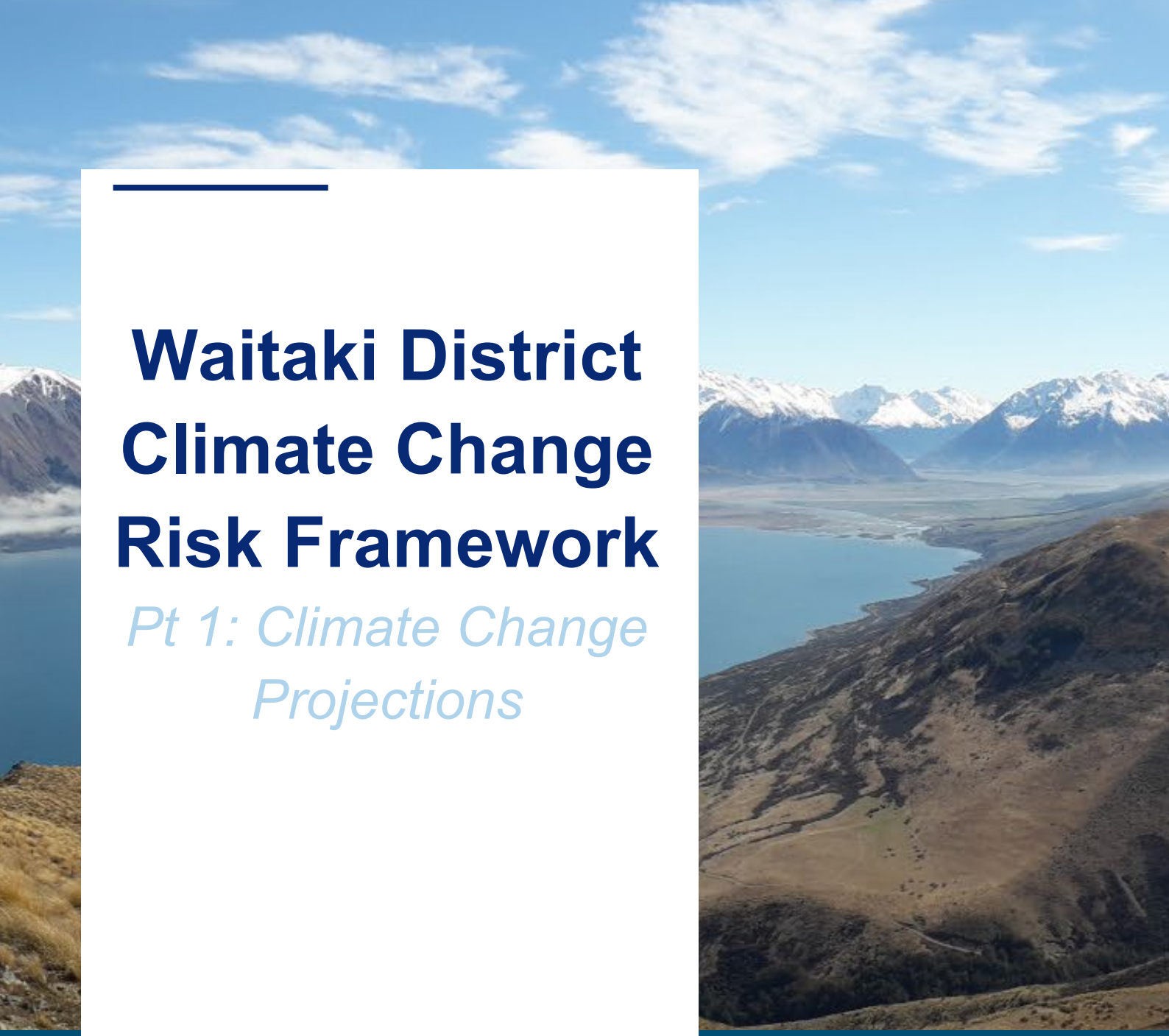


Waitaki District Climate Change Risk Framework

Pt 1: Climate Change Projections

JULY 2023

Waitaki District Council

Waitaki
DISTRICT COUNCIL
TE KAUNIHERA Ā ROHE O WAITAKI

HIGH-LEVEL CLIMATE CHANGE PROJECTIONS

THESE PROJECTIONS ARE BASED ON RCP8.5

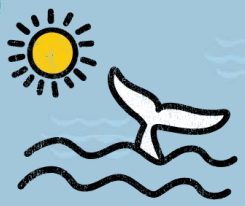
Annual mean temperature is projected to increase by 1.5-3.5°C across the Waitaki District. The largest changes occurring from annual mean maximum temperatures will occur inland during the summer months, with an increase of 2.0-5.0°C. An annual increase of 10-60 hot days is projected.

Annual rainfall is projected to increase by 20-25%, with winter rainfall increasing considerably by 15-40% for parts of Waitaki. A decrease in summer rainfall of 5-15% is projected for inland areas. Extreme, rare rainfall events are also likely to increase in intensity in Waitaki.

Wildfires will become more likely, as hotter, drier summers occur. Rural areas will be more highly exposed.

The sea level is projected to rise by about 0.8m above present-day levels, with an increase of 0.9-1.2m in sea level.

Drought potential is likely to increase across most of Waitaki. Decreases in annual dry days of 2-6 days are projected for coastal areas, with increases of 2-10 more dry days per year for the remaining parts of Waitaki.



Extreme weather events (e.g., severe storms) are likely to happen more often. Inland areas are projected to observe an increase of 6-12% wind, with coastal areas projecting a 0-4% decrease.

Projections suggest that sea-surface temperatures in New Zealand will increase by 0.8°C-2.5°C by the end of this century.

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Executive Summary

Climate change is already affecting New Zealand. Temperatures have increased, glaciers are melting, and sea levels have risen over the past century. Such changes are expected to continue, with far-reaching consequences across all the value domains that underpin well-being in New Zealand – namely, the natural environment, human capital, the economy, the built environment, and governance (Ministry for the Environment, 2020).

The Climate Change Risk Framework aims to provide the first summary report of climate change risks the Waitaki District will be facing, now and in the future, by providing a district-level snapshot of current and climate change projections. This initial report will enable the *second phase* of the risk framework; assessing the impacts of climate change, building an understanding of these risks on the 5 value domains (human, natural environment, built environment, economy, and governance), and how this can be managed in the future to enable adaptive planning for a climate-resilient future. The purpose of this document is not to evaluate the impact of risks and how to respond to them, but rather to acknowledge what the physical risks are.

The Waitaki District crosses the boundary between both the Canterbury and Otago regions; with the inland part of Waitaki being primarily in the Canterbury region, and the coastal part of Waitaki being primarily in the Otago region. Since climate change risk assessments and projections have been carried out in both regions, the bulk of this risk framework is using information sourced from:

- *Climate change projections for the Otago Region (NIWA, 2019).*
- *Otago Climate Change Risk Assessment (Tonkin & Taylor, 2021).*
- *Climate change projections for the Canterbury Region (NIWA, 2020).*
- *Canterbury Climate Change Risk Assessment (Tonkin & Taylor, 2022).*

Introduction

The Intergovernmental Panel on Climate Change (IPCC) has concluded that human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. There has been an increase in global temperature which reached approximately 1°C above its pre-industrial level in 2017 (Figure 1).

