Wellington Regional Climate Change Impact Assessment Methodology Framework

Prepared for Wellington City Council (on behalf of WRCCIA council partners)
Prepared by Beca Limited in association with NIWA Ltd, GNS Sciences Ltd and partners

8 July 2022

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Contents

Revision History

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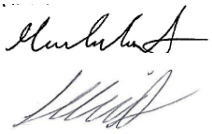
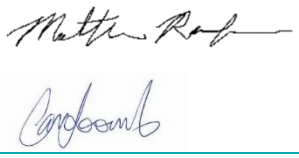
Document Acceptance

Action	Name	Signed	Date
Prepared by	Mike Allis, Lucas Everitt		06/07/22
Reviewed by	Matt Raeburn / Cushla Loomb		07/07/22
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Glossary

We note that the councils have chosen to refer to this project as an 'impact' rather than a 'risk' assessment to emphasise the focus on practical implications. Climate 'risks' and 'impacts' are conventionally defined as below.

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.[1]

Cascading effects: Effects that flow on from a primary hazard, propagating as impacts across other human or natural systems in a dynamic manner.[2]

Climate Driver: A changing aspect of the climate system that influences a component of a human or natural system.[3]

Compound hazards: The combination of multiple drivers and/or hazards that lead to a significant impact.[1]

Consequence: The outcome of an event that may result from a hazard. It can be expressed quantitatively (e.g., units of damage or loss, disruption period, monetary value of impacts or environmental effect), semi-quantitatively by category (e.g., high, medium, low level of impact) or qualitatively (a description of the impacts) (adapted from MCDEM, 2019).[2]

Direct risk: Where there is a direct link between a hazard and an element at risk that is exposed and vulnerable. For example, storms and flooding damaging buildings and infrastructure, droughts leading to crop failure, or extreme temperatures causing heat stress.[2]

Elements at risk: People, values, taonga, species, sectors, assets etc that are potentially vulnerable to climate change impacts.[2]

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by a change in external stresses that a system is exposed to.[3]

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this assessment, the term hazard usually refers to climate-related physical events or trends or their physical impacts.[3]

Impacts: The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather / climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.[3]

Indirect risk: Indirect risks are further removed from a hazard – for example, impacts on mental health, disruptions to supply chains, migration, social wellbeing, and cohesion. They are the result of direct risks elsewhere, which can be local or distant.[2]

[1] IPCC (2021). AR6, Annex VII - Glossary.

[2] MfE (2021). *A Guide to local climate change risk assessments.*

[3] IPCC (2022). Annex II – Glossary.

Sensitivity: Refers to the degree to which an element at risk is affected, either adversely or beneficially, by climate variability or change. Sensitivity relates to how the element will fare when exposed to a hazard, which is a function of its properties or characteristics.[2]

Te Taiao Narrative: Te Taiao is a unique and integrated model for viewing the environment from a Māori perspective. The overarching Te Taiao Narrative of this assessment looks at climate change risk from a holistic "all of environment" perspective. Te Taiao presents an ideal framework for an integrated view on climate risks, enabling integration of western risk frameworks with Te Ao Māori values.

Transition Risks: The process of major, fundamental change in societal or natural systems from one state or condition to another, as opposed to changes that are minor, marginal or incremental.[4]

Uncertainty: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts).[5]

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. See also Contextual vulnerability and Outcome vulnerability.[3]

[2] MfE (2021). A Guide to local climate change risk assessments.

[4] IPCC (2022). Working Group 2 report, Chapter 1.

[5] IPCC (2018). Annex I - Glossary.

Executive Summary

This Methodology Framework report documents the method and approach for the Wellington Regional Climate Change Impact Assessment (WRCCIA). The methodology provides a consistent approach to risk assessment across the whole region that will inform the Wellington Regional Climate Change Adaptation Plan. The Adaptation Plan is due to be developed by 2024, as part of the Wellington Regional Growth Framework.

The methodology builds from the establishment of an overarching Te Taiao Narrative, which looks at climate change risk from a holistic “all of environment” perspective. Te Taiao is a unique and integrated model for viewing the environment from a Māori perspective and enables the integration of western risk frameworks with Te Ao Māori values.

The methodology details how the WRCCIA will be undertaken. It steps through an established risk assessment approach to identify, describe, and assess risks that may arise in the Wellington region from a suite of climate change hazards. Additional innovations are included in the methodology to view risks more holistically and address cascading, compounding, governance, and transition risks in the assessment.

