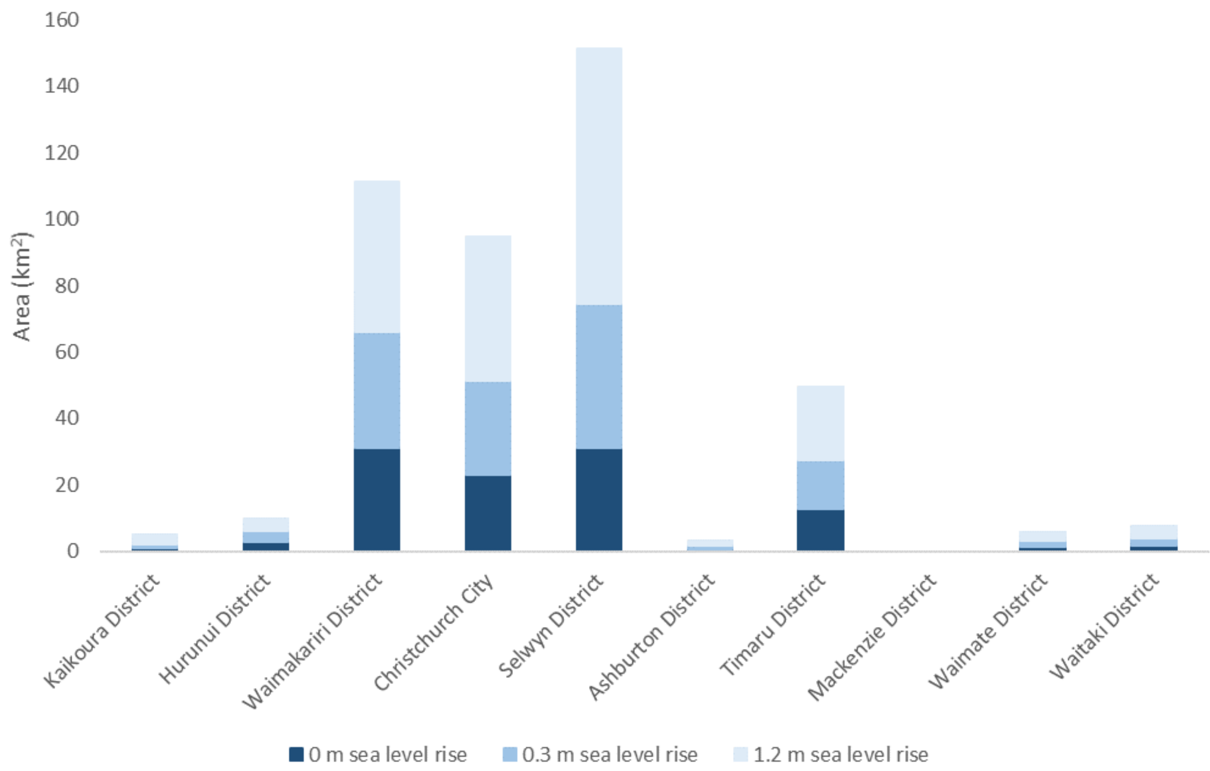


Figure 13.6: Exposure of productive land to coastal flooding under incremental sea level rise (Paulik et al., 2019).

The extensive coverage of suitable agriculture soil types in Canterbury supports the adaptive capacity of agriculture (Figure 13.3). The Region's fertile soils can support a diverse range of crops, and may support varieties that cope well with wetter winters and warmer climate, with fewer frost days and lower humidity. A large body of research is underway to investigate suitable adaptation strategies for agriculture in Canterbury and the rest of the country (Clark et al., 2012).

Gradual changes in the climate may occur in a way that allows farmers to adapt, for example by planting weather tolerant native species for shelter, fire resilience, and waterway protection, or retiring marginal land that is vulnerable to flooding or erosion (MPI, 2019). The history of agriculture is based on adaptation, where farming practices have evolved to adapt to new territories and climates for centuries. Droughts and other climatic challenges pose a constant threat to farmers, and the knowledge gained from previous methods of adaptation may be a valuable key to future adaptation in the face of unprecedented change (AgResearch, 2008).

13.3 Forestry

The highest identified climate change risks to forestry include those due to storms and wind, higher temperatures, and fire. The exposure of forestry to temperature and fire weather is presently rated as low, but this is projected to increase with time. Sensitivity is high, as forests are highly sensitive to damage and have increased maintenance requirements related to fire and storms. Temperatures can also change productivity and cause increased pests and disease.

Table 13.4: Summary of risks to agriculture

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to exotic forestry due to increased fire-weather	Moderate	High	Extreme	Extreme	Pockets of exotic forestry spread across the region will be exposed to increasing fire weather, due to projected increases in temperatures, dry periods and wind. Forestry is highly sensitive to wildfire damage which can case substantial economic losses. Measures to reduce fire risk include pruning, weed control, undergrowth maintenance, fire breaks and off-season burning.
Risk to exotic forestry due to storms and wind	Low	Moderate	High	High	Storms and wind are projected to become more severe, which will increase the exposure of forestry, where young forests are particularly sensitive to damage. Storm damage can cause windthrow, erosion and damage to related infrastructure, with costly repairs and health and safety risks associated with clearing damaged branches. Frequent exposure to high winds can result in sturdier trees of lower grade timber.
Risk to exotic forestry due to higher mean temperatures	Insignificant	Insignificant	Low	Low	Forests will be exposed to projected increases in temperature, particularly in inland areas where temperatures are highest. Temperatures can change productivity (which may increase in many areas) and cause increased growth of weeds and higher rates of pests and disease.

Pockets of exotic forestry are located throughout the Canterbury Region, particularly in the plains and lower foothills of the Ka Tiritiri o te Moana (Southern Alps) and Banks Peninsula (Landcare Research, 2020). These are in similar areas to the agriculture sector, typically on harder, steeper country. As such, they are exposed to similar climate changes, including increased storms and wind and temperatures. Exotic forestry has a moderate adaptive capacity to changing temperature, due to the physiological response of plantation species to a changing climate. Exotic forestry has a limited capacity for changes in plantation species or location, at 25+ year cycles.

Increased temperature can limit growth rates and reduce wood density. The ideal average annual growth temperature for *Pinus radiata* has been estimated at 12°C, with an upper limit of 18°C (Frame et, al., 2018; Whitehead et al., 1992). Present day temperatures within the plains and lowlands are well within this range, sitting around 10-12°C. Late century mean temperatures within these areas are projected to increase by up to 3°C. This may increase productivity, or push some plantations towards the higher limit of optimal growing temperature. Increased temperature is also expected to increase the prevalence of exotic weeds, including wilding pines, which thrive in hot, dry climates (Wyatt, 2018). Increased temperature can also influence mast responses in native forests, which can in turn stimulate growth in the surrounding ecological community, and spur on exotic pests, weeds and disease (McGlone & Walker, 2011).

Increased temperature, reduced drought, reduced summer rainfall, and increased wind all contribute to increased fire risk. This is highest in inland Canterbury where temperature increases are projected to be greatest. Wildfire can lead to significant economic losses in forestry, which can arise from insurance liability and increased fire management requirements. Measures to reduce fire risk and prevent spread include weed control, undergrowth maintenance, inclusion of fire breaks, pruning and controlled off-season burning (NZ Forest Owners Association, 2018).

High winds and floods will increase windthrow and other physical damage related to wind. This has consequences for the quality and volume of harvested timber. Operations to salvage damaged logs can be dangerous, time consuming, and costly. Exposure to frequent high winds often results in sturdier trees with properties such as larger knots, which make them a lower grade timber (Moore, 2014).

Young forests have the highest sensitivity to storm damage. Damage to younger crops may mean that the wood is only useable as pulp, or may not be economically viable at all and must be written off. Young forests and newly harvested slopes are also at increased risk of erosion, which may lead to loss of land, or land instability.

Plantation forestry typically has a crop cycle of 25+ years. Historically, plantation species have been selected to favour the most desirable production qualities. It can therefore be argued that this provides continued adaptation to any changes in climate with each new generation of tree that is planted. Within a crop cycle the adaptive capacity of plantations is limited, however, over longer timespans it may be possible to change the location of new plantations, or adopt climate tolerant species. Such species may have different and more beneficial qualities than *Pinus radiata*, though they may be potentially less productive. Ongoing research initiatives, such as the use of genetic modification, may provide further adaptive capacity for issues such as biosecurity, prevention of wilding pine spread, genetic resistance to pests and pathogens, and improved yield (NZIER, 2017).

13.4 Fisheries and aquaculture

The highest identified climate change risks to fisheries and aquaculture include those from marine heatwaves, ocean chemistry changes, and storms and wind. The exposure of fisheries to marine heatwaves and ocean chemistry changes is rated to increase to extreme towards late century. Water quality impacts in nearshore environments are rated as low, increasing to moderate beyond mid-century. Studies of shellfish and other aquatic ecosystems indicate that fisheries are extremely sensitive to changes in these indicators, and may suffer increased mortality and impacts on condition. Fisheries have potentially high adaptive capacity due to the relatively cool temperatures off the Canterbury coastline, which may be a favourable destination for species from warmer climates.

Table 13.5: Summary of risks to fisheries

Risk statement	Risk: Present	Risk: 2050 *(RCP8.5)*	Risk: 2100 *(RCP4.5)*	Risk: 2100 *(RCP8.5)*	High level description
Risk to fisheries and aquaculture due to ocean chemistry changes	Moderate	Extreme	Extreme	Extreme	Changes in ocean chemistry changes are likely to occur with projected temperature increases. Studies of shellfish and aquatic ecosystems indicate that fisheries are extremely sensitive to heat waves and ocean chemistry changes. Mortality is likely to increase and condition reduce, with potentially high consequences for fisheries.
Risk to fisheries and aquaculture due to marine heatwaves	Low	High	High	Extreme	Sea temperatures and marine heatwaves are projected to increase with climate change, with potential loss in marine species and biodiversity. Fisheries may adapt as the relatively cool temperatures off the Canterbury coastline, may act as a favourable destination for affected species from warmer climates.
Risk to fisheries and aquaculture due to storms and wind	Low	Moderate	Moderate	Moderate	Projected increases in storms and wind may cause increased sediment runoff in nearshore environments. Reduced water quality in inshore environments may impact the health of some major fish species and shellfish, and may smother habitats. Continued efforts to improve stormwater runoff water quality will support improved nearshore water quality.

Fisheries and aquaculture include farmed fish and shellfish such as salmon, mussels, and oysters, as well as wild fish. Canterbury forms part of the Southeast Fishing Region, alongside Otago. The Southeast Region contains New Zealand's second and third largest fishing ports (Lyttleton and Timaru), which service regional inshore trawling and deep-sea trawlers (Fisheries New Zealand, 2020). The Canterbury Region is a dominant player in the seafood processing industry, contributing an average 30% ($388 million) per year to the national revenue from seafood processing across the five years to 2015, and an overall GDP of $132 million (Berl, 2017).

The aquatic coastal environment and ecosystems are at a high risk of temperature increase and chemistry changes towards the late century, as discussed in Section 9.7. Sea temperatures are increasing throughout New Zealand, however measured sea surface temperatures show a relatively lower increase off the coast of Canterbury (Figure 13.7), (Sutton et al., 2019).

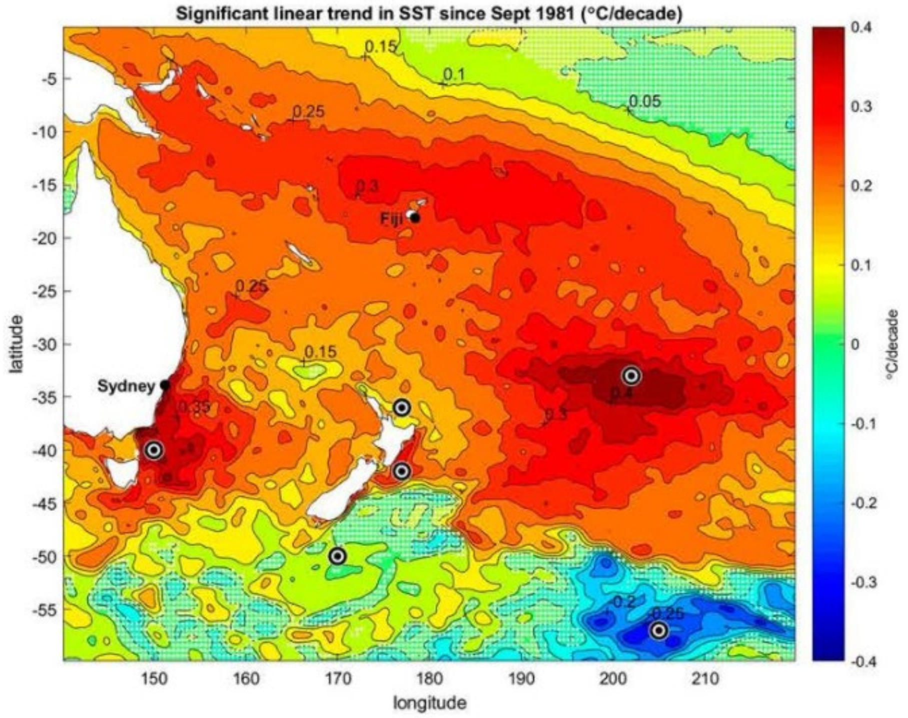


Figure 13.7: Sea surface temperature trend in °C per decade since 1981 (Sutton et al., 2019).

Aquatic species are generally very sensitive to temperature changes. Ocean acidification and warming cause widespread harm to aquatic ecosystems. This is expected to occur throughout New Zealand's coastal waters. The cumulative effects of ocean climate change and other anthropogenic stressors on aquatic ecosystems, likely to be seen in the next 20-30 years, are predicted to be high (MPI, 2017). Ocean acidification is particularly detrimental to calcifying organisms, such as molluscs and echinoderms, which are predicted to decline within Canterbury's marine communities (Hepburn et al., 2011; Tait et al., 2014). The change in ocean chemistry and temperature will also impact the survival and condition of most other marine species, with impacts on the food web and wider ecosystems.

Water quality of nearshore coastal environments can be impacted by storms and wind, due to the harmful impacts of stormwater runoff. Increased frequency and intensity of rainfall events is projected to occur throughout Canterbury. The magnitude of increase in stormwater runoff will vary according to the hydrology of catchments, as well as land use and stormwater management practices. Increasing runoff is likely to cause increased erosion, which often contains contaminants from urban stormwater runoff, and nutrients from agriculture runoff (Hughes et al., 2019). This can smother habitats and rapidly kill most benthic macrofauna, while thin deposits lead to a reduction in species diversity and abundance. The physiological condition and survival rate of marine species is expected to decline as suspended sediment concentrations increases (Kelly, 2010). This is likely to impact fisheries and aquaculture that operate in nearshore environments, impacting species such as snapper, blue cod, tarakihi, lobster and paua, which account for over half of national fisheries GDP. However, increased suspended sediment concentration is unlikely to impact deep sea fisheries, such as Southern bluefin tuna, hoki, ling, arrow squid, Southern blue whiting and orange roughy.

The decline in species along with wider ecosystem changes pose an extreme risk to the fisheries and aquaculture industry, with flow on effects to the seafood processing industry. There may be potential adaptive capacity within the ecosystem to cope with changes associated with temperature and chemistry. Marine species will vary in sensitivity to ocean acidification. Species that currently reside in warmer temperature regions may migrate south to the relatively cooler climates off the

Canterbury Coast (MfE, 2019). Higher CO_2 levels may also provide some adaptive capacity to existing ecosystems, for example, some species, such as seagrasses, may benefit from this. Finally, monitoring and chemical intervention may be a viable management strategy for aquafarming during times of high acidification. This is currently being trialled in the U.S. Pacific Northwest (Capson & Guinotte, 2014).

13.5 Tourism

The highest identified climate change risks to tourism include those from river and surface water flooding, and reduced snow and ice. The exposure of this sector to flooding and reduced snow and ice is currently rated as low, which is expected to rise to extreme by late century. Alpine sports tourism is highly sensitive to warming temperatures, due to the resultant reduced snow base for ski field operation, and safety issues relating to avalanche risks. Tourism may be impacted by more general changes to the natural environment, as well as reduced consumer confidence resulting from increased frequency of climate related issues such as flooding related cancellations.

Table 13.6: Summary of risks to tourism

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to tourism sector due to reduced snow & ice	Moderate	High	High	Extreme	Projected reductions in snow and ice are likely to impact the tourism sector, particularly winter sports such as skiing, and related attractions. Alpine sports tourism is highly sensitive to warming temperatures which can reduce snow base and the length of the ski season. Tourism may also be impacted by more general changes to the natural environment. Alpine sports tourism has low adaptative capacity to reduced snow and ice, however measures exist to compensate for reduced snow such as snow machines.
Risk to tourism sector due to river and surface flooding	Low	High	Extreme	Extreme	Projected increases in extreme rainfall are likely to result in increased flooding. Low lying and riverine attractions are likely to be exposed to flooding, which may also disrupt access routes and change the natural character of the region. The tourism sector is sensitive to flood damage to coastal and riverine attractions and amenities, which can be costly to repair and disrupt services. Related cancellations can reduce consumer confidence, particularly if frequent or recurring. The tourism sector may adapt to climate change as the market is likely to continue to seek tourism destinations. There is potential for increased tourism in Canterbury relative to other destinations that may suffer more severe damage.

Canterbury based tourism spending was over $3 billion in 2020. This contributes to roughly 10% of national tourism spend, and is the second highest regional contribution behind Auckland (MBIE, 2021). The Region supports a diverse range of tourist activities, including (Figure 13.8):

- Hanmer Springs Thermal Pools and Spa.

- Christchurch Adventure Park.
- Tekapo Springs and Hot Pools.
- Natural features and adventure tourism – Aoraki Mackenzie International Dark Sky Reserve, Tasman Glacier and Aoraki Mt Cook Village, Akaroa, Arthurs Pass, Alps 2 Ocean Cycle Trail Kaikōura.
- TranzAlpine Rail Journey.
- Waipara Valley Wineries.
- Ski fields: Mt Hutt, Roundhill – Lake Tekapo, Ohau, Mt Dobson, Porters, Fox Peak, Briken River Ski Field, Cragieburn, Temple Basin, Mount Cheeseman, Hanmer Springs, Awakino, as well as wilderness skiing and heliskiing.

As the transport and economic centre for the Region, Ōtautahi/Christchurch acts as a major hub for tourists travelling to the Region. Annual spending on tourism (Figure 13.9) shows that Ōtautahi/Christchurch has the highest tourism spending within the Region, accounting for almost two thirds of regional tourism spend (MBIE, 2021). These figures are likely to be artificially depressed, as tourism spending has been significantly impacted by the outbreak of COVID-19 and associated lock-down and travel restrictions. This impact is demonstrated in the historical spending pattern from tourist activity in Ōtautahi/Christchurch (Figure 13.10), which shows a sharp drop in early 2020, and lower average spend for the remainder of the year (MBIE, 2021).

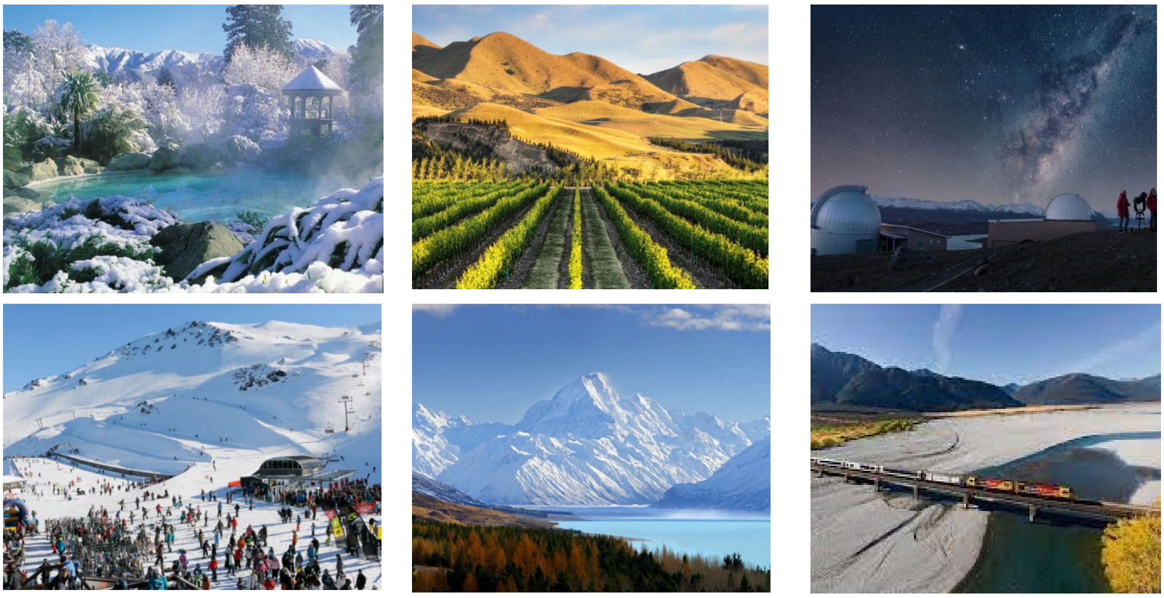


Figure 13.8: Tourist attractions of Canterbury, clockwise from top left: Hanmer Springs Thermal Pools and Spa; Waipara Valley Wineries; Aoraki Mackenzie International Dark Sky Reserve; TranzAlpine Rail Journey; Aoraki Mt Cook; Mt Hutt Ski Field.

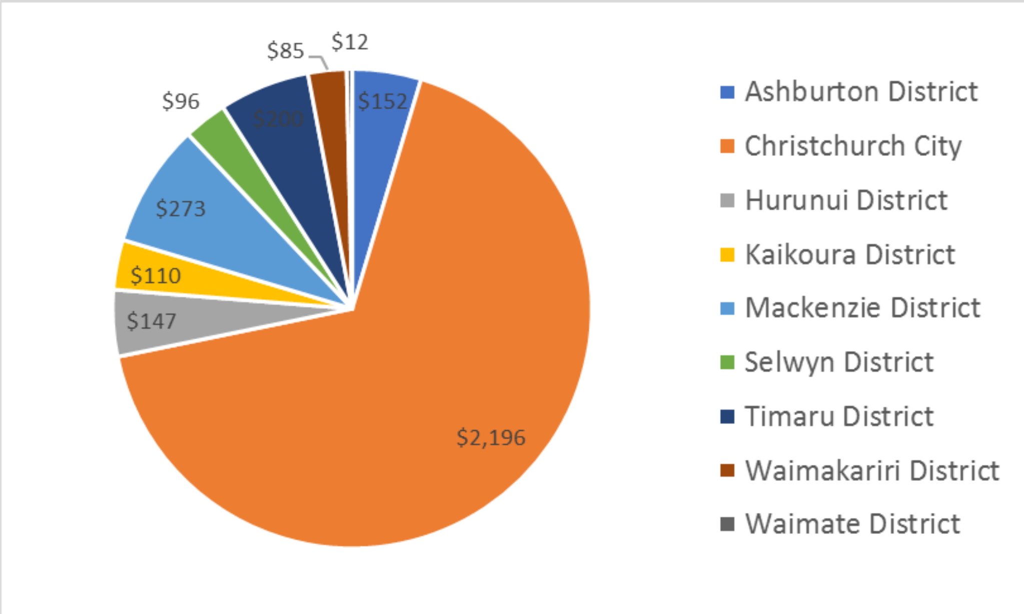


Figure 13.9: Annual tourist spend ($m) by district in the year to October 2020 (right) (MBIE, 2021).

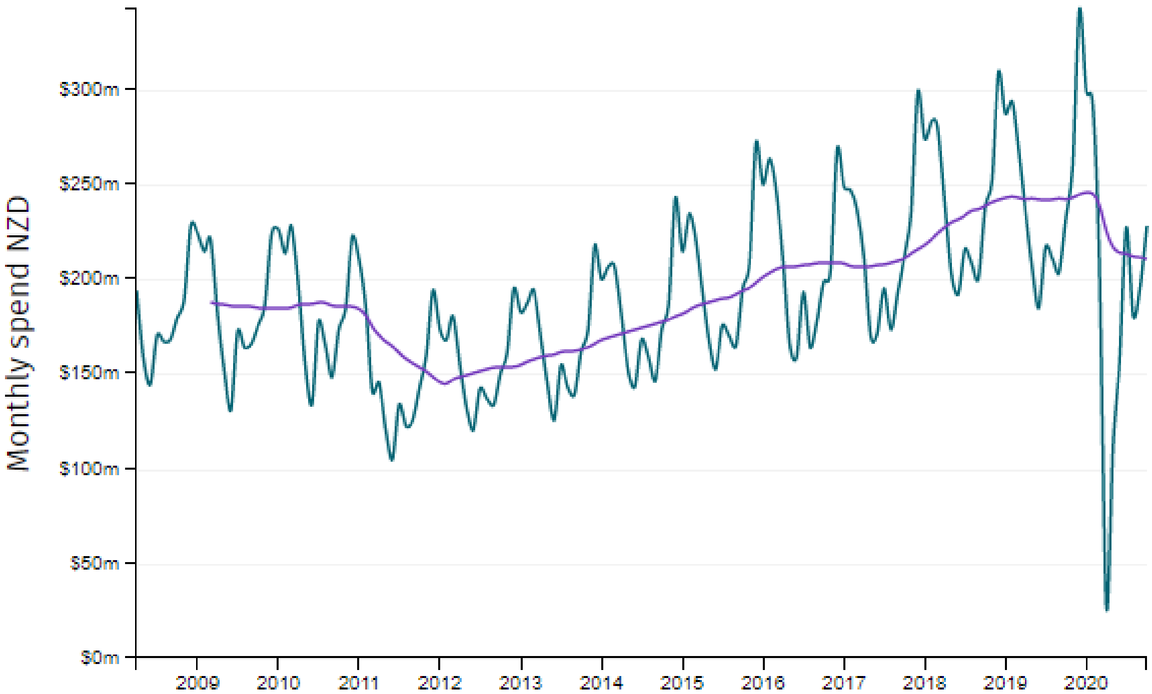


Figure 13.10: Monthly regional tourism spending (turquoise) and annual average tourism spending (dark blue) (MBIE, 2021).

Temperature increases are expected to be associated with rising snow lines and glacial retreat, more frequent hot extremes, and increasing extreme weather events. The number of snow days is projected to reduce an all parts of the Region, with the largest reduction in high alpine areas, where there are a relatively large number of snow days in the baseline climate (Macara 2020).

Nature based winter tourism, including skiing, glacial exploration and other mountain adventuring, is likely to experience adverse effects from warming temperatures. Reduced snow will impact on the duration of the operating season, the extent of operational ski fields, and raise the risk of avalanches and crevasses. In New Zealand, glaciers have retreated significantly over the last 50 years, as climate warming has led to rapid melting and retreat of glacier landscapes. Some glacial landscapes will decline in aesthetics, and may face the prospect of sustained decline and disappearance. Rapid glacial retreat will bring a loss of tourism revenues (Wang & Zhou, 2019). Globally, scientists predict that mountain glaciers could almost disappear by 2100 (PCE, 2019).

Changing avalanche and glacier properties, as well an increasing likelihood of fire, flooding, and extreme events may expose other supporting infrastructure and tourism activity to damage. This may result in increased maintenance costs, increased difficulty of access, and increased skill level requirements for tourists. For example, six huts removed from Aoraki (Mt Cook) National Park due to the impact of retreating glaciers. Hooker Hut alone has been relocated four times since its construction in 1910. It was moved from the crumbling moraine wall three times, having been inaccessible since 1994 after a flood washed out a track. It was then hit by an avalanche in 2005 before finally being removed from the valley in 2015 (Wilderness 2018).

Ski fields may adapt to reduced snow by increasing the use of snow machines. These carry their own economic impacts relating to increased running costs, and a high water demand. There is also a risk that, in an attempt to adapt to changes triggered by climate change (such as glacial retreat), the sector could 'maladapt' to climate change. A maladapted response is one in which the impacts of climate change lead to increased investment in emissions-intensive activities. These in turn not only exacerbate climate change, but also entrench an unsustainable path dependency (PCE, 2019).

Tourism destinations along coastal areas such as Akaroa, Banks Peninsula, and Kaikōura will be exposed to increased sea level rise, and associated coastal flooding and erosion. Lowland and riverine attractions will also be exposed to increased flooding. This increased exposure to flooding and erosion is likely to cause damage to infrastructure (e.g. roads), buildings (e.g. accommodation and other businesses), and recreational sites and activities (e.g. tracks and beaches). As the frequency of extreme weather events increases, causing cancellations of events and temporary closures, confidence in tourism may be affected.

Tourism is likely to be indirectly affected by the impacts of climate change on the wider Region. These include changes in natural landscapes due to changing temperatures, resulting in the loss of native wildlife, increased exotic species, increased pest species, changing water quality, and reduced snow cover. Changing ocean chemistry may impact ocean-based tourism, like whale watching. Biosecurity risks may also increase, such as with the introduction of didymo (*Didymosphenia geminata*) into the South Island. These changes may decrease the appeal of an attraction, particularly if the sight people came to see is no available. At some locations, tourism may increase in the short term, as people exhibit a 'last chance to see' mentality (PCE, 2019).

Canterbury tourism may also see a benefit from climate change. If climate impacts in New Zealand are relatively modest compared to many other countries, New Zealand may become a more attractive destination (PCE, 2019).

13.6 Insurance, business and the cost of living

The highest identified climate change risks to insurance, business, and the cost of living include those from sea level rise, flooding, and extreme weather events. As the climate changes, damages to businesses and services resulting from climate change impacts will cause an increase in cost. Businesses and communities are extremely sensitive to increased costs and will face a range of interrelated risks, including increased insurance premiums or insurance withdrawal, and the potential loss or reduction of support services. The adaptive capacity of businesses is moderate, as changing investment opportunities arise from a transition to a low carbon economy.

Table 13.7: Summary of risks to business and the cost of living

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to the cost of business due to storms and wind	Low	Moderate	Extreme	Extreme	Damages from increased severe weather and sudden events such as fire may lead to various types of costs for individuals, businesses, government (link to governance), and the whole economy. Costs are likely to include those associated with loss or stranding of property and assets (including land), cost of repairing, rebuilding or replacing assets, and the cost of preventative measures. Investment opportunities may arise from the transition to a low carbon economy.
Risk to increase inequalities and cost of living due to climate change	Low	High	Extreme	Extreme	Risks to inequality and living costs are likely to arise from a range of climate hazards, and continue to increase as widespread effects of climate change are felt. Communities with current inequity are likely to be impacted first and most severely in the long term, and have a low capacity to adapt to change.

13.6.1 Business and the cost of living

Business activity is diverse across the Region. Manufacturing, professional services, and construction are dominant in Ōtautahi/Christchurch City, while agriculture, forestry, fishing, and mining are dominant outside of cities (MBIE 2021). Economic activity is most densely concentrated in Ōtautahi/Christchurch City, which generates 71% of the Region's GDP (MBIE 2020).

Financial costs of climate change are expected to increase significantly, and manifest in complex ways across both private and public sectors (Frame et al., 2018). Damages from increased severe weather and sudden events such as fire may lead to various types of costs for individuals, businesses, government (refer to Section *19*), and the whole economy. These costs are likely to include those associated with loss or stranding of property and assets (including land), cost of repairing, rebuilding or replacing assets, and the cost of preventative measures. Other indirect costs relate to foregone production, lower efficiency of production, increased medical costs, and higher insurance premiums (Hughes et al., 2019). Repairs from major damages often result in significant disruption to communities and businesses, albeit often over shorter timespans. Repairs to minor damages, or increased maintenance, may be delayed as major works are prioritised, leading to longer periods of impaired service, or loss of service from other types of infrastructure (Hughes et al., 2019). Ongoing disruption from maintenance or lack of progress on repairs may lead to a loss of consumer confidence in service providers. Over the long term, ongoing disruption to business districts creates an unstable environment for investors, thus asset values in these areas are likely to fall (Hallegatte, Bangalore et al, 2016).

General equilibrium effects can occur when a local extreme event is significant enough to change some important relative prices in the economy. For example, flood damage to crops might lead to (temporary) produce shortages, causing an increase in food prices throughout the whole economy –

not just in the directly affected area. This could lead to equity implications for households that spend a relatively high proportion of their income on food (Hallegatte, Bangalore et al, 2016).

Sudden onset hazards can impact business supply chains, making business continuity difficult and potentially resulting in loss of stock or increased costs. Adopting a 'just-in-time' production and delivery model means that businesses have limited back up stock, and are therefore affected by the smallest delays (Dillingham, 2019). This is particularly important in the supply chain of perishable items, where small delays can equate to loss of stock and have flow on consequences for food security (Yang et al., 2017). Parallels can be drawn with the impacts of COVID-19 on supermarket supplies, where increased demand meant supply chains could not keep up. This resulted in significant low stock across the country for certain items such as flour, pasta and rice (Oshri & Kotlarsky, 2020). Supply chain issues were identified as one of the factors which reduced household spending, impacting the broader Canterbury economy during COVID-19 (Deloitte, 2020).

Slow onset climate change hazards such as sea level rise and increasing temperatures will drive gradual increases in costs of living and doing business. Changes in property availability are likely to increase rent. The costs of utilities and taxes may likewise increase, as suppliers cope with increased maintenance and repair costs. Worker availability may decline, as increased temperatures make some working environments challenging. Alternatively, workers may demand increased wages for operating under harsher conditions. Increased costs may impact the profitability or viability of some businesses, and ultimately, business closures could impact whole communities (Lawrence et al., 2018).

Businesses may decide to invest in resilience or adaptation measures to reduce the impacts of climate hazards. This might be in the form of increased physical protection, such as increased drainage, raised building platforms, or physical barriers. It may also be in the form of changed business practices, such as adopting online services or changing to locally sourced products to reduce supply chain disruption.

Some businesses may have the opportunity to take advantage of a changing business environment due to climate change. This might include adoption of activities suited to warmer climates in agriculture (Kean et al., 2015), or business ventures related to collaborative innovation, adaptation, sustainable practices, and the transition to a low-carbon economy. Businesses that consider and embed climate risks within decisions, incorporating agility, innovation, and adaptation as part of business plans and systems are likely to cope better than those that do not (RBNZ, 2018).

13.6.2 Insurance

Insurance is commonplace in New Zealand. Residential home and business insurance is a requirement for bank lending, and New Zealand has high rates of car insurance, contents, and other types of private insurance. New Zealand is also serviced by government insurance schemes such as the Earthquake Commission (EQC) for natural disasters and the Accident Compensation Corporation (ACC) for accidental injury (New Zealand Now, 2021).

Asset owners, including homeowners, residents, and business owners, are likely to face increasing insurance premiums and excesses due to increased and/or ongoing damage (Surminski and Hankinson, 2018). Homes exposed to coastal flooding in Ōtautahi/Christchurch which currently have a 1% probability of coastal inundation are expected to face a partial insurance retreat from 2030 (Storey et al., 2020). Similar problems with insurability are likely to occur in response to an increased likelihood of extreme events, inland flooding, and fire. Increased insurance premiums or reduction in insurance availability may result in a loss of property value, which has wider economic implications (RBNZ, 2018) and ultimately may affect the viability of some businesses. These risks may impact consumers, increase the cost of living, or result in increased inequities in the economy.

14 Hauora | Wellbeing

Hauora (wellbeing) is fundamental to human life. As described by the Whare Tapa Whā model of health, Māori wellbeing encompasses taha wairua (spiritual health), taha tinana (physical health), taha hinengaro (mental/emotional health) and taha whānau (family health). This holistic model recognises the interrelated nature of wellbeing and identifies that impacts on physical health can extend to spiritual, mental and family health. Physical health is also connected to other aspects of wellbeing, including cultural identity, community, and equity, as well as being strongly linked to the condition of the natural and physical world.

Climate change will result in a range of physical and mental health impacts, some of which are already being experienced in Canterbury. As summarised in Table 14.3, these include trauma and physical injury from large events, impacts from changes to food production and nutrition, increased heat stress, increased stress and anxiety, increases in chronic diseases in older people, changes to disease transmission (for example, increases in animal to human transmission, i.e. mosquito transfer), changes to food and water borne diseases through contamination and temperature changes allowing parasites and diseases to establish and flourish, and increases in allergies through natural environment changes. Additionally, additional pressures on housing supply due to an increase in climate refugees, and impacts on housing resulting from higher humidity and moisture, will have subsequent health impacts for people (Bennett et al 2014).

14.1 Background

The health and wellbeing of Canterbury's population is influenced by its population demographics. The Region has undergone a period of unprecedented population change following the Canterbury Earthquake Sequence (commenced 2010), as Ōtautahi/Christchurch residents have moved from the city to adjacent greater Ōtautahi/Christchurch areas in Selwyn and Waimakariri (CDHB, 2021). Despite this, Canterbury's population is significantly higher in Ōtautahi/Christchurch than any other district, as shown in Figure 14.1 (Statistics New Zealand, 2021). In the 2018 census, 82.4% of Cantabrians identified as NZ European, 11% as Asian, 9.4% as Māori, and 3.2% as Pacific Island (Statistics New Zealand, 2021). Overall, the Māori population of the Region sits lower than the national average of 16.5%, however Kaikōura District has a Māori population of 18% (Statistics New Zealand, 2021). Of Canterbury residents over the age of 15, 18.9% have no formal qualification, while 22.5% hold a Bachelor's degree or higher qualification. 32% of households do not own their own home (Statistics New Zealand, 2021).