The Waitaki District Council (WDC) is committed to better understanding, and preparing for, changes to our local climate and has therefore commissioned this assessment of climate change risks facing the district. The main objectives of this assessment are:

1. To list climate projections within the Waitaki District and the risks associated with these (where information is available).
2. To prioritise these risks in the second phase of this risk framework, in order of urgency for adaptation and to identify where more information or ongoing monitoring is required.
3. To engage and collaborate with council staff and relevant stakeholders in the identification and prioritisation of risks.

4. To consider Māori perspectives on climate change risks and identify issues of relevance to Māori.
5. To provide the background information needed to support the development of an informed and flexible climate change adaptation plan.

There are two ways in which climate change risks and impacts can either be reduced or managed, this is referred to as adaptation and mitigation. Adaptation is the process of adjusting to the actual and expected changes in the environment due to already existing greenhouse gases within the atmosphere, and those that may be released in the future. Mitigation, on the other hand, is focused on reducing greenhouse gas emissions to curb the effects of climate change (IPCC, 2014). The purpose of this report is to focus on the risk assessment parameters that will be adopted for the Waitaki District. Subsequent workstreams will then focus on adaptation and mitigation, as informed by the risks.

All stakeholders, including territorial local authorities, regional councils, communities, iwi, and the business sector recognise that a changing climate will present risks to the district. Waitaki District Council has identified climate change as a priority as part of the Long-Term Plan 2021-31 (LTP). An understanding of climate change related risks and vulnerabilities within the district will enable future prioritisation of risks for adaptation planning. Highlighted risks within this assessment will help direct further information gathering and help to plan for adaptation.

Note: further context around relevant climate change legislation, including obligations as a local council is provided in Appendix A.

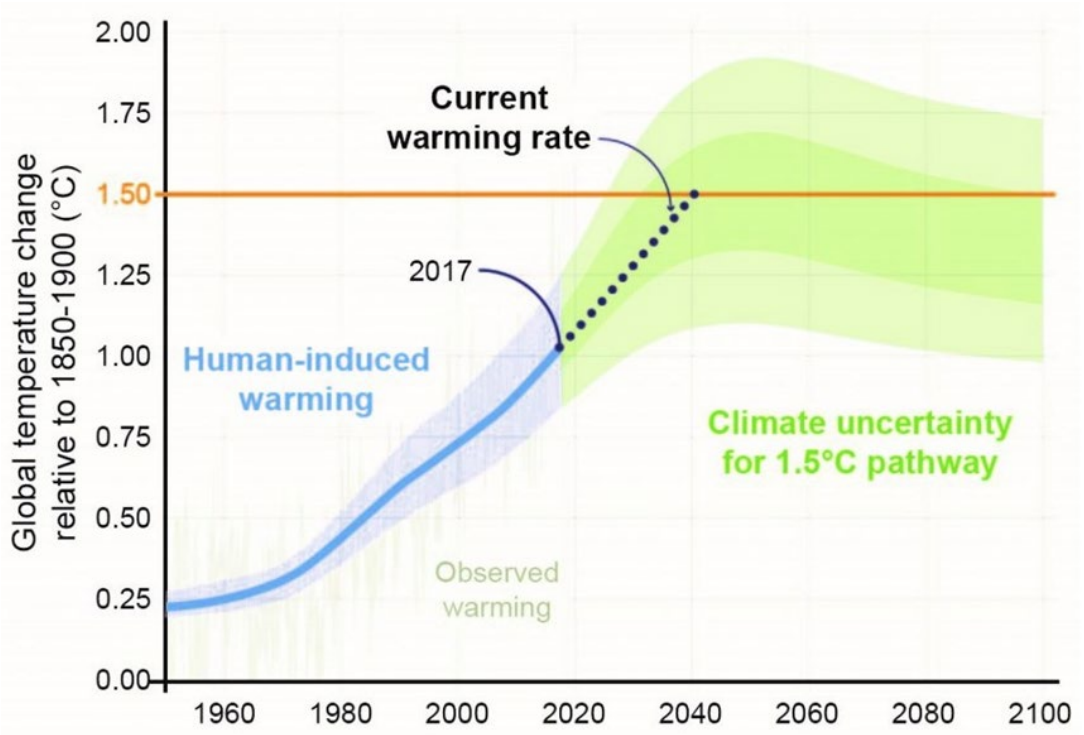

Figure 1. *Human-induced warming reached approximately 1°C above pre-industrial levels in 2017 (IPCC, 2018)*

Climate and environmental risks are the core focus of global risks perceptions over the next decade – and are the risks for which we are seen to be the least prepared. The latest World Economic Forum (WEF) report on global risks has identified the most severe risks occurring on a global scale over the next ten years (Figure 2). Based on the results from the Global Risks Perceptions Survey (GRPS), the long-term global risks are dominated by environmental risks, more specifically climate change risks, which are expected to manifest over the following decade. The top risks here are failure to mitigate climate change, failure of climate-change adaptation, natural disasters and extreme weather events and biodiversity loss, and ecosystem collapse. These are all risks that are present and exacerbating, resulting from climate change. Without a significant change in policy or investment, the interplay between climate change impacts, biodiversity loss, food security, and natural resource consumption will accelerate ecosystem collapse, threaten food supplies and livelihoods in climate-vulnerable economies, amplify the impacts of natural disasters, and limit further progress on climate mitigation (World Economic Forum, 2023).