The assessment will be completed in two phases:

- **Phase 1:** A qualitative assessment of climate change risks at regional and district scale. This includes a high-level risk screening, assessment of direct, indirect, transition, cascading and compounding risks, and risk prioritisation.

- **Phase 2:** Detailed assessment of selected climate change risks following prioritisation in Phase 1. This includes producing a geospatial tool and capacity building opportunities for the WRCCIA partner councils.

This phased approach is consistent with the Ministry for the Environment’s *Guide to Local Risk Assessments* (MfE, 2021), which outlines a systematic and iteratively stepped approach from high-level risk screening through to detailed assessment.

The outcome of the WRCCIA is the creation of reports, a risk register and risk analysis at regional and district scales. Individual councils within the Wellington region can use these outputs to understand the relevant climate change impacts and incorporate these into future planning and adaptation actions. Councils can also draw on this methodology to undertake their own more detailed studies.

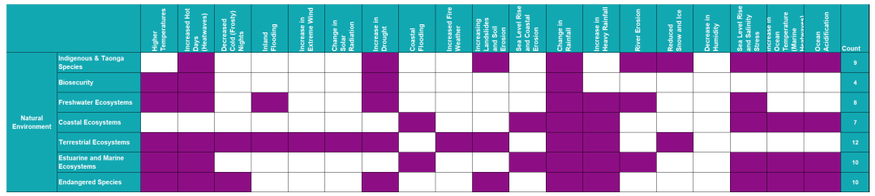
1. Assessment Setup

- Principles
- Purpose
- Level of Assessment
- Domains and Elements at risk
- Climate Hazards
- Timeframes and Climate Scenarios

Phase 1 - Risk Screening and Qualitative Assessment

2.1 First-Pass Risk Screen

- Identify elements at risk to specific climate hazards under an RCP8.5 2100 Scenario



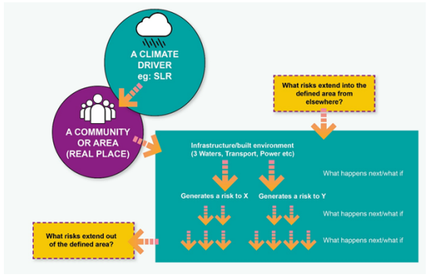
2.2. Governance Risks

- Judged qualitatively in workshops through assessment of risk management frameworks and treaty partnerships

2.3. Cascading Risks

- Identify 3-5 risk descriptions and exogenous impacts that cascade from outside the region

- Generate cascade archetypes that would provide an example of the types of cascades that might exist at numerous locations across the region.



2.4. Transition Risks

- Account for key transition risks and opportunities and consider highest level of materiality

- Align with Task Force for Climate related Financial Disclosures (TCFD) framework

3. Risk Scoring and Assessment

- Populate risk register from Step 2 Outputs

- Qualitative scoring of Exposure, Adaptive Capacity and Sensitivity

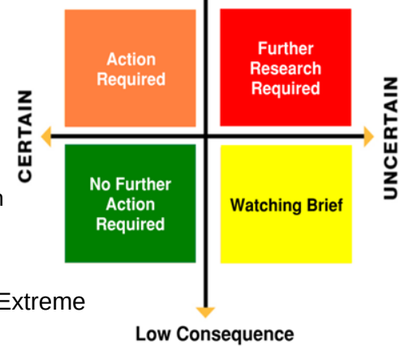
Risk_ID	Climate hazard	Element at risk	Risk statement	Exposure					Sensitivity	Adaptive capacity	Vulnerability	Risk				
				Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5				Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5
1	Sea level rise, coastal flooding	State Highway network	**Risk to the state highway network due to sea level rise & coastal flooding**	Low	Moderate	High	High	Extreme	Extreme	Medium	High	Low	Moderate	High	High	Extreme
2	Changes in rainfall	Agriculture/ horticulture	**Risk to agriculture/horticulture due to changes in rainfall/ drought**	Low	Low	Moderate	Moderate	High	Moderate	Medium	High	Low	Low	Moderate	High	High

4. Prioritise Risks

- Assess Consequence as it relates to holistic value set and domains

- Assess Uncertainty with regard to past investigations and general agreement

- Risks with higher consequence and higher uncertainty will be discussed for prioritisation



Consequence - Minor, Moderate, Major Extreme
Uncertainty - High, Low

Phase 2 - Priority Risks Assessment

5. Detailed Assessment and GIS Viewer

- Quantitative assessment of risk to specific elements at risk for selected climate change risks.

