Waikato Regional Climate Change Risk Assessment

Aromatawai tūraru huringa āhuarangi ā-rohe o Waikato

Report on completion of Phase 1 and planning for Phase 2 September 2022

Background

1. Waikato Regional Council is currently carrying out a climate change risk assessment for the Waikato region in two phases:

    a. Phase 1 - first pass regional climate change risk identification and screening, led and funded by Waikato Regional Council (completed); and
    b. Phase 2 - detailed risk assessment/s and identification of further projects (e.g. to fill critical information gaps), with the approach, leads and funders of Phase 2 work being considered in light of Phase 1 outcomes and national direction.

2. Figure 1 below provides an overview of the project phases.

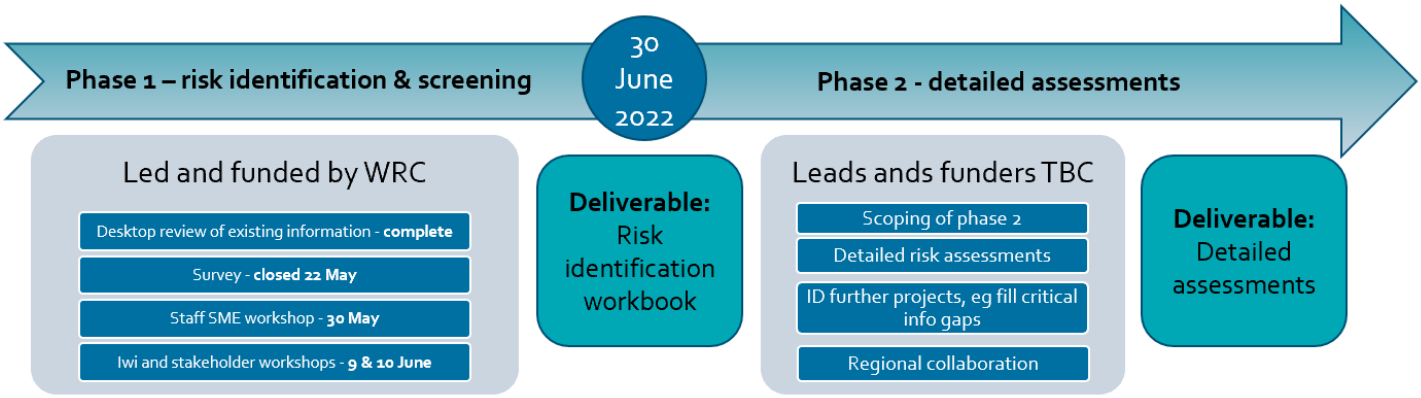

Figure 1: Waikato Regional Climate Change Risk Assessment project phases and deliverables

3. The climate change risk assessment and adaptation planning process is shown in Figure 2 below. The Waikato regional climate change risk assessment is following these steps which are taken from the Ministry for the Environment Guidance for Local Climate Change Risk Assessments (2021).

Figure 2: Overview of the climate change risk assessment and adaptation planning process (from MfE 2021)

4. The first two steps involve the climate change risk assessment itself; the next three relate to climate change adaptation planning, which uses the information from the climate change risk assessment.

5. Council work programmes already reflect some of the adaptation priorities in our region, such as the Regional Resilience Programme and the Thames-Coromandel Shoreline Management Plan. Our planning and responses to climate change will need to be dynamic, so that significant changes in evidence, understanding of risk, community context and legislation can inform how our adaptation approaches evolve.

What is a climate change risk assessment?

6. Climate change risk assessments identify risks to things of value in communities (‘elements at risk’ or ’risk elements’), due to changes in the climate. Elements at risk are the people or systems affected by a physical risk, such as assets, ecosystems, cultural taonga, infrastructure. A climate change risk assessment involves:

    a. Understanding the context, climate hazards and exposure;
    b. Assessing the vulnerability and risk.

7. Carrying out a risk assessment can help to prioritise risks, which can then guide further work and drive targeted action and investment in adaptation in the future. It can also link to other processes/activities, including economic wellbeing, resource management, iwi management plans, land-use planning and regulation, strategic planning, infrastructure management, and emergency management. It can be used to work alongside iwi/Māori as Treaty partners on a range of priorities (social, cultural, economic, and environmental).

8. Local assessments will likely inform the next national risk assessment due in 2026 and will be necessary to support national adaptation planning and legislation. Councils may also be required to report climate risk information under the reporting requirements of section 5ZW of the Climate Change Response (Zero Carbon) Amendment Act 2019.

Objectives

9. The climate change risk assessment for the Waikato region will:

    a. Collate Waikato climate risk information and develop a shared understanding of key climate change risks
    b. Extend Waikato climate risk knowledge and understanding across the five domains used in the National Climate Change Risk Assessment (human; natural environment; economy; built environment; governance)
    c. Identify critical information gaps
    d. Where possible, provide a geospatial analysis and representation of the risks.

10. This will in turn:

    a. Help inform our future work programmes and identify priority work for both Waikato Regional Council, Waikato territorial authorities and key stakeholders in the Waikato region.
    b. Assist current adaptation projects and help us to understand future priority areas for adaptation planning and targeted action.
    c. Help inform the update of organisational climate change risk assessments.
    d. Assist with the communication of key risks to communities and stakeholders.
    e. Support work in relation to the National Adaption Plan and the Resource Management Act system reforms, in particular:
        i. Informing the future regional spatial strategy and combined plans (ensuring appropriate land use in a changing climate, emissions reduction and that our region does not create stranded assets).
        ii. Assisting Waikato Regional Council and Waikato territorial authorities to fulfil obligations to have regard to the National Adaptation Plan (see Resource Management Amendment Act 2020 – having effect from 30 November 2022) when preparing or changing existing RMA plans.