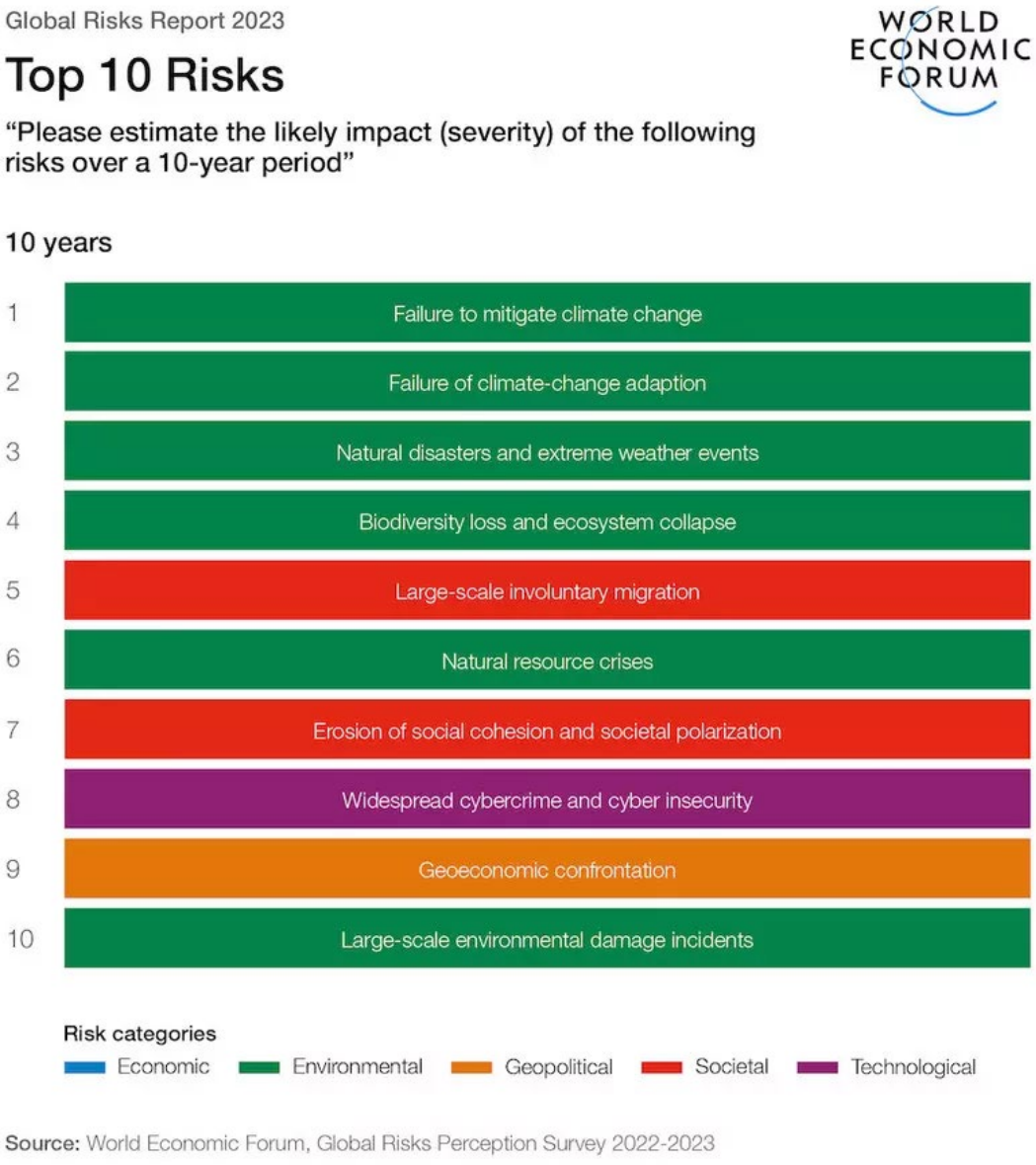

Figure 2. The most severe risks on a global scale over the next 10 years, sourced from the world economic global risks perception survey 2022-2023.

Representative Concentration Pathways

Future climate change projections are considered under four scenarios of future greenhouse gas concentrations, called Representative Concentration Pathways (RCPs) by the IPCC. The reduction and removal of greenhouse gas concentrations within our atmosphere are dependent on local and global efforts. There is an uncertainty that accompanies this, which is captured through four different emission scenarios (Figure 4). RCP2.6 is the lowest emission scenario which represents the most significant reduction in greenhouses gases, RCP4.5 and RCP6.0 are mid-range scenarios, and RCP8.5 is a high scenario, based on the greenhouse gases continuing at their current rates, or otherwise stated as 'business as usual' (Macara, G. R., 2015).

Assessing possible changes in our future climate due to human activity is difficult because climate projections depend strongly on estimates for future greenhouse gas concentrations. Those concentrations depend on global greenhouse gas emissions that are driven by factors such as economic activity, population changes, technological advances, and policies for sustainable resource use. In addition, for a specific future trajectory of global greenhouse gas concentrations, different climate model simulations produced somewhat different results for future climate change.

This range of uncertainty has been dealt with by the IPCC through consideration of 'scenarios' that describe concentrations of greenhouse gases in the atmosphere. The wide range of scenarios are associated with possible economic, political, and social developments during the 21st century, and via consideration of results from several different climate models for any given scenario. In the 2013 IPCC Fifth Assessment Report, the atmospheric greenhouse gas concentration components of these scenarios are called Representative Concentrations Pathways (RCPs). These are abbreviated as RCP2.6, RCP4.5, RP6.0, and RCP8.5, in order of increasing radiative forcing by greenhouse gases (i.e., the change in energy in the atmosphere due to greenhouse gas emissions). RCP2.6 leads to low anthropogenic greenhouse gas concentrations (requiring removal of CO2 from the atmosphere, also called the 'mitigation' scenario), RCP4.5 and RCP6.0 are two 'stabilisation' scenarios (where greenhouse gas concentrations and therefore radiative forcing stabilises by 2100) and RCP8.5 has very high greenhouse gas concentrations (the 'business as usual' scenario). Therefore, the RCPs represent a range of 21st-century climate policies. Table 1 shows the projected global mean surface air temperature for each RCP, whereas Figure 4 displays the rate of warming using the four RCPs over the century. It is important to note that RCP’s, including RCP8.5 may be reviewed in the future.

Table 1: *global mean surface air temperature for the mid-and late-21st century relative to the reference period of 1986-2005 for different RCPs.*

Scenario	Alternative name	2046-2065 (mid-century)		2081-2100 (end-century)	
		Mean	Likely range	Mean	Likely range
RCP2.6	Mitigation scenario	1.0	0.4 to 1.6	1.0	0.3 to 1.7
RCP4.5	Stabilisation scenario	1.4	0.9 to 2.0	1.8	1.1 to 2.6
RCP6.0	Stabilisation scenario	1.3	0.8 to 1.8	2.2	1.4 to 3.1
RCP8.5	Business as usual scenario	2.0	1.4 to 2.6	3.7	2.6 to 4.8