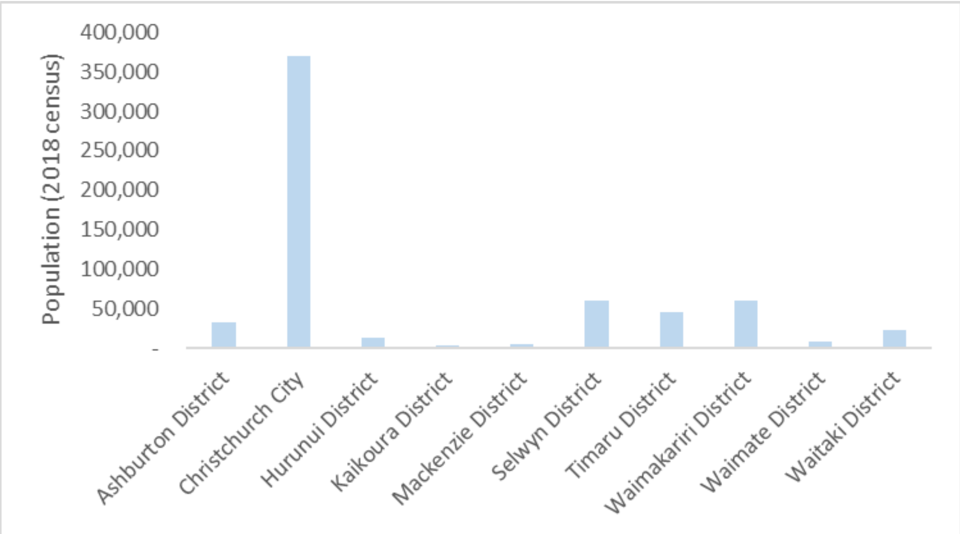


Figure 14.1: Population of Canterbury, by District (Statistics New Zealand, 2021).

In 2015/16, 16% (or 1,772 people) of New Zealand's Skilled Migrant Category principal applicants (permanent migrants) found employment in the Canterbury Region. This is an increase of 21% on the previous year. The Philippines, India, and the United Kingdom were the top source countries of skilled migrants for the Region. The most common occupations of these migrants in Canterbury were Carpenters and Joiners (15%), Painting Trades Workers (6%) and Registered Nurses (4%). Historically (pre-COVID-19), Canterbury was home to the second largest number of international students in the country. In 2015/16, this figure sat at 7,512 (MBIE 2017).

Resilience is often higher in physically and socially active people. Through a study of community resilience following the Canterbury Earthquake Sequence (commenced 2010), it was identified that participation in programmes such as Girl Guides, the Duke of Edinburgh Award, or similar outdoor leadership development programmes, or those involved with voluntary organisations such as St John or the Volunteer Fire Brigade, are generally more resourceful and resilient (MCDEM, 2012).

Māori are disproportionately exposed to adverse social and economic conditions, with consequently higher morbidity and mortality. Nationwide studies suggest that life expectancy for Māori is already seven years lower than for non-Māori, and that Māori have significantly higher rates of most major diseases. These factors are likely to increase vulnerability to the health effects of climate change for Māori in Canterbury (Jones, et al., 2014).

Table 14.1: Summary of risks to hauora (wellbeing) from differing hazards

	Higher mean temperatures			Change in mean annual rainfall			Drought			River and surface flooding			Coastal flooding			Increased coastal erosion			Sea-level rise and salinity stresses			Storms and wind			Increased fire-weather			Increasing landslides and soil erosion			Extreme weather events			Reduced snow & ice			Ocean chemistry changes			Marine heatwaves			Climate change		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Mental wellbeing																																											L	H	E
Physical health																																											L	M	H

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

14.2 Risks to wellbeing

Risks to physical and mental health due to climate change will vary depending on where people live and what they are exposed to, as well as their ability to cope with these events. Age, education, income and livelihood type, housing type and quality, social networks, and cultural relationships all contribute to resilience and vulnerability. It is likely that the impacts of climate change will be felt most strongly by those already marginalised in society.

Table 14.2: Risks to hauora (wellbeing)

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to mental wellbeing due to climate change	Low	High	Extreme	Extreme	Risks to mental health may arise from a range of climate change related issues, and exposure may be widespread across all sections of the community. Some groups within the community already experiencing negative mental health impacts related to climate change stresses. Further mental health issues are likely to stem from a wide range of factors and compound with other physical and cultural health impacts.
Risk to physical health due to climate change	Low	Moderate	High	High	Risks to physical health from climate change are likely to be widespread across all communities. Physical health impacts are likely to be driven by direct exposure to climate hazards such as flooding and fire, which is likely to increase as slow moving climatic changes such as high temperatures begin to impact health. Health impacts may also arise through a range of indirect causes, such as damp housing caused by high groundwater or increased flooding. Medical intervention and public health measures can support communities to adapt, however this may be limited by the capacity for health services to respond effectively.

14.2.1 Risk to physical health due to climate change

Exposure of Canterbury's population to any particular climate hazard will vary throughout the Region. While most hazards will only impact some of the community at any one time, most of the Region will be exposed to hazards from climate change in some form. Those who reside at the coastal fringe will be the most likely to be exposed to sea level rise and storm surges, and those in low-lying or flood prone areas will be most likely to be exposed to harm from flooding. The largest temperature increases are projected to occur inland, and these areas may also be exposed to increased fire risk and drought.

Climate change impacts on physical health can be through direct exposure to hazards (Table 14.2), as extreme, sudden events such as flooding, fires, storm surge and high intensity rainfall pose immediate risks. For example, injury and loss of life can result from being swept away when walking through floodwater or landslides, or being burnt in a fire (Royal Society, 2017). For example, during the June 2021 Canterbury floods, a man was tragically killed when a tree fell on his truck during the storm (NZ Herald, 2021). Direct health impacts can also be categorised into two categories. Acute health impacts are those related to sudden or extreme events, such as include storms, flooding, fire and drought. Chronic health impacts are those related to gradual climatic change, where hazards such as temperature and sea level rise will emerge slowly over decades.

Climate change also impacts physical health indirectly, through consequences and changes that may occur as a result of exposure to climate hazards. These include issues such as water availability and quality, diseases, supply chain disruption, air quality deterioration, and lifestyle and behavioural changes (Table 14.3).

With both temperature extremes and the number of hot-days expected to increase, there will likely be an increase in heat-related illnesses and mortality (Royal Society, 2017). Increasing temperatures pose an increased risk of heat stress, as well as increased occurrences of gastrointestinal infections, infectious diseases, respiratory problems and cardiac problems. Populations that are more vulnerable to these increasing risks are older adults, those with chronic disease, young children, and those who are on low incomes or predominantly work outdoors (Environmental Health Indicators Programme, 2019).

Air quality may be expected to generally improve in areas that experience increases in wind speeds, due to air mixing rates and the more rapid dispersal of pollutants. However, increasing temperature and water vapour (linked to increasing rainfall) are associated with worsening air quality. Changes in climate may also lead to an increasing amount of pollen, and may extend the duration of pollen season, having an impact of allergic disorders such as rhinitis, conjunctivitis, asthma, and hay fever (AAAAI, 2020).

Living and working in damp indoor environments associated with increased rainfall, flooding, and rising groundwater levels may result in an increase in respiratory diseases such as asthma, hypersensitivity pneumonitis, rhinosinusitis, bronchitis and respiratory infections (WHO, 2013; Zang, 2010; The National Institute for Occupational Safety and Health, 2012). Māori, Pacific Island, and low-income groups are identified as being at a greater risk of adverse health impacts from climate change through poor housing quality and overcrowding, as discussed in Section 15.1 below. Low-income groups are also more likely to experience housing supply issues, as climate refugees enter New Zealand (Bennett, et al., 2014).

Loss of recreational opportunities and facilities may occur due to a range of hazards. These include changes to access of coastal areas through erosion and destruction of access such as steps or ramps, loss of tracks to coastal areas due to erosion or flooding, and loss of erosion protection infrastructure such as seawalls. Reduction in snow and ice, as well as increases in landslides, flooding, and fires, may damage inland parks, alpine areas, and ski fields. This will impact recreational amenities, resulting in a reduction in the type of exercise available to people. Lower levels of engagement in physical exercise leads to adverse health outcomes such as weight gain, increases in diseases including heart disease, and/or reduced mobility. Risk to life from pursuing these activities may become too great for some people to engage in them. This may happen as more frequent extreme weather events such as severe storms reduce access to mountainous areas ,and increase the difficulty of maintaining tracks and backcountry facilities.

Potential benefits to physical health may arise from increased adoption of active transportation modes. Communities may increase walking and cycling in response to emissions reduction measures, and through a rise in recognition of other benefits, including cost savings. This benefit is generally limited to individuals who live close to their employment and local amenities (Bennett et al., 2014).

Table 14.3: Summary of wellbeing impacts from climate change (adapted for Canterbury context from Table 1. Western Australia Department of Health (n.d.))

	Hazard/Cause of health impact	Health impact	Commentary
Direct	Flooding	Fatalities, injuries Respiratory illnesses	Direct physical injuries and fatalities from flooding including exposure to contaminated floodwater, being washed away, and related accidents such as electrocution and falling trees. Also, indirect impacts due to ongoing respiratory illnesses and related impacts due to damp and damaged housing.
	Landslides	Fatalities, injuries	Direct physical injuries and fatalities from landslides.
	Fire	Fatalities, injuries	Direct physical injuries and fatalities from burns.
	Temperature increases and heatwaves	Heat stress	Heat stress can cause mild to severe health impacts.
Indirect	Deteriorated water quality	Gastro-intestinal diseases, diarrhoea, vomiting	Run-off from heavy rainfall into recreational swimming areas and untreated water supply can increase exposure to pathogens. Contamination of water supplies from drought related algal blooms, wildlife and stock deaths may increase risks to health.
	High groundwater table	Respiratory illnesses	High groundwater tables can increase dampness in housing. This can result in increased or ongoing respiratory illnesses and related impacts due to damp housing.
	Vector borne illness	Rate of exposure likely to increase	Limited information relating to the impact of climate change on vector borne illnesses for Canterbury. However, these may increase as temperatures increase.
	Food production and storage	Food & seafood poisoning Change in nutritional content and exposure to pesticides	Increased temperatures may increase the rate of food spoilage, posing increased occurrences of food poisoning. Changes in agriculture may change the availability of some types of food, nutrient content and result in increased use of insecticides, pesticides and other chemical treatment.
	Air quality	Respiratory effects	Wildfires may cause reduced air quality. Temperature increases may change air quality due to increased dust, pollen, changes in airflow impacting smog.
	Lifestyle/behavioural	Loss of recreational opportunities and behaviour changes related to a changing climate	Environmental damage reducing exercise based recreational opportunities e.g. damage to coastal walkways and reserves, reduction in ski field operation, snow adventure opportunities, and increased temperatures limiting time outside may result in decreased physical activity and mental health impacts.

14.2.2 Risk to mental wellbeing and health from climate change

Increased risk to mental wellbeing and health from climate change is expected to occur in Canterbury. As with physical health, impacts on mental health and wellbeing may occur throughout the Region, and are unlikely to be spatially linked to exposure to any particular hazard. The level of risk is dependent on a range of factors, including exposure of people, infrastructure, and environment, and demographics including age, income, education, livelihood, housing type, social networks, and cultural relationships. The occurrence of mental health impacts is strongly linked to socio-economic factors. Following the Canterbury Earthquake Sequence (commenced 2010), a study showed that an individual's physical health, physical mobility, mental health, attitude, sociability, and connectedness with others were the most significant factors in determining individual resilience (MCDEM, 2012).

Mental health impacts may arise from a range of climate change related factors, including event related trauma such as from floods or storms, slow onset physical hazards, environmental degradation, erosion of community and culture, loss of livelihood, reduced personal autonomy, and anxiety relating to the occurrence of climate change. These mental health impacts may range from minimal stress and distress symptoms through to clinical disorders such as anxiety, depression, post-traumatic stress and suicidal thoughts.

Other consequences include effects on everyday life, perceptions, and experiences of individuals and communities attempting to understand and respond appropriately to climate change and its implications (Royal Society, 2017). Climate anxiety can also exhibit as a more generalised fear for the future, of global climate crisis and of the threat of environmental disaster (Wu, et al., 2020). This is likely a significant issue occurring at present throughout New Zealand, particularly in youth (RSNZ, 2017; Newsroom, 2019; NZCCP, 2021).

Examples of pathways for impacts on mental health include:

1. Sea level rise and coastal retreat requiring people to leave their homes may cause uncertainty for vulnerable populations (Royal Society of New Zealand, 2017). This can lead to mental health issues from the trauma of leaving familiar situations, breaking social ties, and difficulties of resettlement. Vulnerable populations, such as the elderly or impaired, may struggle to cope with change, or to trust new people in new communities, and take a long time to establish relationships. Moving to larger centres may also mean a support network is less consistent, with a team of people providing support rather than one or two regular support workers. This may in turn lead to physical health impacts through mistrust and reluctance to seek health support when needed (Thornley et al., 2015).
2. The impacts of leaving a community may also impact mental health, as individuals cope with financial impacts (affordability of housing, land values, costs of leaving), loss of family connections to an area or community, and uncertainty for the future.
3. Mental wellbeing can be associated with longer term uncertainty and the cumulative impacts of climate change, such as job losses, reduced housing availability, changes to community fabric, and reduced cultural support.
4. Māori understanding of health emphasizes a holistic perspective incorporating spiritual, intellectual, physical, social and emotional dimensions, and includes relationships with the environment (Jones, et al., 2014). Changes to landscapes and waterways may adversely impact on wāhi tūpuna and marae, cultural practices such as mahinga kai, and access to resources. This could weaken cultural values and connections to whakapapa, and may add to the existing higher rates of mental illness and suicidal behaviour experienced by Māori (Jones, et al., 2014).

Additional mental health support services are likely to be required to support a diversity of needs across a range of age groups. This will range from children suffering increased fear of the unknown, to elderly struggling to cope with the concept of climate change and any potential impacts it has on their lives. Stressors may build to the point where the individual's ability to cope is significantly reduced, requiring greater support from the health system. When a large number of people are experiencing a similar mental health break down, the support system may also be stressed and less able to provide the support required.

Following sudden, extreme events, the capacity for mental health support to respond to short-term wellbeing impacts may be impacted. Overloading of services post-event may prevent the health system from responding quickly, pushing waiting times beyond the period where an individual may need help.

15 Ora rite | Equity

The concept of equity supports fairness and equal opportunities for whānau to thrive and be potent. It is particularly important when addressing basic needs such as healthcare, employment, and education. It also recognises differences between individuals, supports inclusion of diversity, recognises the right to self-determination, and advocates against discrimination. In recent decades the diversity of Canterbury's population has increased significantly in terms of ethnicity, culture, gender identities, religion, values, languages spoken, ages, sexual orientation and whānau structure. New Zealand's founding on firm values of honesty and egalitarianism, as well as its remote location and relatively small size may contributed to a persistent striving for a sense of fairness throughout the community (Royal Society of New Zealand, 2020). The achievement towards women's suffrage made by Cantabrian Kate Sheppard is a leading example of the commitment to equality that New Zealand represents.

Equity through healthcare is a long-established principle of the New Zealand healthcare system. The Ministry of Health acknowledges that in New Zealand, people have differences in health that are not only avoidable, but unfair and unjust. It strives to achieve equity, by recognising that different people with different levels of advantage require different approaches and resources to get equitable health outcomes.

Table 15.1: Summary of risks to ora rite from differing hazards

	Higher mean temperatures			Change in mean annual rainfall			Drought			River and surface flooding			Coastal flooding			Increased coastal erosion			Sea-level rise and salinity stresses			Storms and wind			Increased fire-weather			Increasing landslides and soil erosion			Extreme weather events			Reduced snow & ice			Ocean chemistry changes			Marine heatwaves			Climate change		
Using RCP8.5	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L	P	M	L
Increase inequalities and cost of living																																											L	H	E

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

15.1 Risk of increased inequalities and cost of living due to climate change

Climate change introduces an additional complexity to maintaining equity, where climate change is likely to exacerbate existing inequalities and increase the cost of living. Social inequity will be impacted by many interrelated climate risks, including risks to health, community, culture, community connections, built heritage, prosperity, water, biodiversity and governance. As the impacts of climate hazards increase, communities with current inequity are likely to be impacted first, and most severely over the long term.

Table 15.2: Risks to ora rite | equity

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to increase inequalities and cost of living due to climate change	Low	High	Extreme	Extreme	Risks to inequality and living costs are likely to arise from a range of climate hazards, and continue to increase as widespread effects of climate change are felt. Communities with current inequity are likely to be impacted first and most severely in the long term, and have a low capacity to adapt to change.

Communities and individuals that are exposed to climate hazards will experience the same impacts, however, the ability to respond, adapt or cope with these impacts is uneven, due to existing inequalities (Ellis, 2018). The impacts of climate change will be felt most strongly by those already marginalised in society, by those with higher levels of inequity, or with lower socioeconomic status.

Those experiencing marginalisation due to demographic factors such as age, race, ethnicity, socioeconomic status, gender, literacy or health may be unable to access resources to respond to climate risks (Ton, Gaillard, Adamason, Akgungor, and Ho, 2019). Climate change is likely to exacerbate existing inequities, and create new inequities which can have cascading implications for livelihoods and wellbeing.

The New Zealand Index of Social Deprivation provides one example of a measure of social vulnerability across communities. The Index ranks locations on a scale of decile 1 (least deprived) to decile 10 (most deprived) based on prescribed criteria by Statistical Area 2[7] using averaged data. Using this index, the most deprived populations (i.e. those with a score of 9) reside within Ōtautahi/Christchurch City, particularly in the southern and eastern suburbs, and in pockets surrounding the fringes of the city. Many of these suburbs are located within low-lying or coastal areas, and include the areas of Woolston, Bromley, Linwood, Wainoni, Aranui, Avondale and Bexley. Outside Ōtautahi/Christchurch City, many rural centres have high deprivation scores, including Waimate, Geraldine, Ashburton, Rangiora, Amberley, and the coastal suburbs of Timaru (Figure 15.1).

Other key groups that may experience inequity as a result of climate change impacts include:

- Older adults: This group tends to be less mobile, and is more likely to be physically impaired, with ailments such as hearing or vision loss. The distribution of adults in the Canterbury Region is shown in Figure 15.2. The median age of the population of Canterbury is projected to rise over coming decades. It is projected to increase from 38 years in 2018 to 45 years in 2048. In 2048, one in four people in Canterbury is project to be aged 65 years or over (Environment Canterbury, 2021). Older adults are more likely to have chronic health conditions such as heart disease and diabetes, making them more susceptible to health impacts related to heat stress, or during and after a flood (Environmental Health Indicators Programme, 2019). They may have limited social networks and be socially isolated, particularly if they live alone. They are also likely to need more help to evacuate during a flood, and during the clean-up phase after a flood (Mason et al., 2019).
- The socially isolated: This group includes people living in rental housing and recent immigrants. Both groups may be new to an area, and as such are unlikely to have strong social networks within a community. New members of the community may not know where to go to access information, support services, and other important services. They may also be more

[7] Statistical area geographies are aggregations of meshblocks optimised to be of similar population sizes to enable the release of low-level data (StatsNZ, 2018).

vulnerable to changes in community governance and structure, as they often have relatively high dependence on these support systems (Manning et al, 2015). Migrant communities may have an increased vulnerability due to climate differences from their home nations. They may be more likely to accept poorer quality housing, and less likely to seek medical help if needed, due to barriers such as language, and the inability to use traditional medicine or healthcare practices with which they are comfortable (Bennett et al, 2014). These communities may include the Ashburton-based Filipino community working in the dairy industry, and the South Canterbury Pacific community working in fruit picking industry.

Climate hazards, including exposure to extreme weather events such as flooding or heatwaves, or to ongoing gradual changes such as inundation of low-lying areas, will have a range of impacts on community facilities and housing. The condition of housing may degrade, for example due to improper repairs following floods, leading to increased moisture and less weather tightness, resulting in health impacts. This lower quality housing is more likely to be rented out, or be lower cost purchase options. However, it will probably lead to greater health impacts, such as respiratory disease and chronic preventable illnesses. This was demonstrated in post-earthquake Ōtautahi/Christchurch, and is still prevalent where housing repairs have not been carried out properly or at all, leading to housing conditions exacerbating preventable diseases such as respiratory illness and pneumonia. Lower rents are attractive to those on lower incomes, as they appears to provide greater flexibility in weekly costs. In reality, more income may go on heating or healthcare costs.

Existing socio-economic disparities between Māori and non-Māori communities are likely to be exacerbated with climate change. This is likely to arise from the sensitivity of Māori communities to impacts on ecological systems, their dependence on primary industries for livelihoods, and the impacts of climate change on cultural and spiritual wellbeing, as well as on mahinga kai, food security, and proximity of housing and infrastructure (Ministry for the Environment, 2020; Stephenson et al, 2018; Ministry for the Environment, 2020; Manning, Lawrence, Ngaru King and Chapman, 2015).

Exposure of housing to hazards may force relocation or retreat, forcing communities to move to more expensive or remote areas. This may lead to reductions in the ability to afford rent or land, and may also by accompanied by rising costs of utilities (i.e. water and electricity). Overcrowding of dwellings is likely to be a commonly adopted strategy to reduce cost. A similar situation emerged during post-earthquake Ōtautahi/Christchurch, where a large portion of older housing stock was severely damaged, and classified as the uninhabitable Red Zone (Potter et al 2014). This housing was located in areas typically categorised as lower income, with lower rental value. The residents in this zone were forced to shift to areas dominated by newer housing, with higher rental, or to more distant suburbs such as Rolleston to find cheaper accommodation. Additionally, damaged housing was rented more cheaply, providing worse living conditions arising from damp and cold housing, such as mould, draughts, and insufficient heating, and contributing to respiratory diseases such as asthma, hypersensitivity pneumonitis, rhinosinusitis, bronchitis and respiratory infections (WHO, 2013; Zang, 2010; The National Institute for Occupational Safety and Health, 2012, see also Section 14.2.1).

Increased pressure on housing supply as climate refugees arrive also has the potential to lead to overcrowding and displacement from communities. Low-income groups are likely to be competing for these same properties (Bennett et all., 2014). Groups may be forced to shift away from traditional centres, and there may be an increase in multi-family households.

Relocation to more remote areas may raise transportation costs, and reduce access to support and opportunities such as employment and education. In many small rural townships within the Region (for example Omarama, Fairlie, Oxford), service providers such as doctors, nurses, and teachers do not necessarily reside within the town. This results in additional travel costs and time to access services. For those on lower incomes, access to these services may become compromised as costs to travel are diverted towards meeting their basic needs.

Further increases in the cost of living may arise from changes to rental and property markets. These could come about through increases in insurance costs, or erosion of industries that support real estate and provides jobs. For example, an industry may be unable to maintain profitability in the face of climate change impacts, and eventually close. The resulting job losses might leave workers unable to rent, or force them to move away. Changing hazard profiles may result in in insurance retreat, or unaffordable premiums, and may increase difficulties in selling or buying a property. This may lead to situations where there is household debt against the property, yet to service a mortgage, banks require insurance.

Frequent relocation or upheaval as a result of climate change impacts may result in lower engagement with education providers due to regular movement between institutions. Children and young people in particular may struggle to keep up with education when moving between providers. Resulting gaps in education could lead to longer term impacts, and a cycle of low engagement due to educational limitations and understanding or literacy (UNESCO report 2020).

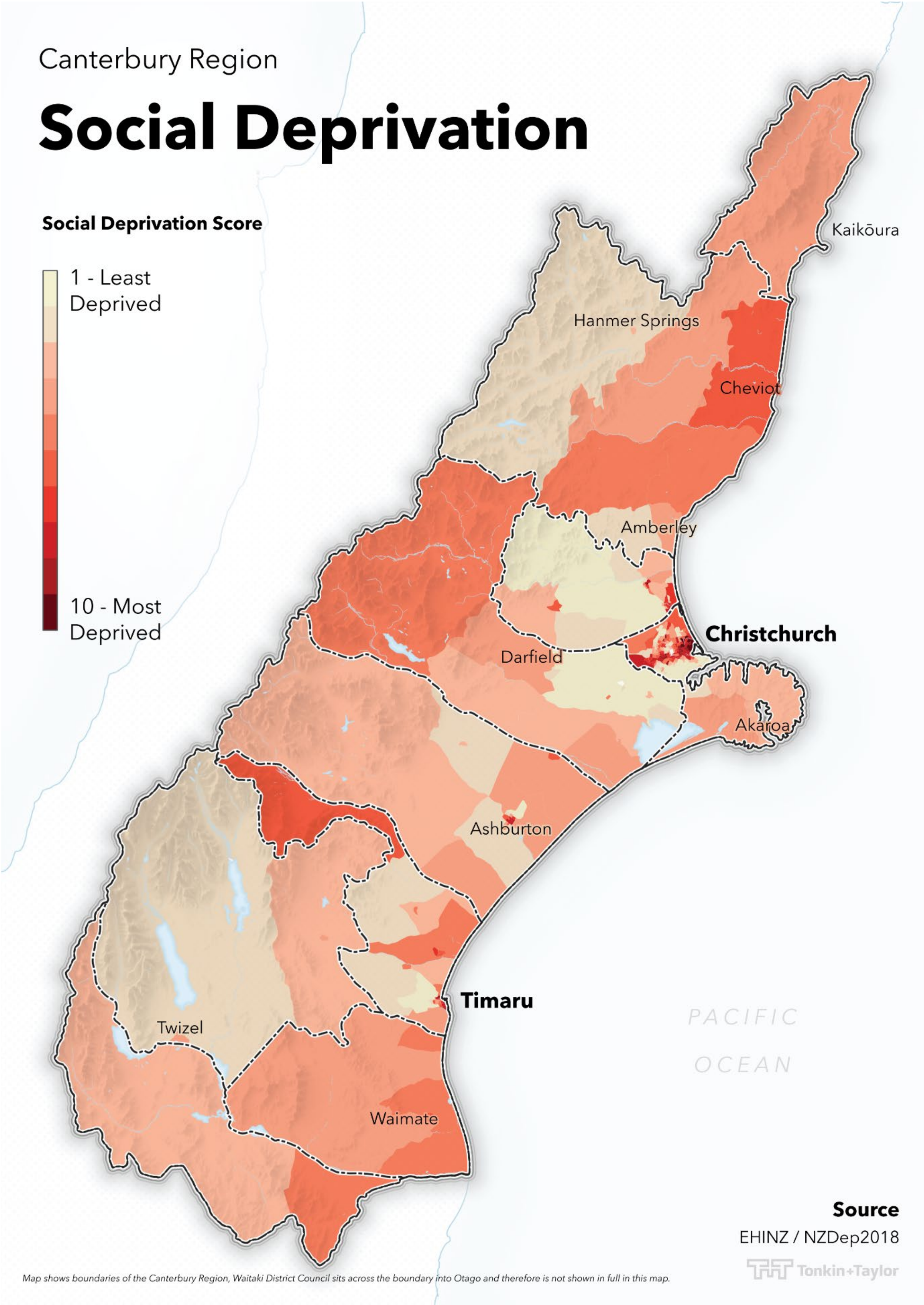


Figure 15.1: Map showing deprivation index score within Canterbury Region.

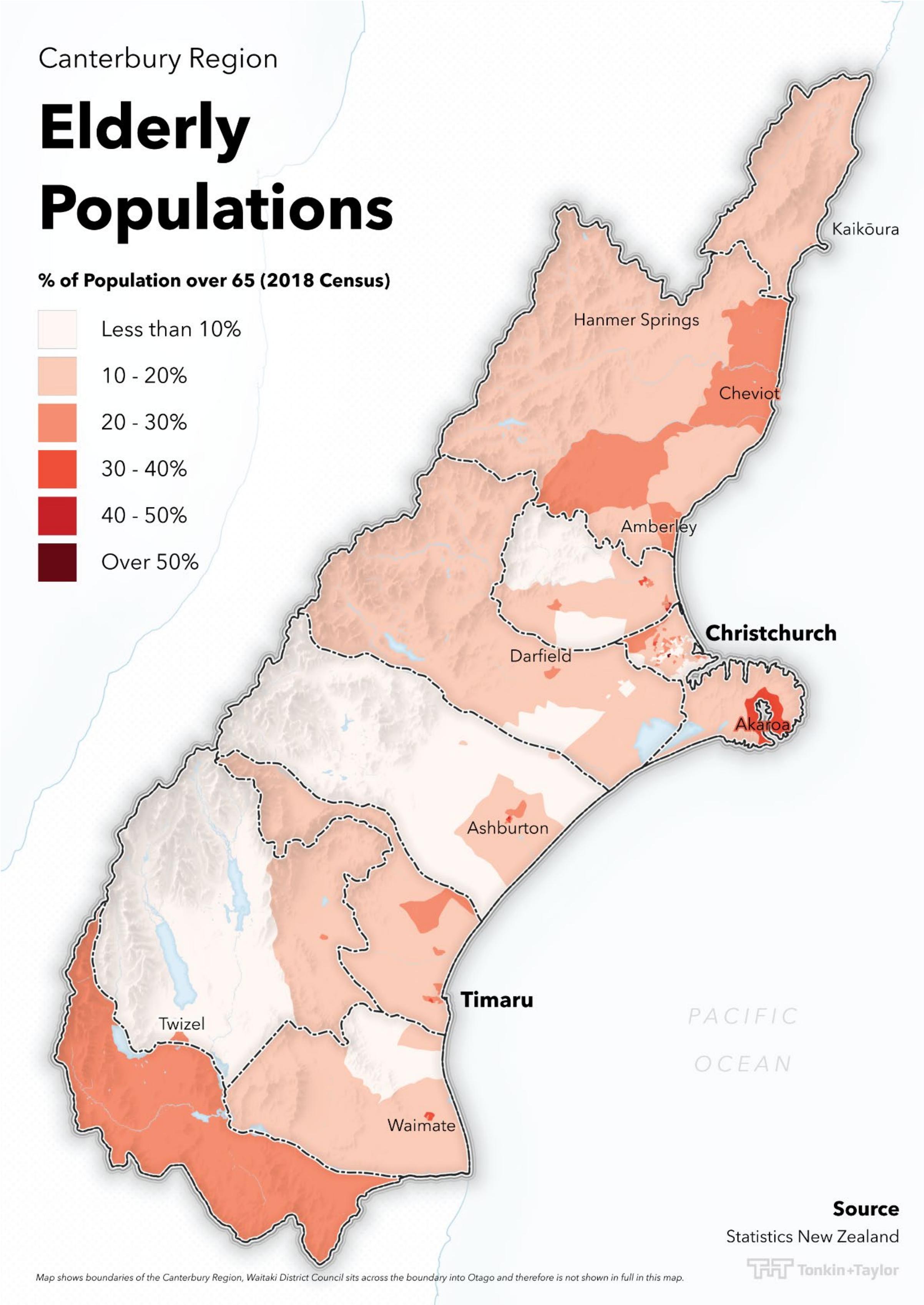


Figure 15.2: Elderly adult populations in Canterbury Region.

16 Hapori | Sense of Community

A sense of community is important, it provides a basis for social cohesion, and is a foundation for a safe and inclusive society. Hapori (a sense of community) can be developed through a range of channels, including neighbourhoods, shared community interactions, iwi, religious groups, cultural groups, and refugee resettlement groups. In a Te Ao Māori world view, community is important in supporting the reciprocal obligations to safeguard and protect the health of the environment and the health of people. It is also important for honouring inter-relationships between Te Ira-Atua, (the spiritual realm) Ira Tangata (people) and Ira Whenua (natural world).

Community networks are important to building resilience. Many outstanding examples of the importance of community cohesion have been observed through the actions of Cantabrians in response to the Canterbury Earthquake Sequence (commenced 2010). Community cohesion and resilience was demonstrated during the immediate responses, when community members worked to support one another during a period where official resources were unavailable. Existing residents' associations were used to form a communication network between local authorities and individual streets (CanCERN, Vallance). This was an effective model, demonstrating the effectiveness of sharing community information as well as connecting residents, including reaching those without telephone or internet. Strong community networks also provided immediate wrap around support to iwi/hapū members. Over time, this support spread to other vulnerable communities, such as refugee groups. These can be viewed as 'informal' networks. There is potential to undervalue these sorts of networks during decision making processes and distribution of support.

Table 16.1: Key risks to Hapori | Sense of community

	Higher mean temperatures	Change in mean annual rainfall	Drought	River and surface flooding	Coastal flooding	Increased coastal erosion	Sea-level rise and salinity stresses	Storms and wind	Increased fire-weather	Increasing landslides and soil erosion	Extreme weather events	Reduced snow & ice	Ocean chemistry changes	Marine heatwaves	Climate change
Using RCP8.5	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L
Rural housing and communities				H E E					M H E						
Settlements and urban communities				H E E	H E E	M H E	L M H								
Community cohesion															L H E

Key

I	Insignifcant
L	Low
M	Moderate
H	High
E	Extreme

P	Present day
M	Mid (2050)
L	Long (2100)

16.1 Risks to settlements and urban communities

The highest risks to settlements and urban communities from climate change include those from inland, surface water, and coastal flooding, and increased fire weather. The frequency and intensity of coastal and inland storms and flooding is projected to increase over time. The exposure of Canterbury buildings to flooding is the highest nationally. The majority of exposed buildings are located in the low-lying parts of urban Ōtautahi/Christchurch City, with older buildings most vulnerable to flood and storm damage. The adaptive capacity of settlements is generally complex and expensive, with high social costs. Exposure to wildfire will also increase as hotter drier summers occur. Rural areas will be most highly exposed, due to larger areas of fallow land and vegetation cover.

Table 16.2: Summary of risks to urban communities

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to settlements and urban communities due to coastal flooding	High	Extreme	Extreme	Extreme	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.
Risk to settlements and urban communities due to river and surface flooding	High	Extreme	Extreme	Extreme	Projected increases in extreme events are likely to cause increased flooding to which some urban communities are highly exposed. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including stop banks and retreat.
Risk to settlements and urban communities due to increasing coastal erosion	Moderate	High	Extreme	Extreme	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.
Risk to settlements and urban communities due to sea-level rise and salinity stresses	Low	Moderate	High	High	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.

Table 16.3: Summary of risks to rural communities

Risk statement	Risk				High level description
	Present	2050 *(RCP8.5)*	2100 *(RCP4.5)*	2100 *(RCP8.5)*	
Risk to rural housing and communities due to river and surface flooding	High	Extreme	Extreme	Extreme	Projected increases in extreme events are likely to cause increased flooding. Relatively low density of dwellings in rural communities mean that there are lower numbers of exposed rural buildings. However, the condition of these buildings may be lower due to age and overall lack of maintenance meaning a higher sensitivity to flood damage.
Risk to rural housing and communities due to increased fire-weather	Moderate	High	Extreme	Extreme	Projected increases in temperature, wind and dry days are likely to increase the fire weather exposure particularly in inland rural communities. Warmer temperatures, increased areas of barren land and high vegetation cover make rural communities sensitive to fire. Defences and strategies can be put in place to increase resilience, such as scrub clearing, pruning and planting of fire resistant trees i.e. deciduous.

Housing and buildings within Canterbury include commercial and public buildings, and rural and urban housing. 27,821 hectares of land is classified as urban within the Canterbury Region (Land Air Water Aotearoa, 2021). This includes 226,806 occupied private dwellings, and 1,293 occupied non-private dwellings (Statistics New Zealand, 2021).

Canterbury's large coastline, many rivers, and high population living within low-lying coastal urban contribute to extreme exposure to surface water and coastal flooding, erosion and sea level rise. Within the national context, Canterbury Region has the most extensive built land area exposed to coastal flooding. The exposed area is just under 15 km^2, most of which is within Ōtautahi/Christchurch City (14.7 km^2). This area is home to New Zealand's highest regional population of 18,122 people exposed to coastal flooding. Of these, 11,941 reside in Ōtautahi/Christchurch City, predominantly within the suburbs of Burwood, New Brighton, Southshore, Woolston, Bromley, Hillsborough, Redcliffs and Sumner. By late century, 9,506 buildings within the Region are projected to be exposed to coastal flooding from the 1% AEP. This increases to 14,338 buildings when including 0.3 m sea level rise, and 25,038 buildings at 0.8 m sea level rise. Ōtautahi/Christchurch City has the highest exposure within the Region, with 6,653 buildings exposed at 0.0 m sea level rise. This is followed by Waimakariri, with 2,293 exposed buildings at the same level. At 0.8 m sea level rise, exposure of buildings in Christchurch increases to 20,068, and in Waimakariri to 3,646 (Figure 16.1) (Paulik, et al., 2019).

Exposure to river and surface water flooding is also highest in Canterbury compared to the national context. A total of 116,713 buildings within Canterbury have been assessed as currently exposed to flooding. Of these, 95,354 are in Ōtautahi/Christchurch City, followed by 11,186 in Waimakariri and 1,654 in Ashburton (Paulik, Craig, & Collins, 2019). Mean annual flood flow and extreme events are projected to increase with climate change. National flood exposure modelling indicates that within Canterbury, 7,481 buildings are located within floodplains that will experience a mean annual flood increase of 20% under RCP 8.5 (Figure 16.2) (Paulik, et al., 2019).