11. The assessment of climate change risk for the Waikato will be an ongoing and cyclical work programme. Knowledge of climate change risks for the region will grow over time through detailed climate change risk assessments by sub-regions and domains, risk assessments and research carried out by other organisations such as iwi or specific sectors, community scale local adaptation planning projects and the completion of subsequent projects.

Phase 1 Methodology and Findings

Overview

12. In February 2022, Waikato Regional Council commenced Phase 1 of the Waikato regional climate change risk assessment, with the deliverable of this phase being a risk identification workbook of climate change risks for the Waikato region. Tonkin+Taylor, who have carried out a number of climate change risk assessments for local government, were engaged to advise council and deliver Phase 1. Governance oversight was provided by a sub-group of councillors from the council's Climate Action Committee.

13. The aim of Phase 1 (risk identification) was to make a *long list* of potential climate change risks, drawing on knowledge from council subject matter experts, iwi and external stakeholders. This was achieved through a combination of a desktop review of in-house information, SME and technical focus group input via workshops and surveys, and external stakeholder and iwi engagement through a combination of surveys and workshops

14. The risks were organised by hazard, then risk element. Domains consistent with the National Climate Change Risk Assessment were used as a further lens applied to the hazards and risk elements.

15. For this Phase 1, the Waikato hazards of interest presented in the table in Attachment 2 was used to identify climate change risks, drive conversation and collate a long-list of risks. The breadth of climate hazards comes from the National Climate Change Risk Assessment and the descriptors have been collated through literature review of the available regional projection information.

16. Key activities and milestones for Phase 1 are summarised in the table below.

Key activities/milestones		
Title	**Description**	**Status**
Initial iwi engagement	Letter to iwi CEs and reports to co-governance committees (March/April 2022)	Complete
LG CE engagement	Report to Waikato Chief Executives Forum (March 2022)	Complete
Committee report	Report to Climate Action Committee (March 2022)	Complete
Planning	Implementation planning workshop (March 2022)	Complete
Survey	Survey period (Week of 2 May 2022 - 22 May 2022)	Complete
Desktop review	Desktop review of existing information held by council and submitted by survey respondents	Complete
Workshops	Workshops (30 May – 10 June) WRC subject matter expert climate risk workshop General stakeholder climate risk workshop Iwi Māori climate risk workshop	Complete
Deliverable	Final risk identification workbook	Complete
Updates	Reporting/updates to partners and stakeholder	From 1 July 2022
Phase 2 scoping	Scoping of phase 2	From 1 July 2022

Table 1: Waikato Regional Climate Change Risk Assessment Phase 1 activities and milestones

Phase 1 deliverable - risk identification workbook

17. The climate change risk identification workbook is essentially a long list of regional climate change risks, informed by the inputs outlined below.

18. The risk identification workbook is in excel format and has also been embedded into the council hazards meta database. The hazards meta database is an internal council database of known natural hazard documents, reports and data and is managed by the Regional Resilience Team. The hazards meta database has been updated to include documents provided internally by our subject matter experts or submitted with survey responses. Identified risks have been cross-referenced to technical information held by Waikato Regional Council or other organisations. The cross referencing will allow easier identification and prioritisation of data required to fill gaps in understanding of climate change risk.

19. Three key inputs were used to develop the content of the risk identification workbook:

    a. A desktop review of existing climate risk information held by council or submitted in the survey
    b. An online risk identification survey (see Attachment 1)
        i. Engagement with the survey was extremely strong and a significant volume of information was shared
        ii. A total of 92 survey responses were received from a range of stakeholders and partners, including:
            - local government
            - iwi Maori
            - energy, agriculture, forestry, aquaculture, tourism sectors
            - Research institutions
            - the Waikato District Health Board
            - Non-governmental organisations and community groups
    c. Three workshops to discuss and refine risks:
        i. WRC subject matter expert workshop (50 attendees)
        ii. General stakeholder workshop (33 attendees)
        iii. Iwi Māori hui (24 attendees)

20. In total, 231 **direct** risks were identified across 44 elements (e.g. terrestrial ecosystems and species, horticulture/productivity of the land, buildings, biosecurity) and 55 **indirect** risks were identified across 37 elements (e.g. social cohesion and community wellbeing, employment and livelihoods, emergency services). Indirect risks are those further removed from the actual climate change hazard, such as impacts on mental health and disruptions to supply chains.

21. A list of Waikato Climate Change Hazards of Interest can be found in Attachment 2, a list of the direct and indirect risk elements identified from the desktop review, survey and workshops can be found in Attachment 3 and a sample of the identified risks in Attachment 4.

Access to the workbook

22. The risk identification workbook contains a substantial amount of detailed information, and requires a degree of excel competency to navigate and work with the data in it. As part of Phase 2 planning, we will work through how we can best share this information and/or the outputs from the detailed assessment in a meaningful, accessible and user-friendly format. In the interim, we are happy to share the workbook on request (please contact Project Manager Lisa Armstrong lisa.armstrong@waikatoregion.govt.nz).

Phase 2 – Detailed risk assessment

Overview

23. The risk identification workbook (Phase 1 deliverable) has drawn on the knowledge, views and local expertise of a broad range of stakeholders and partners to develop a long list of potential climate change risks in the Waikato. Phase 2 of the risk assessment will focus on shortlisting this long list of regional risks, and carrying out a detailed assessment to rate the identified risks. This will be achieved by bringing together focus groups of experts to assess groups of risks relevant to their expertise.