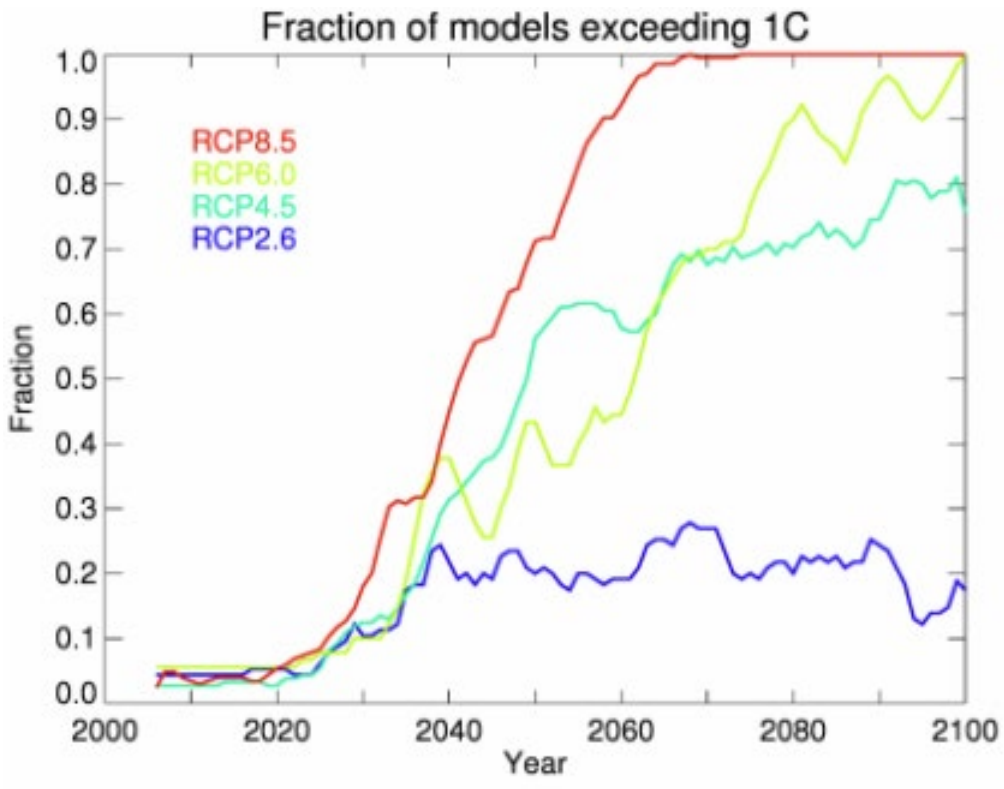

Figure 4. *Different warming rates over the century using RCPs 2.6, 4.5, 6.0, and 8.5 (Ministry for the Environment, 2018)*

Overview of value domains

At a national level, the Ministry for the Environment commissioned the first National Climate Change Risk Assessment (NCCRA) for Aotearoa New Zealand in 2019 (Ministry for the Environment, 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 (Table 2). These value domains will be used to inform the risk assessment for Waitaki District.

Table 2. *Value domain descriptions, including the elements at risk, adapted from the NCCRA (Ministry for the Environment, 2020).*

Value domain	Description	Elements at Risk
Human	People's skills, knowledge, and physical and mental health (human); the norms, rules, and institutions of society (social); and the knowledge, heritage, beliefs, arts, morals, laws, and customs that infuse society, including culturally significant buildings and structures (cultural).	Community wellbeing, social cohesion and social welfare (urban, rural and coastal communities); health, education, sports, recreation, cultural heritage (archaeological sites, museums, arts, theatre), ahurea Māori, tikaka Māori – Māori culture, values and principles, cultural taoka.
Natural environment	All aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), and the ecosystems in terrestrial, freshwater, and marine environments.	New Zealand's indigenous species, including he kura taiao – living treasures, terrestrial ecosystems, freshwater ecosystems, coastal, estuarine and marine ecosystems, biosecurity.
Economy	The set and arrangement of inter-related production, distribution, trade, and consumption that allocate scarce resources.	Primary industries (forestry, agriculture, horticulture, arable land, viticulture, fisheries, aquaculture, marine farming); land use, tourism, technology and business, whakatipu rawa – Māori enterprise, insurance and banking.
Built environment	The set and configuration of physical infrastructure, transport, and buildings.	Built infrastructure across sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications, waste and coastal defences.
Governance	The governance architecture and processes in and between governments, and economic and social institutions. Institutions hold the rules and norms that shape interactions and decisions, and the agents that act within their frameworks	Treaty partnerships, adaptive capacity, all governing and institutional systems, all population groups, including vulnerable groups.

The five value domains represent a group of values, assets, and systems that could be either at risk from climate-related hazards or beneficially affected. They are a hybrid of the New Zealand Treasury's Living Standards Framework and those used in the National Disaster Resilience Strategy (Tonkin & Taylor, 2021) (Figures 2-3). The domains are interconnected, apply at individual, community, and national levels, and include tangible and intangible values. Each value domain consists of a series of 'elements at risk'. These divide the domains into subcategories that can then be assessed by their exposure and vulnerability to climate hazards (Ministry for the Environment, 2020).

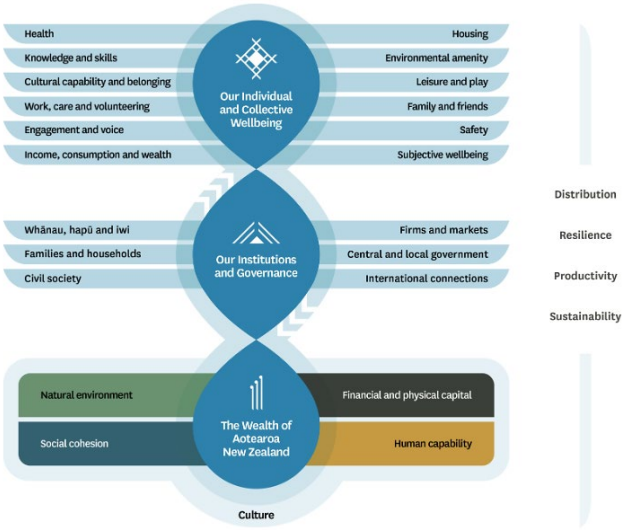

Figure 2. *The Living Standards Framework (The Treasury, 2021).*

Figure 3. *The overview of the National Disaster Resilience Strategy (Ministry of Civil Defence & Emergency Management, 2019).*

New Zealand Climate Change Projections

Climate change is already affecting New Zealand, having consequences on our surrounding environment, communities, and the economy, which is likely to continue posing challenges impacting the livelihoods of New Zealanders (Macara et al., 2019). The observed warming of the global climate system has shown unprecedented changes for decades. These changes include ocean and atmospheric warming, ice and snow loss, sea level rise, and the increase of greenhouse gas concentrations in the atmosphere. Climate change is also influencing the likelihood of increased extreme weather events and their frequency globally (IPPC, 2013). Human influence on the climate has been made clear with the observed impacts growing across all continents and oceans, many of these observations dating back to the 1950s. Continued human activities disrupting the climate result in greater risks of severe, pervasive, and irreversible impacts on people and ecosystems.

We have the means to limit climate change and its risks which will require an urgent and fundamental shift from business as usual to stabilise temperature increases below the 1.5°C pre-industrial level. The longer we wait to act, the more it will cost and the greater the technological, economic, social, and institutional challenges we will face. Similarly, opportunities for adaptation to climate-related risks will likely become constrained, with reduced effectiveness, should 1.5°C global warming be exceeded (IPPC, 2022). The Earth's atmosphere has warmed by 0.85°C on average over the period 1880-2012, while in May 2019, the CO2 concentration reached 415 parts per million in the atmosphere (IPCC, 2013). Over the period 1901-2010, the global mean sea level rose by 0.19m (19cm). Carbon dioxide concentrations have increased by at least 40% since pre-industrial times, which is primarily caused by fossil fuel emissions, with net land use change emissions being the second factor (IPCC,2013). The ocean has absorbed around 30% of anthropogenic CO2 leading to ocean acidification. Due to the influence of greenhouse gases on the global climate system, human influence has likely been the dominant cause of observed warming since the mid-20th century (IPCC, 2013; IPCC, 2018).

As global temperatures increase, it is virtually certain that:

- There will be an increase in hot days, with fewer cold temperature extremes over most land areas, along with increases in the global mean temperature.
- Heat waves will likely occur with a higher frequency and duration.
- The contrast in rainfall between wet and dry regions and wet and dry seasons will increase, with mid-latitude and wet tropical regions experiencing more intense and more frequent extreme rainfall events by the end of the 21st century.
- Warming of the ocean will continue through the 21st century, influencing ocean circulation and sea ice extent.