- Inform second phase of data collation

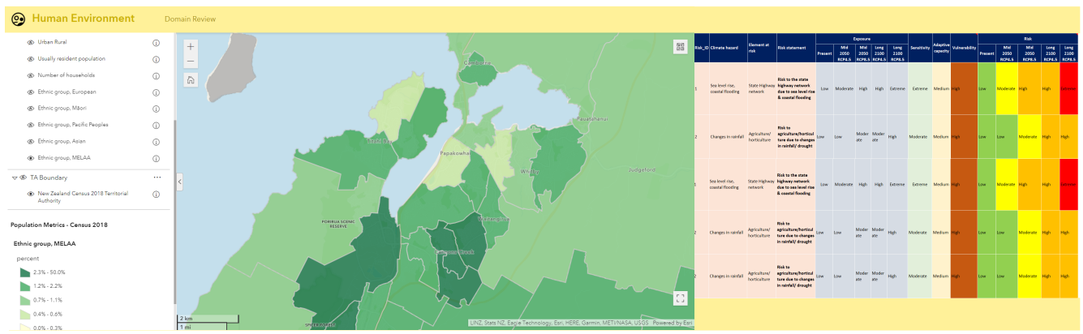
- Exposure, sensitivity and adaptive capacity informed by geospatial methods where possible. Outputs provided at appropriate scale with suitable metrics and presentation in GIS tool.

- Build relationships into RiskScape and FME

- Aggregate scores up to Geo Boundaries (SA2/Suburb)

- Mapped viewer of Climate Hazards and Elements at risk

- Council can score risks at suburb level and adjust risk scores at district level into the future



Part A – Background and Context

Introduction

The Project

The Wellington region is prone to natural hazards, many of which are likely to be exacerbated by climate change. Councils in the region need to make decisions about how to best respond to climate change impacts and identify appropriate strategies to manage these impacts over time.

To support these decisions, a Wellington Regional Climate Change Impact Assessment (WRCCIA) has been proposed that includes all nine councils within the Wellington region (**Figure 2**).