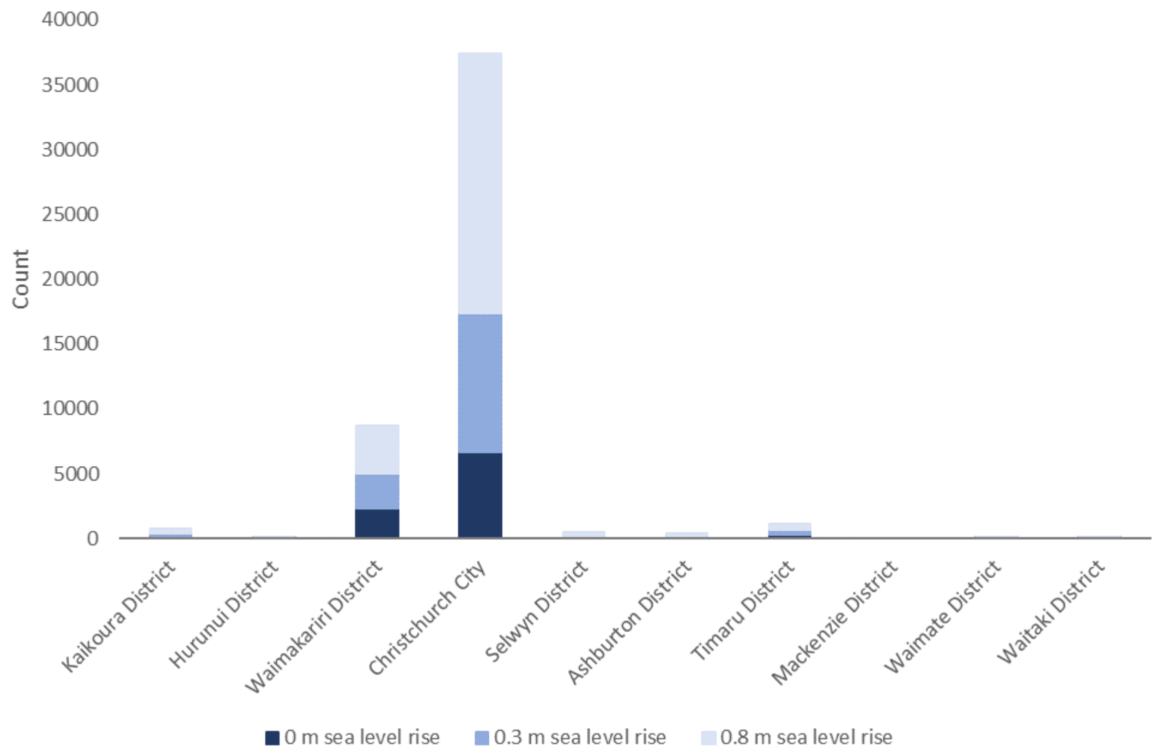


Figure 16.1: Exposure of buildings[8] to coastal flooding and incremental sea level rise by district (Paulik et al., 2019).

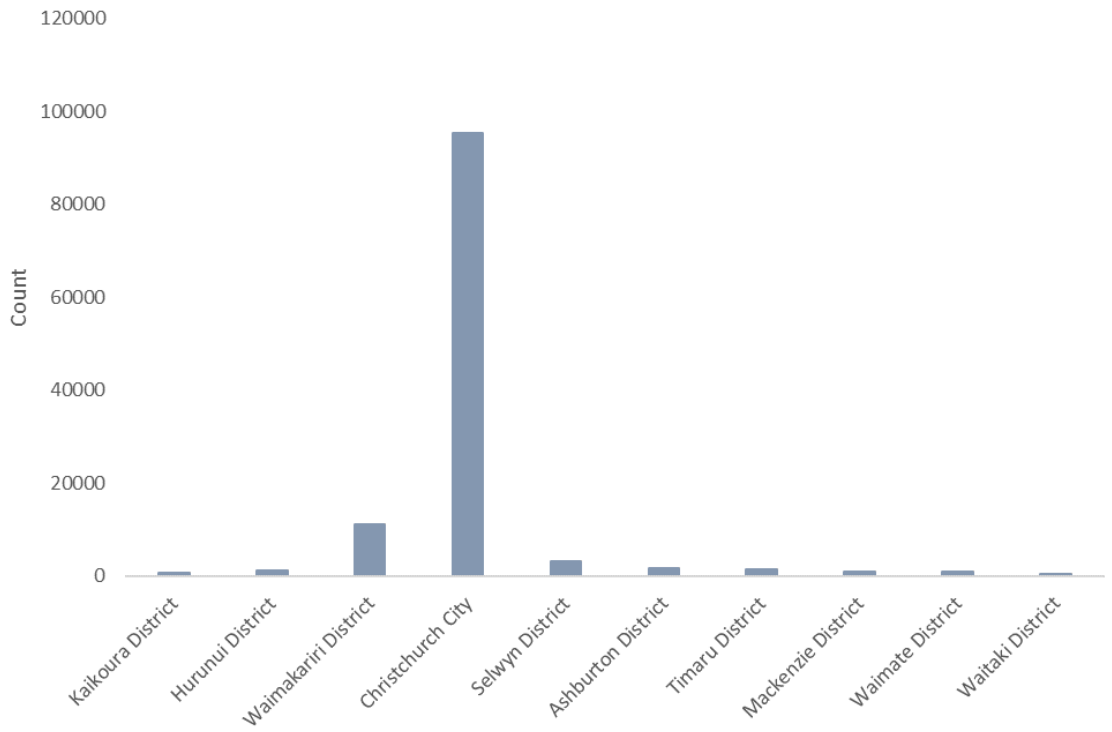


Figure 16.2: Exposure of buildings[8] to present day flooding by district (Paulik et al., 2019.

[8] Building types include residential, commercial, industrial (includes primary production), critical facility, community and other (e.g. out-buildings, garages).

Building design, age and condition can influence sensitivity to climate hazards (Buckett, Marston, Saville-Smith, & Jowett, 2011). Building age is typically around 50 years (based on the national average). Older buildings are likely to be found in rural districts such as Mackenzie, Waimate and Hurunui, where there is generally a lack of maintenance and repair (Jacques, Jones, Marston, Saville-Smith, & Shaw, 2015). However, pockets of newer buildings are likely within Ōtautahi/Christchurch and the surrounding districts, due to high growth and reconstruction following the Canterbury Earthquake Sequence (commenced 2010) (Buckett, Marston, Saville-Smith, & Jowett, 2011; Uma, Bothara, Jury, & King, 2008). Newer buildings are likely to have increased resilience to weather and seismic hazards following seismic strengthening and improvements. These relate to a range of regulatory changes enacted in response to the New Zealand leaky home crisis (BRANZ, 2020). The changed regulatory requirements and professional practice relate to design principles, cladding, weathertightness and construction methods. Unfortunately, despite these improvements, due to a range of complex and related issues, weathertightness of New Zealand buildings remains an ongoing issue (BRANZ, 2020).

Housing stock is typically made from wooden and masonry. Heavy rainfall, coastal, and inland flooding can cause damage to wood and masonry buildings, due to the swelling and damage that can occur to plasterboard wall linings. This problem is exacerbated with older houses, or those in poor condition (Reese & Ramsay, 2010; Jacques et al., 2015). Buildings that have underground car parks and are located in the floodplain are likely to have an increased exposure to surface water/river flooding due to their elevation (Stakeholder Engagement, 2021).

Exposure of rural settlements to fire is projected to increase as wind and the number of hot days increase, and summer rainfall decreases. Wooden houses have a higher sensitivity to increased fire weather compared to concrete houses, due to the higher flammability of that material type (Stakeholder Engagement, 2021). Inland rural communities may be most exposed to fire, where temperatures are projected to rise most severely. Rural communities have large areas of fallow land, and greater vegetation cover. These factors contribute to increased likelihood of generating and sustaining wildfire under the right conditions. However the Port Hills fire of 2017 demonstrates that devastating fires can occur throughout the Region. Recent wildfire at Lake Ōhau (April 2020) highlighted the devastating and expensive impact of wildfire to rural communities (Figure 16.3). During this fire, 48 homes and holiday homes were destroyed, with insurance claims costing nearly $35 million (NZ Herald, 2020).

Generally, existing buildings have low adaptive capacity to flooding, coastal hazard and fire risks, although risk of exposure to river flooding can be reduced with hard defences, such as stopbanks. Adaptive capacity is particularly constrained in urban communities, where complex and expensive intervention is required to relocate settlements and the associated support services. Actions to adapt are likely to have a significant impact on individuals and communities. Catastrophic events and planning legislation can shape the resilience of the Region by influencing where future settlements are built or rebuilt. For example, the Canterbury Earthquake Sequence (commenced 2010) was a catalyst in improving the resilience of the built environment to earthquakes within the Region.

Figure 16.3: Fire damage at Lake Ōhau (source: RNZ, 2020).

16.2 Risk to community cohesion and resilience from climate change

Climate change presents risks to community cohesion and resilience. As climate change impacts take effect, exposure will be widespread across Canterbury in both rural and urban settings. Loss of key community members is a likely result, as stressors build and necessitate movement to less exposed or more prosperous areas. Is likely to be difficult for communities to recover from the loss of key members, or a change in the social fabric. Risks to community cohesion are interrelated with risks to ōhanga (prosperity), rangatiratanga (governance), rerenga rauropi (biodiversity) and kāinga tūturu (historic heritage) and connections.

Table 16.4: Risks to community cohesion

Risk statement	Risk: Present	Risk: 2050 *(RCP8.5)*	Risk: 2100 *(RCP4.5)*	Risk: 2100 *(RCP8.5)*	High level description
Risk to community cohesion due to climate change	Low	High	Extreme	Extreme	Community cohesion with Canterbury may be affected by climate change in both rural and urban settings. Community disruption may be caused by event based hazards such as fire, extreme events, and flooding, or slow-moving hazards, such as sea level rise and temperature. Exposure to hazards may motivate individuals or groups to relocate, where the loss of key community members can have a range of consequences for community cohesion, particularly in small communities. It is likely to be difficult for communities to adapt and recover from the loss of key members or a change in the social fabric. Some opportunities may exist for towns that are less exposed and may see population growth or increased cohesion in the face of adversity, and individuals may find new opportunities to show leadership.

Canterbury is home to a diverse population, ranging from dense urban city living to small urban communities, surrounded by rural communities. These communities differ in nature, from coastal, through to a range of inland geographies. Community disruption may be caused by event based or sudden hazards such as fire, extreme events, and flooding, or slow-moving hazards, such as sea level rise, and warming temperatures. Climate drivers that contribute to community hardship will be specific to individual communities, and there will be a range of circumstances that may contribute to the loss of community cohesion.

The ongoing impacts of climate change may erode the resilience of individuals, or the whole community, as key members move away. Communities may be eroded as individuals move in response to their personal capacity to cope with climate risks or ongoing impacts, or may result from the relocation of whole communities, through managed retreat (discussed further in Section 15, ora rite/equity). Evidence from the Canterbury Earthquake Sequence (commenced 2010) illustrates how some people will move away from areas when they can no longer tolerate the risks. In the two years following the start of the sequence, the population of Ōtautahi/Christchurch City fell by 18,000 people (CDHB, 2021).

The Canterbury Region has a wide range of rural production, including viticulture, dairy, sheep, beef, crops and forestry. Changes to the climate and land availability are projected to affect these primary industries, which feed and support local communities. Communities such as Amberly are supported by viticulture, dairy, sheep and beef, while Ashburton is primarily supported through cropping and dairy. Coastal communities of Canterbury may be primarily concerned with sea level rise, and are also likely to face other related challenges. For example, productive land may be lost due to the rising sea level, or groundwater resources may be lost due to increased salinity. In contrast, a community located further away from the coast may be more concerned about the impacts of lower rainfall and a warmer climate, which may change or reduce the traditional crop types grown in the area (Manning et al, 2014).

Some members of the community, particularly the elderly or disabled, rely on others living nearby or members of a church congregation or iwi or hapū to help with accessing services such as healthcare and supermarkets. This reliance could result from aspects such as limited mobility or access to public transportation, the prohibitive cost of private transport such as taxis, or language barriers. These relationships can be linked to trust of a person, and are not easily rebuilt with another person less well known. When people move away, this impacts on those who are dependent on them for support. Movement or break down of a community may reduce support networks and the ability for some people to access necessary resources, including medical services, food, and suitable housing etc.

Loss of community members, organisers, and key people may impact cultural character and structures, leading to greater challenges in organising the community. This could lead to tension and create changes to a community's sensitivity and ability to adapt. This has been observed in Arowhenua Pā, where in the space of one to two generations, rapid transformations in the character and structure of the community has made it harder to meet the increasingly complex array of challenges facing this hapū-based community (Manning et al., 2015).

A shortage of key community members who have the time (and relevant expertise) to represent and take responsibility or provide leadership for community-related affairs can undermine decision-making or governance. For example, local authorities are often required to 'consult' and 'engage' with Māori on resource management issues. The loss of such community members diminishes their ability to carry out this requirement. Such key community members are also critical as they are more likely to have the understanding and ability to help communities develop resilience and plan for climate change.

The effects of climate change on governance, including lack of official support or engagement, and slow decision making, are identified barriers to social cohesion. They can result in a community feeling less empowered to make a decision or contribute positively, ultimately reducing resilience (Thornley et al., 2015). The uncertainty related to the scale of effects from climate change adds complexity and increased difficulty for communities when developing plans for coping with change.

A range of factors underpins adaptive capacity, and the impacts of climate change will generate differing outcomes for various communities. Throughout Canterbury, the impacts of climate change are likely to alter the social fabric, with impacts also on the adaptive capacity of communities. These changes are expected to arise from tensions and challenges surrounding greatly altered living arrangements, loss of exposed Māori-owned land holdings to inundation, flooding and landslides, a growing reliance on modern services and markets, and increasing individualism. Alteration of the physical environment and increased competition for resources are likely to affect the way community members can engage with traditional lands, waters and other resources. Together, these conditions are recognised as creating new tensions, increasing the sensitivity of a community to climatic risks and undermining certain aspects of adaptive capacity (Manning, et al., 2015). Changes to the social fabric of a community are often negative, as they remove knowledge, relationships or resources. However, there can also be positive impacts, such as introducing new ways of thinking, or perspectives to a community, or providing avenues for leadership from people who otherwise would not normally step into such roles.

17 Kāinga tūturu | Historic Heritage

Settlement within Canterbury was founded by Ngāi Tahu 600-700 years ago, following migration of Māori from the east coast of the North Island. The initial territories inhabited by Ngāi Tahu were around the coastal wetlands and Te Waihora. European discovery of the Canterbury Coast occurred in 1770 with Captain James Cook. The first European landing occurred around 1815-1816, and whaling activities commenced in the 1830s around the Banks Peninsula area. Large scale European migration from England commenced in 1850, with over 3,500 settlers arrived in the area by 1853. As the settlement established, Canterbury connected with the rest of the South Island by 1850-1860, with routes through the Ka Tiritiri o te Moana (Southern Alps) to Nelson, Marlborough and the West Coast.

Canterbury has an extensive network of heritage sites, reflecting the Region's centuries of settlement, exploration, development, transport and defence of the area. Churches, homesteads, early industry, and battlements are spread throughout the Region, with many located in coastal areas. Some of the Region's most fragile historic places were damaged during the Canterbury Earthquake Sequence (commenced 2010) and Kaikōura Earthquake (2016). These included the Provincial Council Chambers, Lyttelton's Timeball Station, the Anglican Christchurch Cathedral and the Catholic Cathedral of the Blessed Sacrament. The loss of these types of landmarks is considered significant, with large investment and public discussion entered into, to find suitable ways to reinstate or compensate for the loss of cultural heritage. The Region also holds sites of archaeological significance, including Monck's Cave, which is of significance to Māori as one of the oldest and rarest taonga (treasures) from their earliest settlement in New Zealand.

The risks to historic heritage from climate change were not prioritised as part of the risk screening process, as their risk ratings were moderate or lower. Therefore, these risks have not been identified and rated. However, climate change will pose a range of hazards to heritage sites, which may damage and degrade these structures and places. Changes in landform associated with climate change, such as increased coastal erosion and landslides, may expose new sites, and risk damaging existing sites. Sea level rise and inland flooding may also damage built heritage and other significant sites.

18 Mātauranga | Knowledge

Mātauranga (knowledge) is a fundamental concept underpinning all aspects of society. Access to information and education is an important component in maintaining an equitable society. It contributes to building a fair and prosperous society by providing opportunities for individuals ,and breaking down barriers to equitable outcomes. In addition to improving opportunities for financial gain, education can broaden an individual's outlook, thereby improving their resilience (Shared Prosperity, 2021). Access to early childhood, primary, and secondary education is freely available to all New Zealanders.

Mātauranga (knowledge) also arises from traditional, cultural and indigenous practices. Mātauranga Māori is an important aspect of Māori culture, embedded in the whakapapa (genealogy) of Māori people and the interconnected relationship of all living things. It is etched into Māori language, genealogies, songs, dance, art and storytelling, and embodies a worldview that is intended to be passed down to future generations. Mātauranga Māori is important to natural resource management, conservation, and biodiversity protection, and may provide important approaches to overcoming challenges related to climate change.

Table 18.1: Summary of risks to mātauranga (knowledge) from differing hazards

	Higher mean temperatures	Change in mean annual rainfall	Drought	River and surface flooding	Coastal flooding	Increased coastal erosion	Sea-level rise and salinity stresses	Storms and wind	Increased fire-weather	Increasing landslides and soil erosion	Extreme weather events	Reduced snow & ice	Ocean chemistry changes	Marine heatwaves	Climate change
Using RCP8.5	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L	P M L
Cultural identity															L H E

Key

- I Insignifcant
- L Low
- M Moderate
- H High
- E Extreme

- P Present day
- M Mid (2050)
- L Long (2100)

18.1 Risk to cultural identity and practices due to climate change

Risks to mātauranga (knowledge) due to climate change are identified as those relating to cultural identity and practices. Many cultural and heritage sites in Canterbury are located in low-lying or coastal areas, and thus will be exposed to climate change hazards. Māori culture also holds a deep connection to place, a value which cannot be transferred to other 'like' places.

Table 18.2: Risks to mātauranga (knowledge)

Risk statement	Risk: Present	Risk: 2050 (RCP8.5)	Risk: 2100 (RCP4.5)	Risk: 2100 (RCP8.5)	High level description
Risk to cultural identity due to climate change	Low	High	Extreme	Extreme	Māori have a deep connection to turangawaewae, and hold a strong significance regarding 'place'. Many cultural heritage sites and Marae are located in coastal and low lying areas and may be exposed to flooding, erosion and related issues such as loss of access. Other changes are also likely to undermine cultural practices, including reduced connectivity, dispersal/relocation of communities and degradation of the natural environment.

Māori communities have strong connections to their tūrangawaewae[9] (place of belonging, through kinship or genealogy), through whakapapa (genealogical connections) that include physical and spiritual connections. Throughout Canterbury, Ngāi Tahu have strong ties to the Region, particularly to the coastal environment. Their whakapapa linkages are widely maintained through whānau (families) and marae (communal gathering places for iwi/tribes or hapū/sub-tribes) and are integral to Māori life. These strong connections help communities to respond and recover from adverse climate impacts and stresses (Manning et al, 2015). However, the loss of access to, and quality of, cultural sites may result in a loss of cultural identity for Māori communities. This is particularly significant given their deep connection to their tūrangawaewae (Koppel Maldonado et al., 2013; Royal Society, 2017).

Many urupā (burial grounds) and marae are located in exposed coastal and low lying locations. They are particularly vulnerable because of the location of valued infrastructure and sacred sites on exposed, erosion-prone coastal lands (Royal Society, 2017). Māori occupation sites around the Banks Peninsula Region and coastal Canterbury cover such areas as Kaiapoi, Sumner, Southshore, New Brighton and Brooklands. These sites include urupā, Pā (fortified village) sites, traditional settlement areas, and traditional migration pathways along the coast. The Kaiapoi Pā (Turakautahi) was a key settlement area and trading post for pounamu (greenstone or jade) sourced from the West Coast (Te Ara, 2021). The Kaikōura coastline is another example of an area of importance to Ngāi Tahu that is highly exposed. Hundreds of sites of cultural significance were identified along the Kaikōura coastline through the reinstatement of the road corridor following the 2016 earthquake, confirming historical high use of this coastal area.

Reduced access to or complete loss of wāhi tapu (sacred sites) and other historic heritage sites may occur due to coastal inundation, erosion, flooding or landslides. Access to remote sites may be further reduced due to increased travel distances and transportation costs (due to people moving further away), or damage to access routes. These losses are likely to damage spiritual and physical connections to the land, reduce knowledge sharing due to spread of key members of iwi (tribes) or hapū (sub-tribes), and erode community connectivity and support networks, ultimately reducing community resilience.

Changes in water quality will impact the mauri (lifeforce/essence) of water, which has special significance in Māori culture as the sustenance of all life. Reduced mauri of water is linked with other biodiversity degradation and habitat loss. This reduction will impact on traditional cultural practices such as mahinga kai (food gathering), and change the availability of other natural resources such as harakeke (New Zealand flax) used in traditional building and weaving (Sesana et al., 2018).

[9] Home grounds through rights of kinship and whakapapa, place to stand.

Cultural heritage may be further threatened by gradual shifts in weather patterns and extreme events. An increased temperature and changed rainfall, humidity, and wind, can negatively impact on the materials that cultural heritage assets are made of. These changes may affect the biological, chemical, and physical properties of traditional construction materials, leading to degradation of the assets (Sesana et al, 2018).

Tourism is often an important resource for the prosperity of iwi. Damage from climate change to cultural and natural heritage may impact tourism. This may lead to reduced revenue, which may then impact the ability for the marae to fund activities that conserve their cultural heritage. This also carries an additional loss, where reduced visitor numbers would result in a lost opportunity to educate visitors and share tikanga Māori (Māori customs) (see also: Section 13.5).

More broadly, cultural heritage sites (including buildings, infrastructure and landscapes) provide a sense of identity and continuity for a place (UK Essays, 2018). Cultural heritage can also play a significant role in economic development for an area or community. If impacted by climate change, can result in a number of economic, mental health and social cohesion impacts (Alexandrakis et al, 2019).

19 Rangatiratanga|Governance

Rangatiratanga (governance) for the purpose of this assessment encompasses the relationships, coordination and processes undertaken to address collective issues that are relevant to the Canterbury Region. These issues are managed primarily through the Regional, City and District Councils, as well as Ngāi Tahu, Kāwanatanga (governance institutions), whānau institutions (family institutions or relationship networks), Nga papatipu rūnanga, Te Tiriti (Treaty of Waitangi) Partnerships, government/local government institutions, other political voice and public service agencies, and public service providers such as Canterbury District Health Board, Canterbury Civil Defence and Emergency Management, the fire service, and the police.

Rangatiratanga (governance) is the value and practice of people exercising self-determination, their independence and determining their choices for governing themselves. Rangatiratanga (governance) is the basis of one of the Articles of Te Tiriti o Waitangi (The Treaty of Waitangi, 1840), the founding document of Aotearoa New Zealand. In relation to political decision makers in Canterbury, Rangatiratanga (governance) reflects the democratic processes that are followed through local government, where locally elected members represent their communities and make decisions on their behalf. We recognise the nuanced distinction of Rangatiratanga from Kawanatanga, which is derived from the English word ‘governor’ and now broadly used to refer to the concept of governance. However, Rangatiratanga recognises an individual’s autonomy, and their interconnectedness with all aspects of social and physical systems within the region.

Rangatiratanga (governance) is connected to the management and protection of rerenga rauropi (biodiversity) and is critically important in the management of the region’s precious wai (water). These flow on to the upholding of cultural knowledge, mātauranga Māori. Rangatiratanga (governance) is connected to the Region’s lifeline services, including the transport connections and waste management systems that enable people and communities to connect and function safely, represented through ngā waihanga (infrastructure services). The public services that are provided in the region support the hauora (physical health, which in Te Ao Māori also incorporates mental health and wellbeing) of communities, and contribute to ora rite (equity), and hapori (sense of community).

19.1 Summary of risks and relationship to NCCRA

Governance risks were identified as part of the National Climate Change Risk Assessment (NCCRA) (MfE, 2020). Many of these national scale risks are relevant to Canterbury, along with others that are uniquely specific to the Region. Nationally identified governance risks were considered when developing the Canterbury specific risks. A summary of the governance risks identified through the engagement process, and how they link to NCCRA risks, is presented in Appendix A. Of the eight NCCRA risks, Risk G7 is the only risk that is not directly relevant to a regional context, as it specifically relates to parliamentary agreement. Summary risks to Governance identified in the NCCRA report are as follows:

1. G1 – Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes.
2. G2 – Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation.

Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms.

3. G3 – Risks to governments and businesses from climate change-related litigation, due to inadequate or mistimed climate change adaptation.
4. G4 – Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change.
5. G5 – Risk of delayed adaptation and maladaptation due to knowledge gaps resulting from under-investment in climate change adaptation research and capacity building.
6. G6 – Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region.
7. G7 – Risk that effective climate change adaptation policy will not be implemented and sustained due to a failure to secure sufficient parliamentary agreement.
8. G8 – Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts.

Table 19.1: Summary of risks to rangatiratanga (governance) with relevance to risks identified in the NCCRA

Risk from climate change	Sub-risk	Relevant NCCRA risk
Funding and public service provision	Ability to fund and maintain public services.	
	Availability and access to funding (including availability of insurance, banking etc).	
	Climate adaptation funding.	G5
Governance structures, planning rules and policies	Effectiveness of planning rules and policies.	G1, G2
	Exacerbation of the challenges associated with different jurisdictional boundaries.	G1, G2
	Short election cycles.	G1

Risk from climate change	Sub-risk	Relevant NCCRA risk
Risk of legal liability, reputational damage and effective decision making to councils and public organisations	Legal liability.	G3
	Reputational risk.	
	Inability to make effective decisions.	G1, G2, G8
Risk to co-governance (including Te Tiriti (Treaty of Waitangi) Partnerships) from climate change	Co-governance (including Te Tiriti Partnerships).	G4
Risk to emergency management and policing from climate change	Emergency management and policing (including planning, response, and recovery).	G6

19.2 Funding and public service provision

Climate change presents a range of additional challenges to funding and the provision of public services, which will exacerbate existing challenges. Specific examples are discussed below.

19.2.1 Risk to the ability to fund and maintain public services

In order to continue operating effectively, Councils need to ensure that funding mechanisms are in place. These must provide for growth, operations, renewals, and maintenance across the range of services they provide to communities (including transport, three waters, community facilities, flood control infrastructure etc). The ability to fund and maintain public services may be at risk as climate hazards increase damage and maintenance costs, reduce levels of service, and potentially lead to renewals being required earlier than planned.

The increasing funding pressures likely to result from climate change can be likened to the impact of the COVID-19 crisis on Christchurch City Council's finances. While Council is recovering from this, it has been forced to make savings to reduce operational spending, and reprioritise its capital works programme, while also increasing borrowing. The council is mindful of the need to support the city's recovery without putting too much added financial pressure on residents and businesses (CCC, 2021).

Increased pressures on council funds will create challenges for decision makers in determining priorities. For example, councils will need to balance increasing costs, with consideration of income from taxes and rates, while maintaining public service quality and coverage. This challenge is exacerbated by evolving community expectations and priorities as climate impacts and risks become increasingly evident. What people are willing to pay for during an emergency is different to what they will support under 'normal' circumstances. This can be seen through increased support for additional (alternate) transport routes, which is often only gained after severe disruption is caused to communities by failure of the primary (and only) access route. Examples of this type of investment occurred following the June 2021 flooding in Canterbury, and the 2016 Kaikōura Earthquake.

Delivery of some critical services is highly dependent on strong governance and management to maintain continuity of supply. These include reticulated services such as water and wastewater, which are connected in networks across communities. This makes them particularly sensitive to disruption, as breakages in critical locations can have widespread impacts for users. Responsibility for service operability is held by the local authority, who must carefully manage and maintain all aspects of these systems to ensure an appropriate level of service. The capacity for councils to manage these systems may come under increasing pressure during both long term events related to climate change (e.g. drought), and event based or sudden hazards (e.g. floods, severe storms), where service disruption amplifies other pressures faced during response and recovery. Damage and disruption to services can have significant impacts on communities, who are reliant on these services and have no alternative options.

19.2.2 Reduced access to insurance

The ability to access insurance may be at risk as a result of climate change. As risks related to climate change become clearer, insurers will likely adjust their products. This is likely to result in higher insurance excesses and premiums, or unavailability of insurance altogether (Storey et al., 2020). Council owned assets, property owners and lenders are all likely to be impacted by changing insurance premiums or insurance retreat (Reserve Bank of New Zealand, 2018).

Many public assets are insured for damage for larger events; however, frequent or regular damages are typically not insured, with repairs funded under Council operational budgets. The reduced availability of insurance may widen the gap between damages that Councils cover through operational budgets, and those covered by insurance. Where insurance is still available, the effects of climate change may also impact on premiums, insurability and reinsurance (and wider underwriting).

With increased risk from climate change, mortgage access for homeowners may also be affected. The misalignment between insurance and mortgage timeframes exacerbates risk to homeowners. Most insurance contracts are renegotiated annually, yet mortgage timeframes can be decades. It has been reported that some insurers in New Zealand have begun adjusting their products and pricing to reflect emerging climate risks. Some existing properties could ultimately become uninsurable. While this supports the efficiency and stability of the insurance sector, it poses widespread challenges for society. The flow on effect of insurance impacts on mortgage access for homeowners may consequently impact their ability to pay rates, turn putting significant stress on wider communities.

The occurrence of insurance retreat and/or managed retreat is expected to increase with increasing exposure to coastal hazards (Storey et al., 2020). Reduction in insurance could lead to cost transfer of uninsurable property to councils. Similar cost transfer occurred in the Red Zone following the Canterbury Earthquake Sequence (commenced 2010), where homeowners were given the option to sell their homes to the Crown at 2007 rating valuations (Noy, 2018).

19.2.3 Risk to the ability to fund climate adaptation

Councils are likely to face an increasing need for climate adaptation funding to develop climate resilience within Canterbury's communities. Climate change presents significant future risks that are generally beyond the typical planning horizon for many Councils. Councils raise much of their funding through rates, investments, fees and charges, and borrowing. Central government also provides some funding or subsidies towards particular activities.

Canterbury regional and local councils face significant and increasing costs to respond and adapt to climate change, in relation to both infrastructure adaptation, and supporting community adaptation. In particular, Canterbury has been identified as having the highest exposure of infrastructure assets to sea level rise (LGNZ, 2018).

Council's levels of funding are effectively linked to their rating base and borrowing limits. These are already stretched to cover current and mid-term issues, and do not necessarily include the investments required to adapt to climate change. Some retrospective contribution is available from government for severe natural hazard impacts on infrastructure (i.e. an 'essential infrastructure recovery programme'), but this is not available for preventative adaptation works which would reduce damages from extreme events (Boston & Lawrence, 2018).

Existing funding structures do not provide for equitable distribution of climate adaptation costs across the population, or intergenerationally (Boston & Lawrence, 2018). Further clarity is needed on how funding may be made available to address adaptation planning, particularly in a way that avoids exacerbating existing or creating new inequities. Additionally, lack of clarity on the responsibility for, and source of, funding for adaptation may result in inaction. Some existing examples that may provide guidance on how adaptation funding challenges may be overcome. For example, small-scale adaptation funding is currently in place for flooding within the region. The experiences from the Ōtautahi/Christchurch Residential Red Zone (RRZ) may also be used as an example of how retreat may be managed.

19.3 Effectiveness of rules and policies, jurisdictional boundaries and election cycles

Risks to governance include those relating to the adequacy and effectiveness of planning rules and policies, exacerbation of the challenges associated with different jurisdictional boundaries, and the impacts of short election cycles.

19.3.1 Risk to the effectiveness of planning rules and policies

Current planning objectives, rules and policies are, generally speaking, inadequate and ineffective in dealing with effects of climate change. They therefore require review, alignment and updating. There is a risk that this does not occur, or does not occur in a timely manner, and in turn exacerbates the effects of climate change. There is further risk that should existing planning rules and policies not accurately reflect the risks from climate change, development or funding using these rules and policies may contribute to maladaptation.

Climate risk reporting is becoming standard practice in both the public and private sectors, and elsewhere. This creates an increasing opportunity to address climate risks and support adaptation. It also presents a risk of misalignment in understanding of and management of climate risk between central government, local government, and other sectors. This can be mitigated by developing planning and policies that facilitate co-ordination at different levels.

At a national level, Aotearoa New Zealand's policy frameworks as they currently stand are poorly equipped to address the nature, magnitude and duration of the problems posed by climate change. Issues include currently restrictive legislation under the Resource Management Act (RMA), and poor alignment of policies and legislation/statutes relevant to the effects of climate change. This results in little coordination or alignment of priorities (Boston & Lawrence, 2018; Climate Change Adaptation Technical Working Group, 2017; Lawrence, 2016; Lawrence, 2015; Hana et al., 2018). Action is being taken by central government to improve the RMA process, this includes consideration relating to the impacts of climate change.

Relevant statutes include but are not limited to the following:

- The Resource Management Act 1991 (RMA). To be repealed and replaced with:
  - The Natural and Built Environments Act (NBA), which as the main replacement for the RMA, aims to protect and restore the environment while better enabling development;
  - The Strategic Planning Act (SPA), which requires the development of long term regional spatial strategies to help coordinate and integrate decisions made under relevant legislation; and
  - The Climate Adaptation Act (CAA), to address complex issues associated with managed retreat.
- The New Zealand Coastal Policy Statement 2010 (NZCPS).
- The Climate Change Response (Zero Carbon) Amendment Act 2019.

- The National Policy Statement on Urban Development 2020 (NPS-UD).
- The Local Government Act 2002 (LGA).
- The Soil Conservation and Rivers Control Act 1941.
- The Civil Defence Emergency Management Act 2002.
- The Building Act 2004.

As an example of misalignment, the Building Act requires a 50 year design life, with no explicit consideration of climate change effects. Meanwhile, the NZCPS uses a timeframe of at least 100 years, and for infrastructure plans, the LGA requires planning for only 30 years. There is also an emphasis on short term planning over long term planning, such as the need for councils to only work under 10 year long term plans or 30 year infrastructure strategies (Climate Change Adaptation Technical Working Group, 2017; Boston & Lawrence, 2018).

The impacts of climate change may also expose or compound problems relating to planning rules. For example, under the NPS-UD rules, there is a requirement that 'significant' plan change requests be considered by councils. This raises the potential for development to override planning boundaries that have been developed to account for natural hazard risk (among other things). Further, climate change is likely to place increasing pressure on Canterbury's resources. Existing planning structures relating to these resources, such as existing use rights for water allocation and land use, may impact the Region's ability to undertake a coordinated approach to climate adaptation. The projected increase in drought and seasonal changes are likely to increase demand for water, and reduce availability (as discussed in Sections 10.4, and 10.5). This will place further pressure on water management catchments that are presently at their allocation limits. Equitable allocation of water may require councils to revisit some existing use rights, particularly in upper catchments that feed into downstream catchments.

19.3.2 Risks relating to the misalignment of jurisdictional boundaries

The many challenges that climate change may bring to governance agencies are likely to exacerbate existing issues, including misalignment of jurisdictional boundaries. During the workshops, examples were identified relating to health and social services, and emergency services.

Different jurisdictional boundaries of councils and public agencies (such as those for District Health Boards relative to other agencies) can make integration between social service agencies difficult. There is a current lack of clarity relating to the roles and responsibilities of existing agencies, particularly between different jurisdictional boundaries. Climate change is likely to increase demand for these services, which will exacerbate existing difficulties. This may undermine processes to provide wellbeing support to those who need it, resulting in increased inequities.

Differences in organisational structures and reporting between public services may also worsen communication issues within emergency services. For example, regional representatives of police and ambulance report to and are directed by national headquarters. In contrast, Civil Defence, District Health Boards and local government report to and are directed locally within the region. Differences in structure and channels of communication mean that different information and processes may be followed under a state of emergency, even when all agencies are operating in the same geographic area. As event based or sudden hazards such as floods and storms occur more regularly, this may lead to increased communication issues between public services and with affected communities.

Increasing climate change risks and effects may ultimately threaten organisational sustainability as agencies struggle to manage increasing climate challenges. The need for long term consistency of governance may lead smaller agencies to amalgamate across different jurisdictions, to gain efficiencies in both cost and institutional operations. While integrating approaches between different localities to tackle seemingly common problems may create efficiencies, it may also result in reduced granularity of knowledge and evidence to support action at a local level, and may inadvertently undermine local values.

Current action at central government level may create a jurisdictional risk through misaligned climate risk management at a local level, due to lack of guidance or mechanisms for the integration of national climate risk assessment and adaptation planning at a local scale. This further highlights the importance of achieving coordination between local governments and central government.

19.3.3 Risks relating to short election cycles

Timescales relevant to the governance of climate change issues do not align well with election cycles. Actions to address the effects of climate change require planning over timeframes that span decades and centuries. The short terms of local and national election cycles may impact on the ability to develop and implement consistent plans and strategies to mitigate and adapt to climate change. Cyclic changing of governance can disrupt policies that require multiple election cycles to be effective.

Processes to reduce this risk have begun at a national level through the Climate Change Commission, however, further action to embed climate action is also required at local government level.

19.4 Legal liability, reputation and decision-making

Risks to governance include those relating to legal liability, reputational damage and effective decision making.

19.4.1 Risks relating to legal liability

Climate change presents legal liability for councils and public agencies. Its evolving nature is introducing new responsibilities, and public opinion on how climate change should be managed is quickly evolving. This rapid change introduces risks to governance, as demonstrated elsewhere in New Zealand. Some recent examples include:

- The Hauraki Coromandel Climate Action group, which recently took legal action against the Thames-Coromandel District Council over its decision not to sign the local government climate change declaration.
- Nelson City Council, where Lawyers for Climate Action and local community groups have expressed concern over a decision to construct a new Library adjacent to the Maitai River. They claim the decision may breach both the Local Government Act 2002, and the Council's own commitments under its Declaration of a Climate Emergency.
- Lawyers for Climate Action in Auckland are challenging the construction of a new highway, due to its potential impact on carbon emissions.

Hodder (2019) in his report for LGNZ, canvassed a wide range of potential climate-related legal issues for local government. He found that *"Without the appropriate national standards and legislation, the government is at risk of allowing a situation where the courts will develop legal rules, which would likely result in ever-changing requirements and tensions that would hinder proper planning and implementation of adaption measures."*

The report also found that without clearer direction from central government, "*increased climate change litigation has potential to consume councils' - and ultimately ratepayers' – resources and time, which would be better spent on ensuring the well-being and prosperity of their communities*."