Climate Change Projections for Waitaki District

The global climate system has evolved over millions of years, with the attribution of increased greenhouse gas emissions which have caused unprecedented changes (IPPC, 2014). Waitaki District will continue to be affected by these changes occurring on a global scale, and these projected changes are to continue over long timescales. How we proceed with limiting greenhouse gas emissions in our atmosphere will change the severity and frequency of climate change, particularly as the global population increases.

In summary, the Waitaki District is projected to experience an increase in the number of hot days (defined by days hotter than 25°C), thus leading to on average warmer temperatures within the district, including fewer frost and snow days. On average, the annual rainfall, frequency of extreme weather events, and drought potential are expected to increase, with coastal hazards expected from additional influence from storm surges and wave heights (Carey-Smith et al., 2018; Macara et al., 2019). In combination, a range of changes to the long-term trends of Waitaki District's climate are expected, some to a greater extent than others, but all with associated risks.

Sea levels are projected to rise by up to 0.9 m by the end of the century under RCP8.5 throughout New Zealand (Ministry for the Environment, 2017). This will result in increased coastal flooding of low-lying areas within the Waitaki District. Due to this, we can expect to see an increased level of flooding events which will have numerous impacts on the community.

RCPs have been adopted and shown through numerous regional assessments such as the Otago Climate Change Risk Assessment (OCCRA) and the Canterbury Climate Change Risk Assessment (CCCRA). Both assessments consist of an RCP 8.5, representing a 'high-end' emissions scenario with high future global greenhouse gas emissions. Climate projections relating to this scenario are considered in 2040 (mid-century), and 2090 (end of century). These projections were developed and used on both a national and regional scale by The National Institute of Water and Atmospheric Research (NIWA) and therefore will be used in this report to maintain consistency.

This report outlines the risks related to physical climate change that the Waitaki District faces. The Waitaki District crosses the boundary between both the Canterbury and Otago regions; the inland part of Waitaki is primarily in the Canterbury region, and the coastal part of Waitaki is primarily in

the Otago region. Since climate change risk assessments have been carried out in both regions, the bulk of this risk framework is using the already existing information from these reports.

National and regional climate change projections were originally developed by NIWA which were based on the IPCC Fifth Assessment Report (2014), these projections were used for the OCCRA which has formed the basis for climate change projections within the Waitaki District. This report and the risk assessment herein are based on RCP8.5. This is a reasonable upper-level scenario and therefore supports the objective to identify the most significant climate-related risks (Macara et al., 2019). An overview of the climate change projections for the Waitaki District is shown in Table 3 which is displayed using RCP8.5 over the mid to long term.

Table 3. Summary of climate change projections within the Waitaki District under RCP8.5 based on data compiled from the Otago Climate Change Risk Assessment and Canterbury Climate Change Risk Assessment (Tonkin & Taylor, 2021; Tonkin & Taylor, 2022).

Climate variable/hazard	Direction of change	Magnitude of change		
		Change in 2040	Change in 2090	
		RCP8.5	RCP4.5	RCP8.5
Temperature				
Annual mean temperature	The annual mean temperature is projected to increase across Waitaki.	Increase of 0.5-1.5°C	Increase of 0.5-2.0°C	Increase of 1.5-3.5°C
Maximum temperature	The annual mean maximum temperature is projected to increase in Waitaki, with the largest changes occurring inland during the summer months.	Increase of 0.5-2.5°C	Increase of 1.0-3.0°C	Increase of 2.0-5.0°C
Minimum temperature	Minimum temperatures are projected to increase across Waitaki from 0-2.5°C.	Increase of 0-1.0°C	Increase of 0.5-1.5°C	Increase of 1.0-2.5°C
Hot days (25°C or higher)	Autumn and spring hot days are projected to increase by 5-20 days, with summer observing 10-30 hot days for relatively low-elevation areas inland.	An annual increase of 10-40 hot days	An annual increase in hot days of 10-20 hot days	An annual increase of 10-60 hot days
Frost days	Frost days are defined as daily minimum temperatures falling below 0°C. There is a considerable reduction in frost days.	A decline of 10-15 frost days	A decline of 15-20 frost days	A decline of 20-40 frost days
Precipitation				
Annual mean rainfall	Annual rainfall is expected to increase across the district.	Annual and seasonal increases of 0-10% are projected, with a 5-20% increase inland in winter and spring, 0-10% for coastal areas, and 0-5% decrease in autumn rainfall for coastal areas.	Annual rainfall is projected to increase by 5-10% for coastal areas.	Annual rainfall is projected to increase by 20-25%, with winter rainfall increasing by 15-40%, and a decrease in summer rainfall of 5-15% is projected for inland areas.
Extreme rainfall events	Extreme, rare rainfall events are likely to increase in intensity in Waitaki.	From 8% higher for a 1:100 year 1-hour duration rainfall event.	Up to 35% higher for a 1:100 year 1-hour duration rainfall event.	

Snowfall	There is a reduction in snow days throughout the Waitaki District, with the largest reductions occurring in mountainous areas.	The number of snow days is likely to decrease by 0-15 days.	The number of snow days is likely to decrease by 0-20 days.
Dry days	The number of dry days is likely to decrease near the coast, with the remaining parts of Waitaki experiencing increases. Seasonally, more dry days are expected for inland parts of Waitaki.	Decreases in annual dry days of 1-4 days are projected for coastal areas with increases of 2-8 more dry days annually for the remaining parts of Waitaki.	Decreases in annual dry days of 2-6 days are projected for coastal areas with increases of 2-10 more dry days per year for the remaining parts of Waitaki.
Flooding	Waitaki is projected to experience an increase in Mean Annual Flood (MAF). This is consistent with the increased mean annual rainfall.	Between -5 to 100% decrease in MAF is projected to occur in parts of Waitaki. The remaining areas projected to increase by up to 50-100% in some places	Generally greater than 20% increase across the district with some areas over 100% increase in MAF.
Sea level rise			
Sea level rise	Sea level rise is occurring throughout New Zealand. Storm surges, waves, winds, and the frequency and intensity of storms are also affected by climate change. These will generate higher extreme water levels which are variable along the coast of Waitaki.	Mean SL is projected to increase by 0.21m.	Up to 0.9-1.2m increase in SL.
Extreme weather			
Wind	Daily mean wind speed is projected to increase in inland areas and decrease in coastal areas.	By 2040 inland areas are projected to observe an increase in wind of 4-6% and a decrease of 0-4% in coastal areas.	By 2090 inland areas are projected to observe an increase of 6-12% wind, with coastal areas projecting a 0-4% decrease.

Temperature

1.1. Annual mean temperature

The annual *mean temperature* is projected to increase by:

- 2040 under RCP8.5: +0.5-1.5°C
- 2090 under RCP4.5: +0.5-2.0°C
- 2090 under RCP8.5: +1.5-3.5°C

Annual and seasonal mean temperatures are projected to increase by 0.5-1.5°C by 2040 under RCP8.5. By 2090, annual mean temperature increases of 0.5-2.0°C (RCP4.5) and 1.5-3.5°C (RCP8.5) are projected for Waitaki. Under RCP8.5, seasonal mean temperatures are projected to increase by 1.5-2.5°C in coastal areas, with increases of 2.0-3.5°C projected for inland areas.