24. Figure 2 below shows the stages of risk assessment, prioritisation and adaptation planning.

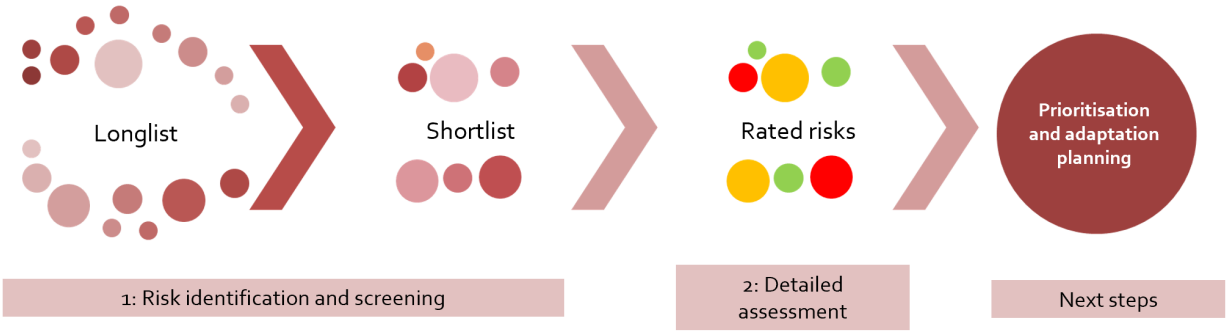

Figure 2: Stages of risk assessment, prioritisation and adaptation planning

Scope and approach to Phase 2

25. It is proposed to carry out Phase 2 in a staged approach with an initial pilot/s to enable a better understanding of the process, resource commitment and benefits and to allow learnings from the pilot/s to be applied to future stages. Figure 3 below shows the high level indicative timeline.

Figure 3: Phase 2 high level indicative timeline

26. The project team is continuing to further develop the scope and approach to Phase 2. Key matters we are currently working through and are keen to receive feedback on from stakeholders and partners are:

- How do we ensure that we obtain 'useful' information from a detailed assessment at a regional scale? For some risks, only assessment at a local/community/district scale will provide sufficient granularity to understand the risks. In addition, risk assessment and adaptation planning at a local/community scale is already planned by district councils over coming years for certain locations.
- How to incorporate a te ao Maori world view in the detailed assessment?
- Increasing our understanding of what information and support Waikato iwi Maori need from council to understand climate change risks for whānau, hapū and iwi.
- How do we best move beyond considering each risk element and risk individually to considering the interconnected nature of the risks and the interdependencies of risks (eg one risk impacts/exacerbates/initiates another risk)?
- Social and economic dimensions are relevant across many if not all of the risk elements. We are considering how to best incorporate consideration of these as we carry out detailed assessments.
- The role of regional council and our sphere of responsibility and influence versus the role of other sectors and central government.
- Ensuring we focus on "Waikato-specific" aspects of risk and do not duplicate climate change risk assessments being undertaken by other sectors or by central government.

Pilot options

27. Although the Waikato regional climate change risk assessment is for broad regional benefit, one key consideration for the initial pilot topic is: 'What area do staff and councillors most need good risk information in order to inform LTP investment priorities for adaptation planning and targeted action?'

28. In confirming the pilot topic, we will also consider whether other organisations are interested in collaborating with us on a particular assessment topic. The project team is currently considering the following options for the pilot topic and invites feedback from stakeholders as to the preferred topic.

Key options being considered for pilot	
Risk focus area	**Considerations**
Critical infrastructure (Lifelines)	• Contributes to WRC and Waikato TA strategic/organisational risk assessments • Supports the development of the Asset Management Plan and Infrastructure Strategy for the next LTP • Builds a consistent understanding of climate risk across Lifeline stakeholders and platform to agree further work priorities • Key functions and services to ensure community safety and wellbeing • Potential to build on recently completed Lifelines Vulnerability Assessment. • May use regional and district scale assessments in order to obtain meaningful risk ratings. • With a broader and larger group of stakeholders, a greater resource commitment and time requirement to establish and run.
WRC and TA flood and drainage infrastructure in the Waikato	• Contributes to WRC and Waikato TA strategic/organisational risk assessments • Supports the development of the Asset Management Plans and Infrastructure Strategies for the next LTP • Builds a consistent understanding of climate risk across Waikato TAs for community resilience and platform to agree further work priorities • Key local government function and service to ensure community safety and wellbeing • May use regional and district scale assessments in order to obtain meaningful risk ratings. • Fewer and more targeted stakeholders than critical infrastructure, potentially less resource commitment and time requirement to establish and run.
A subset of natural environment	• Key local government function • Advised that a more challenging topic/theme to do a risk assessment for. May be preferable for our first detailed assessment topic to be "simpler".
A particular Waikato landscape type	• For example, coastal. • Would need to carefully consider the appropriate scale and avoid duplication with planned community adaptation projects.

Working with iwi Māori

29. Council is committed to working with iwi Māori in our region on climate change and has received specific suggestions from our iwi partners on how we might support whānau, hapū and iwi in the Waikato. We intend to hold hui with iwi partners to discuss how we might best support Waikato iwi

Māori to understand climate change risks in a way that is meaningful and scalable to benefit all iwi Māori across the region.

Transition risk and opportunities

30. While we had initially intended to assess risks from the transition to a low carbon economy, we consider that this should now be progressed as a separate (but related) piece of work. This is primarily because transition risk requires a very different consideration (scenarios related to decarbonising over the short-term) to the approach required to assess the direct and indirect risks arising from physical climate change hazards (climate change over longer time periods).