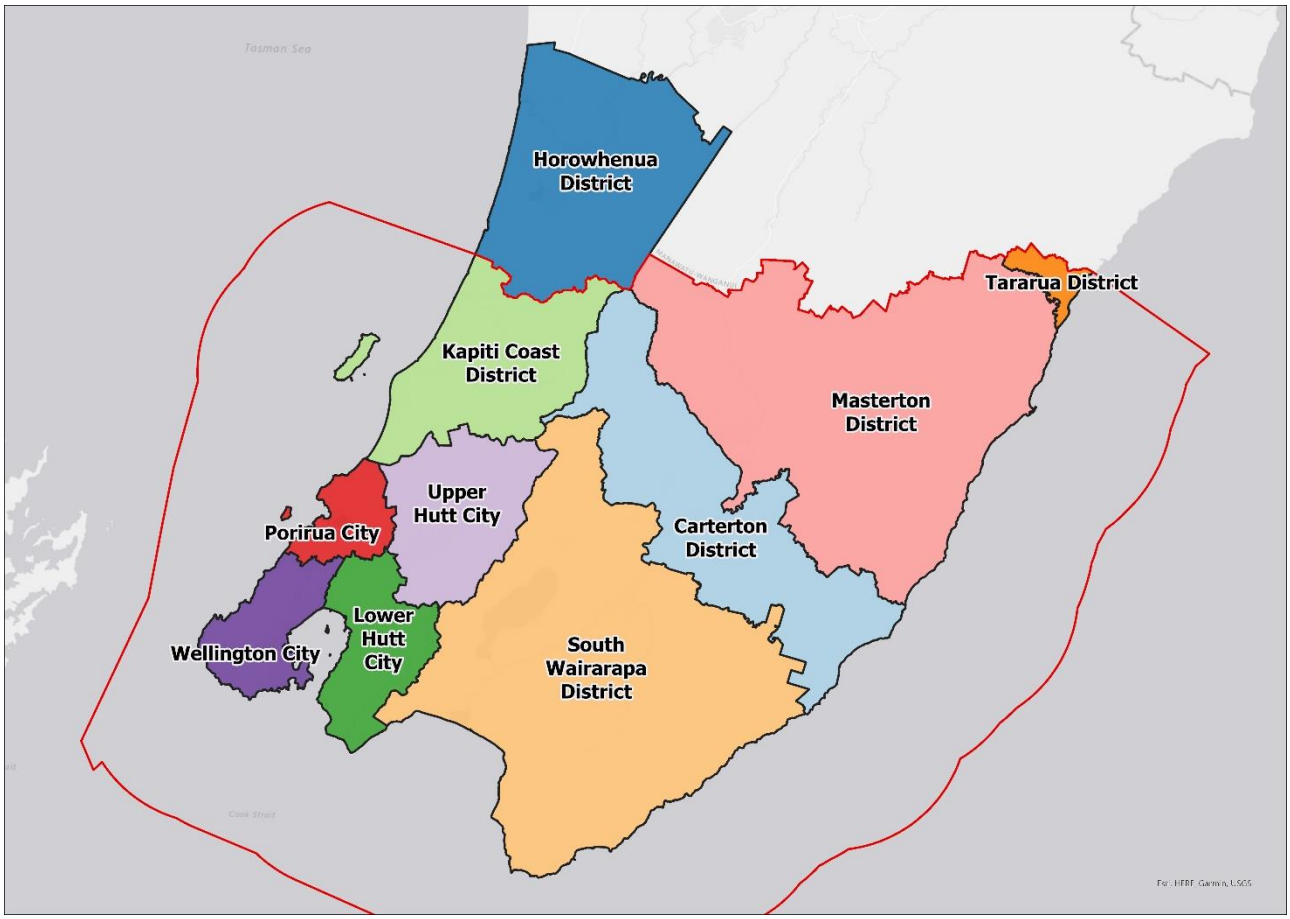


Figure 2. The Wellington Region with council partners of the WRCCIA. Contains data from LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, FAO, METI/NASA, USGS.

The purpose of the WRCCIA is to support a number of climate change risk mitigation and adaptation activities including informing spatial plans such as District Plans, Long-Term Plans, Regional Plans, and the Regional Growth Framework.

The assessment will also form the basis of the Wellington Regional Climate Change Adaptation Plan. That Plan is due to be developed by 2024 as part of the following Wellington Regional Growth Framework objectives:

- ***Objective 5:*** *"Build climate change resilience and avoid increasing the impacts and risks from natural hazards."*
- ***Objective 4:*** *"Encourage sustainable, resilient and affordable settlement patterns/urban form that make efficient use of existing infrastructure and resources."*

Narrative - Connection to Papatūānuku: Te Taiao | The Earth

A core element of the WRCCIA is a foundation in Te Ao Māori. We propose to incorporate this using a Te Taiao Narrative, which can be developed further through on-going Mana Whenua engagement. This section introduces the Te Taiao Narrative and discusses how the Narrative underpins the WRCCIA methodology.

The Narrative begins through the Ancestral Pūrakau (Story) of the separation of Papatūānuku and Ranginui by their children. From this Narrative emerges the lens by which Māori interact in balance with, and as a part of, nature. The four key elements that Papatūānuku upholds are drawn from delving inside Te Taiao (Nature): Whenua (Land), Wai (Water), Āhuarangi (Climate and time) and Koiora (Life, Communities of Life).

Table 1. Four elements of Te Taiao

Whenua — Our ground, our Land	Wai – Water
The recognition that the whenua provides sustenance and whakapapa, and we need to care for it so that Papatūānuku can continue to provide for us and future generations.	The tears of Ranginui. In his grief over a separation from Papatūānuku, his tears fell as water and became the essence of mauri and life force - Te Mana o te Wai.
Āhuarangi — Climate and Time	**Koiora — Life and Communities**
Living and existing within the cyclical terms that Papatūānuku provides us. Learning, listening, and aligning our actions to yearly climactic cycles.	We live in constant connection with the environment - we are an integral part of a living community, and it is a part of us.

The concept of Te Taiao is an established and holistic way to visualise and conduct risk assessment with respect to climate change and the collective outcomes that influence the multiple threads of Te Taiao. Connecting this narrative to the western risk assessment framework, described below, not only contextualises and helps group risks; it also maintains the view that each risk and grouping of risks is part of a single system and is all inter-related.

This is not to be confused or assumed to be the inputs from Mana Whenua as this is a general Māori concept to help the project visualise and incorporate Mana Whenua inputs to the methodology.