As local government becomes aware of increasing risks from climate change, they may also be exposed to liability for inaction. There is also risk related to decisions based on rapidly changing information under high levels of uncertainty, over long timeframes, using emergent risk assessment methods, tools and decision supporting information. Decisions related to climate change are generally subject to some or all of these constraints. While they may be considered the best available information at the time, but ultimately be viewed as sub-optimal.

Councils should strive for a full knowledge of liability through understanding of risk, across all levels of governance. This may include ensuring good communication and transparency of information between central and local government, together with a climate risk management framework which supports aligned, robust decision making at all layers of government.

19.4.2 Reputational risk

Canterbury Regional Council demonstrated its commitment to taking action on climate change by declaring a climate change emergency in 2019. Since then, a program of work has been implemented. This assessment is part of that program.

In general, there is a strong community interest and desire for action, however this will vary significantly between individuals. As climate risks and damages grow, there is a risk that public opinion will shift. "Climate emergency" language implies immediate action, which may lead to increased frustration within the community over lack of visible progress. The ability of councils to be able to react quickly may play a significant role in an increased reputational risk. The Office for the Auditor General is also closely monitoring Council actions relative to their commitments, following widespread deferral on action in 2018 Long Term Plans (OAG, 2019).

19.4.3 Risks relating to effective decision making

Alongside the potential for legal liability, ineffective and poorly aligned decision making could lead to increased risk and maladaptation. Navigating climate change risk management, adaptation and mitigation is extremely complex, for which much of local government does not currently have appropriate tools or capability. Some guidance is available, for example the Coastal Hazards and Climate Change Guidance (Ministry for the Environment, 2017), and A Guide to Local Climate Change Risk Assessments (Ministry for the Environment, 2021). However, further tools and guidance will be required to help address the complexities relating to climate change adaptation. This will include support to ensure a holistic approach is applied, and that decisions are not made in isolation.

Avenues for communication on climate change issues between local authorities within Canterbury are well established. The Mayoral Forum's Canterbury Climate Change Steering Group (CCSG) provides a forum for discussion of Region-wide governance issues. This forum is valuable to governance at a local government level, but is limited in scope as there is no systematic mechanism to engage or collaborate with other sectors on climate change.

The Greater Christchurch Partnership (GCP 2050) initiative has also been established to connect agencies with significant governance roles in the Greater Christchurch Region. Participating agencies include Environment Canterbury, Te Rūnanga o Ngāi Tahu, Canterbury District Health Board, Christchurch City Council, Waimakariri District Council, Selwyn District Council, Waka Kotahi New Zealand Transport Agency, and the Department of Prime Minister and Cabinet (Greater Christchurch Group). The GCP 2050 will help inform development of partners' long term work programmes and budgets, in order to recover from the impacts of COVID-19 and position the area for a prosperous, inclusive, sustainable and resilient future. The initiative provides an opportunity to engage the community on values and priorities related to climate change, and to inform integrated response planning across relevant agencies. However, it does not yet have a strong focus or mandate to progress with this aspect.

Decision making regarding flood and water management within the region is also complex, and includes local committee oversight, as well as scheme, district and regional considerations. Specific roles and responsibilities are potentially unclear – particularly in terms of ensuring water supply and infrastructure resilience under increasing exposure to drought, flooding and other hazards.

19.5 Co-governance (including Te Tiriti Partnerships)

Climate change presents risks relating to co-governance (including Te Tiriti (Treaty of Waitangi) Partnerships), which will require innovative, coordinated solutions to manage. In addition to the importance of honouring Te Tiriti o Waitangi (the Treaty of Waitangi), partnership with Māori may support the development of integrated adaptation planning by drawing on the holistic perspectives of Te Ao Māori.

Broad and profound differences in the nature of and approach to governance between Māori and non-Māori are at risk of being exacerbated by the impacts of climate change. This may result in departure from existing or planned co-governance structures, and may risk voices being lost or marginalised.

Māori communities at an iwi or hapū level are already identified as having greater socio-economic disadvantage. They may be further disadvantaged through any loss of representation within governance structures. Within the Region, there has been significant investment by Māori in climate-sensitive industries (e.g. forestry, dairying, and fisheries), making their ōhanga (prosperity) vulnerable both to climatic changes, and to broader decisions taken within those sectors.

Within Canterbury there is currently a relatively strong relationship between local government and Ngāi Tahu. Iwi partnership and involvement in the climate change risk assessment has been an important step to identify risks that are of relevance to their hapū. Further establishment or leveraging of co-governance partnerships within governance structures (e.g. with mana whenua (those with territorial rights to the land), youth, etc) are likely to support action to address climate change matters.

19.6 Emergency management and policing

The impacts of climate change are likely to place increasing demands on existing emergency management and policing services. The increasing frequency, severity, and nature of natural hazard events will demand more time from staff, and existing systems and resources may not be adequate. Funding for improving emergency management capability and capacity is also limited. When the capacity of emergency services is exceeded, this places additional demands on Council business-as-usual services. Climate hazards are also likely to impact on the capacity of communities to recover, as increasing frequency and/or severity of events, or repeated events, may make recovery difficult.

The effectiveness and coordination of emergency services planning is also at risk from increasing climate change. As discussed in Section 19.3.2 above, the handover of governance during a declared emergency to a regional Controller can cause uncertainty and confusion in responsibilities.

A further risk to emergency services planning is that the regional response to the National Disaster Resilience Strategy duplicates or misaligns with the outcomes and actions relating to this Regional Climate Change Risk Assessment.

20 Interacting Risks

The impacts of climate change will not occur in isolation, with risks interacting and propagating through systems, creating multiple pressures across value areas (Pescaroli & Alexander, 2018). Given the nature of this assessment, the term *interacting risks* has been used to represent the broad categories of indirect, cascading, and second order risks.

There can be feedback loops and complex interactions between risks due to broader systemic changes, for example, as a response to government policies or concurrent events. The connections and interdependencies mean that these effects occur across sectors and values, and can be felt across communities, governments, and the private sector (Lawrence et al., 2018). Interactions of risks were mapped during early engagement activities such as the domain focused workshops. Analysis was done using the NCCRA value domains, and, while it is indicative only, and strongly dependent on those participating, Figure 20.1 provides an initial picture of the types of interactions that can be seen across risks. The strongest interactions are visible with the largest segments for each risk, and include interactions with agriculture, houses and buildings, cultural identity and practices, community cohesion, and resilience to name a few. The interactions intersect both within and beyond domains, with the complexity of interactions demonstrating how individual climate change risks cannot be viewed in isolation.

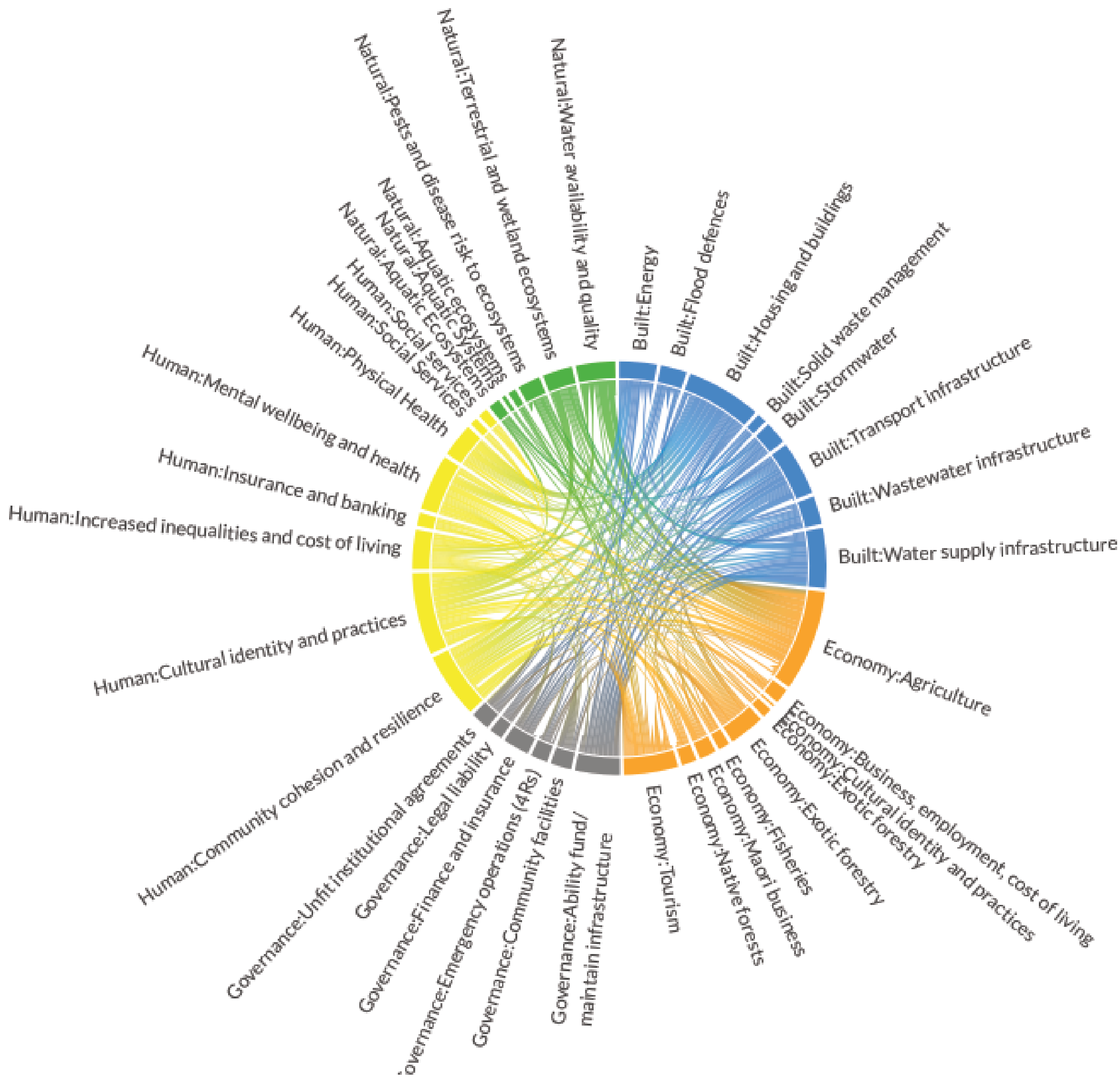


Figure 20.1: Interacting risks (chord) diagram – noting that this has been produced based on participant outputs throughout engagement activities for this project, and therefore relate to the NCCRA value domains. The connections depicted reflect a sub-set of the Region, and as such should not be relied upon.

20.1 Methodology

Following detailed analysis of the priority risks, we also looked to identify how these risks interrelate with each other. This was initially achieved by looking at the level of interconnection, or interrelationships, between each of the priority risks, within the five NCCRA value domains. Completed during stakeholder engagement, participants were asked to connect priority risks to each other, demonstrating a strength of connection. Given that all risks have some level of connection, participants were asked to focus specifically on those connections they felt were most prominent, or noteworthy.

Beyond this, five case studies, chosen by participants, were taken forward to consider interactions across differing risks. These case studies are reference points to enable development of interactions, and may not denote risks in their own right. The five case studies are:

- Electricity outages.
- Community flooding.
- Mahinga Kai.
- Tourism.
- Heat-stress related illnesses.

To assess interacting risks, a qualitative approach was used, involving both stakeholder consultation and a literature review. In the interacting risks engagement workshop, an activity was undertaken using bow-tie analysis principles. Bow-tie analysis allows for visualisation and depiction of direct 'upstream' and 'downstream' risks, often referred to as 'causes' and 'effects' respectively.

The bow-tie analysis and related literature review summarises the following information on the selected interacting risk case studies:

a Climate hazards.

b Upstream drivers related to climate hazards.

c Upstream external factors which can act to compound risks.

d Downstream impacts.

The results of this analysis are captured below.

20.2 Electricity outages case study

20.2.1 Context

The provision of electricity is a lifeline service in the Canterbury Region. A continuous power supply is critical for the functioning of modern society and economic activity. Power outages can be caused at different points in the electricity network, including power stations, distribution lines and substations, and transmission lines. Outages can create cascading risks which propagate to other value areas.

Changes in climate could lead to a risk of increased incidence and duration of electricity outages. As discussed in Section 10, this is due to electricity infrastructure being exposed to increased fire weather, extreme weather events (e.g. wind and storms), temperature rise, coastal erosion, and sea level rise. Distribution and transmission infrastructure located near vegetation is also highly sensitive to extreme wind and storm events, as vegetation may damage the lines. Electricity infrastructure also presents a risk to the surrounding environment, as fire may start from sparking infrastructure operating in higher temperatures.

Furthermore, the Canterbury Region has several hydroelectric power stations which would be affected by changes in temperature and rainfall.

The upstream hazards, drivers and external factors and downstream impacts of the risk of increased electricity outages are illustrated in a bow-tie diagram in Figure 20.2.

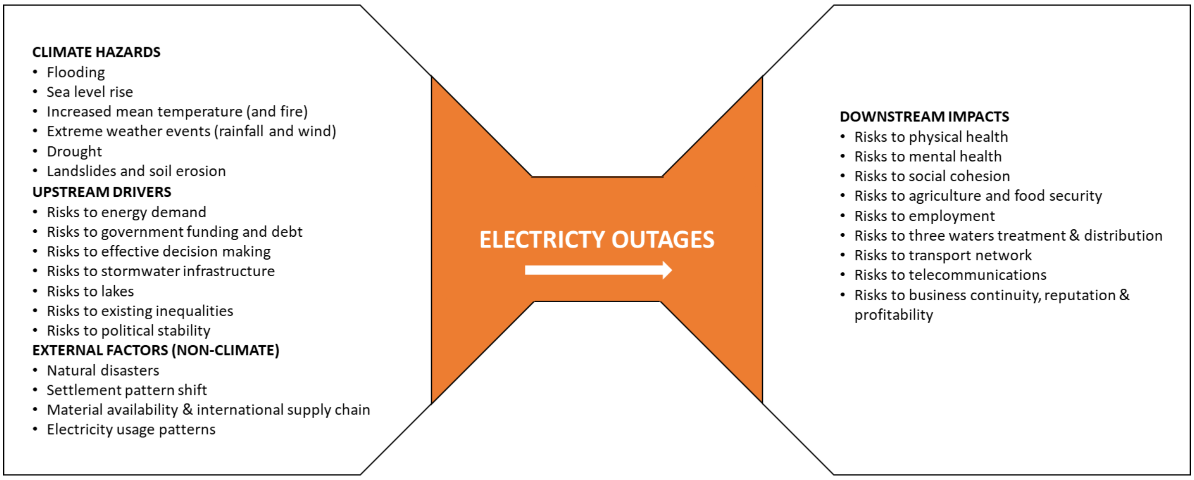


Figure 20.2: Bow-tie analysis of risk to increased electricity outages.

20.2.2 Upstream climate hazards, climate drivers and external factors

The risk of increased incidence of electricity outages can be attributed to a combination of climate hazards and upstream drivers. These may be further exacerbated by non-climatic factors.

Climate hazards which cause risk to increased incidence of electricity outages are further detailed in Table 20.1.

Table 20.1: Climate hazards impacting electricity infrastructure

Climate Hazard	Cause of risk to increased incidence of electricity outages
Extreme weather events (e.g. wind and storms)	• Projected increase of wind speed of 2-10% in 2100 (RCP 8.5 scenario). – Wind and storm events cause objects (such as fallen trees) to be in contact with power lines, causing outage.
Temperature and fire	• Drought potential is expected to increase. • The average temperature is expected to increase by 1.5-3.5°C by 2100 (RCP 8.5 scenario). • Increased temperatures and fires will cause failure and power infrastructure destruction.
Sea level rise and coastal erosion	• 0.8 m of sea level rise is projected. – Low-lying electricity infrastructure is at risk from sea level rise and coastal erosion.
Seasonal rainfall variability and flooding	• There is a projected 15-40% in winter rainfall for many eastern, western and southern parts of Canterbury. – Increased risk of flooding can cause damage to above and below ground power infrastructure.
Landslides and soil erosion	• Projected increase in landslides and soil erosion. – Landslides and soil erosion may cause damage to above and below ground infrastructure.

Electricity infrastructure interacts with several ngā pono (values). Upstream risks that can relate to increased power outages are shown in Figure 20.3. The arrows in the figure indicate that in some cases, there can be a bi-directional relationship between the risks. For example, risks to stormwater infrastructure may cause flooding, potentially leading to risks to electricity outages. The risk of electricity outages can also cause risks to the functioning of stormwater infrastructure, such as pumps.

Figure 20.3: Upstream risks to increased electricity outages. Arrows indicate direction of risk interaction, colours indicate ngā pono (values).

Upstream risks mentioned in Figure 20.3 are across different ngā pono. Table 20.2 provides further details on these risks.

Table 20.2: Ngā pono (values) areas and upstream drivers

Ngā pono (values)	Upstream drivers
Ōhanga | Prosperity	• **Risks to funding** may cause risk of increased incidence of electricity outages. This may be due to inadequate funding allocation available for electricity network upgrades and maintenance to meet the more variable climate conditions. Similarly, increased electricity outages and maintenance of electricity infrastructure may also result in risks to funding availability and allocation, which in turn could lead to increased risk in other value areas.
Hirihiri | Energy	• **Risks to energy demand** from climate hazards, resulting for example, from increased temperatures causing an increase in the use in air conditioning devices (Mideska & Kallbekken, 2010). This may cause surges in the electricity network and can cause unusually high electricity demand, leading to outages. Risks of increased incidence of electricity outages can also cause risks to critical medical customers.
Wai | Water	• **Risks to the stormwater network** from increased rainfall and sea level rise resulting in flooding may cause damage to above and below ground electricity infrastructure. This leads to a risk of increased incidence of electricity outages. • **Risks to lakes** due to an increase in temperatures (affecting runoff from snow and ice) could impact **hydroelectricity generation** in the Canterbury Region (Caruso et al., 2017). This could exacerbate risks to incidences of electricity outages.
Rangatiratanga | Self governance	• **Risks to effective decision making** around asset management, maintenance and operations of the electricity networks due to climate hazards. • **Risks to political stability** from climate hazards may cause delay in asset decisions, causing increased vulnerability of electricity infrastructure to outages.

Climate risks to electricity supply infrastructure have potential to be amplified and compounded by other non-climate factors. These include:

- Changes to electricity usage (due to non-climate reasons, such as technology changes) may also cause unusually high demand, placing stress on the network.
- Natural disasters (such as earthquakes and tsunamis) will exacerbate the risk of increased incidents of electricity outages, as they cause electricity infrastructure to be more vulnerable, or could directly cause an outage.
- A shift in urban development patterns may also cause an increased likelihood in buildings and new vegetation being near existing electricity infrastructure. This can contribute to wind damage, as falling trees or branches may damage lines during extreme events; vegetation also contributes to fire risk.
- Risks to supply chains (especially to the international supply chain links for materials manufacturing and transportation), in combination with increased carbon emissions regulations (Dasaklis and Pappis, 2013), may lead to risks to electricity supply infrastructure maintenance and renewal. These risks could also contribute to increased outage duration, for example, through material shortages and lack of labour availability.

20.2.3 Downstream Impacts

An increase in incidences of electricity outages can cause a wide number of cascading risks, which can propagate into other value areas. Table 20.3 details a range of potential downstream impacts on other ngā pono (values).

Table 20.3: Downstream impacts of electricity outages on ngā pono (values)

Ngā pono (values)	Downstream impacts of increased incidents of electricity outages
Ōhanga | Prosperity	• Electricity asset owners may face **risks to business continuity and profitability** if there is an increased incidence of electricity outages. This could lead to *difficulties in servicing debt, reduced shareholder returns, inability to retain staff* and the *need for increased public intervention* in privately owned electricity infrastructure assets. • There will be **risks to business continuity** as businesses depend on electricity to operate and provide their services. Electricity outages could lead to *reduced supply of goods/services, and for example, food wastage within supermarkets*. There could also be **reputational risks** and **profitability risks** to businesses from disruptions to electricity supplies. • Agricultural business operations are also at risk, leading to **risks to food security and employment**.
Hauora | Physical health	• Increased electricity outages could increase **risks to physical health** through impacts on electrical home medical equipment (Mango et al., 2021), heating and cooling devices, and food preparation and storage equipment. Electricity outages *will be more severe for medically vulnerable households*. • Electricity outages may also lead to **risks to mental health**, especially as a result of physical health impacts and economic losses.
Ora rite | Equity	• **Inequities could be exacerbated**, and **communities could be isolated** due to certain areas experiencing higher incidents of electricity outages. This can also lead to **risks to social cohesion.**
Wai | Water	• There are **risks to the three waters' networks (treatment and distribution).** Although some networks may have backup generators, there are increased risks to continuity in operation and asset maintenance and management.
Ngā Waihanga | Infrastructure services	• There will be **risks to transport infrastructure** (such as trains, trams, traffic lights, level crossing barriers and alerts, and electric vehicle charging), which may cause *disruption and stress to transport networks*. • There will be **risks to the telecommunications network**, as many parts of the network (such as residential fibre) rely on electricity.

The effects to ngā pono (the values) above will also interlink with other risks. For instance, the risk to telecommunications networks from increased outages may result in additional risks to businesses, education, healthcare, community connection, and the provision of public services etc.

Figure 20.4 illustrates an example showing risks of electricity outages to the agricultural sector, illustrating the interrelationships between ngā pono (the values). The effects of these risks to agriculture compound across ngā pono (the values).

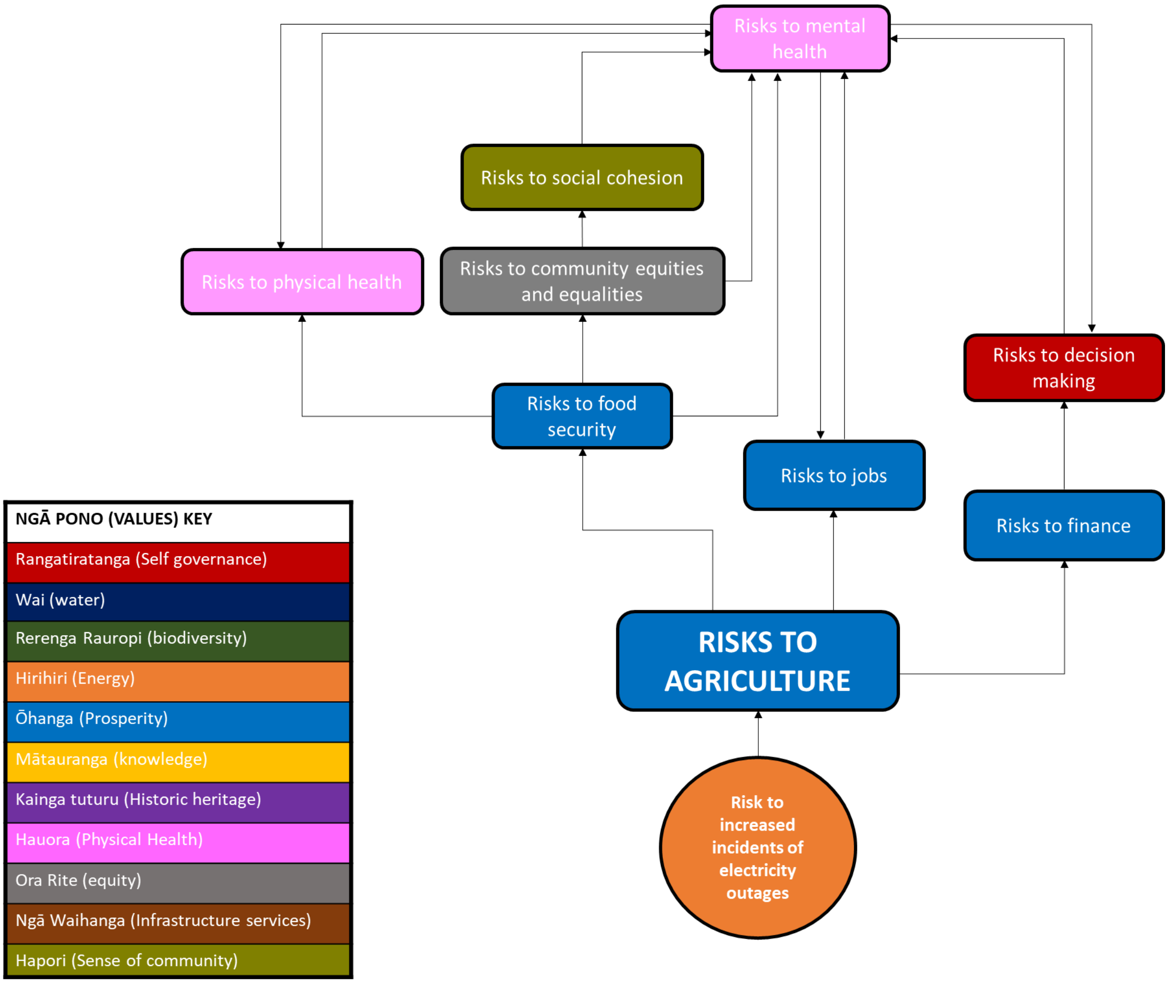


Figure 20.4: Case study of the risks interacting with the risk to agriculture from risks to electricity outages case study

Figure 20.4 shows that electricity outages can cause risks to agricultural businesses, as these operations often depend on electricity, for example, irrigation, milking, milk pasteurising, and milk cooling machines. Although most businesses will have back up electricity generators, duration of generation is limited by the amount of fuel. As a result, risk to food security may be exacerbated as commercial agricultural businesses may struggle to maintain production levels as electricity outages combine with other climate hazards. An inability to maintain production levels may reduce profitability, causing business owners to reduce staff or default on loans for assets. Financial hardship for agricultural businesses may lead to government intervention, causing risk to government decision making. Risk to food security may exacerbate existing inequities and inequalities due to price instability, impacting social cohesion and civil order (UK-US Taskforce on Extreme Weather and Global Food System Resilience, 2015). Negative effects on health and nutrition are also associated with food insecurity (Gunderson and Ziliak, 2015). Risks to mental health are interwoven across all these risks in different ways.

20.3 Community flooding case study

20.3.1 Context

Canterbury faces some of the highest levels of community flood risk in the country, with a high population exposed to surface water and coastal flooding, erosion, and sea level rise (Tonkin + Taylor, 2018; Giberson, 2019). For many of Canterbury's coastal communities, there is a projected increase of exposure to sea level rise towards the end of the century (Paulik, et al., 2019). Exposure to river and surface water flooding is high at present, with mean annual flood flow and extreme events projected to increase over time as a result of climate change. The majority of exposed buildings are in Ōtautahi/Christchurch City, however, Waimakariri and Ashburton also have high exposure levels (Paulik, Craig, & Collins, 2019). Increasingly severe and frequent community flooding risks may result in complex interactions across multiple ngā pono (values).

Figure 20.5: Bow tie diagram showing upstream hazards, drivers and external factors which lead to community flooding risk, and the downstream impacts of this risk.

20.3.2 Upstream climate hazards, climate drivers and external factors

The climate hazards that will directly lead to increasingly severe and frequent community flooding events are increased rainfall and associated river flow increases, extreme weather events, and sea level rise, with associated coastal flooding and storm surges (refer to Table 20.4).

Table 20.4: Climate hazards impacting community flooding

Climate Hazard	Description of climate hazards impacting the risk of community flooding
Extreme weather events (e.g. wind and storms)	• Projected increase of wind speed of 2-10% in 2100 (RCP 8.5 scenario): – Extreme weather events can contribute to storm surges and coastal flooding.
Sea level rise and coastal inundation	• 0.8 m of sea level rise is projected: – Coastal communities are at risk due to sea level rise, and associated coastal flooding and storm surges.
Seasonal rainfall variability and flooding	• There is a projected 15-40% in winter rainfall for many eastern, western and southern parts of Canterbury: – Increased risk of surface water and river flooding for communities.

Increased community flooding events are also driven by *upstream* risks, as these can cause, amplify, and exacerbate flooding impacts, as well as by *compounding* risks from multiple climate hazards, which exacerbate and amplify the risk posed by climate change. For instance, coastal communities may be impacted by both sea level rise and surface water and river flooding simultaneously. Existing conditions may also increase impacts, for example the projected increased number of dry days may result in reduced permeability of soil.

The interactions between community flooding with other ngā pono (values) is shown in Figure 20.6 and detailed in Table 20.5.

Figure 20.6: Upstream risks to community flooding. Arrows indicate direction of risk interaction, colours indicate ngā pono (values).

Table 20.5: Upstream risk drivers

Ngā pono (values)	Description of upstream risk drivers
Wai | Water	• **Risk to flood defences.** The Region's communities are protected by a network of flood defence assets, including stopbanks and pump stations, and coastal barriers and sea walls, which are vulnerable to deterioration and degradation as a result of climate hazards. In addition, flood defence assets that were designed for historical flood levels will be subject to more overtopping events, and therefore reduced levels of service. • **Risk to stormwater systems**. Community flooding risk may also be exacerbated by undersized or poorly designed stormwater systems, blockages due to debris, or increased sedimentation of stormwater pipe networks, which is itself caused by climate-related factors including increased incidences of community flooding and further sedimentation in rivers.
Rerenga Rauropi | Biodiversity	• **Risk to coastal wetlands.** Flood risk in coastal communities may be exacerbated by a loss of coastal wetlands, which can provide flood protection services (Narayan et al, 2017). • **Risk to terrestrial native biodiversity.** Loss of terrestrial native biodiversity in flood plains, especially trees and vegetation along rivers, could also result in increased community flooding events in both rural and urban communities across Canterbury (Dixon et al, 2016).
Rangatiratanga | Self governance	• The **risks to institutions and governance frameworks** could also result in an increased risk of community flooding. Key risks include impacts on running and maintaining public services, particularly flood defence mechanisms, and poor availability of climate adaptation funding.

Community flood risk in the future will be primarily driven by climate change, but flood risk will also be influenced by external factors such as land use changes and urban development. For example, a focus on increased urban density (through a range of market and policy drivers), has the potential to increase the population and assets exposed to flooding. Future development of greenfield areas may also contribute to increased flooding risk, as these will reduce the permeability of catchments and thereby increase flood risk.

20.3.3 Downstream Impacts

As shown in Table 18.6, risks as a result of community flooding will have downstream impacts on a number of ngā pono (the values).

Table 20.6: Downstream impacts

Ngā pono (values)	Description of downstream impacts
Wai | Water	• **Risk to water supply infrastructure** from community flooding could include contamination of drinking water sources, particularly in rural communities (MfE, 2020). Potential drinking water contamination could lead to health impacts. • **The risk to wastewater infrastructure** could be amplified by coastal and inland flooding, which could result in reduced performance, damage, and overflows (White et al, 2017). The exposure of communities to wastewater could result in poor health outcomes.
Ngā Waihanga | Infrastructure services	• **The transport system is at risk** due to increasingly severe and frequent community flooding events, which could result in damages to roads, bridges and vehicles (Pregnolato et al, 2017). Frequent and severe flooding could also lead to reduced access to public services, including emergency services, particularly for

Ngā pono (values)	Description of downstream impacts
	rural communities. In the 2021 floods in Canterbury, access to a number of communities was disrupted (Stuff, 2021).
Ōhanga | Prosperity	• Increasingly frequent and intense flood events could result in **risks to financial stability**. Communities at high risk may experience house price devaluations and difficulties accessing insurance, which could result in home loan defaults (Lawrence et al, 2016). Extreme flooding events could impact the financial robustness of banks, and other systemic economic consequences (Klomp, 2014).
Hauora | Physical health	• Increased incidence of community flooding may increase **the risk to community cohesion**, particularly if people are required to move away from their communities (MfE, 2020). Impacts on community cohesion could result in reduced resilience and adaptive capacity, which could further amplify community flood risk (Jakes and Langer, 2012). • Community flooding may result in a **higher risk of poor mental health outcomes**. This could as a result of mental trauma from experiencing flooding, and long-term psychological distress from associated social and economic impacts (World Health Organization, 2019). • Community flooding events will result in **risks to physical health** through potential injury and mortality, and reduced water quality and other impacts on health determinants (Royal Society | Te Apārangi, 2017; MfE, 2020). Impacts on health services, such as disruption to roads, could also result in increased risk to physical health. • Damaging flood events could amplify **the risk to increased inequality and cost of living**, particularly for communities with high rates of socio-economic deprivation. Inequality could be increased as households with more economic resources may voluntarily relocate to less exposed communities (MfE, 2020).
Rangatiratanga | Self governance	• Increased community flooding could result in **increased legal liability of regional and territorial authorities**. Councils may face increased litigation from households that incur costs due to a variety of factors including: the lack of, inadequacy of, or failure of flood management infrastructure (e.g. defences), or the provision of flood hazard information that property owners feel is overly conservative. Local authorities in New Zealand have previously faced lawsuits from households seeking compensation for flood damage (RNZ, 2017). • There are range of other governance risks that may result from increased community flooding (MfE, 2020): – There could be increased risk to decision making processes, as present day central and local government regulatory and policy frameworks are insufficient for managing climate risks and implementation of adaptation actions. – Increasingly severe floods may also result in **risks to planning rules and policies**, as present frameworks characterise risks as static and rely on historical parameters. – Financial impacts on councils from increased community flooding may result in **risks to the ability to maintain and run public services**. – Impacts on transport networks may increase the **risks to emergency management and policing**, and reduce community access to these services.

As outlined in Table 20.6, there are complex interactions between and across risk frameworks that need to be understood and managed. A case study of these interactions is also illustrated in Figure 20.7, which shows the impact of community flooding events on housing and the cascading risks that emanate from this interaction. These risks can cascade across the ngā pono (values), impacting communities and the Canterbury Region in a number of ways.

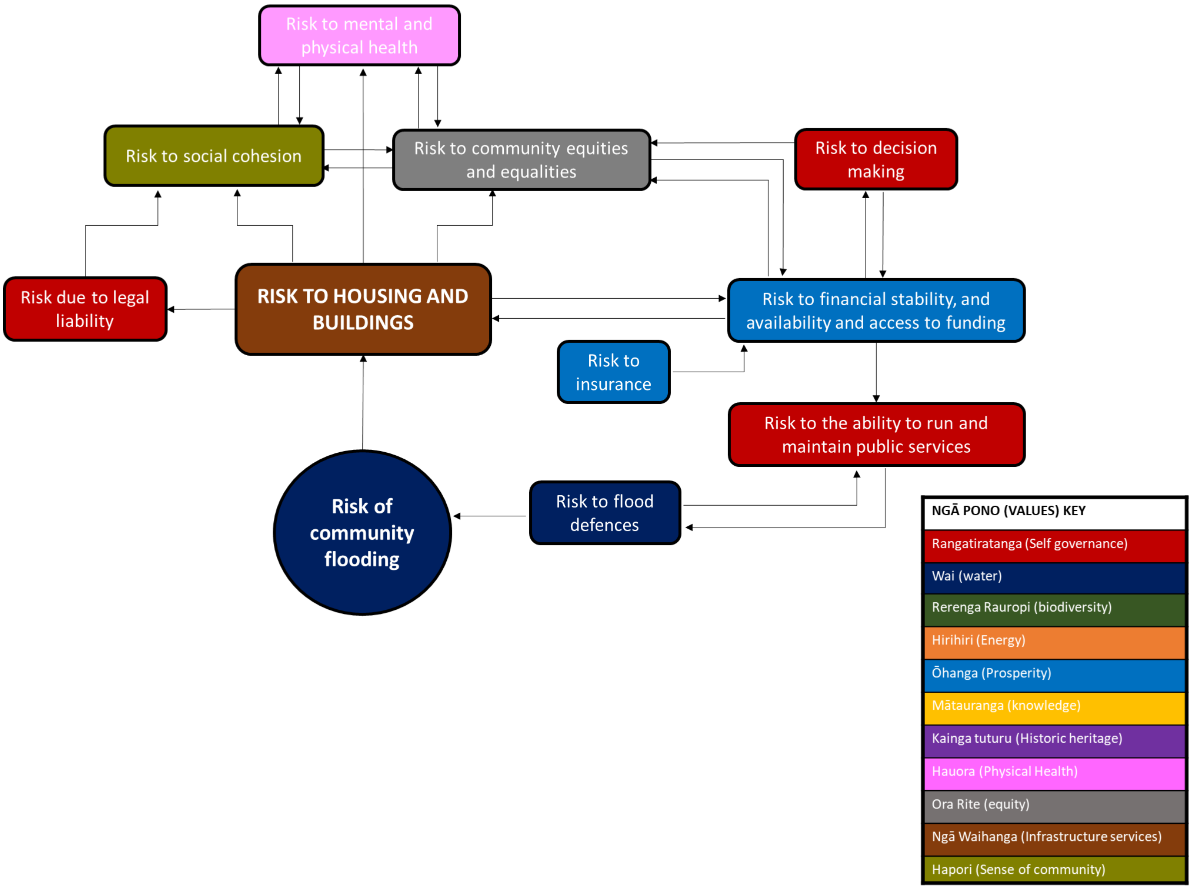


Figure 20.7: Case study of risk interactions with the risk to housing and buildings from the risk of community flooding.

The damage caused to housing from increasingly frequent and severe flooding events could impact on rangatiratanga (governance) through local authorities facing an increased risk of litigation and impacts on the availability of adaptation funding. Adaptation finance will be necessary for responding to flood events and reducing long-term risk, but there may be insufficient funding for maintaining key public services such as flood protection assets. Households may also seek compensation for flood damage. These risks may impact on decision making as the roles and responsibilities of central and local government may require clarification (MfE, 2020).

Increasing flood risk in communities could also result in insurance impacts. High-risk areas may experience insurance retreat, which would result in financial impacts on households and the broader financial system (Lawrence et al, 2016). Major flooding events could also result in impacts to the insurance sector, which could include distress or failure of insurance companies (French et al, 2015).