31. Transition is an important context in which to understand regional risk, and will also offer opportunities for our region. Phase 2 will therefore continue to gather any relevant information to inform our understanding and approach to transition risk and opportunities (noting that any work on transition risk will be a separate piece of work).

Further work and projects

32. As well as assessing and understanding climate change risks in the Waikato, a key objective of Phase 2 is to identify a range of further work and projects to fill information gaps and improve understanding of climate change risk in the Waikato.

33. Regional collaboration will be necessary to reach agreement on how to prioritise, fund and resource the further work and projects identified in Phase 2. The publication of the National Adaptation Plan in August 2022, together with the upcoming resource management reforms, provide a prime opportunity to work together with our iwi partners, Waikato territorial authorities and other partners/stakeholders to ensure a robust, consistent and co-ordinated approach to climate change adaptation in the Waikato.

34. To this end, the Regional Resilience Programme, which is funded through council's LTP 21-31, provides an implementation vehicle to achieve this.

Next steps

35. The high level indicative timeframe is noted in Figure 3 above. Immediate next steps are as follows:

    a. Update iwi partners and stakeholders and seek partners for collaboration
    b. Map long list of risks against actions proposed in National Adaptation Plan
    c. Progress discussions on a climate change hui with iwi partners and hold if in agreement
    d. Complete scoping work for Phase 2
    e. Confirm pilot and those organisations interested in collaborating on the pilot
    f. Carry out detailed risk assessment for pilot topic.

Feedback

36. We invite feedback from our stakeholders and partners as to:

    a. The key scope and approach questions outlined in this report
    b. Their preferred option/s for the pilot topic
    c. Desire to collaborate as partners on Phase 2.

Disclaimer

This report and the included examples have been prepared to summarise work undertaken on the Waikato Climate Change Risk Assessment and are not intended for use as a technical or reference document, nor do they constitute council's policy. Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved, and is accurately reflected and referenced in any subsequent spoken or written communication.

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Document control

Name	Status	Date	Version
Lisa Armstrong, Project Manager	Author	31/8/22	V1.0
Karen Bennett, Manager Chief Executives Office	Approve	8/9/22	V1.0
Climate Action Committee	Approve	8/9/22	V1.0
Lisa Armstrong, Project Manager	Minor edits to prepare for public release. Addition of further risks to Appendix.	13/9/22	V2.0
Lisa Armstrong, Project Manager	Correction to contact details	20/9/22	V3.0

Attachment 1: Climate risk survey

Link to survey content

Attachment 2: Waikato Climate Change Hazards of Interest

Hazard	Description	Variable
Higher temperature (including increased hot days)	The average number of hot days could increase from 24 days per year to up to 84 days per year by the end of the century under a high emissions scenario. Average annual air temperature in Waikato could increase by as much as 3.1°C by the end of the century under a high emissions scenario. Spring is projected to warm the least and summer the most.	Temperature
Dryness and drought	The number of dry days per year could increase by 5 to 15 days per year. By 2090, the time spent in drought ranges from minimal change through to more than double, depending on the climate model and emissions scenario considered. Parts of the Hauraki district, Matamata and Thames-Coromandel are especially likely to experience increased drought risk. More frequent droughts are likely to lead to water shortages, increased demand for irrigation and increased risk of wild fires.	Temperature, PED, rainfall, wind
Increased fire weather	Fire climate severity is likely to rise significantly with climate change in many parts of the country as a result of increases in temperature, wind speed and lower rainfall and/or humidity. The number of days with very high and extreme fire danger could increase significantly.	Temperature, wind, rainfall
Increased inland flooding (fluvial and pluvial)	Mean annual flood (MAF) projected to increase but extent, particularly for large flood flows, is uncertain. Projected increase in intensity of extreme rainfall events will mean flooding events become more severe. As shown in Table 2 above, under RCP8.5 at 2100, the 1% AEP flood event is projected to increase by 39%. Sea-level rise resulting in increased groundwater level will also influence flood risk.	Rainfall, sea level rise
Changes in variability and seasonality of rainfall	Winter rainfall depth shows the biggest potential change of up to 4% under a high emissions scenario by the end of the century while annual rainfall shows little change overall.	Rainfall
Increased hail frequency or severity	No information available	Rainfall and extreme weather
Extreme weather (wind, storms, extreme rainfall)	Ex-tropical cyclone intensity is projected to increase particular for the most extreme events. Occurrence conditions conducive to storm development are projected to slightly increase. Extreme precipitation intensity is projected to increase. This may mean that longer dry spells are followed by more intense rainfall events. Climate change projections for New Zealand indicate an increase in mean westerly wind speed across New Zealand suggesting that gale or storm force westerly winds are likely to increase during the 21st century. Frequency of extreme winds is likely to increase in winter and decrease in summer.	Extreme weather
Sea level rise and	Sea-level rise projected to reach 0.79m above 1986-2005 baseline by	Sea level