Seasonal mean temperatures are influenced by proximity to the sea, such that coastal locations are typically cooler in summer and warmer in winter compared to inland areas.

In inland low-elevation and coastal areas, the summer mean temperatures range between 12-18°C, with the winter mean temperatures ranging between 2-8°C. Mean temperatures at high-elevation

mountainous areas remain several degrees Celsius colder than the remainder of Waitaki throughout the year.

Consequently, in the short to medium term higher temperatures will result in increased inflows from glacial melt. It is expected that inflows from this source will eventually be exhausted if glacial storage shrinks significantly or disappears completely. Glacial melt represents approximately 6-10% of inflows into the Waitaki catchment. It is also expected that snowmelt inflows will be affected, by reduced snowfall, higher snowlines, and warmer temperatures.

1.2. Maximum mean temperature

Annual *mean maximum temperatures* are projected to increase:

- 2040 under RCP8.5: +0.5-2.5°C
- 2090 under RCP4.5: +1.0-3.0°C
- 2090 under RCP8.5: +2.0-5.0°C

Maximum temperatures are generally recorded in the afternoon and therefore are known as daytime temperatures. The average maximum temperature is expected to be higher for inland areas in comparison to coastal areas. Annual mean maximum temperatures range between 16-18°C for most low-elevation inland locations and 14-16°C for most coastal locations.

For inland low-elevation locations summer mean maximum temperatures range between 20-24°C, whereas for coastal areas, it ranges between 18-20°C. For inland low-elevation locations winter mean maximum temperatures range between 8-10°C, whereas for coastal areas, it ranges between 10-12°C.

By 2040 (RCP8.5), the annual mean maximum temperature is projected to increase by 0.5-2.5°C. By 2090, annual mean maximum temperature increases of 1.0-3.0°C (RCP4.5) and 2.0-5.0°C (RCP8.5) are projected. Notably, some alpine parts of Waitaki can expect to observe a 5.0-6.0°C increase in spring and summer mean maximum temperatures by 2090 under RCP8.5.

1.3. Minimum mean temperature

Annual *mean minimum temperatures* are projected to increase:

- 2040 under RCP8.5: +0-1.0°C
- 2090 under RCP4.5: +0.5-1.5°C
- 2090 under RCP8.5: +1.0-2.5°C

At present, annual mean temperatures range between 8-12°C for inland low-elevation locations. Summer mean temperatures range between 14-18°C, and winter mean temperatures range between 4-8°C. Seasonal mean temperatures are influenced by proximity to the sea, such that coastal locations are typically cooler in summer and warmer in winter compared to inland parts of the district. For coastal areas of Waitaki, summer temperatures range between 13-20°C (Weather Spark, n.d.)

For inland low-elevation locations, summer mean minimum temperatures range between 6-10°C, and winter mean minimum temperatures range from just below freezing (-2°C) to just above freezing (2°C).

By 2040 (RCP8.5), the annual mean minimum temperature is projected to increase by between 0-1.0°C. By 2090, annual mean minimum temperature increases of 0.5-1.5°C (RCP4.5) and 1.0-2.5°C (RCP8.5) are projected. Seasonal mean minimum temperatures are projected to increase by 0.5-2.5°C for much of Waitaki (by 2090 under RCP8.5).

1.4. Hot days

The annual number of *hot days* is projected to increase:

- By 2040 (RCP8.5) annual number of hot days is projected to increase by 10-40 days.
- By 2090 (RCP4.5) the annual number of hot days is projected to increase by 10-20 days.
- By 2090 (RCP8.5) the annual number of hot days is projected to increase by 20-60 days.

When the maximum temperature is 25°C or higher, this is considered a 'hot day'. Hot days occur most frequently in summer, with most low-elevation areas of Waitaki observing between 10-30 hot days during this season.

Exceptions to this may occur with annual increases of 60-85 hot days projected for some inland areas, especially southern parts of the Mackenzie Basin. By 2090 (RCP8.5), 20-60 hot days are projected, and autumn and spring hot days are projected to increase by 5-20 days for relatively low-elevation areas.

1.5. Frost days

The annual number of *frost days* is projected to decline:

- By 2040 (RCP8.5) annual number of frost days is projected to decline by 10-15 days.
- By 2090 (RCP4.5) annual number of frost days is projected to decline by 15-20 days.
- By 2090 (RCP8.5) the annual number of frost days is projected to decline by 20-40 days.

A frost day is defined in this report as when the modelled daily minimum temperature falls below 0°C. The annual number of frost days increases considerably for inland and high-elevation parts of the region. For example, many inland parts of Waitaki typically observe 75-100 days of frost per year. For coastal parts of Waitaki, 25-50 frost days per year are experienced. In the future, the number of frost days per year is projected to decline throughout the district.

By 2040, reductions of 10-15 frost days per year are possible for low-elevation inland parts of the district under RCP8.5. By 2090, considerable reductions in frost days are projected for inland areas, with around 15-20 fewer frost days for those areas under RCP4.5 and 20-40 fewer frost days under RCP8.5. Larger reductions are projected for high elevations (i.e., a decrease of >40 days under RCP8.5 at 2090). In addition, there is anticipation that future frost season length (i.e., the time between the first and last frost in a given year) will reduce.

Minimum temperatures are also projected to increase throughout the region by up to 2°C by the end of the century. In conjunction, the duration of the frost season and number of frost days is expected to decrease, particularly inland, where 10-15 fewer frost days are projected to occur by 2040 and up to 40 fewer frost days per year by 2100. The number of snow days is likely to decrease between 0-20 days. with the greatest reductions projected to occur in the coldest, mountainous areas (Macara et al., 2019). This is likely to result in more rainfall events in winter that would previously have been snow events, therefore changing the flood risk, as well as snow melt patterns.

In general, the impacts of climate change on snowlines in the Waitaki District may depend on factors such as changes in precipitation patterns, temperature, and weather extremes. If temperatures continue to rise, the snowline will likely retreat to higher elevations, and some glaciers and snowfields could disappear altogether.

Precipitation

2.1. Annual rainfall/Flooding

Summary of annual *rainfall days:*

- By 2040 (RCP8.5) an annual and seasonal increase between 0-10% rainfall is projected. At a seasonal scale, an increase of 5-20% in rainfall in winter and spring is projected for inland areas, whereas during summer an increase in rainfall (generally 0-10%) is projected for coastal areas. Autumn rainfall is projected to slightly decrease (0-5%) in coastal areas.
- By 2090 (RCP4.5) annual rainfall is projected to increase by 5-10% for coastal areas.
- By 2090 (RCP8.5) annual rainfall is projected to increase by 20-25%, with winter rainfall increasing considerably by 15-40% for parts of Waitaki. A decrease in summer rainfall of 5-15% is projected for inland areas.

Changes in annual average rainfall across Waitaki are expected to vary by +/- 5% by 2090 under RCP8.5. However, seasonal rainfall is projected to have higher variability. By 2090 increases of 15-40% in winter rainfall are projected, while small decreases of up to 5-15% in inland areas are projected for summer. These projections indicate increasing seasonality of annual rainfall, potentially with winter rainfall more strongly associated with storm events.