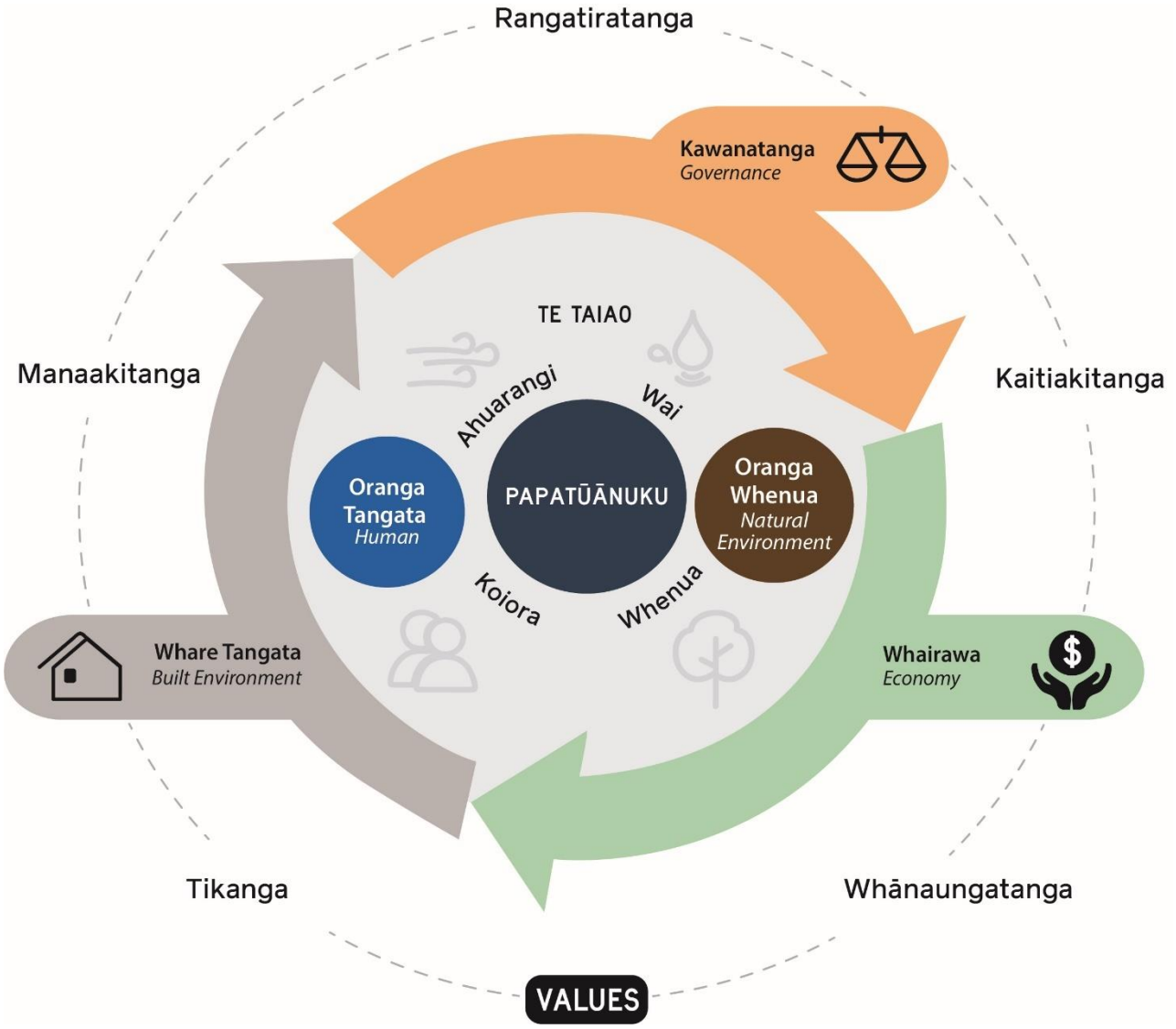


Figure 3. Te Taiao Framework

This approach develops a connection to environmental wellbeing through Oranga Tangata and Oranga Whenua. The Te Taiao framework suggests the evolution of this model toward a holistic sense of wellbeing and our desire to return respect to Papatūānuku, helping her to also go on this journey of climate change in a way that upholds Manaakitanga and Kaitiakitanga.

The purpose of this Narrative within the WRCCIA is twofold. Firstly, it helps connect people at an emotional level to the health of the whenua and to everything connected to it. These values support an understanding of the goals of the project. It is a fundamentally Māori world view that provides for the overall goals at a holistic level.

Secondly, the narrative provides a Tomokanga - a doorway or entrance that, in this case, is a metaphor for the way that engagement with Mana Whenua across the project geography can begin. It provides a set of considerations from a Te Ao Māori perspective. It can be used to begin a conversation and understanding of Mana Whenua values and outcomes that Mana Whenua may wish to see embedded into the project outcomes.