Hazard	Description	Variable
coastal flooding	2100 under a high emissions scenario. Coastal inundation will increase for low-lying coastal areas.	
Increased coastal erosion	Coastal erosion will increase in frequency and intensity with sea-level rise and changes to extreme weather events. Exposure to extreme storm tides will increase with further sea-level rise. Extreme sea levels that are expected to be reached once every 100 years (on average) at present-day MSL, will occur at least once per year or more (on average) by 2050-2070.	Sea level, extreme weather
Groundwater rise and salinity stress in low lying areas	No information about projections for salinization of aquifers, except that this will increase under higher levels of SLR. Changes to salinity will also depend on rainfall and runoff patterns. Exposure to extreme storm tides will increase with further sea-level rise. Extreme sea levels that are expected to be reached once every 100 years (on average) at present-day MSL, will occur at least once per year or more (on average) by 2050-2070.	Sea level, rainfall
Marine heatwaves and ocean chemistry changes	Marine heatwaves are projected to increase in frequency and intensity with ongoing atmospheric and ocean warming. For the Tasman Sea, warming could exceed 3.1°C by ~2100 under a high emissions scenario. Overall, there is an expected reduction in macronutrients, net primary production, and chlorophyll. Reductions are larger with time and emissions scenario.	Temperature
Increased landslides and soil erosion	Increasing rainfall intensity due to climate change means landslide probability could at least double during the 21st century. Changes in rainfall intensity could also lead to a broader geographical area susceptible to landslide risk. Increases in earthflow, gully, sheet, and bank erosion are expected with increased rainfall and temperature.	Rainfall, temperature
Decreased frost	Frosts will become increasingly rare as the number of cold nights decreases. Much of NZ (outside of alpine areas) to become frost-free under a high emissions scenario by ~2100. Snow accumulation projected to decline by up to 79% at 1000m under a high emissions scenario by ~2100.	Temperature

Attachment 3: Examples of Direct and Indirect Risks from Risk Identification Workbook

Examples of Direct Risks

Risk statement	Summarised risk description	Gap identification
Risk to transmission and distribution due to increased fire weather	The electricity network is at risk of damage or loss of assets due to wildfire. It also acts as a catalyst to increase the risk of fire caused by arcing/sagging within lines. Risks can arise due to vegetation fires impacting local networks or networks outside of the region. The high-voltage direct current (HVDC) transmission system connecting the electricity generation-rich South Island to the more populous North Island. Located in the inland area of the mid-South Island, the HVDC is both vulnerable to the emergent risk of severe wildfire and very extreme wildfire conditions, so a catastrophic fault of the HVDC could result in a cascading failure and outage of an entire island	Power infrastructure mapped against regional wildfire projections: Overhead power trans-mission lines can be a source of ignition, but they also are at risk from wildfires. There are several choke points in New Zealand's overhead power transmission network that coincide with the emergence of more extreme wildfire weather conditions, for example, the Islington Substation in Christchurch, whereby power flows to an entire city, district, or region through a single line.
Risk to water quality due to increased fire weather	Wildfire can pose a risk to water quality due to ash fall, and contaminated run off from barren earth after wildfires. Runoff from fire fighting suppressants into source water for supplies. Scarce water resources being put under further pressure drying drought and dry weather as a result of fires (e.g. water being used for fire fighting).	
Risk to buildings due to increased fire weather	Increased temperatures, changing precipitation patterns, changing humidity, and increased plantation forestry can increase the likelihood of wildfires which can lead to the damage of properties. Over time this could lead to increase in insurance premiums or insurance retreat. Note: Fire has not been a major hazard before, therefore modelling may be needed in the future to better understand this hazard.	Fire has not been a major hazard before, therefore maybe modelling is needed, modelling of fire spread at different wind weather etc
Risk to freshwater (lakes) ecosystems and species due to changes in variability and seasonality of rainfall	Variability in rainfall may result in longer dry summers with periods of low flow. Changes to flows can impact habitats, and species behaviours (breeding/migration). E.g. margin nesting birds and galaxiids. Our shallow lakes are a sink for many contaminants from a combination of built and natural environments: e.g. Whangamarino wetland is one of our most valuable wetlands for biodiversity, yet it is also where stormwater from Waikato River is diverted during high rainfall. These conflicting needs result in biodiversity suffering. Inundation of plants and animals can also lead to the eutrophication of decaying plants. High rainfall can result in significant habitat disruption for freshwater species, possibly reduced habitat availability if sedimentation occurs as well. Also direct impacts during storms (e.g. wildlife being crushed between moving rocks.) Rapid increase of water levels in freshwater systems can lead to: - the drowning of plants and animals that aren't adapted to rapid change in water level. This may cause loss of some ecosystem types in flood prone areas such as Kahikatea forest, which does not like rapid change in water levels. (Kahikatea is one of our most threatened ecosystem types- only 1.5% of original extent remaining. Any further loss will significantly impact gene diversity for this species, not to mention other species that utilise this habitat.) - the loss of nests of threatened wetland birds (bittern, marsh crake, spotless crake, banded rail) if during breeding season. This could lead to local extinction of threatened birds in flood prone areas. - Will cause 'forced migration' of freshwater invertebrates and fish downstream if substrates are destabilised. Can cause large die-off within populations which may take generations to recover. "Could take generations to recover" is a big problem if 1 in 100 year events become yearly events!	The nature of relationships between rainfall/river flow and whitebait/galaxiids migrations is poorly understood for many species.