River systems within Waitaki are projected to have up to a 50% decrease in flows by 2090. Increased annual dry days, temperature, and annual hot days may lead to increased frequency and duration of drought conditions within Waitaki. This is projected to occur due to the decrease in summer rainfall within most catchments. More frequent and intense flood events through river systems are expected due to the increase in severity of extreme storm events coupled with increasing rainfall, resulting in an increase in river flow volumes for many of the river systems within the district (Macara et al, 2019). NIWA projections are that precipitation will increase by 5-15% by 2055 in the Waitaki catchment area (Security and Reliability Council, 2018).

Flooding is another known issue in the Waitaki District affecting rural areas as well as urban townships, such as Oamaru (Waitaki District Council, 2017). Flooding and extreme weather events

can lead to water supply contamination, as experienced in Oamaru in late 2018, where heavy rainfall caused an influx of contaminants and sediment into the Waitaki River, leading to severe water restrictions for several days (Tonkin & Taylor, 2021). Coastal areas are also likely to experience increased severity of extreme weather events, and the coastal and marine ecosystems are likely to experience increased discharge of sediment and freshwater from increased rainfall throughout the catchment of rivers across the region (Macara et al, 2019).

2.2. Extreme rainfall events

Summary of *extreme rainfall events*:

- Extreme, rare rainfall events are likely to increase in intensity in Waitaki because a warmer atmosphere can hold more moisture.
- Increases in rainfall events are projected at both future periods (2040 and 2090) under all climate change scenarios; the greatest increases are projected by 2090 under RCP8.5 (up to 35% higher for a 1:100 year 1-hour duration rainfall event).
- Short-duration rainfall events have the largest relative increases.

A "1:100-year rainfall event" is a term used in hydrology to describe an extreme precipitation event that has a statistical probability of occurring once every 100 years, on average, in a particular location. This means that the event has a 1% chance of occurring in any given year. It is important to note that this does not mean that the event occurs exactly once every 100 years or that it cannot occur in successive years. Instead, it is a statistical estimate of the likelihood of such an event occurring in any given year.

Extreme rainfall events (and floods) are often considered in the context of return periods (e.g., 1-in-100-year rainfall events). A return period, also known as an average recurrence interval (ARI), is an estimate of the likelihood of an event. It is a statistical measure typically based on historic data and probability distributions which calculate how often an event of a certain magnitude may occur. Return periods are often used in risk analysis and infrastructure design.

The theoretical return period is the inverse of the probability that the event will be exceeded in any one year. For example, a 1-in-10-year rainfall event has a 1/10 = 0.1 or 10% chance of being exceeded in any one year and a 1-in-100-year rainfall event has a 1/100 = 0.01 or 1% chance of being exceeded in any one year. However, this does not mean that a 1-in-100-year rainfall event will happen regularly every 100 years, or only once in 100 years. The events with larger return periods (i.e., 1-in-100-year events) have larger rainfall amounts for the same duration as events with smaller return periods (i.e., 1-in-2-year events) because larger events occur less frequently (on average).

2.3. Snowfall

Summary of *snowfall:*

- The number of snow days reduce through the Waitaki District, with the largest reductions occurring in the colder mountainous areas where there is a relatively large number of snow days currently present.

- The number of snow days is likely to decrease between 0-15 days by 2040, and 0-20 days by 2090.

Snow days have been estimated by counting precipitation days where the mean temperature is below the freezing point. Although it is a crude measure of snow days and the likely modelled number of historic (1986-2005) snow days is underestimated, particularly for low elevation locations where snowfall often occurs when the ambient air temperature is at or above 0°C, nevertheless, this measure provides a reference to which future changes can be compared.

Modelled historic conditions suggest that 1-10 days per year occur for inland areas. 25-100 snow days per year occur in higher elevation alpine areas. In the future, the number of snow days reduces everywhere, with the largest reduction (typically 10-25 days) in the coldest mountainous areas where there are a relatively large number of snow days in the historic climate.

2.4. Droughts/Dry days

Summary of *dry days:*

- The number of dry days is likely to decrease near the coast, with the remaining parts of Waitaki experiencing increases. Seasonally, more dry days are expected for inland parts of Waitaki.
- By 2040, decreases in annual dry days of 1-4 days are projected for coastal areas, with increases of 2-8 more dry days annually for the remaining parts of Waitaki.
- By 2090, decreases in annual dry days of 2-6 days are projected for coastal areas, with increases of 2-10 more dry days per year for the remaining parts of Waitaki.

When less than 1mm of rainfall is recorded, it is considered a 'dry day'. Between the period 1986-2005, the largest number of dry days for Oamaru were 275-300 days per year, winter being the season with the highest number of dry days (60-80 days) and spring typically having the fewest dry days (50-70 days). Mullan et al., 2005 suggested that severe droughts could increase and become more frequent by the 2080s. Further risks result from drier conditions, notably wildfires and the spread of fires lit by humans. While the predictions for wind severity have not been modelled for Waitaki District, there is potential for this to also contribute to an elevated fire risk.

Sea level rise

3.1. Sea level rise

Summary of *sea level rise:*

- Sea level rise is occurring throughout New Zealand. Storm surges, waves, winds, and the frequency and intensity of storms are also affected by climate change. These may generate higher extreme water levels which are variable along the coast of Waitaki.
- By 2040, the mean SL is projected to increase by 0.21m across New Zealand.
- By 2090, there is projected to be an increase of up to 0.9-1.2m in SL.

Throughout New Zealand, sea levels are projected to rise by up to 0.9m by 2100 under RCP8.5 (Ministry for the Environment, 2018). This may result in increased coastal flooding of low-lying areas within Waitaki District, affecting coastal communities such as Kakanui and Oamaru waterfront (Otago Regional Council, 2012). Groundwater rises, and coastal and inland flooding contributes to the exposure of landfills, cemeteries, and urupā.

Extreme weather

4.1. Wind

Summary of *wind:*

- Daily mean wind speed is projected to increase in inland areas and decrease in coastal areas.
- By 2040: inland areas are projected to observe an increase in wind of 4-6% and a decrease of 0-4% in coastal areas.
- By 2090: inland areas are projected to observe an increase of 6-12% wind, with coastal areas projecting a 0-4% decrease.

Extreme wind is considered as the 99th percentile of daily mean wind speeds, equating to the top 1% of daily mean winds recorded, i.e., about the top three windiest days each year.

Limitations

The Climate Change Projections for Otago Region (2019) NIWA report only outlines Oamaru, not the Waitaki District. Only data that was readily available from previous studies were used, therefore gaps exist, and weather patterns may not align. There are also limitations for how the projections are perceived for the Waitaki District given this is based on a regional scale study (Otago/Canterbury). For example, climate projections are calculated using complex computer models that simulate the Earth's climate system, taking into account a wide range of factors that can influence climate change. These factors include natural phenomena such as volcanic activity and solar radiation, as well as human activities such as the burning of fossil fuels and deforestation. The models typically use mathematical equations to represent the physical and chemical processes that occur in the atmosphere, oceans, and land. They divide the Earth's surface into a grid system and simulate the interactions between different regions and components of the climate system over time, typically spanning several decades or centuries. The models incorporate various climate scenarios based on different levels of greenhouse gas emissions and other factors that can affect climate change, such as changes in land use and population growth. These scenarios are typically based on assumptions about future trends in economic and social development, as well as technological advances and policies to address climate change.