Aspects of Te Taiao

- Te Taiao is a singular Māori lens and name for “The Environment.”

- Water, Land, Life (Communities of all life) and Climate Change over time are all in Te Taiao in equal measure.
- Human health and wellbeing are intrinsically linked to not only how we feel and live our lives, but how we assist and help Papatūānuku through the effects of climate change. She is hurting too. Respecting her is key to how we assess risk and adapt in the longer term. Helping her to change and to adapt will in turn help us.
- Climate Change from a Māori perspective opens the narrative up to Māori models for adaptation and the need to live within the means of what is provided cyclically. These cyclical provisions include the rhythms of the moon (Maramataka), the changing temperatures, and the impact of these phenomena as a whole.

Aspects of Local Government

Aspects of local government that influence and are influenced by the whenua and tangata aspects of Taiao:

- Kawanatanga (Governance)
- Whairawa (Economy)
- Whare Tangata (Built Infrastructure)

Binding Values

These are the values that support the behaviours and role humans can and should play as we assess risk and ultimately adapt. This framework of Te Taiao defines the narrative for the WRCCIA, and the narrative to which we anchor the project outcomes. Some key features of the Te Taiao Narrative:

- It anchors the approach from within Te Ao Māori as an indigenous model to help visualise the inter-connectivity of each component part.
- It provides a lens and a gateway to the risk assessment that is more accessible to Mana Whenua view and aligned to Mana Whenua outcomes.
- It connects, at a human level, the reasons why the risk assessment is important and resonates with individual and collective health outcomes.
- It contextualises risks as a nested and connected set of interrelated features, including human-environmental outcomes, as all being part of a singular view of the world in which we live.

In summary, the Te Taiao model helps us to adapt, while caring for the environment, by understanding risks and acting on them. It is a model fundamentally rooted in Te Ao Māori by virtue of Oranga Tangata Oranga Whenua. Health People and Healthy Land are interrelated and reliant on each other, because they are one and the same.

Climate Risk Assessment

The methodology described in this report aligns with existing risk assessment methodology guidance (e.g. MfE, 2021; ISO14091, 2021). We have built on the existing guidance by presenting additional tools and methods for identifying and assessing indirect, compounding, cascading and transition risks with a strong focus on community, place and space.

At its core, a climate change impact assessment requires developing an understanding of the **Exposure** of a particular **Element-at-Risk** to an identified **Climate Change Hazard**. The **Vulnerability** of an element encompasses the **Sensitivity** to harm and **Adaptive Capacity** of that element to respond to climate pressures. Each of these elements informs the final risk scoring. This established approach to assessing climate risk is presented in **Figure 4**.

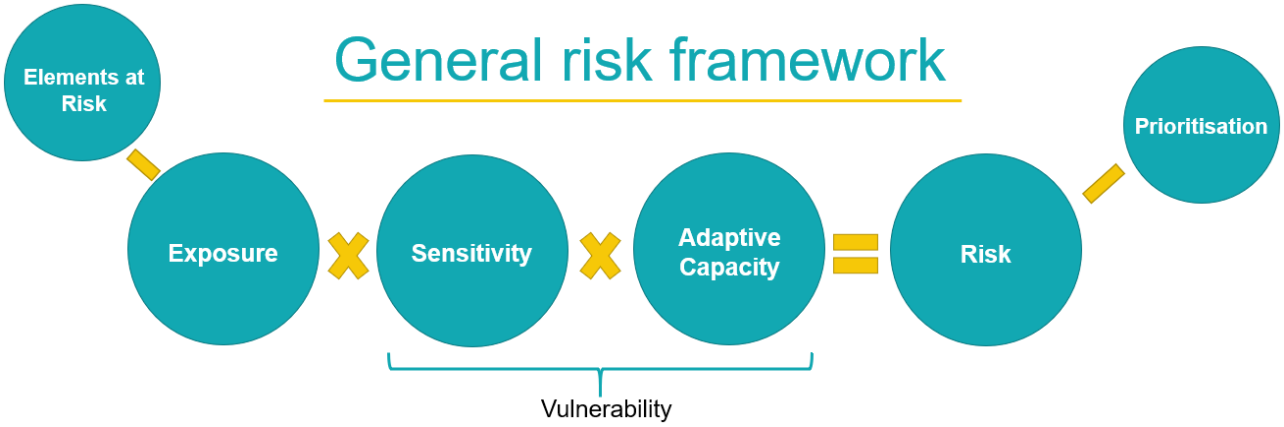


Figure 4. Risk Assessment Framework. Adapted from MfE's Guide to Local Climate Change Risk Assessments (2021).