The risk to housing and buildings from community flooding could also lead to cascading risks across the Hapori ngā pono. Damaging flood events could result in reduced social cohesion and impacts on vulnerable communities, which may result in poor mental and physical health outcomes (Brydsten et al, 2018; BERL, 2020). Impacts on social cohesion will also result in a number of cascading risks to governance and economic frameworks, which are not assessed in Figure 20.7. Lastly, there may be *direct* impacts on mental and physical health, such as the trauma associated with extreme flood events (World Health Organization, 2019).

20.4 Mahinga kai case study

20.4.1 Context

Te toto o te tangata, he kai; te oranga o te tangata, he whenua

Food supplies the blood of people; their welfare depends on the land.

Mahinga kai has significant value to Ngāi Tahu. The ability to collect mahinga kai contributes to physical, spiritual, social, and economic well-being. It is important for mahinga kai to be managed and gathered as was done by Ngāi Tahu ancestors. Mahinga kai enables ngā pono (the values) of mana and manaakitanga (respect and hospitality) to be demonstrated, empowering Ngāi Tahu to thrive (Environment Canterbury, 2021). Mahinga kai, or mahinga kai areas, can include species (such as manu (birds), kai moana (seafood), rākau (plants), natural habitats, materials and practices for harvesting food, and places where food or resources are, or were, gathered (Environment Canterbury, 2017).

Due to the connection which mahinga kai has with other values areas, climate risks to mahinga kai can initiate interacting risks that propagate, spread, and influence other ngā pono (values). Risks to mahinga kai can also originate from upstream risks.

Major climate hazards which affect mahinga kai include flooding, sea level rise, increasing temperatures, change in rainfall, fire and drought weather.

The upstream hazards, drivers and external factors and downstream impacts of the risk to mahinga kai are illustrated in a bow-tie diagram Figure 20.8.

Figure 20.8: Bow tie analysis of the risk to mahinga kai.

20.4.2 Upstream climate hazards, climate drivers and external factors

The risk to mahinga kai can be caused by a combination of climate hazards and upstream risks. These can then be exacerbated by non-climatic factors.

Further explanation of how climate hazards (identified in Figure 20.8) cause risk to mahinga kai is detailed in Table 20.7.

Table 20.7: Climate hazards causing risk to mahinga kai

Climate Hazard	Description of climate hazards causing risk to mahinga kai
Sea level rise and salinity stresses	• 0.8 m of sea level rise is projected, affecting coastal ecosystems: – Higher salinity pressures on the coastal margins, eventually leading to the complete loss of coastal margin environments and their associated ecosystems. – Intertidal habitats reduction, leading to the endangerment of species traditionally relied upon for mahinga kai (e.g. Kanakana/Piharau/Lamprey).
Seasonal rainfall variability and floods	• There is a projected 20-40% increase in winter rainfall by 2100 for eastern Canterbury: – Resulting high flows (floods) in Canterbury rivers stressing freshwater mahinga kai species. – Increasing erosion and sedimentation rates from high flows, potentially contributing to river and lake eutrophication and/or shallower waters. – High flows potentially leading to habitat and breeding displacement. – Erosion of urupā on river banks can create a tapu (sacred/prohibited) mahinga kai environment. • There is a projected rainfall decrease of up to 10-15% in inland/western Canterbury and Banks Peninsula in the summer by 2100: – Resulting low flows (floods) in Canterbury rivers stressing freshwater mahinga kai species. – Montane/hill country experiencing increased frequency of low flows. This will cause river temperature rises due to reduced flushing flows, formation of stagnant pools, and shallower waters (Jowett and Richardson, 1989). – Increasing river temperatures affecting the habitats and metabolism of mahinga kai species.
Increase in mean temperature, fire and drought	• Drought potential is expected to increase: – Decline of mahinga kai species in these inland, montane/hill country areas after severe events due to: typically slow self-recovery mechanisms, displacement by exotic species, and habitat loss. • Projected increase in average temperature of 1.5 – 3.5°C by 2100 (RCP 8.5 scenario): – Some mahinga kai water species are sensitive to water temperature changes. Lakes and rivers with less shading will experience the most fluctuation in water temperature.
Decrease in ocean pH	• Surface water pH is projected to decrease by 0.33 under the RCP8.5 scenario. • Acidification from the increase in carbon dioxide uptake from oceans will cause risks to hard shelled mahinga kai species (MfE, 2020).

The interdependencies between mahinga kai and other ngā pono (values) can cause upstream risks to compound. These will impact the availability and accessibility of mahinga kai, for example due to increased exposure and vulnerability to disease, or unfavourable growing or habitat conditions, leading to the decline of species and usability of species as a food/medicine source. Figure 20.9 shows the upstream risks and relationships with mahinga kai.

Figure 20.9: Upstream risks to mahinga kai. Arrows indicate direction of risk interaction, colours indicate ngā pono (values).

As mahinga kai is found in a range of aquatic and terrestrial environments it is exposed to a multitude of risks. Mahinga kai can be found in in alpine/high country, montane/hill country, lowland and coastal, wetland, native freshwater, and aquatic coastal and marine ecosystems. Table 20.8 details the causes of risks to mahinga kai from different ngā pono (values).

Table 20.8: Upstream risks to mahinga kai across different ngā pono (values)

Ngā pono (values)	Description of causes
Wai | Water	• **Risks to wastewater infrastructure** due to excessive rainfall and flooding can cause discharge of poorly treated or untreated wastewater to rivers. This will affect Mauri and subsequently, mahinga kai near these bodies of water.
Kāinga tūturu | Historic heritage	• **Risks to settlements and communities** due to flooding, coastal erosion and sea level rise may displace people, reducing the ability and availability to source mahinga kai as people may be less familiar with the area or unable to get to mahinga kai areas.
Ngā Waihanga | Infrastructure services	• **Risks to roads and bridges** due to increasing coastal erosion, flooding (river and surface water), and sea level rise may cause permanent road closures and may impact the accessibility of certain mahinga kai areas.
Ōhanga | Economy	• **Risks to crops and livestock** due to drought may cause an excessive increase in demand for mahinga kai. Concurrently, the link between these areas mean that an increase in risk to mahinga kai could lead to increase in pressure on the primary industries.
Rerenga Rauropi | Biodiversity	• **Risks to terrestrial, freshwater, and marine pests and diseases** due to higher mean temperatures, mean annual rainfall and reduced snow and ice will cause risk to mahinga kai. This is due to a change in biodiversity, which may impact mahinga kai.

These upstream risks may lead to increased demand, reduced favourable growth conditions, and decreased accessibility, exacerbating the risk to mahinga kai.

Other non-climate factors may also influence and exacerbate risks., these include:

1. Cultural identity – mahinga kai contributes to the cultural identity of Ngāi Tahu. Risks to cultural identity, such as loss of knowledge of mahinga kai through the legacy effects of colonisation, can be a risk to mahinga kai. Conversely, the decline of mahinga kai species and areas may lead to risk in cultural identity and mahinga kai knowledge.
2. Excessive groundwater pumping – this may cause saltwater intrusion, exacerbating the effects of sea level rise and salinity stresses. This may also lead to the stream depletion effect (Environment Canterbury, 2000).
3. Land ownership and land-use planning – this may reduce the availability or the accessibility of mahinga kai.
4. Natural disasters – habitats and planting may be damaged by natural disasters such as tsunamis.

Moreover, as discussed in Section 8, exotic species can exacerbate risks by displacing mahinga kai, where native species are slower to regrow.

20.4.3 Downstream impacts

Risks to mahinga kai will cause interacting risks to propagate across other ngā pono (values) due to the relationships and dependencies between ngā pono (values). Table 20.9 details these risks.

Table 20.9: Downstream impacts of risks to mahinga kai

Ngā pono (values)	Downstream impacts
Hauora | Physical health and wellbeing	• **Risks to physical health** could occur due to an increase in food and water-borne diseases found in mahinga kai. • **Physical health** could also be impacted if accessibility to mahinga kai is reduced due to food insecurity. • There may be **risks to mental well-being and health** due to reduced self-determination and loss of a significant aspect of cultural identity.
Mātauranga | Knowledge	• There may be **risks to cultural identity** due to the potential loss of intergenerational knowledge if it becomes increasingly difficult to find or access mahinga kai (which can cascade to creating risks to mental health). Further risks to cultural identity may arise through the values of manaakitanga (hospitality) and kaitiakitanga (guardianship) as Māori are less able to source mahinga kai to provide for manuhiri (guests) and are unable to active protection for natural resources.
Ōhanga | Prosperity	• There may be **risks to agriculture, horticulture and fisheries** caused by risk to mahinga kai. These increased pressures will also add pressure to infrastructure for the primary industries (such as irrigation, roads and buildings).
Rerenga Rauropi | Biodiversity	• Mahinga kai, biodiversity and biosecurity are closely related and risk to one will lead to risks to another.
Hapori | Sense of community	• **Risks to social cohesion** may occur due to the exacerbation of existing inequities and reduction of natural resources. Sense of belonging may be impacted with reduced accessibility to mahinga kai.
Ora rite | Equity	• **Risks to exacerbating existing inequities** due to a reduction in mahinga kai (leading to food insecurity).

The interaction between mahinga kai and the other areas identified in Table 20.9 is complex. For instance, risks to physical health could be impacted by an increase in water-borne diseases. For communities already experiencing health inequalities, water-borne diseases could create further health issues, which then reinforce these inequalities (Levy et al., 2018).

Figure 20.10 illustrates a case study on the risk interaction between different ngā pono (values) by analysing the effects of the risks to mahinga kai on the risks to Māori cultural identity.

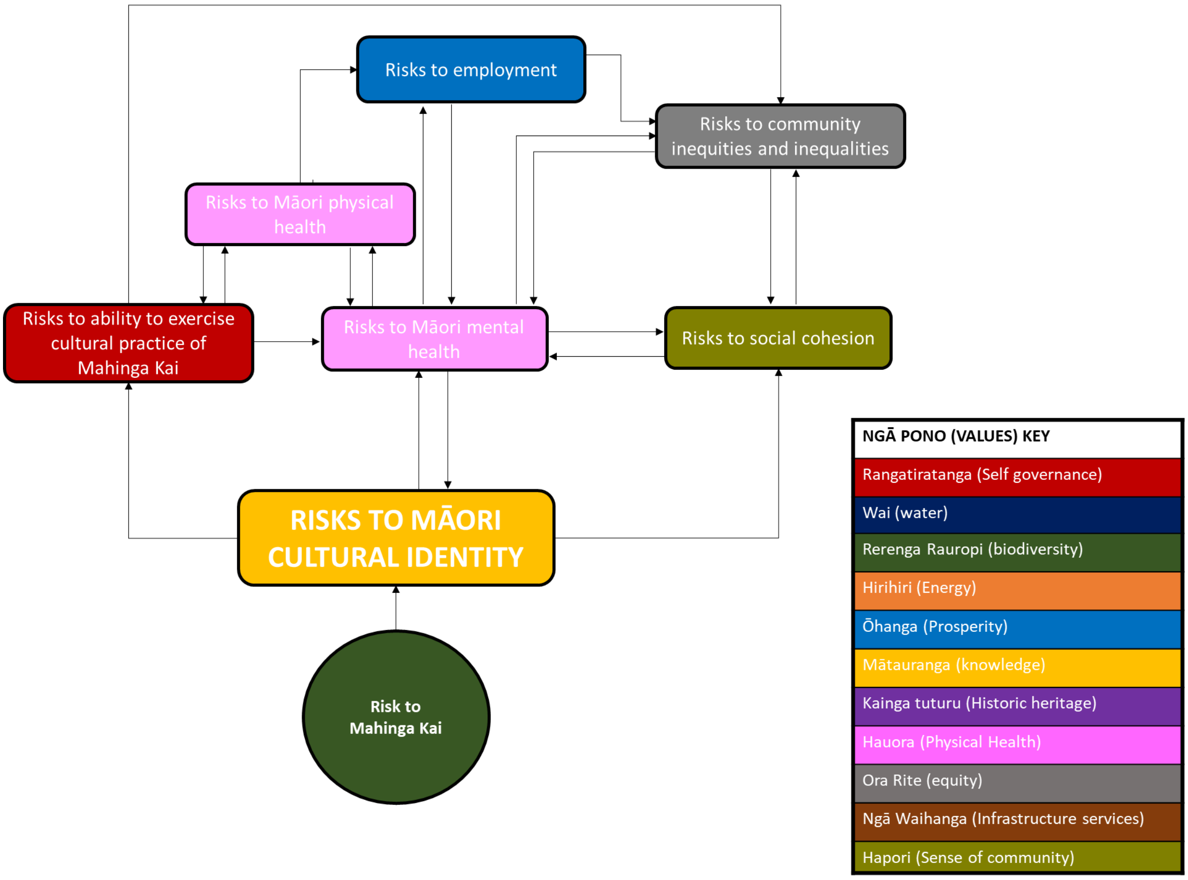


Figure 20.10: Case study of interactions across ngā pono (values) from risks to Māori cultural identity from the risk to mahinga kai

Figure 20.10 demonstrates that risks to mahinga kai can cause risk to Māori cultural identity. In the Te Whare Tapa Whā model of wellbeing, there are four 'walls' of wellbeing – taha wairua (spiritual health), taha tinana (physical health), taha hinengaro (mental/emotional health) and taha whānau (family health). Risks to one of these walls will reduce overall wellbeing. Risks to cultural identity could lead to risks to the ability of Māori to exercise the practice of mahinga kai. Risks to cultural identity are also known to lead to poor mental health (taha hinengaro) outcomes (Williams et al., 2018) and reduced sense of belonging (Shepherd et al., 2017). Poor mental health outcomes can also lead to employment risk, as people may voluntarily or involuntarily leave their employment (Greenwod et al., 2019). It can also result in increased risks to physical health. Poor mental and physical health outcomes not only reduce overall wellbeing (as the four walls are not equal), they can contribute to the exacerbation of community inequities, and also compound mental health risks. For example, inequities are worsened as Māori are less likely to have access to appropriate healthcare (Poulter, 2019). Growing inequities can cause risks to social cohesion (Khambule & Siswana, 2017), which when undermined, can further compound into poor mental health outcomes.

20.5 Tourism case study

20.5.1 Context

Canterbury based tourism spending was over $3 billion in 2020, with Ōtautahi/Christchurch having the highest tourism spending within the Region (MBIE, 2021). The tourism sector is also an important driver of the economy for coastal towns such as Kaikōura, and inland areas including Lake Tekapo and Mt Hutt.

The highest identified climate change risks to tourism include those from reduced snow and ice, sea level rise and associated coastal flooding, and river and surface water flooding. Alpine tourism sites, such as the Mt Hutt Ski Area, are highly sensitive to warming temperatures. This is expected to lead to a reduced snow base and changing natural landscapes. Tourism destinations along coastal areas such as Akaroa, Banks Peninsula, and Kaikōura are at risk due to ongoing sea level rise, and associated coastal flooding and erosion. Tourism attractions and operations in lowland and riverine areas are also at risk from increased flooding.

The upstream hazards, drivers and external factors and downstream impacts of the risk to tourism are illustrated in a bow-tie diagram Figure 20.11.

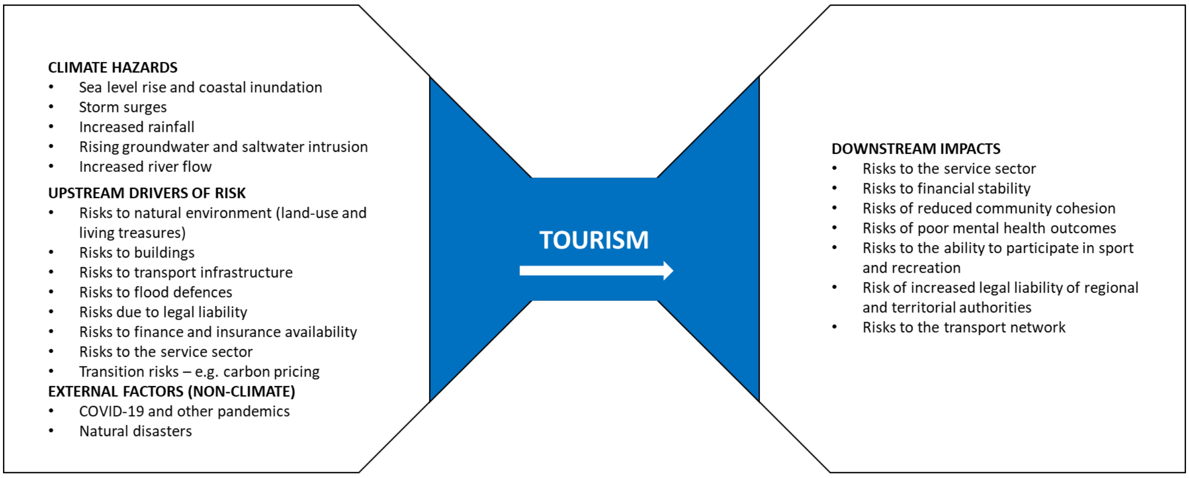


Figure 20.11: Bow tie diagram of the risk to tourism.

The climate risks faced by the tourism sector may result in complex interactions across the ngā pono (values) in the integrated framework.

20.5.2 Upstream climate hazards, climate drivers and external factors

The primary climate risks to the tourism sector are from reduced snow and ice, river and surface water flooding, and coastal flooding. Temperature increases will result in particularly high risk to alpine areas, which are expected to face rising snow lines and glacial retreat, more frequent hot extremes, and increasing extreme weather events. Reduced snow will impact on winter tourism operations, especially skiing and glacier tourism. Tourism activities, assets and infrastructure are also at risk due to river and surface water flooding, and coastal flooding.

Table 20.10: Climate hazards impacting tourism

Climate Hazard	Cause of risk to increased incidence of power outages
Temperature	• Reduced snow and ice will impact ski fields and alpine tourism.
Sea level rise and coastal erosion	• 0.5 – 0.7 m of sea level rise is projected. • Coastal tourism sites, assets and operations are risk.
Seasonal rainfall variability and flooding	• There is a projected 20-40% increase in winter rainfall by 2100 for eastern Canterbury • Inland tourism sites, assets and operations are risk due to surface water and river flooding.

The tourism sector may also be impacted by compounding risks from multiple climate hazards, which exacerbate and amplify the risk posed by climate change. For instance, the operation of ski fields may be impacted by multiple physical risks simultaneously, including reduced snow and ice cover in winter affecting profitability of ski fields, the operation of chairlifts impacted by extreme weather events, and access disruptions due to flooding of roads.

The tourism sector is also at risk due to its interdependencies with other value areas, as shown in Figure 20.12 and Table 20.11. This could result in the compounding of risk to tourism assets and operations. These risks could be described as upstream risks, as the tourism sector is the risk receptor in these cases.

Figure 20.12: Upstream risks to tourism. Arrows indicate direction of risk interaction, colours indicate ngā pono (values).

Table 20.11: Upstream risk drivers

Ngā pono (values)	Description of upstream drivers
Ngā Waihanga | Infrastructure services	• **Risk of damage to transport infrastructure**, particularly rural roads, are a major source of risk to the tourism sector through disruption of access to tourism sites. • The **risks to tourism-related buildings**, **and the flood defences** that protect tourism assets and infrastructure, will compound and amplify the risk faced by the tourism operators. • **Risks to roads and bridges** due to increasing coastal erosion, flooding (river and surface water), and sea level rise may cause permanent road closures and may impact the accessibility to tourism sites.
Ōhanga | Economy	• **Risks to service sector and its supply chains.** Impacts on service sector, including the supply chains, could reduce the availability of goods consumed by tourists. • **Risk to insurance availability** for tourism providers, particularly commercial property insurance. If the risks to tourism businesses from climate change are deemed as being both probable and costly, insurers may no longer be willing to provide insurance to tourism businesses, particularly for property impacts as result of flooding.
Rerenga Rauopi | Biodiversity	• **Risk to Region's landscape and flora and fauna.** Tourism is also reliant on the natural environment, and a number of tourism sites derive value from the region's landscape and flora and fauna. The risks to the natural environment could result in compounding risks to the tourism sector, as it could impact the "clean and green" reputation of the Region.
Rangatiratanga | Self governance	• **Increased legal liability from climate impacts on tourism operations.** Tourism businesses may be at risk due to increased legal liability from climate impacts, as tourism businesses may face increased legal liability if they fail to protect their customers from climate risks, e.g. flooding causing injury.

The tourism sector will also be subject to a range of other risks in future, including:

- Transition risks as a result of carbon pricing and a reduced demand for carbon-intensive forms of transport, particularly aviation (The Royal Society of New Zealand, 2016).
- Global pandemics, such as the COVID-19 pandemic, which may become more likely as a result of climate change (Gossling et al, 2020).
- Natural disasters (such as earthquakes and tsunamis) - which could damage tourism infrastructure.
- Economic recessions and financial crises (Munshi et al, 2020).

20.5.3 Downstream impacts

As shown in Table 20.12, the risks to the tourism sector will also result in risks to other ngā pono (values) areas. Given the interconnectedness of the tourism sector, the climate risks to tourism businesses may increase and amplify risks across ngā pono (the values).

Table 20.12: Downstream impacts

Ngā pono (values)	Description of downstream impacts
Ōhanga | Economy	• Potential economic impacts on the tourism sector would also affect other sectors of the economy, particularly the service sector which is highly dependent on expenditure from tourists. • Insurance withdrawal from at-risk tourism business may contribute to cascading risks to financial stability, as these businesses may face increasing difficulties in servicing loans (MfE, 2020). • Climate risks to the tourism sector may result in stranded tourism assets, as businesses, such as ski fields, close down. This could also result in economic risks, as tourism businesses could default on debt and face asset revaluations (Semieniuk et al, 2020).
Hauora | Physical health	• The climate risk to the tourism sector could also amplify the **risk of reduced community cohesion**, as economic impacts on tourism businesses could exacerbate social inequities and reduce social capital. • Reduced wellbeing and a higher **risk of poor mental health outcomes**, particularly for tourism dependent communities. For example, the tourism sector may experience job losses, which could result in reduced wellbeing and a higher risk of poor mental health outcomes, particularly for tourism dependent communities (Stuff, 2020). • There could be **risks to the ability to participate in sport and recreation** as a result of climate risks faced by the tourism sector – in particular, the risk to alpine sports due to reduced snow cover.
Rangatiratanga | Governance	• **Increased legal liability of regional and territorial authorities** from damages to tourism infrastructure and assets. Tourism businesses may sue councils for not providing sufficient protection from climate change risks – for example, in 2019, the Scenic Hotel Group sued West Coast councils for losses from a flood stopbank failing (Stuff, 2019).
Ngā Waihanga | Infrastructure services	• **Risk to transport infrastructure** from decreased tourism revenue. For example, declining tourist visitor numbers could reduce airport revenues and lead to reduced flight routes, as shown by COVID-19 (IFC, 2020).

As outlined in Table 20.12, there are complex interactions between and across risk frameworks that need to be understood and managed. A case study of these interactions is also illustrated in Figure 20.13, which shows the impacts from tourism risks to the broader service sector. The climate risks in the tourism sector could impact the broader service sector, including hospitality, retail and transport, which are all closely interlinked (UNCTAD, 2020). This example could be applied to any area which is highly dependent on tourism, of which there are multiple within the Canterbury Region.

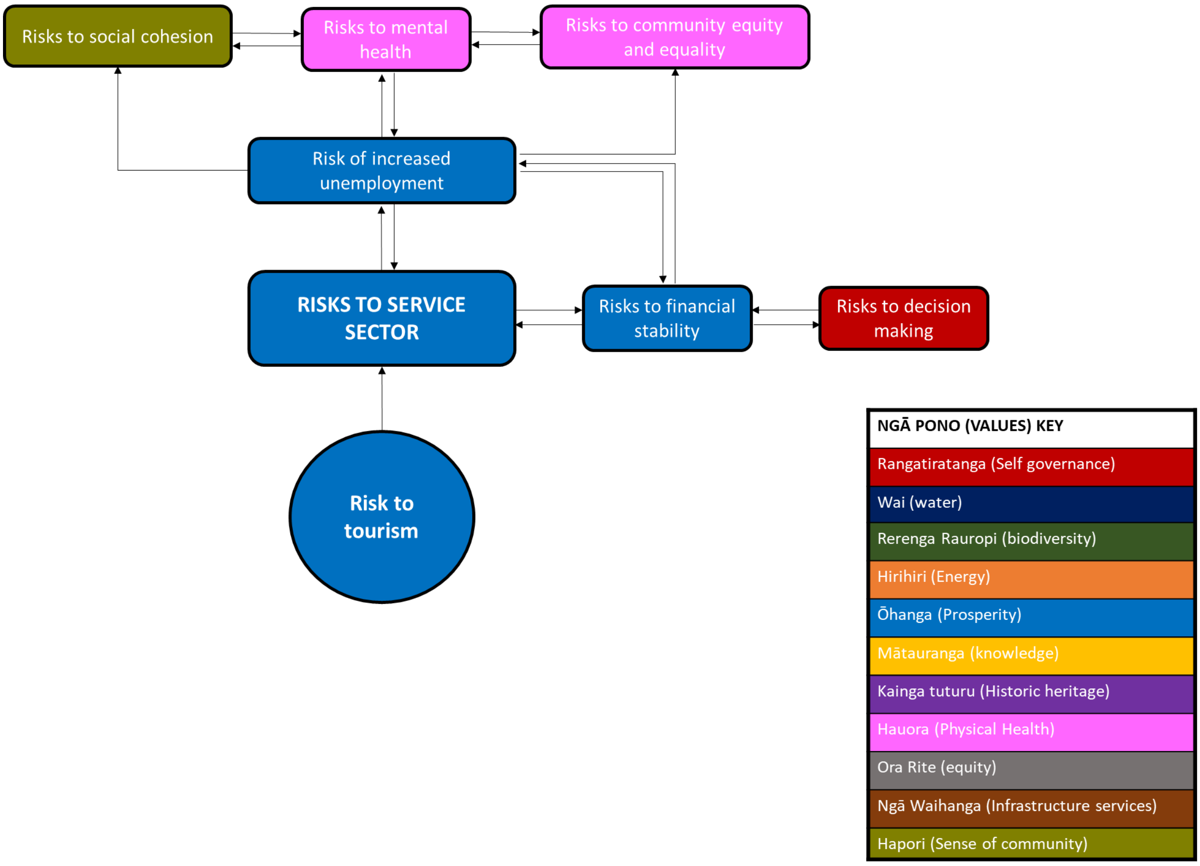


Figure 20.13: Case study of the risks interacting with the risk to service sector from the risk to tourism.

As shown in Figure 20.13, impacts on the service sector could include reduced profitability from declining tourist spending, and could result in increased unemployment and difficulties for business to service debts. Widespread disruption could conceivably result in risks to financial stability, which could result in calls for public sector intervention to support failing businesses (MfE, 2020). Current governance frameworks could result in risks to decision making, as it is unclear at present whether local government or central government would be responsible for providing financial support (MfE, 2020). The impacts on unemployment could result in declining mental health, reduced social cohesion, and a reduction in equity and equality (Brydsten et al, 2018; BERL, 2020). These impacts, moreover, could compound and further interact. Poor mental health outcomes could, for example, result in further unemployment within a community, further exacerbating social and human risks (Olesen et al, 2013). These impacts would disproportionately affect vulnerable populations with limited access to social and economic resources.

20.6 Heat-stress related illnesses case study

20.6.1 Context

Heat-stress related illnesses, such as heat exhaustion, heat stroke, cramps, swelling and rashes, may occur when people are exposed to temperatures which do not allow their bodies to naturally cool sufficiently (Centers for Disease Control and Prevention, 2017). Extreme heat contributes to cardiovascular and respiratory related deaths, particularly in elderly people (World Health Organisation, 2018). Permanent disability and death can also be caused by heat stroke (the most serious heat-related illness) if not treated by emergency treatment (Centers for Disease Control and Prevention, 2018). Although other species may also experience ill health due to heat stress, this section covers human heat stress related illnesses.

Heat-stress related illnesses are caused by an increase in mean temperature. Medically vulnerable people with pre-existing and chronic health conditions are more likely to experience illness due to heat stress.

The upstream hazards, drivers and external factors and downstream impacts of the risk of heat-stress related illnesses are illustrated in a bow-tie diagram Figure 20.14.

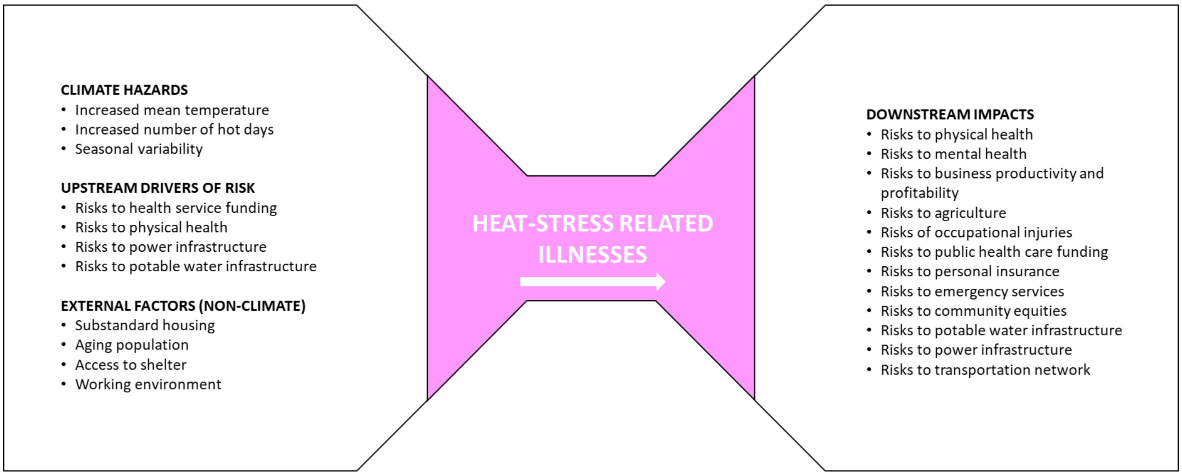


Figure 20.14: Bow tie diagram illustrating the causes and effects of risks to heat-stress related illnesses.

20.6.2 Upstream climate hazards, climate drivers and external factors

Using the RCP 8.5 scenario, it is estimated that by 2100 the average temperature will increase by 1.5 – 3.5°C. The average number of hot days is expected to increase by 20-60 days. The increase in the number of hot days mean that there is more exposure to these unfavourable conditions. Coastal and inland low-elevation areas in Canterbury will experience higher temperatures than the mountainous areas.

Upstream risks to heat stress illnesses are shown in Figure 20.15.

Figure 20.15: Upstream risks to heat-stress related illnesses. Arrows indicate direction of risk interaction, colours indicate ngā pono (values).

Further details on these upstream risks in relation to the ngā pono (values) are shown in Table 20.13.

Table 20.13: Upstream drivers to heat-stress related illnesses

Framework	Upstream drivers
Ōhanga | Prosperity	**Risks to public health funding** from other climate hazards, such as may cause risk of increased incidence of illnesses relating to heat stress. This is because there may be inadequate funding available to help people manage chronic conditions, making them more vulnerable to heat stress related illnesses. Subsequently, the risk of illnesses relating to heat stress can cause risk to public health funding if there are an unexpected large amount of people who require medical treatment for these illnesses.
Ngā Waihanga | Infrastructure services	**Risks to power infrastructure** from climate hazards, such as increased temperatures, can cause power outages. Power outages create risks to illnesses from heat stress as air-conditioning units and medical equipment may not be able to be used.
Wai | Water	**Risks to the potable water network** from increased rainfall and sea level rise resulting in flooding, as well as drought events, may cause inaccessibility to water. Hydration is critical in relieving and treating heat related illnesses.

Non-climate factors also compound with the climate hazards and upstream risks to worsen their effects on heat stress. These factors include:

- Substandard housing conditions, creating hotter living environments. This would make dwellers of substandard housing more vulnerable and susceptible to heat stress.
- Population growth and aging population. Elderly are more susceptible to heat stress related illnesses.
- Lack of access to shelter (reducing the ability for people to remove themselves from the heat). This may cause people to be more exposed to hot conditions.
- Work environments. Working outdoors will expose people to conditions which may lead to illnesses related to heat stress developing.

20.6.3 Downstream impacts

Increase in illnesses relating to heat-stress can increase risks in other areas. These risks can then compound and intensify the situation. Consequences of heat stress illnesses can affect rangatiratanga (governance), hauora (physical health), ōhanga (prosperity), wai (water), ngā waihanga (infrastructure services), and ora rite (equity). Table 20.14 provides further detail into the risks for each of ngā pono (the values).

Table 20.14: Downstream impacts of an increase in heat stress related illnesses

Ngā pono (values)	Downstream impacts of increased incidents of heat stress related illnesses
Ōhanga | Prosperity	• **Risks to business productivity and profitability** from employees requiring more sick leave, being unable to work certain vocations, and being unable to return to work due to long term effects of heat stress related illnesses. This may also cause businesses to have to close due to the inability to find suitable workers. Business closure may cause the abandonment of assets and loan defaulting. • **Risks of occupational related injuries** from increased accident risk due to diminished performance capacity (Kjellstrom et al., 2016). • **Risks to agriculture** as heat stress may impede on the agricultural workers' ability to work (Lima et al., 2021).
Rangatiratanga | Self governance	• **Risk to availability and access to funding** for public health care treatment. • **Risks to personal insurance** (such as health and life insurance) due to increased claims. This may result in changes to insurance policies and bigger cost share of heat stress related health expenses.
Hauora | Physical health	• **Risks to physical health** due to side effects of heat stress related illnesses. • **Risks to mental health** due to the changes which heat stress related illnesses cause to a person's lifestyle, capabilities, and health. • **Risks to emergency services** as there may be an increased demand for emergency services due to an increase in people suffering from heat stress related illnesses.
Ora rite | Equity	• **Risk to community equities** as vulnerable communities may experience these illnesses more and have less access to healthcare to treat these illnesses.
Wai | Water	• People may use potable water for treatment of or prevention against illnesses related to heat stress, putting pressure on and creating **risks to potable water infrastructure.**
Ngā Waihanga | Infrastructure services	• Unusually high demand for power to cool people may cause stress and **risks to power infrastructure**, causing power outages. • Reduced travel using active transport modes, placing pressures on other transport modes. This may cause **risks to the transportation network**.

These effects can then become causes of other risks. For example, increased illnesses caused by heat stress can impede the ability for agricultural workers to work. This reduces their incomes, and will have flow on effects on the economy. Food security may also be impacted. Furthermore, the loss of work or reduction in the ability to work can lead to risks to mental health.

The diagram in Figure 20.16 illustrates how ngā pono (values) interact.

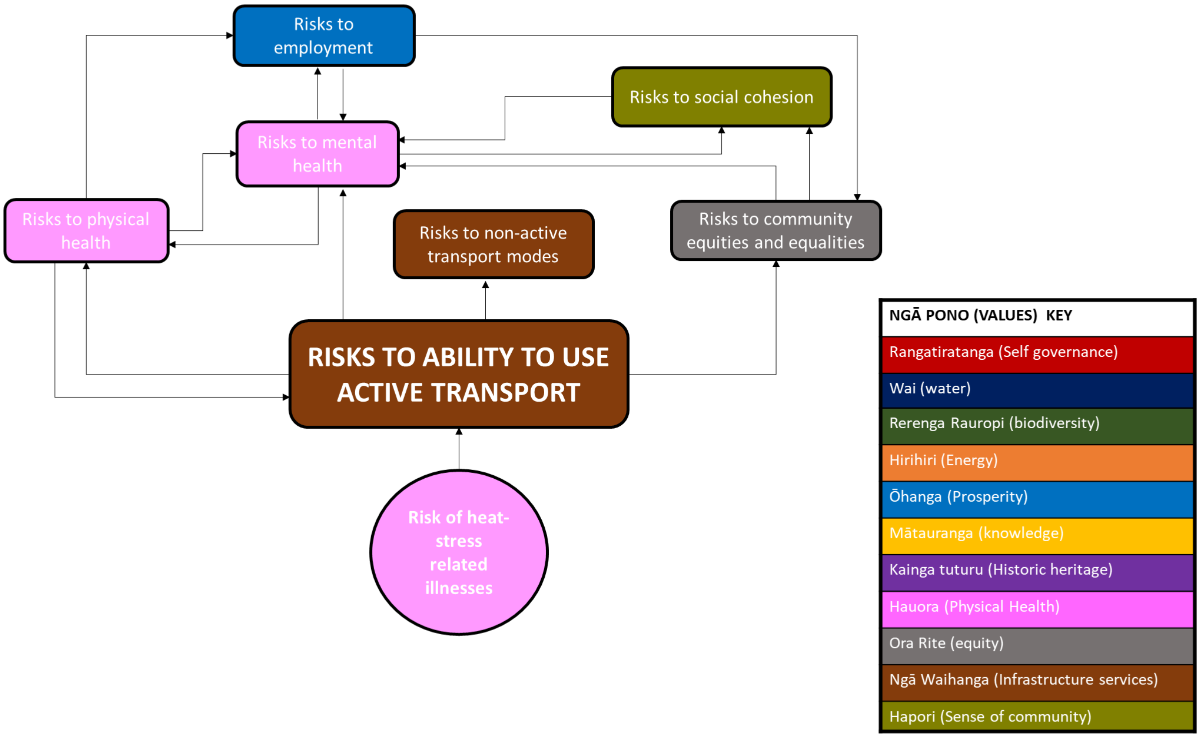


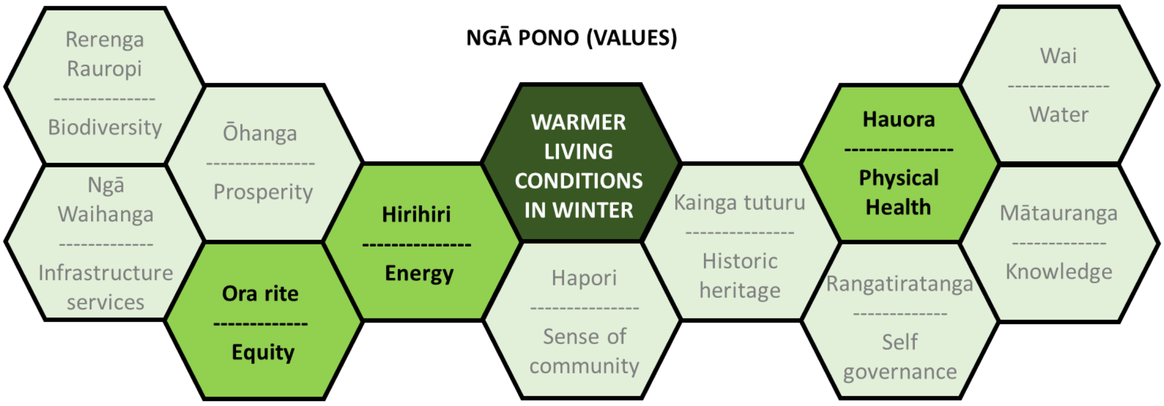
Figure 20.16: Case study of risk interactions with the risk to the ability to use active transport as a result of the risk of increased heat-stress related illnesses.