Risk statement	Summarised risk description	Gap identification
Risk to community health due to extreme weather (wind, storms, extreme rainfall)	Extreme events can reduce access to health care and emergency services. Certain critical lifeline facilities are at risk of flooding - e.g. Thames Hospital. Waikato hospital has risks due to landslides and water ingress. Thunderstorm asthma events where pollen particles get broken in to smaller particles and result in extreme asthma like effects on those who breath in the particles. These events are becoming more prevalent overseas and a suspected event occurred in Hamilton in 2016 which lead to an increase in hospital admissions for asthma like symptoms. Could result in the inability of people to attend work or school. Short and Long-term mental health and wellbeing consequences for individuals (i.e. anxiety over events and forecasts moving forward)	
Risk to marine ecosystems, estuaries and species due to climate change	The ocean's capacity to absorb CO2 will lessen, resulting in irreversible changes to ocean chemistry (acidity/pH). The reduction in pH will threaten the lifecycles of a multitude of marine species, many of which are taonga. These chemical changes threaten ecosystem function and the resiliency of coastal marine ecosystems. Acidification in the Firth of Thames (which is currently in bad condition) due to human activities on farm land (sediment, nutrients), coupled with increased run off, and warmer temperatures. Current acidification level is close to that predicted for 100 years in the future. Unsustainability of industry (aquaculture) and possibly a tipping point crossed in Firth of Thames Water quality is poor, its currently taking 2 years to grow mussels out and spat collection is zero in the Firth. Further acidification will add to this problem, and may make aquaculture unviable in a large proportion of the lower firth. There are many knock-on and interconnected effects, - there is a lot more research we need to do on acidification working with our partners and also focusing on biogeochemical cycling (e.g. denitrification). we need to work more effectively with our partners. https://www.waikatoregion.govt.nz/services/publications/tr202016/ e.g. Availability of kai moana decreases, which directly impacts communities who rely on this food source. Reduction in viable Aquaculture species. Changes in biogeochemical cycling underpinning the health of the marine ecosystem require improved understanding and monitoring. Stratification of Firth of Thames may change and high nutrient water at depth mix with warmer surface waters - see coastal science team	
Risk to community facilities due to increased coastal erosion	Coastal community facilities could be damaged or lost. These include schools, community buildings and facilities, public toilets, etc.	
Risk to marae due to sea level rise and coastal flooding	Buildings such as Marae are at risk of increasing flooding due to sea level rise and coastal flooding. This is usually accompanied with damages to property or infrastructure. Can lead to loss of access and also use of marae as centre of cultural activity for local Māori, loss of traditional connection to area, loss of traditional practices associated with a particular site, and loss of ability to hold tangihanga and other hui. This can also lead to loss of alternative marae community development due to need to spend funding on emergency responses and/or adaptation (e.g. defence or relocation). Loss of the physical building (marae) will result in adverse impacts to community wellbeing Loss of ability to demonstrate manaakitanga to marae guests (manuwhiri) in traditional way until relocation occurs Loss to wellbeing of individuals and community from inability to follow/learn cultural practices according to local tikanga specific to marae site and associated area	

Risk statement	Summarised risk description	Gap identification
Risk to riverine ecosystems and species due to higher temperature (including increased hot days)	Higher temperatures may increase water temperatures, particularly during times of low flow. This can be damaging to the health of native fish or cause increased mortality. Warmer water may also promote algal blooms. Could lead to increased range and productivity of invasive species (e.g. insects, weeds, pests) . e.g. increased temperatures increase breeding of red eared slider turtles which severely impact biodiversity. Reduction of suitable areas for native frog habitat.	Decreased species permitted to NZ, that have been previously permitted due to weather restraining breeding. i.e. red eared slider turtles permitted due to cold NZ temperatures, but are now breeding in NZ.
Risk to residential buildings due to higher temperature (including increased hot days)	Heatwaves can lead to soil shrinkage and subsidence, more rapid concrete deterioration and internal overheating of buildings.	
Risk to parks and reserves due to dryness and drought	Increased temperatures / drought will adversely impact public parks and green spaces. This will have consequent impacts to community health and wellbeing if people are unable to use parks. Planting season is being shortened due to drought. Instead of the first rainfall of the year happening around Feb-Mar, it is now occurring in May. Likewise, it stops raining around September where previously it would rain until November. Our planting season has contracted by about 4 months, putting parks staff under additional resource strain. Drought is also limiting the species that can be planted. This will result in restored ecosystems being significantly different than natural ones. Also could result species extinctions if the species are lost in natural ecosystems.	
Risk to terrestrial ecosystems and species due to dryness and drought	Increased dryness and drought may cause stress on native ecosystems and forests due to drying. This may lead to increased fire risk (and subsequent loss of forest - an important carbon sink), increased spread of disease e.g. kauri dieback, and increased 'edge effect' where the edges of forest die back because of exposure to drying/high winds. Native species that are not drought tolerant will perish and be replaced by more tolerant species that could be invasive. Potential for significant forest dieback when temperatures are above 25 degrees for extended periods of time. Dry weather can lead to soil erosion exacerbated by a lack of growth to protect soils. This can be also made worse by extreme rainfall events following periods of drought/dry weather. Drought can lead to hydrophobic soils that if followed by extreme rainfall can increase flooding impacts by increasing floods flows (speed and quantity). Drought/flood dynamics. Reduced water availability will adversely impact long-tailed bat corridors and other native birds (including any ongoing restoration work). Reduced water available for native forests (i.e. kahikatea forest, peatbogs and wetlands) Combination of increased temperatures and weather events are the issues. i.e. warmer temperatures increase pathogen loads (amount of pathogens) in the environment. Decrease the ability of natural resilience in highly modified environments. Trees have lower fruit and nectar yields when drought stressed, which results in less food availability for native birds and invertebrates. We are already having reports of birds dying of starvation in summer, when they should be at their fattest. This is going to result in population declines as individual birds die and have insufficient energy to breed/insufficient food for chicks. Increased impact upon diseased environments. i.e. where pathogens (biosecurity threats) are already present. Amplified impact, i.e. disease triangle / environment.	Need strong tie-in between biodiversity crisis and climate change crisis. They can't be treated as separate issues. RMA is replacing natural environments with replacement environments, which has significantly less resilience to cope with dryness and draught. Gap: higher protection status on important natural biodiversity areas. Gap: integrated management.