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Imagery:

It's time Canterbury (2023). Canterbury's climate is changing | It's time, Canterbury (itstimecanterbury.co.nz)

Appendix A

New Zealand participates in international climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), its Kyoto Protocol, and the Paris Agreement. As a party to the Paris Agreement, New Zealand has certain obligations to address climate change and reduce its greenhouse gas emissions. These obligations are outlined in the country's Nationally Determined Contribution (NDC) under the Agreement, as well as in its domestic climate policies and legislation.

New Zealand's NDC under the Paris Agreement includes the following commitments:

- New Zealand is focused on the Paris Agreement goal related to pursuing efforts to limit global temperature increase to 1.5°C above pre-industrial levels. With a target to reduce greenhouse gas emissions by 50% below 2005 levels by 2030.
- A commitment to a five-yearly review of its climate targets and progress towards them.

Legislation and initiatives have since been passed to enable New Zealand to meet its obligations under the Paris Agreement, such as:

- The Zero Carbon Act, which sets a legally binding target of net-zero emissions by 2050 and establishes a Climate Change Commission to provide independent advice on emissions reduction and climate adaptation.
- A comprehensive emissions trading scheme, which places a price on carbon and covers emissions from all sectors of the economy, including agriculture.
- Investment in renewable energy, such as wind and geothermal, and the phasing out of coal-fired electricity generation.
- The development of low-emissions transport options, such as electric vehicles and public transport.
- Afforestation and other measures to increase the uptake of forestry and land-use practices that sequester carbon.

In response to the Zero Carbon Act, Ministry for the Environment has undertaken the first National Climate Change Risk Assessment (Ministry for the Environment, 2020) Consequently, the government has released new requirements for organisations to report climate-related information under the Climate Change Response (Zero Carbon) Act (Government of New Zealand, 2019). This reporting requirement applies to organisations that provide essential public services in New Zealand such as local authorities and can request information on how organisations are responding to risks from climate change.

The Zero Carbon Act and related reporting requirements build on the existing responsibilities of local government to respond to climate change. Existing legislation controls the WDC’s activities and responsibilities as set out in the Local Governance Statement (WDC, 2019). Legislation particularly relevant to the management of climate change and natural hazards at the local government level includes the:

Local Government Act 2002 (LGA): The LGA requires local authorities to take a holistic and forward-looking approach to decision-making that considers the impacts of climate change on their communities and the environment. Relevant considerations are as follows:

- **Social, economic, environmental, and cultural well-being:** The LGA requires local authorities to consider the social, economic, environmental, and cultural well-being of their communities, including the impacts of climate change on these aspects of community well-being.
- **Community engagement and participation:** The LGA emphasizes the importance of community engagement and participation in decision-making processes. Local authorities are required to engage with their communities on issues related to climate change and to take their views into account when making decisions.
- **Integrated decision-making:** The LGA promotes an integrated approach to decision-making. Local authorities must consider the long-term and cumulative effects of their decisions, and consider the interrelationships between social, economic, environmental, and cultural factors, including those related to climate change.
- **Climate change adaptation and mitigation:** The LGA recognizes the need for local authorities to take action to address the impacts of climate change. This may involve developing strategies to adapt to the impacts of climate change and to reduce greenhouse gas emissions.
- **Asset management:** The LGA requires local authorities to manage their assets sustainably and cost-effectively. This includes considering the risks and opportunities associated with climate change when making decisions about asset management.

Local authorities must work closely with their communities to identify and respond to climate change risks while assessing opportunities to ensure that their decision-making is sustainable and resilient in the face of climate change.

Resource Management Act 1991 (RMA): Under the Resource Management Act 1991 (RMA), local governments in New Zealand have a range of requirements related to climate change. Relevant considerations are as follows:

- **Planning for climate change:** Local government is required to plan for the known hazards, including climate change (Part II of the RMA, section 7(i)). Local authorities are required to incorporate the principles of the New Zealand Coastal Policy Statement (NZCPS) into their planning documents, which includes consideration of the impacts of climate change. This means that local authorities must plan for the effects of sea level rise and other climate change impacts on the coastal environment.
- **Mitigating greenhouse gas emissions:** Local authorities are also required to take action to reduce greenhouse gas emissions. This may include developing policies to encourage sustainable land use, promoting the use of public transport, and encouraging the development of renewable energy sources.
- **Adapting to climate change:** Local authorities must also consider how to adapt to the impacts of climate change. This may involve developing policies to protect against the risks of flooding, coastal erosion, and other climate-related hazards.

- **Engagement and consultation:** The RMA require local authorities to engage with the public and seek their input on climate change issues. This may involve consulting with iwi, hapū, and other interested parties to ensure that their views are considered.

In addition to these requirements, the RMA also provides for the establishment of climate change adaptation and mitigation strategies at both the national and local levels. Local authorities are encouraged to work with the central government, iwi, and other stakeholders to develop and implement these strategies.

Civil Defence Emergency Management Act 2002: Under the Civil Defence Emergency Management Act 2002 (CDEM Act), local governments in New Zealand have several key requirements related to climate change. These include:

- **Identification of hazards and risks:** The CDEM Act requires local authorities to identify hazards and risks, including those related to climate change, in their hazard and risk assessments.
- **Emergency planning and response:** Local authorities must develop emergency plans and responses that consider the impacts of climate change. This may include developing evacuation plans for areas that are vulnerable to flooding or coastal erosion or establishing emergency shelters for those affected by extreme weather events.
- **Coordination with other agencies:** The CDEM Act emphasizes the importance of coordination between local authorities and other agencies, including central government and non-governmental organizations, in emergency planning and response. Local authorities must work with these agencies to ensure a coordinated and effective response to climate-related emergencies.
- **Community education and awareness:** Local authorities must educate and raise awareness among their communities about the risks and impacts of climate change, and about what individuals can do to prepare for and respond to climate-related emergencies.
- **Recovery and rehabilitation:** The CDEM Act require local authorities to develop plans for the recovery and rehabilitation of communities following a climate-related emergency. This may include supporting the restoration of damaged infrastructure, providing temporary housing for those displaced by extreme weather events, and supporting the mental health and well-being of affected communities.

Overall, the CDEM Act requires local authorities to take a proactive and coordinated approach to emergency management and response, with a particular focus on the risks and impacts of climate change. By working closely with their communities and other agencies, local authorities can help to build resilience and preparedness in the face of climate-related emergencies.

Waitaki District Council has demonstrated its commitment to addressing climate change through its Long-Term Plan 2021-2031, and the resolution that:
“Council’s Strategic Framework has identified meeting environmental and climate change challenges as a key community outcome. We need to consider the impact that climate change will have, and the investment required under different response approaches”.