The National Climate Change Risk Assessment (NCCRA, 2020) for New Zealand and local guidance to climate risks assessment (MfE, 2021) use this traditional risk assessment approach grouped around five Value Domains:

Human | Natural Environment | Economy | Built Environment | Governance

This approach is effective for assessing the overall impact of individual climate hazards to isolated elements within each value domain, known as **Direct Risks.** This approach is also effective when aggregating and assessing climate change hazards at a regional and district scale.

It has been agreed that climate risks to elements do not occur in isolation, and the impacts of a single climate hazard can have ramifications across multiple value domains. These types of risks can be classified as **Indirect**, **Compounding** and **Cascading** risks.

The Intergovernmental Panel on Climate Change Sixth Assessment Report (AR6) *Climate Change 2022: Impacts, Adaptation and Vulnerability, the working Group II contribution* (IPCC, 2022), highlights indirect and cascading risks as having the greatest potential impacts on people, places, and spaces. The methodology outlined in this document looks to advance the traditional 'direct risk' assessment and broaden the focus to address cascading, linked and compounding risks in recognition that they may cause the highest level of effect in Wellington.

For example, if one of the state highways leading into Wellington were affected by increased land-slide activity resulting from increased rainfall intensity, then the direct risk is to the road network. Meanwhile, the cascading risk assessment identifies the flow-on effects for economy and society in the local area as a result of the impact on the road network (e.g. community access/interruptions) and across the region (e.g. freight linkages affecting regional productivity an delivery of good for export).

Structure of this Report

Part A of this report provides the background and context to the WRCCIA, including the principles behind the methodology.

Part B of this report outlines the methodology for setting up and undertaking the WRCCIA.

Section 1 of Part B identifies the steps to prepare for the assessment. The framework must be established by selecting the:

- Scale and type of assessment
- Climate change projection scenarios and timeframes
- Climate change hazards
- Organising themes of the assessment (domains and elements at risk)

The assessment is completed in two phases:

- **Phase 1:** Qualitative Assessment of climate change risks at regional and district scale (**Sections 2, 3 and 4**). This includes high-level risk screening, assessment of direct, indirect, transition, cascading and compounding risks, and risk prioritisation.
- **Phase 2:** Detailed Risk Assessment of prioritised climate change risks, including quantification of risk if data allows (**Section 5**). This includes producing a geospatial tool and capacity building opportunities for councils.

This phased approach is consistent with MfE's *Guidance for Local Risk Assessments* (MfE, 2021) which outlines a systematic and iteratively stepped approach from high-level risk screening through to detailed assessment.

Wider Principles Underpinning the WRCCIA

High-level principles for the methodology have been agreed with the nine wellington councils. These principles were identified from the project brief included in the WRCCIA Request For Proposals (WCC, 2021) and developed in discussion with the council project team and through a workshop with council representatives.

Table 2. High-level principles considered in the development of the WRCCIA methodology

Objective	Methodology approach
Robust, repeatable, and appropriately scaled	Systematic, region-wide and district scale assessments
Aligned with best practice for Climate Risk Assessments	Based on MfE guidance (2021), ISO 14091 (2021), and the NCCRA
Consistent with adjacent regional council assessments for overlapping districts (Horowhenua District Council)	Consistent but expands from Horizons Regional Council approach, which was also based on MfE Guidance (2021) and the NCCRA
Align with Te Tiriti o Waitangi and meaningfully include Te Ao Māori worldview	Centred around Te Taiao Narrative that allows ongoing opportunity for mana whenua to be involved and engage on the journey
A mixture of qualitative and quantitative assessment methods	Phased approach moving from qualitative to quantitative assessment (where data allows)
Avoidance of bias (information bias)	Holistic assessment through cascading risks
Promoting a Just Transition – considering the most vulnerable first	Holistic assessment through cascading risks
Able to incorporate future (new) information	GIS tools updatable with values and GIS layers
Address weaknesses in the NCCRA	Draws from NCCRA and provides innovative extensions
Innovate	Inclusion of cascading risks, compounding risks and digital tool
Compelling approach to communicate findings to relevant parties	Graphics, takeaway GIS tools
Prioritise impacts which are most urgent for Councils to address	Prioritisation assessment step
Increase the capacity to collectively understand and manage climate change risks	Upskilling opportunities and collaborative process of council steering group. Capacity enhancement opportunities