Risk statement	Summarised risk description	Gap identification
Risk to roads due to dryness and drought	Increased frequency of drought conditions resulting in drop in groundwater levels will result in oxidation of acid sulfate soils followed by more extreme heavy rain events resulting in production of sulphuric acid which mobilises metals and nutrients from the soil profile which can be transported to waterways. This can impact on surface water and groundwater quality, and buried infrastructure. Can also lead to fish kill events in water ways. Buried infrastructure such as foundations of bridges and building can become compromised due to acid corrosion. Drinking water can become compromised.	The position in NZ is not widely or well understood. It is a known issue in Australia but there is a lot we don't know about applying this knowledge in the NZ situation, eg our specific soil structure.

Examples of Indirect Risks

Risk statement	Summarised risk description	Gap identification
Risk to amenity and recreation due to climate change	Risk of worsening amenity and recreation within the region due to increasing damage and other impacts from climate change. The amenity of the region may be degraded as a result of a range of increasing risks, these include; coastal erosion which can degrade beaches and restrict access to the coast, loss or damage of indigenous ecosystems, reduced water quality. This can lead to a loss in connectedness to the natural environment and a loss of recreational areas. Risk to events and other economic activities, such as Fieldays, due to increasing extreme weather events. Increased likelihood that green spaces and biodiversity are damaged, or rendered unusable, by increasing climate change related hazards resulting in negative impacts on community wellbeing. Parks, green spaces, and biodiversity are a key part of many people's health, wellbeing, and culture (especially native species and gully networks that are key to Hamilton's history).	
Risk to community health due to climate change	A range of climate changes and extremes will impact the environment, and human health within the region, due to increased temperature, flooding, sea level rise and deteriorating water quality. Climate related risks can increase the frequency of infections from contaminated water, injury, bacterial and viral infections, crop failure, waterborne diseases, loss of property and loss of livelihood, homelessness, violence, and psychosocial stressors and destruction of food sources (tikanga risk). It is likely to have significant physical and mental health implications including climate change related anxiety, loss of livelihood, displacement after hazard events, loss of employment, insurance changes, land use changes, loss of amenity, degradation of indigenous ecosystems, and loss or disruption of cultural practices and values etc. Risks will be exacerbated for coastal Māori communities due to increased frequency of coastal flooding. Warmer and wetter conditions are likely to increase the frequency of human illnesses such as facial eczema and increase likelihood of internal parasites. Damp conditions can lead to respiratory illness among lower socio-economic groups. Extreme weather events may damage crops and contaminate water resulting in increased consumption of unhealthy food or contaminated water, directly affecting health and putting additional pressure on health services.	
Risk to community health due to dryness and drought	Drought conditions can lead to water shortages, which can result in the following impacts: dehydration, the inability to complete safe hygiene practises, infectious diseases and nutritional deficiencies that come from a lack of food availability. There are also a range of risks to commercial water users, which lead to impacts on peoples well-being (e.g. increased costs). Global examples of increased suicide rates amongst farmers during drought (e.g. Australia and India) Compromised air quality from airborne dust Undermine viability of small communities and marae to support themselves Vulnerable community members adversely impacted by heatstroke (linked to ID129) Compromised flow pressure to meet firefighting requirements could put the community at risk.	
Risk to council services due to climate change	Natural hazards, such as increased coastal erosion will limit the ability of the council to support the community and deliver services. Government agencies will be unable to meet the needs of the community due to increased frequency of extreme rainfall events. If flood defences fail or overtop, there is potential for large scale loss of services. Flood defences overtopping can lead to legal liability for the council.	