Figure 20.16 shows that heat stress related illnesses can cause physiological changes reducing the ability to undertake physical activity. This leads to reduced travel using active modes of transport, such as cycling, walking and scootering (Kjellstrom et al., 2016). This is likely to compound existing inequities, as research shows that lower income households are more likely to use active transport (Shaw et al., 2017). If low socio-economic households have their ability to commute reduced, there may be further risks to employment, food security and physical and mental health. In turn, this could cause risks to social cohesion. A decreased ability to use active transport will also increase the risk of obesity, which could lead to poor physical and mental health outcomes (Kjellstrom et al., 2016). Risks to physical and mental health can affect employment, in turn further accentuating risks to mental health.

21 Opportunities

This section explores some of the opportunities that Canterbury may experience with climate change. These opportunities cannot be considered in isolation due to the inherent synergies with climate risks. In some cases, climate risks may outweigh the benefits from the opportunities outlined below.

21.1 Warmer living conditions in winter



A reduction in cold days in winter will contribute to warmer living conditions, providing the opportunity to reduce energy use and improve health outcomes.

Currently, 15% of typical household electricity in Aotearoa New Zealand is used for space heating (Electricity Authority, 2018).

Under RCP 8.5, this opportunity will continue to grow from present day until 2100. This opportunity can also be enhanced with better housing quality. To take advantage of warmer winters (and to contribute to adapting to other temperature related risks), the opportunity to improve housing quality could be taken immediately. This includes making improvements to heating solutions, insulation, ventilation, and lighting. However, there would be significant financial implications.

21.1.1 Benefits of warmer living conditions in winter

This opportunity can lead to benefits within the Ngā Pono (values) of Hirihiri (energy), Hauora (physical health) and Ora Rite (equity).

- **Hirihiri (Energy):** Warmer temperatures will likely decrease residential energy demand over the winter months, where energy use is traditionally high. This decrease could contribute to the flattening of the annual energy demand when also considering the anticipated energy increase in summer months (Security and Reliability Council, 2018). As a result, the pressure on infrastructure and inter-seasonal hydro storage may reduce (Security and Reliability Council, 2018). There may be changes to hydro lake inflows with expected changes to snowfall and melt[10], aligning better with demand. However, more research is required to better understand the expected inflow changes.

[10] Refer to Section 10 for more details on risks to hydro lake inflows.

Furthermore, LPG consumption is projected to decline as the government focuses on reducing emissions (Botzen et al., 2021)[11] . The decline in LPG and natural gas could be further accelerated due to temperature increases, and reduced demands for heating in winter.

- **Hauora (physical health):** Cold temperatures can affect several cardiovascular, peripheral circulation, musculoskeletal, and respiratory diseases (Hassi et al., 2005). The risk of respiratory infections increases where indoor temperatures drop below 16°C. When temperature drops below 12°C, the cardiovascular system can become stressed (World Health Organisation, 2011). Having warmer temperatures in the winter months could contribute to more favourable health outcomes and a possible decrease in hypothermic illnesses and cold-related deaths. It can also reduce risk to vulnerable communities (particularly the medically vulnerable and/or people living in poor quality housing).

  A reduction in wood burner use due to warmer temperatures may lead to better respiratory health outcomes. Older and incorrectly used wood burners are associated with negative impacts on respiratory health (Asthma Foundation New Zealand, 2020).

  However, temperature is only one factor when considering health outcomes in living conditions. Other factors include household crowding, second-hand smoke, unflued gas heaters and open fires, and ventilation (EHINZ, n.d.).

- **Ora rite (Equity):** Fuel poverty is defined as households which cannot afford adequate household energy (including heating indoor areas to the World Health Organisation recommended temperatures) (O'Sullivan et al., 2015). Approximately a quarter of New Zealand households are estimated to be in fuel poverty (Howden-Chapman et al., 2012). Warmer winter temperatures could reduce the financial pressure on households. However, temperature is not the only factor contributing to fuel poverty. Other non-climate related factors include energy prices, housing quality, and energy policy (MfE, 2020a).

21.1.2 Associated risks

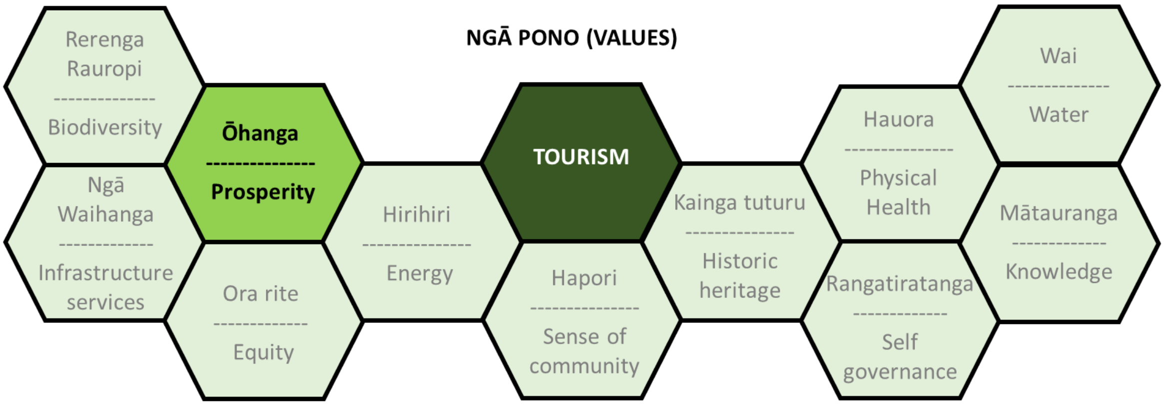
As discussed in Section 11.1 and 13.2.1, there will be risks to energy and health associated with the increase in average temperatures. These risks must be considered alongside this opportunity to understand the impact of increasing average temperatures.

21.1.3 External considerations

This opportunity will be limited or enhanced by a range of non-climate factors, such as prices, policies, housing standards, living conditions, and energy infrastructure. Also, the quality of housing between 2050 and 2100 will be different. Most of the buildings that will be present in the 2050s already exist (BRANZ, 2021), meaning that overall housing quality will not have changed extensively. By 2100, more iterations of building regulations will have been made, likely improving housing quality.

[11] Natural gas and LPG will be phased out by 2050 in New Zealand.

21.2 Increased tourism



An increase in average temperature and changing seasonal climates may extend the summer tourism season, providing job and business opportunities for Canterbury.

The COVID-19 pandemic has temporarily stopped international tourists visiting Canterbury since March 2020. This section assumes that international tourism will resume over the next two years. It is noted that the Mackenzie District and Kaikōura have been identified as target focus areas for the New Zealand government in the tourism sector rebuild (RNZ, 2021).

It is noted that this opportunity may only exist while temperatures are considered favourable by visitors. Perceived optimum climatic conditions for travelling vary across different areas of the world (Scott et al., 2007).

21.2.1 Benefits of increased tourism

This opportunity can lead to benefits within the Ngā Pono (values) of Ōhanga (prosperity) and Ngā Waihanga (infrastructure services).

- **Ōhanga (prosperity):** An increase in tourism may create opportunities for new jobs and businesses to emerge (Ministry for Business, Innovation and Employment [MBIE], 2018). It is estimated that for every $178,000 of visitor spend, one new job is created in tourism (Tourism New Zealand, 2020). This suggests that as more visitors visit Canterbury due to a more favourable climate, there is opportunity for the tourism industry and associated service industries to grow. With these growth opportunities, there will be other interacting opportunities (and risks) to most values of the integrated framework.

  There is also opportunity for Canterbury tourism to move to being a low-emissions industry.

21.2.2 Associated risks

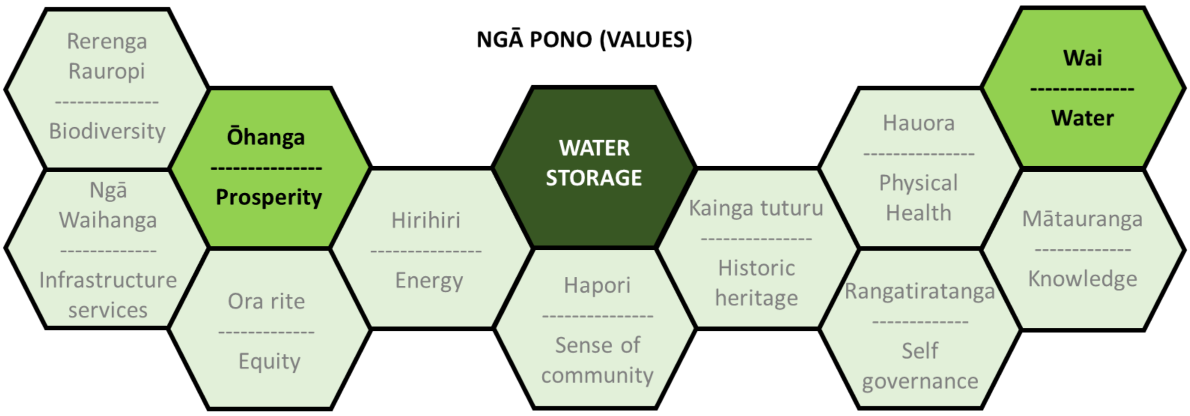
As discussed in Section 13.5, with increasing temperatures there will be risks to tourism operators (such as ski field operators and glacial exploration operators). There may also be an increase in heat stress related illnesses. With some tourism businesses operating mainly outdoors, this could expose employees to unfavourable temperatures. High temperatures can also cause other stresses on tourism related infrastructure, for example, pavements (Mills et al., 2020).

Furthermore, the increase in hot days may deter visitors from visiting. Droughts and lower flows may reduce the viability of outdoor recreational tourism (such as fishing and canoeing) (National Integrated Drought Information System, n.d.) and mahinga kai.

21.2.3 External factors

There are a range of external factors which can impact the tourism industry and may offset (or enhance) the potential increase in tourism due to warmer temperatures. These factors include visas and international visitor levies, the number of scheduled flights, marketing, international and domestic aviation prices, fuel prices, broader awareness of carbon footprints, available transport modes, and travel restrictions (such as border closures due to unprecedented situations).

21.3 Water storage



An increase in winter rainfall[12] presents an opportunity to capture and store excess river flows for beneficial uses. These may include storage for municipal and commercial uses (e.g. agriculture/horticulture). Storing water in high flow conditions (flood) will provide more resilience when water resources are unavailable or lower in the summer months.

Importantly, any consideration of water storage must consider and give effect to the National Policy Statement for Freshwater Management 2020 (NPSFM) and the principle of Te Mana o te Wai (for example, the mauri of the environment can be reduced by altering natural flows (MfE, 2020c)).

This opportunity is likely to increase with time. In certain areas of Canterbury, projections indicate a significant increase in rainfall from 2050 to 2100. Therefore, there is opportunity to investigate suitable water storage solutions now in preparation for future rainfall scenarios (considering both 2050 and 2100 scenarios).

21.3.1 Benefits of water storage

This opportunity leads to benefits within the Ngā Pono (values) of Wai (water) and Ōhanga (prosperity).

- **Wai (water):** An increase in winter rainfall and provision of storage can provide benefits to municipal water supplies for urban and rural areas around the Canterbury region. Currently groundwater supplies are plentiful, however, this opportunity may merit consideration under a future climate where drought is more prevalent (refer to Section 9.4 and 9.5).
- **Ōhanga (prosperity)**: An increase in winter rainfall and provision of storage can provide benefits to agricultural and horticultural sectors within the Canterbury region. It is understood that farmers are already looking for more water storage to increase the reliability of their

[12] Winter rainfall, particularly in eastern, southern and western Canterbury, is expected to increase significantly by 2100. It is also noted that summer rainfall is expected to decrease, specifically in Banks Peninsula and inland areas.

irrigation water supply (NIWA, 2018). This benefit needs to be carefully weighed against associated risks that may arise due to continued or increased irrigation and intensive farming.

21.3.2 Associated risks

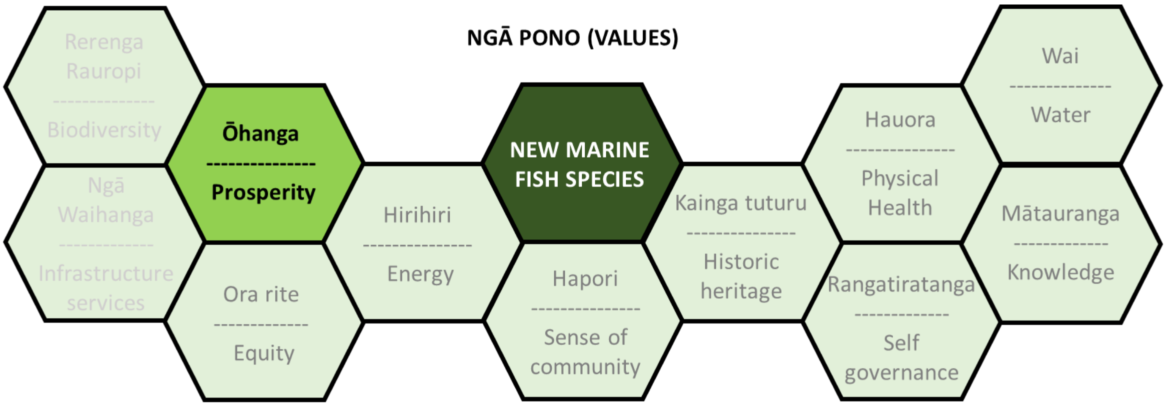
There are several associated risks with changing precipitation rates. Higher flowing rivers are only projected to occur in the winter. During the summer season there will be lower flows, potentially offsetting the higher winter flows.

As discussed in Sections 9 and 10, high flowing rivers can increase erosion and sedimentation rates, contributing to river and lake eutrophication. This has significant risks for mahinga kai and freshwater species.

21.3.3 External considerations

This opportunity will be limited by external factors such as water use policies, land use changes, efficiency of irrigation systems, and food demand. There is opportunity to consider future opportunities for water storage in developing the long-term vision for local waterbodies and catchments, under the principles of Te Mana o te Wai in the National Policy Statement for Freshwater Management 2020 (MfE, 2020b). This long-term vision, which is currently underway, intends to identify Papatipu Rūnanga and community aspirations in Canterbury. It will set the precedent and contribute to future water storage and irrigation decisions.

21.4 New marine fish species



An increase in air and ocean temperatures may provide a more favourable environment for new marine fish species, providing an opportunity to the fisheries industry.

In the 2050 RCP8.5 scenario, warm water species from the sub-tropics may migrate south to New Zealand waters (KPMG, 2020). Further research into fisheries and aquaculture opportunities under a warmer climate is recommended in order to better understand the nature of the opportunity. This section looks at opportunities between now and 2050.

21.4.1 Benefits of new marine fish species

The opportunity leads to benefits within the Ngā Pono (values) of Ōhanga (prosperity).

- **Ōhanga (prosperity):** Warmer ocean temperatures will have the potential to bring more species (such as tāmure/snapper, pākirikiri/blue cod and haku/*Seriola lalandi* or mātataharaki/*Rexea solandr*, types of kingfish) into the Quota Management Area (QMA)

(KPMG, 2020). This could provide more opportunities to the fisheries industry in southern areas of New Zealand.

21.4.2 Associated risks

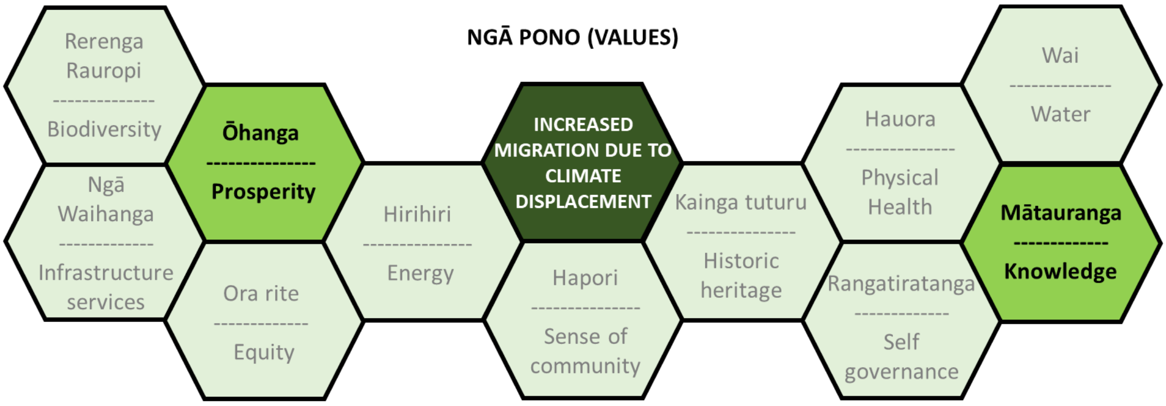
As discussed in Section 8, there are significant risks from warmer ocean temperatures and more acidic ocean conditions to native species and mahinga kai. These risks will be further exacerbated by an increase in exotic species, for example exotic species may out-compete native species. This opportunity cannot be considered in isolation.

New marine fish species may also lead to biosecurity challenges.

21.4.3 External factors

External factors which may influence this opportunity include global seafood demand, food security concerns, international and domestic marine governance, fuel prices and taxes on fish exports. There is also a potential transition opportunity to position the New Zealand (and Canterbury) fisheries industry to the global market as low-carbon and sustainable (KPMG, 2020). This may enhance the economic opportunities in the fisheries industry.

21.5 Increased migration from climate displacement



As the world experiences the effects of climate change. there will be persons displaced from their countries, lands and homes ("climate refugees"[13]). Some of these refugees will make their way to New Zealand.

Over the next 50 years, it is projected that in some scenarios, 1-3 billion people around the world will be left in temperatures which are outside of the climate conditions which humanity has experienced over the past 6000 years (Xu et al., 2020).

Increased migration can lead to two key opportunities: an increase in knowledge and skills, and the potential for enhanced prosperity. To realise these opportunities, migrants may require assistance to overcome linguistic barriers, validate/recognise past qualifications, access education, and overcome discrimination. The opportunities with increased migration due to climate displacement should be

[13] The 1951 Convention Relating to the Status of Refugees defined a refugee as "someone who is unable or unwilling to return to their country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion" (United Nations Refugee Agency, 2010). Due to climate change not being legally defined in the definition, the United Nations Refugee Agency (UNHCR) does not endorse the term "climate refugee" and instead uses the term "persons displaced in the context of disasters and climate change."

considered alongside other factors, such as hardships people may experience - including (United Nations Educational, Scientific and Cultural Organisation, 2020):

- Risks of landlessness, joblessness, homelessness, marginalization, food insecurity, increased morbidity and mortality and social disarticulation.
- Poorer access to or quality in education.
- Trauma.

21.5.1 Benefits of increased migration due to climate displacement

This opportunity leads to benefits within the Ngā Pono (values) of Mātauranga (knowledge) and Ōhanga (prosperity).

- **Mātauranga (knowledge):** Climate refugees may contribute diverse thoughts, experiences, knowledge and qualifications to all areas of Cantabrian society (in particular, in the area of climate change adaptation).
- **Ōhanga (prosperity):** Refugees can contribute to the economy and the wider prosperity of the region through meeting labour market gaps and enhancing productivity.

21.5.2 Associated risks

Associated climate risks include the increase in temperature and extreme weather events which may place pressures on food and housing (further discussed in Section 12.6.1 and 15.1). Risks to food security, housing, and social services may also be exacerbated by an increase in population.

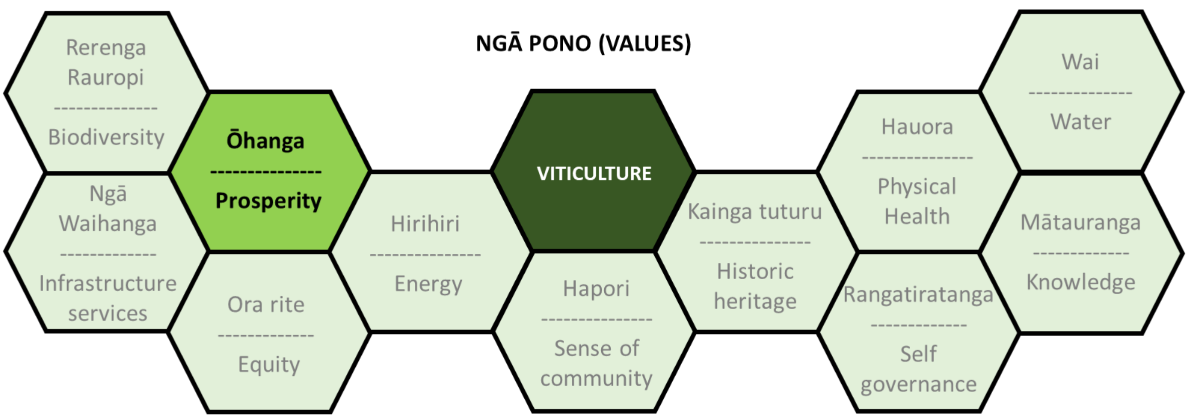
Furthermore, climate migrants may be housed in low socio-economic areas, which are often most exposed to climate hazards. This will directly impact the welfare and living conditions of persons displaced by the effects of climate change.

21.5.3 External factors

External factors will also impact this opportunity, such as immigration and refugee quotas and policies, housing supply, and resources to integrate and support these displaced people.

Furthermore, decreasing global fertility rates may induce global competition for migrants (Gallagher, 2020), ultimately reducing migration to New Zealand. This may offset the benefits of increased migration from climate displaced people.

21.6 Viticulture



Increased temperatures present an opportunity for winegrowers to grow different grape varieties within new locations, including new varieties that have not previously been successful under current climate conditions. This can lead to increased economic opportunities for the viticulture industry.

Typically, wine grapes grow in areas where temperatures average 12 - 22°C during growing season (McAllister, 2021).

As temperature increases, different wine grape varieties will become more favourable between present day, 2050 and 2100. Wine styles and grape ripening characteristics and profiles change with climate (Jones, 2017). To prepare for this opportunity, research could be undertaken into new locations with appropriate geological conditions for different wine grape varieties.

21.6.1 Benefits of viticulture

This opportunity leads to benefits within the Ngā Pono (values) of Ōhanga (prosperity).

- **Ōhanga (prosperity):** There are opportunities for winegrowers to grow grapes in different locations and to use different varieties to suit warmer temperatures (Dangerfield, 2020). A shift in wine styles may potentially expand the Canterbury wine industry.

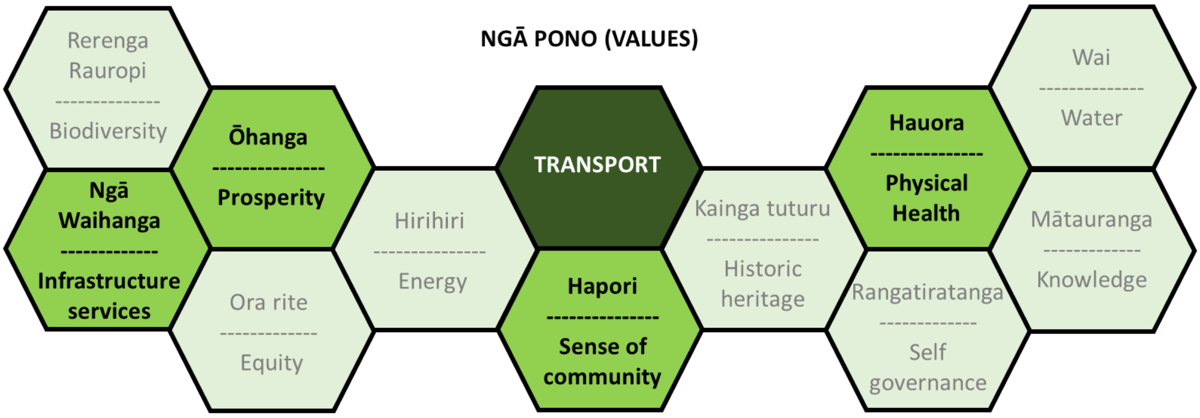
21.6.2 Associated risks

As discussed in Section 12.2, associated risks to viticulture (and the wider agriculture industry) include the increase in extreme events and seasonal variability (Dangerfield, 2020), pests and water availability.

21.6.3 External factors

Other factors which will impact the opportunity of growing a larger variety of grape species include horticulture policies, viticulture research, and consumer demand.

21.7 Reduced transport disruptions



Fewer instances of snowfall and icy conditions will likely result in reduced disruptions to the transportation network. Disruptions can subsequently impact surrounding communities, freight, and the broader economy. Reducing the instances of transportation disruptions presents an opportunity to reduce direct disruption costs to businesses and communities, operations and maintenance costs, as well as injuries and fatalities.

Across the Canterbury region, there are several major routes (such as Arthur's Pass and Lewis Pass (ECan, 2019)) which are regularly disrupted multiple times per annum due to snow and ice.

Under RCP 8.5, this opportunity will continue to grow from present day until 2100.

21.7.1 Benefits of reduced transport disruptions

This opportunity leads to benefits within the Ngā pono of Hauora (physical health), Hapori (sense of community), Ngā Waihanga (infrastructure services), and Ōhanga (prosperity).

- **Hauora (physical health):** Reduced snow and ice road conditions will likely contribute to the reduction of the number and severity of vehicle incidents, as well as the severity of physical and mental health impacts.

  Active modes users will also benefit from reduced snow and icy conditions due to less potential for falls and associated injuries. Currently, there is a decrease in active transport use in winter, with a 40% reduction in e-scooter trips in Ōtautahi/Christchurch between winter and summer months (Ensor et al., 2021). A decrease in snow and ice conditions may lead to fewer incidents and increased use of active transport modes (contributing to better health outcomes).
- **Hapori (sense of community):** Transport gives people the ability to connect and travel beyond their communities for work, services, recreation, community, family, and religious and cultural purposes (Rees et al., 2020). Reduced transport interruptions may foster better community connections, resulting in better mental health outcomes.
- **Ngā Waihanga (infrastructure services):** With warmer temperatures, road freeze-thaw cycles could reduce. This could limit the damage to paved surfaces, potentially leading to reduced transportation disruptions and winter maintenance costs (Andersson and Chapman, 2011).
- **Ōhanga (prosperity):** Road closures or difficult driving conditions on key road linkages (such as Lewis Pass and Arthur's Pass) can cause delays in freight movements as truck drivers have to drive to the conditions or take alternative routes. A reduction in snow and ice conditions on roads may provide safer driving conditions and better freight reliability.

21.7.2 Associated risks

As discussed in Section 10.2, there are a range of other risks to transportation which may result from an increase in average temperatures, flooding, and extreme weather events.

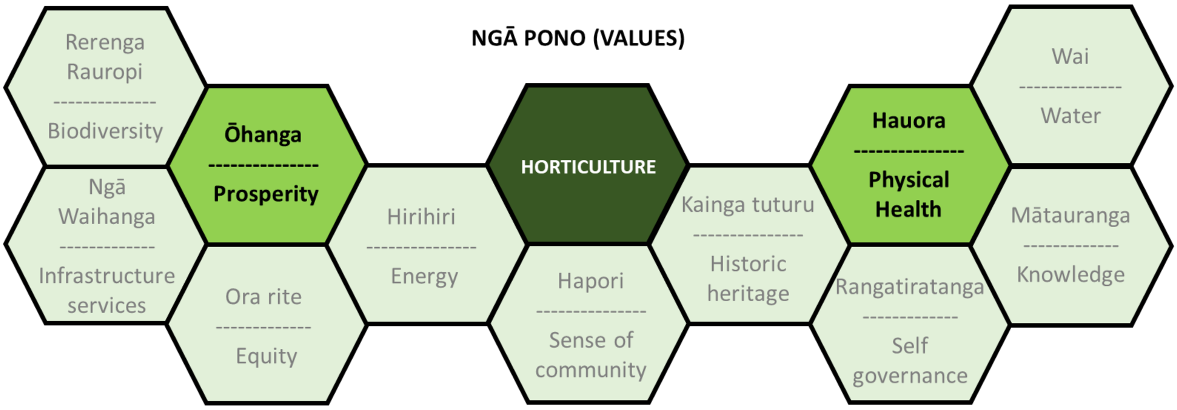
Active transport modes may also be used less due to heat-stress related illnesses. Bridges and pavements may need increased frequency of repairs due to expansion, bleeding and rutting (Dawson et al., 2016). There could also be a risk of increased air pollutants from exposure of asphalt to hot weather (Storer, 2020).

The increase in extreme weather events (such as extreme rainfall, which may lead to landslides and flooding) may also lead to further disruptions, balancing or negating the effect of reduced disruptions from reduced snow and ice.

21.7.3 External factors

External factors, such as uptake of alternate low-carbon modes, asset management, transport related policies, fuel and congestion taxes, and fees, may impact transport disruptions.

21.8 Increased horticulture productivity



An increase in average temperature, fewer frosts and a longer growing season all present opportunities for the horticulture sector to increase productivity and grow different varieties within new locations. This may include new varieties that until now have not been successful under current climate conditions.

Canterbury currently produces a wide range of vegetables, fruit, flowers, seeds and grains. Canterbury produces 47% of carrots and parsnips, 46% of potatoes and 16% of lettuce (Horticulture New Zealand, 2017) and the majority of New Zealand's grains and seeds (Millner and Roskruge, 2013).

Under RCP 8.5, this opportunity will continue to grow from present day until 2100. To prepare for and take advantage of this opportunity, investigations could be undertaken into potential new crops, ground suitability, and locations for growing.

21.8.1 Benefits of increased horticulture productivity

This opportunity leads to benefits within the Ngā Pono (values) of Ōhanga (prosperity) and Hauora (physical health).

- **Ōhanga (prosperity):** Increased horticultural productivity can lead to increased incomes, and broader economic benefits and prosperity. Reduced crop waste from fewer occurrences of frost, longer growing seasons, and the ability to grow new species which currently cannot be grown in Canterbury can also contribute to potential export and economic growth.
- **Hauora (physical health):** Increased horticultural productivity contributes to food security, ultimately impacting on physical health and well-being.

21.8.2 Associated risks

There are several major risks with climate change to horticulture productivity, as discussed in Section 13.2. These include increases in extreme weather events which may damage crops and increased occurrences of drought which could lead to water shortages and restrictions. The risk of pests and diseases may also impact on productivity levels (Ministry for Primary Industries, 2014).

High temperatures causing occupational hazard may also be a risk, reducing the number of people able to work in the horticulture industry. It may increase the number of heat-stress related illnesses and deaths in the industry.

21.8.3 External factors

There are several external factors which may influence horticulture sector productivity, including domestic and international policies regarding the primary industries, tariffs and trade agreements, food demand, and immigration policies. 28% of new entrants to the horticulture industry in 2013 were temporary migrants (Ministry for Primary Industries, 2019). There may be serious labour shortages experienced in the horticulture industry if immigration or international travel policies change (as shown by the impacts of COVID-19 border closures (Flaws, 2020)).

22 Knowledge Gaps and Future Research

Climate change presents a range of risks to the Region. However, uncertainty in the nature and severity of all aspects of climate risks is generally high. While assessment of these risks has been made using the best available information at the time, some gaps in knowledge can be clearly identified (Table 22.1). This is to be expected, and through identification of these knowledge gaps, it is possible to best set the context of the report, and associated potential next steps.

Some of the identified knowledge gaps may be filled through additional research into climate change and adaptation. This could build on the large body of established research. Extensive work is underway to gather data at local, national and international scales to further understand climate risks, and develop strategies to adapt to climate change. Research streams and data collection managed through Environment Canterbury, Universities and Crown Researchers, Sector representatives, and the National Science Challenges are of particular relevance to this regional climate risk assessment.

Table 22.1: Summary of identified knowledge gaps

Value	Research area	Comment
All	Risk assessment – screening of climate hazards	Risk screening of climate hazards and risk elements was used to inform this detailed risk assessment. As a result of this process some risk elements (e.g. historic buildings) have not been assessed. Further, for many of the elements that were assessed, the risks from a range of climate hazards that were not priorities in the screening process have not been assessed.
	Risk assessment – further detail	This risk assessment has discussed a wide range of risks at a regional scale. Many of these warrant further detailed assessment at local or sector scale.
All, particularly relevant to hapori (sense of community) and ora rite (equity)	Transition risks	Risks associated with the transition to a low-carbon economy, and those associated with an equitable transition to climate adapted communities are not included in this assessment but warrant further research.
Rerenga rauropi (biodiversity)	Ecosystem and specific element responses to climate change	Some types of natural environment are expected to exhibit threshold responses – particularly aquatic ecosystems where the level of adaptive capacity may buffer climate change effects. The level to which this effect may occur for different types of environments and the time periods until thresholds are reached (and rapid changes ensue) are unknown and require further research.
Wai (water)	Surface water	Canterbury has extremely complex interactions between snow fall, rainfall, land cover, groundwater and water use. Climate projections relating to the hydrology of the Region account for these interactions, however the results to date show unexpected results in some areas (Macara et al., 2020). Further research may be useful to understand climate projections relating to the hydrology of the Region with improved confidence.
	Groundwater	Sensitivity of groundwater to climate change is of significant relevance to water availability and ecosystems in the Region. Ongoing research is underway to reflect this importance. Further work to quantify the risk of salinisation of coastal groundwater aquifers would be beneficial, especially for those

Value	Research area	Comment
		coastal aquifers where abstraction forms a major part of potable water supply.
	Water availability	Continued research on water availability, including accounting for changes in groundwater, river flows, and changing demand from users during drier summer months.
	Extreme events and flooding	Canterbury has extremely high exposure to present day flooding. National assessment of high intensity rainfall indicates that the intensity and frequency of rare events will increase. The impact of these increases on flooding in the Region is not fully understood. Further research into the modelling of floodplains, accounting for the impact of climate change will improve the understanding of flood exposure.
	Flood protection	Detailed assessment of the capacity of flood protection assets has not formed part of this assessment. A regional scale assessment of flood protection that is provided to communities, as well as assessment of the condition of existing assets will support resilience to flooding.
Ngā waihanga (infrastructure services)	Asset vulnerability	A range of critical infrastructure sectors would benefit on further research into specific vulnerabilities.
Hirihiri (energy)	Vulnerability	The energy sector would benefit on further research into specific vulnerabilities relating to transmission and supply, across further sources than hydro.
Ōhanga (prosperity)	Financial implications and adaptations	Planning and budgeting for the growing financial burden of climate change is critical across all public and private sectors. It relies on an improved understanding of specific sectoral risks, as well wider business, insurance, and governance risks. This could be in the form of research to assist businesses and local government to consider climate risks to their services and operations, and incorporate agility, innovation, and adaptation as part of business plans and systems.
	Sector vulnerability	A range of critical infrastructure sectors would benefit on further research into specific vulnerabilities.
	Impacts and interacting risks	Studies of economic risks, impacts and interacting economic impacts, including modelling of global markets.
	Sustainable agriculture	Research into sustainable farming practices, mitigation of impacts and innovation for autonomous adaptation.
	Agriculture - biosecurity	Biosecurity/resistance to invasive pest species. Canterbury may benefit from further investment in understanding new biosecurity threats, and control or mitigation measures as the changing climate accommodates new pest species.
	Sustainable fisheries and opportunities	General research into fisheries, changing aquatic ecosystems and this relationship with commercial fishing practices.
Hauora (physical health), hapori (sense of	Physical health	Further research into understanding the impacts and implications of gradual climate hazards on mental and physical health, including research into increased prevalence of disease.

Value	Research area	Comment
community) & ora rite (equity)	Mental wellbeing, equity and community	Climate change is expected to have greater impacts on the health and wellbeing of vulnerable groups. Further research into these impacts and a method to classify and assess vulnerability to climate risk may improve outcomes for these groups.
Kāinga tūturu Historic heritage	Built heritage	Detailed climate change risk assessment.
Mātauranga Knowledge	Mātauranga Māori	Impacts and risks from climate change on mahinga kai and taonga.
Rangatiratanga Governance	Crown and mana whenua relationships	Crown and mana whenua (those with territorial rights to the land) relationships. Research into understanding the impact of climate change on the effectiveness of frameworks which outline relationship obligations and responsibilities between the Crown and mana whenua.
	Policy, guidance, and coordination	Policy, guidance, and tools to support local governance to adapt to climate change. Also, support is required to provide coordination between various governance groups, including other local government, sectors, and central government.
	Lifeline utilities	A range of critical infrastructure sectors would benefit on further research into specific vulnerabilities. Also requires support to coordinate with other services and across jurisdictional boundaries.

22.1 Interacting risks

Due to the interaction and interdependencies between ngā pono (values), individuals, communities, businesses, and industries, impacts can quickly compound and escalate across different values. Public authorities in the Canterbury Region could further explore interacting risks. Specific areas of future research to assess and address these risks include (Nichols et al., 2018):

- Undertaking additional thematic and sectoral risk assessments to strengthen understanding of these risk interactions and relationships.
- Introducing a holistic management approach to anticipate these risks. This could include a framework for monitoring and tracking risks to identify potential cascading impacts and other complex risk interactions.
- Undertaking adaptation actions, including enhancing preparedness of stakeholders to manage these risks. This could be achieved by undertaking adaptation planning and building partnerships with public and private organisations.

23 Next Steps

Understanding the risks and opportunities from climate change now and into the future is a vital step in the climate change journey. This report provides a technical basis for climate change, encapsulating a broad understanding of climate change risks within the Canterbury region currently, along with how these may shift over time, based on current understanding of climate science. Through engaging with Papatipu Rūnanga representatives and Stakeholder organisations through this process, it is hoped that individuals and organisations continues on the journey toward climate adaptation.

To support the progression toward adaptation, the next steps include consideration of risks highlighted within this report, and agreeing which should be prioritised for adaptation planning. This process is strongly dependent on the input of Local Government, Papatipu Rūnanga representatives and Stakeholder Organisations, each of which will be risk owners. For the Canterbury Mayoral Forum, this will include understanding the role of Local Government for each risk. These roles could include direct ownership, advocating for, and informing other risk owners.

Recently released Local Government Guidance provides potential next steps for the prioritisation of risks, highlighting the importance of Governance when making value judgements around consequences and urgency.

Urgency is defined as ‘a measure of the degree to which further action [including adaptation] is needed in the next five years to reduce a risk or realise an opportunity from climate change’ (Committee on Climate Change, 2017). Urgency provides a further prioritisation of risks based on the breakdown of the risk against key urgency criteria, shown in Table 23.1below.

Table 23.1: Urgency criteria

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

Rating urgency is strongly dependent on the institutional knowledge within Local Government, Papatipu Rūnanga representatives and wider stakeholder organisations. A stocktake of current climate change action underway for the region could enable urgency ratings to be established, providing a natural next step for the adaptation journey.

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

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25 Te Reo Terminology

Haku	Kingfish, *Seriola lalandi.*
Hao	Shortfin eel. *See also tuna.*
Hapori	Sense of community, social cohesion, community facilities, interlayers of whakapapa, relationships across the generations. Strengthening inter-relationships between Te Ira-Atua, (spiritual realm) Ira Tangata (people) and Ira Whenua (natural world). The reciprocal obligations to safeguard and to protect the health of the environment and the health of people.
Hapū	Sub-tribes.
Hāpuku	Groper.
Harakeke	New Zealand flax.
Hauora	Wellbeing, including te taha hinengaro, te taha tinana, te taha wairua me te taha whanau.
He kura taiao	Living treasures.
Hirihiri	Energy.
Hoiho	Yellow-eyed penguin, *Megadyptes antipodes.*
Īnanga	A whitebait species, *Galaxias maculatus.*
Ira Tangata	People.
Ira Whenua	The natural world.
Iwi	Tribes.
Kai	Food.
Kai moana	Seafood.
Kāinga tūturu	Historic heritage, landscapes of importance to mana whenua, including urupā, historic buildings and heritage.
Kākahi	Freshwater mussel.
Kāmana	Southern crested grebe.
Kanakana	Lamprey. *See also piharau.*
Ka Tiritiri o te Moana	The Southern Alps.
Kāwanatanga	Governance.
Kēwai	Freshwater crayfish. *See also waikōura*.
Ki Uta ki Tai	From the mountains to the sea.
Kororā	White-flippered penguin, *Eudyptula minor albosignata.*
Kōwaro	Mudfish.
Kōura	Crayfish, *Paranephrops zealandicus.*
Kupu	Word.
Mahinga kai, mahika kai	Food gathering.
Mana	Authority and influence.
Mana whenua	Territorial rights, the right of an iwi to a particular area of land.

Manu	A bird or birds.
Marae	Communal gathering place for an iwi or hapū.
Mātataharaki	Kingfish, *Rexea solandr.*
Mātauranga	Knowledge, tāonga tuku iho (heritage), access to information, education.
Mātauranga Māori	Māori cultural knowledge, embedded in the whakapapa (genealogy) of Māori people and the interconnected relationship of all living things.
Mauri	Lifeforce/essence.
Mauriora	Divine spark.
Moki	Blue moki.
Nga papatipu rūnanga	Ngai Tahu's marae communities.
Nga pono	Values.
Ngā waihanga	Infrastructure services, how people have basic needs met. Includes networked infrastructure enabling physical and virtual connections (e.g. transport, telecommunications, technology, energy, shelter).
Ōhanga	Prosperity, including business, livelihoods, tourism, agriculture, fisheries.
Ora rite	Equity, including gender equality, social equity, equal opportunities for whanau to thrive and be potent.
Pā	Fortified village.
Pākirikiri	Blue cod.
Piharau	Lamprey. *See also kanakana.*
Pingao	Golden sand sedge.
Pounamu	Greenstone or jade.
Rakahuri	The Ashley River.
Rākau	Plants.
Rangatiratanga	Governance, kāwanatanga, whanau institutions, nga patatipu runanga, te tiriti partnerships, government/local government institutions, other agencies, political voice.
Rerenga rauropi	Biodiversity, including the natural environment, ecosystems, carrying capacity, taonga species, mahinga kai, kai (food).
Rūnanga	Tribal groupings.
Taha wairua	Spiritual health.
Taha tinana	Physical health.
Taha hinengaro	Mental/emotional health.
Taha whānau	Family health.
Tāmure	Snapper.
Taonga	Treasures.
Tapu	Sacred.
Te Ao Māori	The Māori world.
Te Ao Mārama	The safe place for humanity and the natural living world
Te Ira-Atua	Supernatural force, the spiritual realm.

Te mana o te wai	The health and wellbeing of water.
Te Tiriti, Te Tiriti o Waitangi	The Treaty, The Treaty of Waitangi.
Te Whare Tapa Whā	A hauora (wellbeing) model developed in the early 1980s by Professor Mason Durie. It looks at wellbeing across the areas of taha wairua, taha tinana, taha hinengaro, and taha whanau, and remains a widely applied way to approach wellbeing in a holistic manner.
Tikanga Māori	Māori customs.
Tītī	Hutton's shearwater, *Puffinus huttoni*
Tōrea pango	Variable oyster catcher, *Haematopus unicolor*
Tororaro	Wiggy wig plant.
Tuna	Shortfin eel. *See also hao.*
Tūrangawaewae	Place of belonging through kinship and whakapapa.
Urupā	Burial ground.
Wāhi tapu	Sacred sites.
Wai	Water, including marine, freshwater, wetlands, as well as concepts of water quality, water quantity, wastewater, water conveyance, water storage, and water management.
Waikōura	Freshwater crayfish. *See also kēwai*.
Whakapapa	Genealogy.
Whānau	Family.
Whānau institutions	Family institutions, relationship networks.

26 Glossary

Adaptability	*See: Adaptive capacity.*
Adaptation	The process of adjustment to actual or expected climate and its effects (IPCC, 2021).
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 (IPCC, 2021).
Alpine environment	An environment in a high mountain area.
Annual Exceedance Probability (AEP)	The probability of an event happening in any given year. A 1% AEP means that there is a 1% chance that an event will occur in any given year, and that on average, one event of that size/type will happen every 100 years.
Anthropogenic	Resulting from or produced by human activities (IPCC, 2021).
Atmosphere	The gaseous envelope surrounding the earth (IPCC, 2021).
Benthic macrofauna	Organisms that live on, or in, or at the sediment-water interface, that are larger than 0.5 mm.
Biodiversity	The variability among living organisms from all sources including, inter alia, 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 (UN, 1992, referenced in IPCC, 2021).
Biosecurity	Safety from pests and diseases.
Biomass	Living or recently-dead organic material (IPCC, 2021).
Climate	Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2021).
Climate change	a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes (IPCC, 2021).
Coastal flooding	Flooding along a coastline.

Consequence	The outcome of an event that may result from a hazard. It can be expressed quantitatively (eg, units of damage or loss, disruption period, monetary value of impacts or environmental effect), semi-quantitatively by category (eg, high, medium, low level of impact) or qualitatively (a description of the impacts) (adapted from Ministry of Civil Defence and Emergency Management [MCDEM], 2019). It is also defined as the outcome of an event affecting objectives (ISO/IEC 27000:2014 and ISO 31000: 2009) (Ministry for the Environment, 2019).
Diadromous	Fish that migrate between the sea and fresh water.
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery (IPCC, 2021).
Drought	A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, so any discussion in terms of rainfall shortage must refer to the particular rainfall-related activity that is under discussion.
Ecosystem	An ecosystem is a functional unit consisting of living organisms, their non-living environment and the interactions within and between them (IPCC, 2021).
Equity	The principle of fairness in burden sharing and is 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. It is often aligned with ideas of equality, fairness and justice and applied with respect to equity in the responsibility for, and distribution of, climate impacts and policies across society, generations, and gender, and in the sense of who participates and controls the processes of decision making (IPCC, 2021).
Erosion	The geological process where earthen materials are worn away and transported by natural forces such as wind or water.
Eutrophication	The process by which a body of water, or parts of it, becomes progressively enriched with minerals and nutrients. It is characterised by excessive plant and algal growth.
Evapotranspiration	The sum of evaporation from the land surface plus transpiration from plants.
Evidence	Data and information used in the scientific process to establish findings (IPCC, 2021).
Exposure	The presence of 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. (IPCC, 2021). Lack of protection against loss or harm in a hazard zone, affecting the number, density or value of people, property, services, or other things we value (taonga) (MCDEM, 2019).
Extreme weather event	An extreme weather event is 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. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season). (IPCC, 2021)

Fecundity Fertility. The ability to produce an abundance of offspring or new growth.

Fire weather A combination of conditions that set the stage for the rapid spread of wildfires.

Flood The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged (IPCC, 2021).

Food security A situation where all people, at all times, have access to sufficient, safe, nutritious food that meets their dietary needs and food preferences (IPCC, 2021).

Fossil fuels Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas (IPCC, 2021).

Governance A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing and monitoring policies and measures. Whereas government is defined strictly in terms of the nation-state, the more inclusive concept of governance recognizes the contributions of various levels of government (global, international, regional, sub-national and local) and the contributing roles of the private sector, of nongovernmental actors, and of civil society to addressing the many types of issues facing the global community (IPCC, 2021).

Greenhouse gas Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H^2O), carbon dioxide (CO^2), nitrous oxide (N^2O), methane (CH^4) and ozone (O^3) are the primary greenhouse gases in the earth's atmosphere (IPCC, 2021).

Gross domestic product (GDP) The sum of gross value added, at purchasers' prices, by all resident and non-resident producers in the economy, plus any taxes and minus any subsidies not included in the value of the products in a country or a geographic region for a given period, normally one year. GDP is calculated without deducting for depreciation of fabricated assets or depletion and degradation of natural resources (IPCC, 2021).

Groundwater Water found underground in the cracks and spaces in soil, sand and rock.

Hazard The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2021).

Heatwave A period of abnormally hot weather. Heat waves and warm spells have various and in some cases overlapping definitions (IPCC, 2021).

HVAC High voltage alternating current.

HVDC High voltage direct current.

Hydrological	Related to the study of water on earth.
Impacts (consequences, outcomes)	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts can be positive or negative (IPCC, 2021).
Inland flooding	Flooding that occurs inland.
ISO14091	A standard for adaptation to climate change.
Land use	Land use refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, conservation and city dwelling) (IPCC, 2021).
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically (IPCC, 2021).
Lifeline Utilities	Lifeline utilities are entities that provide essential infrastructure services to the community such as water, wastewater, transport, energy and telecommunications (IPCC, 2021).
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 historic developments (IPCC, 2021).
Low carbon economy	An economy based on low-carbon power sources, with minimal outputs of greenhouse gases.
Maladaptation, maladapted response	Maladaptation, or a maladapted response, is one in which the impacts of climate change lead to increased investment in emissions-intensive activities, increased vulnerability to climate change, or diminished welfare. It is usually an unintended consequence (IPCC, 2021).
Mitigation (of climate change)	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2021).
Montane environment	An environment in a hilly or mountainous area.
Moraine	Accumulations of dirt and rocks that have fallen onto the surface of a glacier.
Ocean acidification	Ocean acidification refers to a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide (CO2) from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity (IPCC, 2011, referenced in IPCC, 2021).
Poleward	Moving in the direction of either the South Pole or the North Pole.
Potential Evapotranspiration Deficit (PED)	A drought index to measure the difference between how much water could potentially be lost from an environment and how much is actually lost.
Projection	A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realized (IPCC, 2021).

Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and Transformation. Note this is closely related to the concept of adaptation (IPCC, 2021).
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur (IPCC, 2021).
Risk assessment	The qualitative and/or quantitative scientific estimation of risks (IPCC, 2021).
Risk management	Plans, actions, strategies or policies to reduce the likelihood and/or consequences of risks or to respond to consequences (IPCC, 2021).
Risk - Extreme	An extreme risk, requiring immediate attention.
Risk – High	A high risk, requiring detailed research and planning.
Risk – Moderate	A moderate risk, requiring a change in approach.
Risk – Low	A low risk, requiring attention through routine processes.
Risk – Insignificant	An insignificant risk, to be monitored and reviewed in time.
Runoff	The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ice melt that does not evaporate or refreeze, and is not transpired (IPCC, 2021).
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change (TC), prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions (IPCC, 2021).
Sea surface temperature	The sea surface temperature is the subsurface bulk temperature in the top few meters of the ocean, measured by ships, buoys, and drifters (IPCC, 2021).
Sensitivity	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change (IPCC, 2021).
Socio-economic	How economic activity affects and is shaped by social processes.
Stress	A long-term issue with an important and often negative impact for New Zealand (NCCRA, 2020). Also the feeling of being overwhelmed or unable to cope with mental or emotional pressure. Both are relevant to this project.
Stressor (climate)	Persistent climatic event (eg, change in seasonal rainfall) or rate of change or trend in variables such as the mean, extremes or the range (eg, ongoing rise in mean ocean temperature or acidification), which occurs over a period of time (eg, years, decades or centuries), with important effects on the system exposed. This in turn increases vulnerability to climate change (Ministry for the Environment, 2019).
Surface water flooding	Flooding caused by a volume of rainfall that is unable to drain away through existing drainage systems or by soaking into the ground, but lies on or flows over the ground instead.

Sustainability	A dynamic process that guarantees the persistence of natural and human systems in an equitable manner (IPCC, 2021).
Three waters	Drinking water, wastewater and stormwater.
Transition	The process of changing from one state or condition to another in a given period of time. Transition can be in individuals, firms, cities, regions and nations, and can be based on incremental or transformative change (IPCC, 2021).
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (IPCC, 2021, see also IPCC, 2004; Mastrandrea et al., 2010; Moss and Schneider, 2000).
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2021).
Wildfire	A bush or forest fire that is unplanned, unwanted, or uncontrolled.

Appendix A: Summary of 2019 Canterbury Climate Change Risk Screening Assessment

The Canterbury Climate Change Working Group, under the Canterbury Mayoral Forum (referred to as "the Working Group" throughout) carried out a Climate Change Risk Screening assessment for Canterbury. This aimed to understand the existing and future climate change risks and opportunities for the region. The project was undertaken at the end of 2019, allowing an opportunity for results of the assessment to feed into the National Climate Change Risk Assessment (NCCRA).

Completed through a process of elicitation, this project provided a broad overview and screening of the identified risks and opportunities presented by climate change. It was recommended that the screening should be followed by a risk assessment, which would go into more detail on the priority risks and opportunities identified through the initial screening process. Further detail on the priority risks, and the process undertaken to identify them, can be found in the Canterbury Climate Change Screening Report (2020).

The risk screening was undertaken using the NCCRA Framework. The risk screening process was done via stakeholder input, but involved limited participation from Te Rūnanga o Ngāi Tahu. Further input was identified as a priority for the subsequent risk assessment.

The screening included the five ngā pono, or value, domains: the built environment, natural environment, human, governance and economy domains. Risks were measured based on the climate hazards that affected the stakeholder audience, and the impact that the risk is likely to have on the region. A list of over 180 climate-related risks that could have the greatest effect across the Canterbury region was developed. Of these, over 80 (46%) were identified as priority risks, projected to have a big impact on the region.

These priority risks have been taken forward from the screening as the basis for a more detailed assessment. Some direct risks within each value domain are listed below.

A1.1 Built environment domain risks

Climate hazards most likely to present risk to the built environment include sea level rise, flooding, coastal erosion, fire, higher temperatures, drought, storms, landslides, and reduced snow and ice. These hazards are likely to affect all aspects of the built environment for both urban and rural communities. This includes flood management schemes and stopbanks, water supply infrastructure, irrigation and water races, wastewater treatment plants, roads and bridges, rail, marine facilities, airports, solid waste and contaminated sites, and coastal barriers and seawalls.

Table A.1: Risk screening summary for built environment

Risk Element	SLR	Flooding	Coastal Erosion	Fire	Higher air temp.	Drought	Storms & wind	Landslides	Mean annual rainfall	Reduced snow & ice
Settlements and urban communities	■	■	■							
Rural housing and communities		■		■						
Stopbanks and flood management schemes	■	■								
Water supply infrastructure	■	■				■	■			
Irrigation and water races						■			■	■
Wastewater treatment plant	■		■							
Roads and bridges	■	■	■							
Rail	■		■		■			■		
Marine facilities	■						■			
Airports		■								
Solid waste and contamination sites	■	■	■				■			
Coastal barriers and seawalls	■	■	■				■			

A1.2 Economy domain risks

Climate hazards that might affect the economy domain include flooding, fire, higher temperatures, drought, storms and wind, reduced snow and ice, marine heatwaves, and changes in ocean chemistry. These hazards will likely affect livestock, crops, forestry, fishing and aquaculture, and tourism.

Table A.2: Risk screening summary for economy

Risk element	Flooding	Fire	Higher air temp.	Drought	Storms & wind	Mean annual rainfall	Reduced snow & ice	Marine heatwaves	Ocean chemistry
Livestock			■	■					
Crops	■		■			■			
Exotic forestry		■	■		■				
Fishing and aquaculture					■			■	■
Tourism	■						■		

A1.3 Natural environment domain risks

Key climate hazards in the natural environment domain include sea level rise, flooding, coastal erosion, fire, higher air temperature, drought, storms and wind, annual rainfall changes, reduced snow and ice, marine heatwaves, and changes in ocean chemistry. These hazards are likely to affect native terrestrial, freshwater, and marine biodiversity; ground and surface water availability and quality; water quality in marine, estuaries, harbours, lakes, and rivers; natural coastal habitats (such as dunes, estuaries, and rocky shores); coastal wetlands; lowland and coastal environments; montane/hill country environments; alpine/high country environments; and terrestrial, freshwater, and marine pests and disease.

Table A.3: Risk screening summary for natural environment

Risk element	SLR	Flooding	Coastal Erosion	Fire	Higher air temp.	Drought	Storms & wind	Mean annual	Reduced snow &	Marine heatwaves	Ocean chemistry
Native terrestrial biodiversity				■		■			■	■	
Native freshwater biodiversity		■			■			■			
Native marine biodiversity										■	■
Surface water availability and quality		■						■	■		
Ground water availability and quality	■					■		■			
Water quality in marine, estuaries and harbours	■							■			■
Water quality and quantity in lakes and rives	■				■			■			
Natural coastal habitats (dunes, estuaries, rocky shores)	■										
Coastal wetlands	■	■	■								

Lowland and coastal environments											
Montane/hill country environments											
Alpine/high country environments											
Terrestrial, freshwater, and marine pests and disease											

A1.4 Human domain risks

We used a slightly different methodology to measure this domain because of the challenge of measuring the indirect effects that different climate hazards could have on people and communities. Some of the biggest risks that climate hazards could cause in the human domain include direct and indirect impacts on health, impacts on mental health and wellbeing, impacts on community cohesion and stability, a reduction in community capacity and resilience, impacts on Māori, and impacts on the capacity of government agencies.

Table A.4: Summary of extreme and major *direct* risks in the human domain

Element	Climate hazards	Direct risk description
Coastal communities	• River flooding • Sea level rise • Coastal erosion	Large coastal communities are within Canterbury. Sea level rise may make coastal communities uninhabitable.
Rural communities	• Temperature • Reduced land supply (due to managed retreat elsewhere)	Farming and rural communities highly impacted – high risk of financial failure for farmers.
Direct health impacts	• Heat stress • Impact on food Extreme weather • Floods	Vulnerable populations more at risk (younger and older people, homeless population, and households without air conditioning). Increase in food insecure population. Increased deaths in vulnerable populations, including younger and older people.
Indirect health impacts	• Increased temperature • Climate change	New diseases and illness.
Psychosocial impacts	• Drought and floods for rural communities • All climate hazards	At risk groups more vulnerable - these include farmers, those with a mental illness, and young people (b/c of climate anxiety). Need to support communities to plan for uncertainty (and be aware cultures may respond differently).
Ability to work outdoors	• Increased temperature • Extreme events	Reduced productivity; increased exposure to heat stress.
Marae, Urupā, Wāhi Tapu, Taonga	• Increased rainfall • Flooding • Sea level rise • All climate hazards	Impact of sea level rise on marae; coastal inundation of food beds; and impact on rock art.
Ability to practice Tikanga Māori	• Ocean impacts • All climate hazards	Increasing water temperature impacting on Mahinga kai and taonga species.
Infrastructure servicing sites of cultural importance	• Sea level rise • Flooding	Disruption to access to sites of cultural importance.
Community capacity and resilience	• Extreme weather events	Unequal distribution of, and access to, resources. Increased cost of living, and changing labour market.
Social fabric of community/Inequity	• Sea level rise • Extreme weather events	Less social capital due to relocation of households and communities, and increases in inequity.
Agency capability impacts	• Sea level rise • Extreme flooding • Migration (climate refugees)	Relocation of coastal communities. Resettlement challenges (multicultural integration).

A1.5 Governance domain risks

Climate change will present significant challenges and risks for governance, including impacts on emergency planning and response as well as recovery operations; the ability to fund and maintain infrastructure and public services; the functioning of planning rules and policies; insurance and banking systems; the functioning of social service agencies; legal liability; water governance; and reputation of institutions.

Table A.5: Summary of risks in governance domain

Element	Climate hazards	Risk description
Emergency planning and response, and recovery operations	• Flooding • Erosion • Storms • Fire • Heat waves	Base systems are currently in place for emergency planning and response, but systems for responding to heat waves and fires are at present inadequate. Also, climate hazards will negatively impact emergency recovery operations.
Ability to fund and maintain infrastructure and public services	• All climate hazards	Climate hazards will increase the demand on public funds, negatively impacting the ability to fund and maintain infrastructure and public services – this includes water supply and agriculture/irrigation. The increased need for adaptation funding will have significant impact on council budgets.
Functioning of planning rules and policies	• All climate hazards	Climate hazards will negatively impact on the functioning of planning rules and policies.
Insurance and banking system	• Sea level rise • Erosion • Flooding • Droughts • Increase in fire weather	Impact of climate hazards on insurance availability. Higher risk to banks, due to mortgage timeframes.
Functioning of social service agencies	• Disease • Heat waves • Droughts • Sea level rise	Increased burden on social service agencies.
Functioning of police	• Floods • Increase in fire weather • Extreme weather events	Increased resources required for emergencies, and the potential for exacerbating social unrest.
Jurisdictional issues	• Dependent on hazard	Lack of jurisdictional clarity of councils and public agencies.
Legal liability	• Especially coastal erosion, sea level rise and flooding	Risk of increased legal liability of councils and public agencies.
Community facilities	• Flooding, sea level rise, and coastal erosion	Impact of climate hazards on community facilities and events.

Appendix B: Subject Matter Experts for Stakeholder Engagement

B1.1 Workshop attendees

This list provides the majority of organisations that attended each workshop.

Built	Economy	Natural	Governance	Human
Ashburton District Council	Ashburton District Council	Ashburton District Council	Ashburton District Council	CCC climate change curriculum
Christchurch Airport	Christchurch City Council	Christchurch City Council	Christchurch City Council	Christchurch City Council
Christchurch City Council	Department of Conservation	Department of Conservation	Environment Canterbury Youth Ropu	COMMUNITY AND PUBLIC HEALTH
Department of Conservation	Environment Canterbury	Environment Canterbury	Mackenzie District Council	Department of Conservation
Environment Canterbury	Federated Farmers	Forest & Bird	Tutehuarewa Marae	Environment Canterbury
Mackenzie District Council	Foundation for Arable Research	Manaaki Whenua – Landcare Research New Zealand Limited	Waimakariri District Council	Heritage NZ
Orion	Horticulture NZ	Pioneer Energy		Mackenzie District Council
Timaru District Council	Mackenzie District Council	Selwyn District Council		Manaaki Whenua – Landcare Research New Zealand Limited
Tutehuarewa Marae	Plant & Food Research	Tutehuarewa Marae		New Zealand Society of Local Government Management
University of Canterbury	Rayonier Matariki Forests	University of Canterbury		Strike 4 Climate
Waimakariri District Council	Scion (New Zealand Forest Research Institute)	Waimakariri District Council		Tutehuarewa Marae
Waitaki District Council	Strike 4 Climate			Waimakariri District Council
	The AgriBusiness Group			
	Tutehuarewa Marae			
	Waimakariri District Council			
	University of Canterbury			

B1.2 Workshop invitees

AgResearch Limited
Apiculture NZ
Aquaculture NZ
Ashburton District Council
Ashburton District Council Biodiversity Advisory Group
Ashburton Economic Recovery/Advisory Group
Ashburton Museum
Association for Resource Management
Beef & Lamb
Biosecurity New Zealand
Business NZ Energy Council
Canterbury Chamber of Commerce (CECC)
Canterbury District Health Board (CDHB)
Canterbury Engineering Lifelines Group
Canterbury Mayoral Forum
Canterbury Women's Legal Association
Christchurch City Council
Christchurch NZ
Dairy NZ
Deer Industry NZ
Department of Conservation
Department of Internal Affairs
Environment Canterbury
ECan - CDEM Canterbury
Electricity Ashburton
Environment Canterbury Youth Ropu
EQC
Federated Farmers
Financial Markets Authority
Fire and Emergency New Zealand (FENZ)
Fish & Game - Central SI
Fish & Game - North Canterbury
Fisheries Inshore NZ
Forest & Bird - Ashburton
Forest & Bird - NC
Forest & Bird - SC
Generation Zero
Hinds Drains Working Party
Hurunui DC
Kainga Ora - homes and communities (HNZ)
KiwiRail
Lifeline Group
Lyttelton Port Company
Mackenzie District Council
Manaaki Whenua – Landcare Research New Zealand Limited
Meat Industry Association
Mental Health Foundation
Meridian
Ministry for Culture and Heritage
Ministry for the Environment
Ministry for Women
Ministry of Education
Ministry of Health
Ministry of Primary Industries
Ministry of Social Development (MSD)
Museums Aotearoa
National Emergency Management Agency (NEMA)
New Zealand Archaeological Association
New Zealand Planning Institute (NZPI)
New Zealand Winegrowers
Ngāi Tahu Capital
Ngāi Tahu Farming
Ngāi Tahu Holdings
Ngāi Tahu Property
Ngāi Tahu Seafood
NIWA
North Canterbury Winegrowers
NZ Forest Owners Association
NZ Insurance Council
NZ Law Society Canterbury-Westland branch
Pacific Youth Leadership and Transformation
Prime Port Timaru
Royal New Zealand College of General Practitioners
SCDHB
Selwyn District Council
Strike 4 Climate
Sustainable Business Network
Taumutu Rūnanga and Ngāi Tahu
Te Rūnanga o Ngāi Tahu
Timaru Airport
Timaru District Council
University of Canterbury
Victoria University of Wellington
Waimakariri District Council
Waitaha Primary Health – Georgie McLeod
Waitaki District Council
Waka Kotahi NZTA
Young Farmers

Appendix C: Risk Workbook

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability: Sensitivity			Vulnerability: Adaptive capacity	Risk				Commentary	NCCRA Domain
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Rerenga Rauropi	Biosecurity - safety from pests and diseases	Terrestrial, freshwater, and marine ecosystems from pests and diseases	higher mean temperatures	Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to higher mean temperatures	Moderate	High	High	Extreme	Moderate	High	Extreme	Low	Moderate	Extreme	Extreme	Extreme	Risks to biosecurity are likely to increase in response to projected rising temperatures. This may result in an increased range of invasive species, particularly where exotic species have higher temperature tolerance relative to indigenous species. Native species are often specifically adapted to the environment and climate, and may be out-competed by versatile invasives.	Natural
Rerenga Rauropi	Biosecurity - safety from pests and diseases	Terrestrial, freshwater, and marine ecosystems from pests and diseases	change in mean annual rainfall	Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to change in mean annual rainfall	Moderate	Moderate	Moderate	High	Moderate	High	High	Low	Moderate	High	High	Extreme	Risks to biosecurity are likely increase in response to projected changes in rainfall. Increasing peak flows in rivers may disturb habitats resulting in opportunities for exotic species to establish. Reduced rainfall or drought may further contribute to habitat loss and provide conditions for drought tolerant exotic species. Native species are often specifically adapted to the environment and climate, and may be out-competed by versatile invasives.	Natural
Rerenga Rauropi	Biosecurity - safety from pests and diseases	Terrestrial, freshwater, and marine ecosystems from pests and diseases	reduced snow & ice	Risk to terrestrial, freshwater, and marine ecosystems from pests and diseases due to reduced snow & ice	Moderate	High	High	Extreme	Moderate	High	High	Medium	Low	High	High	Extreme	Risks to biosecurity are likely to increase in response to projected decreasing snow and ice. Reducing occurrence of frosts mean that frost sensitive invasive species may have an increased survival rate.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Native freshwater biodiversity - flora & fauna	higher mean temperatures	Risk to native freshwater biodiversity - flora & fauna due to higher mean temperatures	Low	Moderate	High	High	Moderate	High	Extreme	Medium	Insignificant	Moderate	Extreme	Extreme	Projected increases in temperatures are likely to raise the temperature of waterbodies, particularly shallower lakes and rivers and streams that are not fed by snowmelt. Many native species are sensitive to temperature increases and are adapted to a narrow range of water temperatures, while others are highly adaptive. Warmer temperatures can further alter water quality by contributing to algal blooms.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Native freshwater biodiversity - flora & fauna	River and surface flooding	Risk to native freshwater biodiversity - flora & fauna due to river and surface flooding	Moderate	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Low	Low	Moderate	High	Projected increases in high flows and extreme events may cause increasing disruption to river systems. High flows may cause erosion, sedimentation and damage from storm debris which can degrade habitats.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Native freshwater biodiversity - flora & fauna	change in mean annual rainfall	Risk to native freshwater biodiversity - flora & fauna due to change in mean annual rainfall	Low	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Insignificant	Low	Moderate	High	Projected increases in seasonal extremes are likely to stress freshwater ecosystems. Increased frequency of low flows can cause stress due to includes reduced flushing flows and can lead to the formation of stagnant pools and shallower waters which are more prone to temperature increases, which are harmful to aquatic ecosystems. The effect of reduced summertime rainfall in some river systems will be buffered by snowmelt.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Native marine biodiversity - flora & fauna	marine heatwaves	Risk to native marine biodiversity - flora & fauna due to marine heatwaves	Moderate	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Low	High	High	Sea temperatures and marine heatwaves are projected to increase with climate change as sub-tropical currents penetrate further south. Marine species are sensitive to temperature changes which can cause physiological and behaviour changes, such as reduced phytoplankton abundance and alterations to species migration routes in fish, immobile species are likely to be particularly sensitive. Mobile species may adapt through migration to new habitats which may also see new species entering Canterbury's cooler waters.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Native marine biodiversity - flora & fauna	ocean chemistry changes	Risk to native marine biodiversity - flora & fauna due to ocean chemistry changes	Moderate	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Low	Low	Moderate	High	Ocean acidification is occurring as oceans absorb excess CO_2 from the atmosphere. These changes to ocean chemistry are projected to increase as atmospheric greenhouse gas concentrations rise. Ocean acidification may result in reduced availability of calcium carbonate, which impacts on the life cycle of calcifying organisms such as molluscs and echinoderms. Wider ecosystem disruption may result in increased mortality and population decline.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Coastal wetlands	River and surface flooding	Risk to coastal wetlands due to river and surface flooding	Moderate	High	Extreme	Extreme	Moderate	High	High	Low	Moderate	Extreme	Extreme	Extreme	Projected increases in rainfall intensity is likely to increase the occurrence of flooding. This may cause sediment deposition within wetlands from upstream which can make wetlands shallower, smother habitats and carry additional nutrients or contaminants. Many wetland species are specifically adapted and may suffer from habitat degradation and loss.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Coastal wetlands	increasing coastal erosion	Risk to coastal wetlands due to increasing coastal erosion	Moderate	High	Extreme	Extreme	Moderate	Moderate	High	Low	Moderate	High	Extreme	Extreme	Low-lying coastal wetlands are at risk from coastal erosion which may degrade habitats and cause sediment deposition.	Natural
Rerenga Rauropi	He Kura Taiao – Living treasures	Coastal wetlands	sea-level rise and salinity stresses	Risk to coastal wetlands due to sea-level rise and salinity stresses	Moderate	High	High	Extreme	Moderate	High	High	Medium	Low	High	High	Extreme	Sea level rise and coastal inundation are projected to increase, which will lead to increasing salinity stress to coastal wetlands. Species composition and biodiversity (species richness) is expected to change as a result of periodic or permanent salination of coastal wetlands. Mobile species (some plants and birds) can relocate however, many species of invertebrates, some species of plants, and fish species are specifically adapted to coastal wetland conditions and cannot tolerate large changes in salinity.	Natural
Rerenga Rauropi	Land use	Alpine / high country environments	reduced snow & ice	Risk to alpine / high country environments due to reduced snow & ice	Low	High	High	Extreme	Moderate	Moderate	High	Low	Low	High	Extreme	Extreme	Alpine and high country environments are projected to be exposed to reduced snow and ice as temperatures warm. Alpine ecosystems are likely to be adversely affected as alpine adapted flora and fauna change elevation tolerance, suffer from a reduction and loss of habitats and face increased competition from low-land species. Alpine adapted species often have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.	Natural

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability				Risk				Commentary	NCCRA Domain
									Sensitivity			Adaptive capacity						
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Rerenga Rauropi	Land use	Alpine / high country environments	higher mean temperatures	Risk to alpine / high country environments due to higher mean temperatures	Low	Moderate	High	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	High	Projected increases in mean temperature are likely to change the elevation tolerance of alpine species, cause reduction and loss of habitat, and cause increased competition from low-land species. Many alpine adapted species have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.	Natural
Rerenga Rauropi	Land use	Alpine / high country environments	change in mean annual rainfall	Risk to alpine / high country environments due to change in mean annual rainfall	Low	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Insignificant	Low	Moderate	High	Projected changes in rainfall patterns may cause increased dry periods and drought. This may lead to reduced water availability causing plant stress, leading to reduction or loss of alpine habitat and increased competition from species adapted to the lower altitudinal zones (e.g. montane), and possible changes of alpine ecosystems to montane ecosystems. Many alpine adapted species have a low capacity to adapt due to a limited range, geographic isolation and slow reproductive rates and dispersal mechanisms.	Natural
Rerenga Rauropi	Land use	Lowland and coastal environments	increased fire-weather	Risk to lowland and coastal environments due to increased fire-weather	Moderate	High	High	High	Moderate	Moderate	High	Low	Moderate	High	Extreme	Extreme	Projected increases in wind, temperatures, and number of dry and hot days may increase the likelihood of wildfire. Lowland environments are sensitive to event type disturbances such as wildfire which may cause high rates of mortality and habitat destruction from which local ecosystems may not easily recover.	Natural
Rerenga Rauropi	Land use	Lowland and coastal environments	sea-level rise and salinity stresses	Risk to lowland and coastal environments due to sea-level rise and salinity stresses	Moderate	High	High	Extreme	Moderate	Moderate	High	Medium	Low	Moderate	High	Extreme	Projected sea level rise is likely to cause inundation, erosion and salinity stress. Sea level rise and erosion may compress or degrade coastal habitats, eventually leading to habitat or species loss. Coastal environments can adapt to sea level rise by shifting inland, however this is often limited by geographical constraints or existing land use.	Natural
Rerenga Rauropi	Land use	Lowland and coastal environments	Coastal flooding	Risk to lowland and coastal environments due to coastal flooding	Moderate	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Low	High	High	Projected sea level rise is likely to contribute to increased coastal flooding which may cause erosion, salinization and degrade coastal habitats.	Natural
Rerenga Rauropi	Land use	Montane/hill country environments	increased fire-weather	Risk to montane/hill country environments due to increased fire-weather	Moderate	High	High	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increases in wind, temperatures, and number of dry and hot days may increase the likelihood of wildfire in montane/hill country environments. Montane ecosystems within hill country environments are highly prone to species and habitat loss during fires. Wildfires can cause widespread mortality from which there can be long recovery times.	Natural
Rerenga Rauropi	Land use	Montane/hill country environments	storms and wind	Risk to montane/hill country environments due to storms and wind	Moderate	High	High	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increases in storms and wind may damage montane/hill country environments. The erodible soils within these environments are particularly sensitive when bare. Depletion of native vegetation associated with grazing, pests and other hazards contributes further to erosion. These factors are likely to cause degradation of montane/hill country ecosystems.	Natural
Rerenga Rauropi	Land use	Montane/hill country environments	Drought	Risk to montane/hill country environments due to drought	Moderate	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Low	High	High	The occurrence of drought in montane/hill country environments is projected to increase over time. Ecosystems within these environments are currently relatively tolerant of hot dry conditions, however drought may cause water shortages stressing ecosystems, and contributing to species mortality. The slow recovery of ecosystems may lead to increasing establishment of exotic species.	Natural
Rerenga Rauropi	Land use	Montane/hill country environments	higher mean temperatures	Risk to montane/hill country environments due to higher mean temperatures	Low	Moderate	High	High	Moderate	Moderate	High	Medium	Insignificant	Low	High	High	Temperatures are projected to increase in montane/hill country environments over time. Ecosystems within these environments are currently relatively tolerant of hot dry conditions, however the adaptive capacity of species may reduce once temperature tolerance thresholds are reached.	Natural
Wai	Flood defences	Coastal barriers and sea walls	increasing coastal erosion	Risk to coastal barriers and sea walls due to increasing coastal erosion	High	Extreme	Extreme	Extreme	Low	Moderate	Moderate	Medium	Low	High	High	High	Projected increases in sea-level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.	Built
Wai	Flood defences	Coastal barriers and sea walls	Coastal flooding	Risk to coastal barriers and sea walls due to coastal flooding	High	Extreme	Extreme	Extreme	Low	Moderate	Moderate	Medium	Low	High	High	High	Projected increases in sea-level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.	Built
Wai	Flood defences	Coastal barriers and sea walls	storms and wind	Risk to coastal barriers and sea walls due to storms and wind	High	Extreme	Extreme	Extreme	Low	Moderate	Moderate	Medium	Low	High	High	High	Projected increases in sea level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.	Built