Risk statement	Summarised risk description	Gap identification
	Extreme events can disruption waste collection services, causing pollution. (I.e. Katrina in Louisiana where rubbish and sewage was part of the flooding). This can include the inability of rubbish and recycling to be collected due to extreme weather, or for recycling and organics to go to landfill where a normal service is interrupted. 100-year rainfall events could become annual events in the near future. Councils may not have the capacity to deliver the outcome that the community needs and meet legislative responsibilities.	
Risk to emergency services due to climate change	Risk to the capacity of emergency services due to increasing occurrence of natural disasters caused by climate change. Increased occurrences of emergencies such as wildfire, flooding and extreme weather will place an increased pressure on the capacity of emergency services, especially in rural areas. Implications for emergency response at a regional/national level (e.g. responding to an extreme wildfire). Increased need for evacuation facilities (i.e. schools marae). Infrastructure across the city may be impacted by combinations of hazards or events happening in quick succession, for example high temperatures and drought followed by extreme rainfall and flooding may compromise roading, pipes, etc. Inability to provide services for our community leading to health and wellbeing impacts, economic losses, lack of trust in Councils	Gap: need for evacuation structures/facilities for displaced people during emergencies. Gap: Training and maintenance of workforce to respond to increased emergencies
Risk to engineered solutions that incorporate biological systems into their design due to climate change	Climate change related plant stress may compromise the performance of engineering solutions that incorporate plants into their design (green infrastructure). Flood defence integrity could be compromised from reduced plant cover; which could occur as a result of higher temperatures. Performance of wetlands, bioretention and other stormwater treatments that rely on plants also may not perform correctly as plant species are impacted by higher temperatures, changing rainfall patterns and drought. Interaction between biological systems and engineered solutions: stopbanks for resilience may block movement of ecosystems moving inland due to SLR.	
Risk of exacerbating existing inequities and creating new inequities due to climate change	Risk that climate change will exacerbate existing inequities and create new inequities. Social inequities are at risk of being exacerbated due to a range of climate change hazards. This can lead to increasing health risks, economic costs, disruption to communities, loss of employment etc Often volunteers that respond to emergencies are in a state of poverty themselves and through manaakitanga they often put others before themselves. This is likely to exacerbate vulnerabilities within communities. Vulnerable groups will increasing live on hazardous land that is affected by climate change because housing is cheaper in these locations. They will be more exposed to further impacts from climate change, exacerbating already existing inequalities. Māori are already disproportionately represented among vulnerable groups such as low-income families.	
Risk of loss, damage and lost productivity due to climate change	Job losses and reduced economic activity due to changing climate (e.g. reduced productivity of agriculture and horticulture, changing tourism). The local and wider economy is likely to be impacted by climate changes. Loss in productivity and employment due to gradual changes and climate-related disasters can increase the likelihood of economic loss, this will be compounded by increasing costs relating to repair of damages, preventative and adaptive measures and increasing demand for support services (e.g. healthcare and emergency services). Pressure increases will occur on disaster relief funding. Extreme weather may cause damage of farm amenities and assets, livestock and pasture. This will have an economic impact on the agricultural sector. Increased economic impacts to supply alternate water supply to communities if reservoirs become contaminated due to gradual changes and climate-related disasters. Loss of aquaculture and fisheries due to marine heatwaves and changes in chemistry could lead to a complete loss of this industry in New Zealand. Loss of productivity in general can mean fewer funds for community facilities in coastal or flood prone areas and lead to net migration out of coastal areas.	
Risk to treaty obligations due to climate change	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.	
Risk to kotahitanga due to climate change	There is a risk to kotahitanga (unity, connection, community 'togetherness', transmission of knowledge) from climate change. When aspects of the natural environment are impacted from climate change and community cohesion is affected it can impact on the kotahitanga of a community. Loss of taonga species central to Māori identity and can mean the loss of knowledge and tikanga associated with those resources, which are also lost to future generations. Fragmentation, feelings of isolation, and loss of connectivity within iwi, especially if iwi are unable to visit, interact, and use cultural sites due to climate change impacts.	
Risk to tikanga due to climate change	Traditional (tohu) signs/indicators used to forecast changes in the environment are becoming less reliable, affecting planting and daily decision-making and activities like resource gathering and hunting. Loss of taonga species central to Māori identity and can mean the loss of knowledge and tikanga associated with those resources, which are also lost to future generations. Manaakitanga especially important on marae where local delicacies are offered to manuwhiri as a sign of mana and generosity.	

Risk statement	Summarised risk description	Gap identification
	Continued coastal flooding and sea level rise may result in iwi moving away from iwi land resulting in loss of Māori stories and learnings for the younger generations. Other implications include: - Impacts on traditional mahinga kai leading to implications of expressing tikanga. - Transmission of mātauranga from generation to generation - Access to marae as tūrangawaewae - Return to the cultural landscape (Hukanui, Te Kopuatai) - Water sovereignty issues due to risk to water availability - Climate anxiety and the ability to continue traditional practices	
Risk to mahinga kai due to climate change	Risk that climate change will limit the availability of and access to kai moana. Climate change may cause the reduction or loss of mahinga kai (such as tuna, eels and watercress). Increased nutrient run-off will, in turn, increase algal blooms that damage ecosystems and mahinga kai. Erosion or leaching of landfills due to increased extreme weather or inland flooding could result in contaminants entering the natural environment and affecting mahinga kai. Drought conditions can lead to the reduced habitat, and increased heat stress on native species, reducing the population of taonga and mahinga kai. Reduce access to, and loss of, traditional kai moana gathering areas for iwi/Māori due to sea level rise and coastal flooding. Adverse impacts on communities who traditionally rely on this food source, leading to impacts on physical and mental health. Impacts on Rangatahi, food sovereignty, and hunting, diving and food gathering.	
Risk to not meeting emissions reduction targets due to climate change	Risk of not meeting national emission reduction targets due to climate change such as increased temperatures, or extreme weather. For example people choosing to drive instead of more active forms of transport resulting in reduced health and wellbeing and increased emissions. Or increased wildfires reducing Aotearoa's ability to sequester carbon through forestry. Recent research (Duffy et al., 2021) suggests ability of plants to sequester carbon could be halved in the next 20 years if temperatures continue rising at similar rates as photosynthesis declines beyond a temp threshold.	
Risk of community displacement due to climate change	Risk to social cohesion and community wellbeing due to community displacement from climate change. Various different climate change hazards can lead to community displacement, and potentially managed retreat from exposed areas. This can lead to economic issues, increased pressure on infrastructure, as well as loss of connectedness, and social cohesion. Temporary or permanent displacement of communities can occur from a range of climate hazards and is likely to become more frequent with the intensity of storms and coastal flooding events. This can have implications for Māori (iwi and hapu) who are connected to the land and can exacerbate existing inequalities. Stress and associated impacts with relocation / affordability can result in adverse impacts for individuals. Increased risk of fragmented and dispersed communities from managed retreat and the flow on effects to community wellbeing as a result. Increase in disrupted communities (communities people are leaving as well as moving to) as a result of climate change. It is anticipated that an influx of people to Hamilton as a major inland area of the Waikato/North Island could adversely impact culture and wellbeing in Hamilton, putting added pressure on infrastructure, housing, healthcare, etc.	