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability: Sensitivity			Vulnerability: Adaptive capacity	Risk				Commentary	NCCRA Domain
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Wai	Flood defences	Coastal barriers and sea walls	sea-level rise and salinity stresses	Risk to coastal barriers and sea walls due to sea-level rise and salinity stresses	High	Extreme	Extreme	Extreme	Low	Moderate	Moderate	Medium	Low	High	High	High	Projected increases in sea level rise, storms and wind and coastal flooding will increase exposure of sea walls and barriers as these are located along the coastal edge. These structures are designed to protect against coastal hazards, however damage may occur if the design capacity is exceeded, or due to sustained and increasing exposure. High costs and limited land availability limit the capacity to adapt.	Built
Wai	Flood defences	Stopbanks and flood management schemes	River and surface flooding	Risk to stopbanks and flood management schemes due to river and surface flooding	High	High	Extreme	Extreme	Moderate	High	High	Medium	Moderate	High	Extreme	Extreme	Projected increases in the size and frequency of flood events may effectively lower the level of service currently provided by stop banks and increase the occurrence of overtopping or flood damage. Although the structures are designed to convey floods, exceeding the design capacity or frequent exposure to high flows may cause damage or failure. is exceeded, or increasing damage may occur with high flows. Options to adapt or upgrade may be limited by high construction costs and limited land availability.	Built
Wai	Flood defences	Stopbanks and flood management schemes	sea-level rise and salinity stresses	Risk to stopbanks and flood management schemes due to sea-level rise and salinity stresses	Moderate	High	High	High	Moderate	Moderate	Moderate	Medium	Low	Moderate	Moderate	Moderate	Projected increases in sea-level rise will increase the exposure of stopbanks located near the coastal edge to related flooding and erosion damage. A relatively small portion of schemes may be exposed to coastal hazards relative to fluvial flooding, with sensitivity, to damage influenced by the condition and age of the structure. Options to adapt or upgrade may be limited by high construction costs and limited land availability.	Built
Wai	Freshwater	Groundwater - availability and quality	sea-level rise and salinity stresses	Risk to groundwater - availability and quality due to sea-level rise and salinity stresses	Moderate	High	High	High	High	High	Extreme	Low	High	Extreme	Extreme	Extreme	Projected sea level rise may cause salinization of coastal aquifers which may be compounded where abstraction occurs near the coastal edge. The adaptive capacity of aquifers is considered low as most have reached the upper limit of the allowable allocation.	Natural
Wai	Freshwater	Groundwater - availability and quality	change in mean annual rainfall	Risk to groundwater - availability and quality due to change in mean annual rainfall	Moderate	High	High	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Changes in rainfall patterns are projected, with wetter winters and drier summers. Wetter winters may cause higher groundwater tables in winter, with dry summers and increasing evapotranspiration contributing to lower water tables in summer.	Natural
Wai	Freshwater	Groundwater - availability and quality	Drought	Risk to groundwater - availability and quality due to drought	Moderate	High	Extreme	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	The occurrence of drought is projected to increase with climate change. This will lower water and reduce rates of recharge. Increased water demand is likely to coincide with extended dry periods and drought, placing further pressure on aquifers.	Natural
Wai	Freshwater	Water quality (lakes and rivers)	River and surface flooding	Risk to water quality (lakes and rivers) due to river and surface flooding	Moderate	Moderate	High	High	Moderate	Moderate	High	Medium	Low	Low	High	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. Erosion and scour resulting from flooding may result in increased sediment in waterways, reducing water quality and disturbing habitats. Runoff entering rivers may also introduced increased nutrient and other contaminants. Modified rivers with constrained floodplains may be particularly sensitiveto degradation from flooding, and have limited	Natural
Wai	Freshwater	Water quality (lakes and rivers)	change in mean annual rainfall	Risk to water quality (lakes and rivers) due to change in mean annual rainfall	Low	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Insignificant	Low	Moderate	High	Projected changes in rainfall are likely to result in increased frequency of low flows in most rivers. Increased frequency of low flows may reduce flushing flows and compound the effects of warmer temperatures, promoting the growth of algae and macrophytes.	Natural
Wai	Freshwater	Water quality (lakes and rivers)	reduced snow & ice	Risk to water quality (lakes and rivers) due to reduced snow & ice	Low	Moderate	Moderate	High	Moderate	Moderate	High	Medium	Insignificant	Low	Moderate	High	Projected changes to snow and ice are likely to contribute to the increasing occurance of low flows. Increased frequency of low flows may reduce flushing flows and compound the effects of warmer temperatures, promoting the growth of algae and macrophytes.	Natural
Wai	Freshwater	Water quality (lakes and rivers)	higher mean temperatures	Risk to water quality (lakes and rivers) due to higher mean temperatures	Moderate	High	Extreme	Extreme	Moderate	High	Extreme	Medium	Low	High	Extreme	Extreme	Projected increases in temperature are likely to be detrimental to water quality in lakes and rivers. Warmer temperatures can be harmful to native frehwater biodiversity and promote the growth of algae and macrophytes. Smaller, shallow waterbodies, and those that are not snowmelt fed are likely to be most sensitive to warming temperatures.	Natural
Wai	Freshwater	Water quality (lakes and rivers)	increasing landslides and soil erosion	Risk to water quality (lakes and rivers) due to increasing landslides and soil erosion	Moderate	High	High	High	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	Increased erosion and sediment from landslides may result in increased sediment in waterways, reducing water quality and disturbing habitats.	Natural
Wai	Freshwater	Water quality (lakes and rivers)	sea-level rise and salinity stresses	Risk to water quality (lakes and rivers) due to sea-level rise and salinity stresses	Low	Moderate	High	High	Moderate	Moderate	High	Medium	Insignificant	Low	High	High	Projected sea level rise may cause salinization and flooding or coastal rivers and lakes with increasing frequency. Saltwater intrusions have a profound impact on the water quality of lakes and rivers changing the types of ecological communities they can support.	Natural
Wai	Stormwater	Stormwater assets	River and surface flooding	Risk to stormwater assets due to river and surface flooding	Moderate	High	High	High	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. Overloading of stormwater systems are likely to cause flooding of surrounding communiites, damage to components of the stormwater network, and have consequences for the water quality of recieving waterbodies. Older systems are likely to be particularly sensitive as these are often in poorer condition with smaller capacities.	Built

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability				Risk				Commentary	NCCRA Domain
									Sensitivity			Adaptive capacity						
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Wai	Wastewater	Wastewater treatment plants	sea-level rise and salinity stresses	Risk to wastewater treatment plants due to sea-level rise and salinity stresses	Moderate	High	High	High	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	Projected sea level rise may cause erosion damage, and increased occurance of inundation resulting in overflows. Rising groundwater may introduce flotation of buried components, and increased infiltration to wastewater pipelines, causing increased loading on pumping stations. Salinization of wastewater may cause corrosivity and have implications for wastewater treatment plant operations.	Built
Wai	Wastewater	Wastewater treatment plants	increasing coastal erosion	Risk to wastewater treatment plants due to increasing coastal erosion	Moderate	High	High	High	Moderate	Moderate	Moderate	Low	Moderate	High	High	High	Projected sea level rise may cause erosion damage to components of the wastewater system that are located near the coastal edge. Wastewater assets can be expensive to upgrade, and options to relocate are limited as these systems perform best when located at the downstream point of the network.	Built
Wai	Water	Surface water availability and supply	Drought	Risk to surface water availability and supply due to drought	Moderate	High	Extreme	Extreme	Extreme	Extreme	Extreme	Medium	High	Extreme	Extreme	Extreme	Projected increases in drought are likely to impact water availability and supply. Water supply is highly sensitive to drought due to extensive water abstraction. Reduced availability due to drought is likely to coincide with increasing demand. Strategies are currently in place to monitor and manage water sources to adapt to climate change. Further, measures to reduce demand may be adopted.	Built
Wai	Water	Surface water availability and supply	change in mean annual rainfall	Risk to surface water availability and supply due to change in mean annual rainfall	Moderate	High	High	High	High	High	High	Medium	Moderate	High	High	High	Projected changes in rainfall are likely to impact water availability and supply, with reductions in surface water availability in some parts of the region. Reduced availability due to low rainfall and river flows is likely to coincide with increased demand. Strategies are currently in place to monitor and manage water sources to adapt to climate change. Further, measures to reduce demand may be adopted.	Built
Wai	Water	Surface water availability and supply	reduced snow & ice	Risk to surface water availability and supply due to reduced snow & ice	Low	Moderate	Moderate	High	High	High	High	Medium	Low	Moderate	Moderate	High	Projections of reduced snow and ice are a component of complex hydrological changes that may contribute to reduced water availability. Reduced snow and ice may result in lower summer flows in the headwaters of many major Canterbury rivers.	Built
Wai	Water	Water supply infrastructure	River and surface flooding	Risk to water supply infrastructure due to river and surface flooding	Moderate	High	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	Moderate	High	The frequency and intensity of storms are projected to increase over time, which may cause increased flooding. High flows, sediment and debris may cause damage and disruption to water supply facilities, particularly above ground infrastructure such as intakes. Poor condition or ageing components may be upgraded to improve resilience. However, the potential to adapt water supply infrastructure may be limited by the need to draw water from exposed locations, and service existing communities.	Built
Wai	Water	Water supply infrastructure	storms and wind	Risk to water supply infrastructure due to storms and wind	Moderate	High	High	Extreme	Moderate	Moderate	Moderate	Medium	Low	Moderate	Moderate	High	The frequency and intensity of storms are projected to increase over time. High flows, sediment and debris may cause damage and disruption to water supply facilities, particularly above ground infrastructure such as intakes. Poor condition or ageing components may be upgraded to improve resilience. However, the potential to adapt water supply infrastructure may be limited by the need to draw water from exposed locations, and service existing communities.	Built
Hirihiri	Energy	Energy generation	Drought	Risk to energy generation due to drought	Low	Moderate	High	High	High	High	High	Medium	Low	Moderate	High	High	The potential for drought is projected to increase over time, which may impact water availability. Hydropower generation is the dominant source of energy generation in region, and is highly dependent on water availability. The adaptive capacity of hydropower generation is low for existing schemes, however there is potential for increased establishment and uptake of diverse energy sources regionally and nationally.	Built
Hirihiri	Energy	Energy transmission	Extreme weather events	Risk to energy transmission due to extreme weather events	Low	Moderate	Extreme	Extreme	High	High	High	Medium	Low	Moderate	Extreme	Extreme	Extreme weather events are projected to increase, with increasing exposure of transmission lines to wind, rainfall and flooding. Overhead transmission lines are particularly sensitive to damage from wind and flooding. Measures to reduce exposure of transmission lines include burying lines, however this can be prohibitively expensive for existing infrastructure.	Built
Hirihiri	Energy	Energy transmission	River and surface flooding	Risk to energy transmission due to river and surface flooding	Low	Moderate	Extreme	Extreme	High	High	High	Medium	Low	Moderate	Extreme	Extreme	Extreme weather events are projected to increase, with increasing exposure of transmission lines to wind, rainfall and flooding. Overhead transmission lines are particularly sensitive to damage from wind and flooding. Measures to reduce exposure of transmission lines include burying lines, however this can be prohibitively expensive for existing infrastructure.	Built
Hirihiri	Energy	Energy transmission	Coastal flooding	Risk to energy transmission due to coastal flooding	Low	Moderate	Extreme	Extreme	High	High	High	Medium	Low	Moderate	Extreme	Extreme	Projected sea level rise will increase the exposure of transmission lines to coastal flooding. Overhead transmission lines are particularly sensitive to damage from wind and flooding. Measures to reduce exposure of transmission lines include burying lines, or relocating lines inland. However, this can be prohibitively expensive for existing infrastructure.	Built
Ngā Waihanga	Transport infrastructure	Airports	River and surface flooding	Risk to airports due to river and surface flooding	Moderate	High	High	High	Moderate	Moderate	High	Low	Moderate	High	Extreme	Extreme	Increased extreme weather events are projected to occur, which may lead to increased surface and riverine flooding. Very few airports are currently exposed, however the flooding of the Christchurch International Airport is not yet fully understood. Flooding can cause damage to airport buildings, runways and underground infrastructure, as well as causing disruption to services.	Built

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability				Risk				Commentary	NCCRA Domain
									Sensitivity			Adaptive capacity						
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Ngā Waihanga	Transport infrastructure	Marine facilities	storms and wind	Risk to marine facilities due to storms and wind	Moderate	High	Extreme	Extreme	High	High	High	Medium	Moderate	High	Extreme	Extreme	Sea level rise and increased storminess is projected to increase with climate change. This may cause disruption to port operations as storm surge and severe weather prevents normal operation and increases the risk of damage to cranes. The capacity for ports to adapt is limited by the need to remain at coastal locations, however these facilities can be upgraded to provide improved protection to sensitive equipment	Built
Ngā Waihanga	Transport infrastructure	Marine facilities	sea-level rise and salinity stresses	Risk to marine facilities due to sea-level rise and salinity stresses	Low	Moderate	High	High	High	High	High	Medium	Low	Moderate	High	High	Sea level rise is projected to increase with climate change and may cause inundation of some facilities. The capacity for ports to adapt is limited by the need to remain at coastal locations, however low lying and sensitive parts of these facilities may be upgraded or raised.	Built
Ngā Waihanga	Transport infrastructure	Rail	increasing coastal erosion	Risk to rail due to increasing coastal erosion	Moderate	Moderate	High	High	High	High	High	Low	High	High	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increasing storminess. Sections of rail are exposed to coastal erosion, particularly along the Kaikoura Coast. Coastal erosion may damage tracks severely, and cause disruption to services. Some coastal routes have limited options for alternative inland routes, and are required to continue to serve existing communities.	Built
Ngā Waihanga	Transport infrastructure	Rail	increasing landslides and soil erosion	Risk to rail due to increasing landslides and soil erosion	Moderate	High	Extreme	Extreme	High	High	Extreme	Medium	Moderate	High	Extreme	Extreme	A large section of the Kaikoura rail line is located adjacent to coastal cliffs. Coastal erosion may erode or destroy the track causing disruptions and damage. There is potential for strengthening of these sections of cliff face or improved coastal defences.	Built
Ngā Waihanga	Transport infrastructure	Rail	higher mean temperatures	Risk to rail due to higher mean temperatures	Low	Moderate	High	High	High	High	High	Medium	Low	Moderate	High	High	Projected increasing temperatures may increase the occurrence of buckling of tracks. Maintenance can be done to avoid buckling i.e. destressing	Built
Ngā Waihanga	Transport infrastructure	Rail	sea-level rise and salinity stresses	Risk to rail due to sea-level rise and salinity stresses	Low	Moderate	High	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	High	Projected sea level rise may cause inundation and increase salinity stress for coastal rail routes such as those along the Kaikoura Coast. This may cause coastal erosion, disruption to services and increase corrosion due to salt water intrusion. Some coastal routes have limited options for alternative inland routes, and are required to continue to serve existing communities.	Built
Ngā Waihanga	Transport infrastructure	Roads and bridges	increasing coastal erosion	Risk to roads and bridges due to increasing coastal erosion	Low	Moderate	High	High	High	High	High	Low	Moderate	High	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increased storminess. Coastal roads and bridges may be exposed to erosion which can damage bridge footings, road foundations, and erode surfaces. Options to adapt include retreat or abandonment.	Built
Ngā Waihanga	Transport infrastructure	Roads and bridges	River and surface flooding	Risk to roads and bridges due to river and surface flooding	Moderate	High	Extreme	Extreme	Moderate	High	High	Medium	Low	High	Extreme	Extreme	Projected increases in extreme rainfall events are likely to result in increased surface and riverine flooding. Bridges exposed to flooding may be damaged through erosion, debris strike or washout. Flooding can cause disruption and damage to roads, which is influenced by material, type of structure, condition and age. Improved resilience can be achieved though maintenance and provision of alternative routes.	Built
Ngā Waihanga	Transport infrastructure	Roads and bridges	sea-level rise and salinity stresses	Risk to roads and bridges due to sea-level rise and salinity stresses	Low	Moderate	High	High	High	High	High	Medium	Low	Moderate	High	High	Projected sea level rise is likely to increase exposure of roads to inundation and salinity stress. Roads exposed to inundation may be damaged and travel routes disrupted.	Built
Ngā Waihanga	Waste management	Solid waste management and contamination sites	increasing coastal erosion	Risk to solid waste management and contamination sites due to increasing coastal erosion	Moderate	High	Extreme	Extreme	Moderate	High	High	Low	Moderate	Extreme	Extreme	Extreme	Coastal erosion is likely to increase with projected sea level rise and increased storminess, which may expose some coastal landfills to erosion. Old landfills are particularly sensitivity to erosion due to often poor lining and capping protection. Increased leachate my be produced, or the integrity of landfill may be compromised. Landfills have a low adaptive capacity as they are permanent features that are expensive and complex to remove. Remedial works may increase protection against erosion and leachate.	Built
Ngā Waihanga	Waste management	Solid waste management and contamination sites	sea-level rise and salinity stresses	Risk to solid waste management and contamination sites due to sea-level rise and salinity stresses	Moderate	High	High	Extreme	Moderate	High	High	Low	Moderate	Extreme	Extreme	Extreme	Projected sea level rise may expose some coastal landfills to salinity stress and inundation. Old landfills have high sensitivity due to likely poor lining and capping protection. Water ingress may cause Increased leachate to be produced, which may be a contaminant if the integrity of the landfill is compromised. Landfills are permanent features that are expensive and complex to remove, however remedial works may increase protection against erosion and leachate.	Built
Ngā Waihanga	Waste management	Solid waste management and contamination sites	River and surface flooding	Risk to solid waste management and contamination sites due to river and surface flooding	Moderate	Moderate	High	High	Moderate	Moderate	Moderate	Low	Moderate	Moderate	High	High	Projected increases in extreme rainfall events are likely to increase riverine and surface flooding, increasing the number and frequency of landfills that are exposed. Flooding can cause erosion and cause floodwater to enter the cap. This is of particular concern for old landfills due to the often poor lining and capping protection. Landfills have a low adaptive capacity as they are permanent features that are expensive and complex to remove. Remedial works may increase protection against erosion and leachate.	Built

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability: Sensitivity			Vulnerability: Adaptive capacity	Risk				Commentary	NCCRA Domain
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Ōhanga	Agriculture	Crops	Drought	Risk to crops due to drought	Moderate	High	Extreme	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increase in drought potential is likely to impact crops. Crops are extremely dependent on water availability for irrigation.	Economy
Ōhanga	Agriculture	Crops	storms and wind	Risk to crops due to storms and wind	Moderate	Moderate	High	High	High	High	High	Medium	Moderate	Moderate	High	High	Projected increases in storms and wind will increase exposure of crops to flooding, wind and storm damage. Crops are highly sensitive to damage from flooding and storms which can destroy crops. Change of crop cycle, timing or varieties may provide some adaptive capacity, also changing management measures such as wind shelter breaks	Economy
Ōhanga	Agriculture	Crops	higher mean temperatures	Risk to crops due to higher mean temperatures	Low	High	Extreme	Extreme	Low	Low	Low	Medium	Insignificant	Low	Moderate	Moderate	Projected increase in temperatures may increase pests and irrigation demand. Change of crop cycle, timing or varieties may provide some adaptive capacity or increased use of pesticides.	Economy
Ōhanga	Agriculture	Livestock	Drought	Risk to livestock due to drought	Moderate	High	Extreme	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increase in drought potential is likely to impact livestock farming. Livestock farming is extremely dependent on water availability to sustain optimum grass growth and for stock drinking water. Relocation of stock or feed supplementation may reduce impacts of drought on stock.	Economy
Ōhanga	Agriculture	Livestock	higher mean temperatures	Risk to livestock due to higher mean temperatures	Low	Moderate	High	High	Moderate	Moderate	Moderate	Medium	Insignificant	Low	Moderate	Moderate	Projected increase in temperature are likely to impact livestock farming. Livestock are moderately sensitive to temperature, which can lead to heat stress and lower milk production. The impacts of temperature on herds may be reduced through breeding for temperature resilience.	Economy
Ōhanga	Finance and insurance	The cost of business	storms and wind	Risk to the cost of business due to storms and wind	Low	Moderate	High	High	High	High	Extreme	Medium	Low	Moderate	Extreme	Extreme	Damages from increased severe weather and sudden events such as fire may lead to various types of costs for individuals, businesses, government (link to governance), and the whole economy. Costs are likely to include those associated with loss or stranding of property and assets (including land), cost of repairing, rebuilding or replacing assets, and the cost of preventative measures. Investment opportunities may arise from the transition to a low carbon economy.	Economy
Ōhanga	Finance and insurance	Supply chains	increasing landslides and soil erosion	Risk to supply chains due to increasing landslides and soil erosion	Low	Low	Moderate	Moderate	High	High	High	Medium	Low	Low	Moderate	Moderate	Sudden onset hazards can impact business supply chains, making business difficult and can result in loss of stock or increased costs.	Economy
Ōhanga	Finance and insurance	Insurance	sea-level rise and salinity stresses	Risk to insurance due to sea-level rise and salinity stresses	Low	High	High	Extreme	High	High	Extreme	Medium	Low	High	Extreme	Extreme	Asset owners, including home owners, residents, and business owners, are likely to face increasing insurance premiums and excesses due to increased and/or ongoing damage. Increased insurance premiums or reduction in insurance availability may result in a loss of property value, which has wider economic implications and ultimately may affect the viability of some businesses.	Economy
Ōhanga	Fisheries	Fisheries and aquaculture	ocean chemistry changes	Risk to fisheries and aquaculture due to ocean chemistry changes	Low	High	High	Extreme	High	High	High	Low	Moderate	Extreme	Extreme	Extreme	Changes in ocean chemistry changes are likely to occur with projected temperature increases. Studies of shellfish and aquatic ecosystems indicate that fisheries are extremely sensitive to heat waves and ocean chemistry changes. Mortality is likely to increase and condition reduce, with potentially high consequences for fisheries.	Economy
Ōhanga	Fisheries	Fisheries and aquaculture	marine heatwaves	Risk to fisheries and aquaculture due to marine heatwaves	Low	High	High	Extreme	Extreme	Extreme	Extreme	High	Low	High	High	Extreme	Sea temperatures and marine heatwaves are projected to increase with climate change, with potential loss in marine species and biodiversity. Fisheries may adapt as the relatively cool temperatures off the Canterbury coastline, may act as a favourable destination for affected species from warmer climates.	Economy
Ōhanga	Fisheries	Fisheries and aquaculture	storms and wind	Risk to fisheries and aquaculture due to storms and wind	Low	Moderate	Moderate	Moderate	High	High	High	Medium	Low	Moderate	Moderate	Moderate	Projected increases in storms and wind may cause increased sediment runoff in nearshore environments. Reduced water quality in inshore environments may impact the health of some major fish species and shellfish, and may smother habitats. Continued efforts to improve stormwater runoff water quality will support improved nearshore water quality.	Economy
Ōhanga	Forestry	Exotic forestry	increased fire-weather	Risk to exotic forestry due to increased fire-weather	Low	Moderate	High	High	High	High	High	Low	Moderate	High	Extreme	Extreme	Pockets of exotic forestry spread across the region will be exposed to increasing fire weather, due to projected increases in temperatures, dry periods and wind. Forestry is highly sensitive to wildfire damage which can case substantial economic losses. Measures to reduce fire risk include pruning, weed control, undergrowth maintenance, fire breaks and off-season burning.	Economy
Ōhanga	Forestry	Exotic forestry	storms and wind	Risk to exotic forestry due to storms and wind	Low	Moderate	High	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	High	Storms and wind are projected to become more severe, which will increase the exposure of forestry, where young forests are particularly sensitive to damage. Storm damage can cause windthrow, erosion and damage to related infrastructure, with costly repairs and health and safety risks associated with clearing damaged branches. Frequent exposure to high winds can result in sturdier trees of lower grade timber.	Economy
Ōhanga	Forestry	Exotic forestry	higher mean temperatures	Risk to exotic forestry due to higher mean temperatures	Low	Moderate	High	High	Low	Low	Low	High	Insignificant	Insignificant	Low	Low	Forests will be exposed to projected increases in temperature, particularly in inland areas where temperatures are highest. Temperatures can change productivity (which may increase in many areas) and cause increased growth of weeds and higher rates of pests and disease.	Economy

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability				Risk				Commentary	NCCRA Domain
									Sensitivity			Adaptive capacity						
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Ōhanga	Tourism	Tourism sector	reduced snow & ice	Risk to tourism sector due to reduced snow & ice	Low	Moderate	Moderate	Extreme	High	High	High	Low	Moderate	High	High	Extreme	Projected reductions in snow and ice are likely to impact the tourism sector, particularly winter sports such as skiing, and related attractions. Alpine sports tourism is highly sensitive to warming temperatures which can reduce snow base and the length of the ski season. Tourism may also be impacted by more general changes to the natural environment. Alpine sports tourism has low adaptative capacity to reduced snow and ice, however measures exist to compensate for reduced snow such as snow machines.	Economy
Ōhanga	Tourism	Tourism sector	River and surface flooding	Risk to tourism sector due to river and surface flooding	Low	High	Extreme	Extreme	High	High	High	Medium	Low	High	Extreme	Extreme	Projected increases in extreme rainfall are likely to result in increased flooding. Low lying and riverine attractions are likely to be exposed to flooding, which may also disrupt access routes and change the natural character of the region. The tourism sector is sensitive to flood damage to coastal and riverine attractions and amenities, which can be costly to repair and disrupt services. Related cancellations can reduce consumer confidence, particularly if frequent or recurring. The tourism sector may adapt to climate change as the market is likely to continue to seek tourism destinations. There is potential for increased tourism in Canterbury relative to other destinations that may suffer more severe damage.	Economy
Hauora		Mental wellbeing	Climate change	Risk to mental wellbeing due to climate change	Low	High	Extreme	Extreme	Moderate	Moderate	High	Low	Low	High	Extreme	Extreme	Risks to mental health may arise from a range of climate change related issues, and exposure may be widespread across all sections of the community. Some groups within the community already experiencing negative mental health impacts related to climate change stresses. Further mental health issues are likely to stem from a wide range of factors and compound with other physical and cultural health impacts.	Human
Hauora		Physical health	Climate change	Risk to physical health due to climate change	Low	Moderate	High	High	High	High	High	Medium	Low	Moderate	High	High	Risks to physical health from climate change are likely to be widespread across all communities. Physical health impacts are likely to be driven by direct exposure to climate hazards such as flooding and fire, which is likely to increase as slow moving climatic changes such as high temperatures begin to impact health. Health impacts may also arise through a range of indirect causes, such as damp housing caused by high groundwater or increased flooding. Medical intervention and public health measures can support communities to adapt, however this may be limited by the capacity for health services to respond effectively.	Human
Ora rite		Increase inequalities and cost of living	Climate change	Risk to increase inequalities and cost of living due to climate change	Low	High	Extreme	Extreme	Moderate	Moderate	High	Low	Low	High	Extreme	Extreme	Risks to inequality and living costs are likely to arise from a range of climate hazards, and continue to increase as widespread effects of climate change are felt. Communities with current inequity are likely to be impacted first and most severely in the long term, and have a low capacity to adapt to change.	Human
Hapori	Housing and buildings	Rural housing and communities	River and surface flooding	Risk to rural housing and communities due to river and surface flooding	Moderate	High	Extreme	Extreme	High	Extreme	Extreme	Low	High	Extreme	Extreme	Extreme	Projected increases in extreme events are likely to cause increased flooding. Relatively low density of dwellings in rural communities mean that there are lower numbers of exposed rural buildings. However, the condition of these buildings may be lower due to age and overall lack of maintenance meaning a higher sensitivity to flood damage.	Built
Hapori	Housing and buildings	Rural housing and communities	increased fire-weather	Risk to rural housing and communities due to increased fire-weather	Moderate	High	High	Extreme	High	High	Extreme	Medium	Moderate	High	Extreme	Extreme	Projected increases in temperature, wind and dry days are likely to increase the fire weather exposure particularly in inland rural communities. Warmer temperatures, increased areas of barren land and high vegetation cover make rural communities sensitive to fire. Defences and strategies can be put in place to increase resilience, such as scrub clearing, pruning and planting of fire resistant trees i.e. deciduous.	Built
Hapori	Housing and buildings	Settlements and urban communities	Coastal flooding	Risk to settlements and urban communities due to coastal flooding	Moderate	High	High	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.	Built
Hapori	Housing and buildings	Settlements and urban communities	River and surface flooding	Risk to settlements and urban communities due to river and surface flooding	Moderate	High	Extreme	Extreme	High	High	High	Low	High	Extreme	Extreme	Extreme	Projected increases in extreme events are likely to cause increased flooding to which some urban communities are highly exposed. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including stop banks and retreat.	Built

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure: Present	Exposure: 2050	Exposure: 2100 RCP 4.5	Exposure: 2100	Vulnerability – Sensitivity: Present	Vulnerability – Sensitivity: 2050	Vulnerability – Sensitivity: 2100	Vulnerability – Adaptive capacity	Risk: Present	Risk: 2050	Risk: RCP4.5 2100	Risk: 2100	Commentary	NCCRA Domain
Hapori	Housing and buildings	Settlements and urban communities	increasing coastal erosion	Risk to settlements and urban communities due to increasing coastal erosion	Low	Moderate	High	High	High	High	High	Low	Moderate	High	Extreme	Extreme	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.	Built
Hapori	Housing and buildings	Settlements and urban communities	sea-level rise and salinity stresses	Risk to settlements and urban communities due to sea-level rise and salinity stresses	Low	Moderate	High	High	Moderate	Moderate	Moderate	Low	Low	Moderate	High	High	Projected increases in sea level rise and storminess are likely to lead to increased coastal flooding and erosion. Urban communities will be increasingly exposed to flooding, as many are located in low lying coastal areas. Buildings are sensitive to flood damage which can destroy interiors and cause loss of property. Older buildings, and those with timber construction are particularly sensitive. Adaptation options are available including sea walls, sand dune remediation and retreat.	Built
Hapori		Community cohesion	Climate change	Risk to community cohesion due to climate change	Low	Moderate	Extreme	Extreme	Moderate	High	High	Low	Low	High	Extreme	Extreme	Community cohesion with Canterbury may be affected by climate change in both rural and urban settings. Community disruption may be caused by event based hazards such as fire, extreme events, and flooding, or slow-moving hazards, such as sea level rise and temperature. Exposure to hazards may motivate individuals or groups to relocate, where the loss of key community members can have a range of consequences for community cohesion, particularly in small communities. It is likely to be difficult for communities to adapt and recover from the loss of key members or a change in the social fabric. Some opportunities may exist for towns that are less exposed and may see population growth or increased cohesion in the face of adversity, and individuals may find new opportunities to show leadership.	Human
Mātauranga		Cultural identity	Climate change	Risk to cultural identity due to climate change	Low	Moderate	Extreme	Extreme	Moderate	High	Extreme	Low	Low	High	Extreme	Extreme	Māori have a deep connection to turangawaewae, and hold a strong significance regarding 'place'. Many cultural heritage sites and Marae are located in coastal and low lying areas and may be exposed to flooding, erosion and related issues such as loss of access. Other changes are also likely to undermine cultural practices, including reduced connectivity, dispersal/relocation of communities and degradation of the natural environment.	Human
Rangatiratanga		Legal liability	Climate change	Risk to legal liability due to climate change													•Risk of increased legal liability of Councils and public agencies. Councils should strive for a full knowledge of liability through understanding of risk, across all levels of governance. This includes educating government to ensure that the correct information is available for effective decisions. This needs to look beyond today and tomorrow. •Lack of legal framework to deal with climate change.	Governance
Rangatiratanga		Ability to fund and maintain public services	Climate change	Risk to ability to fund and maintain public services due to climate change													•Climate hazards will negatively impact the ability to fund and maintain public services – this includes water supply agriculture/irrigation, community facilities and events, leading to Governance limiting the ability to respond to societal values. •Beyond this, where do decisions sit around maintaining future infrastructure and services, looking at efficiencies vs redundancies. •Reticulation of services relies on governance, with current policy supporting reticulation.	Governance
Rangatiratanga		Availability and access to funding	Climate change	Risk to availability and access to funding due to climate change													•Impact of climate hazards on Council budgets, insurance and reinsurance (and wider underwriting) availability, and for mortgage access. •The mis-alignment between insurance and mortgage timeframes further exacerbates this risk. •Strategic planning within local government looks ahead for planning, but do budgets align to the timeframes that climate change presents. Uncertainty in who pays. •Reduction in insurance and cost transfer to council is a consequence of lack of funding availability (e.g. Red Zone).	Governance
Rangatiratanga		Co-governance (including Te Tiriti Partnerships)	Climate change	Risk to co-governance (including te tiriti partnerships) due to climate change													•The failure to establish / leverage co-governance partnerships within governance structures (with Māori, Youth etc) to address Climate Change matters. •Broad and profound differences in the manner and approach to governance which are at risk from being exacerbated by climate change, with voices lost or marginalised, departing further from (existing or planned) co-governance structure.	Governance

Integrated Framework	Category	Element at risk	Climate hazard	Risk statement	Exposure				Vulnerability				Risk				Commentary	NCCRA Domain
									Sensitivity			Adaptive capacity						
					Present	2050	2100 RCP 4.5	2100	Present	2050	2100		Present	2050	RCP4.5 2100	2100		
Rangatiratanga		Emergency management and policing	Climate change	Risk to emergency management and policing due to climate change													•Systems are currently in place, but systems for responding to heat waves and fires are currently inadequate, and climate hazards negatively impact on recovery. •No capacity for extreme weather events, leading to impact on Council business as usual services. •Changing governance structures during declared emergencies over to Controller. Group plan too short in outlook for climate change, considering present day risks leaving little room for adaptation. Linked to finance, with major funding coming from central government, putting access on recovery rather than risk reduction through adaptation.	Governance
Rangatiratanga		Exacerbating the misalignment of juristictoral areas	Climate change	Risk to exacerbating the misalignment of juristictoral areas due to climate change													•Lack of jurisdictional clarity of Councils and public agencies (i.e. the differing jurisdictional boundaries for District Health Boards vs other agencies) further burdening integration between social service agencies. This risk will ultimately undermine process and increase inequities. Given that community wellbeing is not a feature and responsibility within the Local Plan, Local Government and wider public services will struggle given the lack of clarity with roles and responsibilities. •The risk of organisational sustainability and the associated impacts of long-term existence of governance and the future needs to amalgamate across differing jurisdictions. T •he benefits of reduced organisational costs could result in reduced granularity of knowledge and evidence to support action, loosing local values through integration of approaches to tackle seemingly common problems.	Governance
Rangatiratanga		Functioning of planning rules and policies	Climate change	Risk to functioning of planning rules and policies due to climate change													•Climate hazards will negatively impact on the functioning of planning rules and policies. •Increased risk from mis-funding, where planning rules and policies lead to enabling funding that contributes to mal-adaptation.	Governance
Rangatiratanga		Inablilty to make effective decisions	Climate change	Risk to inability to make effective decisions due to climate change													•Interlinked with legal liability, the inability to make effective decisions could lead to increased risk, mal-adaptation, and discourse. •Existing tools not fit for purpose to address climate change trade-offs that may be required, and the complexities that need to be considered. •Holistic approach required to ensure decision making is not in isolation, something that is not consistent or effective currently across governance.	Governance
Rangatiratanga		Reputational damage	Climate change	Risk to reputational damage due to climate change													•Intrenched within the declaration of a climate emergency with lack of action, reputational risk from inaction is ever present. The choice of the “climate emergency” language implies immediate action, leading to increased frustration from community over lack of visible progress. •The pace of governance to be able to react plays a significant role in the increased reputational risk.	Governance
Rangatiratanga		The availability of climate adaptation funding	Climate change	Risk to the availability of climate adaptation funding due to climate change													•Increased need for adaptation funding due to natural hazards, and how this funding is made available to address adaptation planning.	Governance
Rangatiratanga		Voting structures	Climate change	Risk to voting structures due to climate change													•Inability for governance to navigate consistently through decision making, and beyond election cycles. •The misalignment of climate change and voting timeframes results in risk of failure of governance as a result of voting structure.	Governance