Part B – The Methodology

Framework of the WRCCIA

Overview

The assessment is completed in increasing levels of detail as follows:

- Setting up the assessment.
- First-pass/high-level qualitative screening at regional scale boundaries.
- Qualitative assessment of exposure and vulnerability at regional and district scale boundaries.
- Identification and assessment of transition, governance, compounding and cascading risks.
- Prioritisation of risks and selection of key risks for detailed assessment.
- Detailed assessment, including quantitative and geospatial analysis where applicable, with the use of downscaled climate projections and data attributed to geospatial datasets.

The high-level stepwise methodology for the WRCCIA is presented in **Table 3**. Each step is described in further detail in the following sections of this report.

Table 3. WRCCIA Stepwise Methodology

Step	Aim	Consideration	Output
1 – Assessment setup	Confirm RCP scenarios, Timeframes, Climate Hazards and Organising Themes	**Activity Lead: Consultant Methodology Team** Available data at regional level (both climate projections and timescales), alignment with assessments by other key stakeholders and identifying what is of value	Structure of assessment
Phase 1 – Risk Screening and Qualitative Assessment			
2.1 – Screen of direct risks and opportunities	Identification of notable direct risks and opportunities, along with identification of indirect and compounding risks.	**Activity lead: Domain leads** Subject matter experts (SMEs) review the influence of each climate hazard on each element at risk under an RCP8.5 scenario at 2100.	Risk screening matrix and risk descriptions
2.2 – Identification of governance risks	Identify and understand key governance risks that are not captured in the risk screening approach	**Activity lead: Judy Lawrence** Review of governance material alongside key regional agencies (Central Govt, Waka Kotahi, etc.) to assess the key governance risks	Recommendations for how these risks might be reduced through additional governance actions and by whom
2.3 – Identification of cascading risks	Identify and understand key cascading risk archetypes	**Activity lead: Paula Blackett** Develop, assess causal links to consider cascading and cross-cutting risks at a community and higher level of detail	Illustrative maps of impact interdependencies Illustrative spatial map of nodes of impacts across the region with some standout examples
2.4 – Identification of transition risks and opportunities	Account for key transition risks and opportunities as part of the risk assessment process	**Activity lead: Matt Raeburn** Align with the Task-force for Climate-related Financial Disclosures (TCFD) framework and the requirements of the Zero Carbon Act.	A shortlist of transition risks and opportunities with the highest materiality scores for inclusion risk prioritisation workshop.
3 – Qualitative Risk Assessment	Qualitative score of exposure, sensitivity and adaptive capacity for risks identified in previous steps	**Activity lead: Domain leads** Use of GIS hazard/element viewer to understand exposure, along with subject matter experts and literature to inform sensitivtiy and adaptive capacity	Completed register of climate risks
4 – Prioritisation	Develop list of prioritised risks to inform adaptation efforts and identify top risks to put through to detailed assessment	**Activity lead: Consultant Methodology Team** Assessment of consequence and uncertainty The tendency for using quantitative and geospatial methods Whether pre-existing hazard studies are available and assessments do not need repeating	Prioritised register of climate risks
Phase 2 – Priority Risks Assessment			
5 – Detailed Assessment supported by geospatial analysis	Detailed assessment of risk. Assessed by building geospatial relationships between GIS layers of selected risks where possible.	**Activity lead: Consultant Geospatial Team** Data availability and scale of reporting Informed relationships between elements and hazards	The results will be incorporated into a GIS reporting tool displaying the results of the detailed assessment across the pre-determined climate/RCP scenarios.

1 Assessment Setup

WRCCIA Step	Aim	Considerations	Output
1 – Assessment setup	Confirm: • RCP scenarios • Timeframes • Climate Hazards • Organising Themes	**Activity Lead: Consultant Methodology Team** Available data at regional level (both climate projections and timescales), alignment with assessments by other key stakeholders and identifying what is of value	Structure of assessment

1.1 Climate Change Scenarios and Timeframes

1.1.1 Representative Concentration Pathways

The climate change projections recommended in this assessment align with those in the NCCRA framework and MfE guidance. They are derived from two of four representative concentration pathways (RCPs) used by the Intergovernmental Panel on Climate Change (IPCC) in its fifth Assessment Report (2013–2014) (IPCC, 2014).

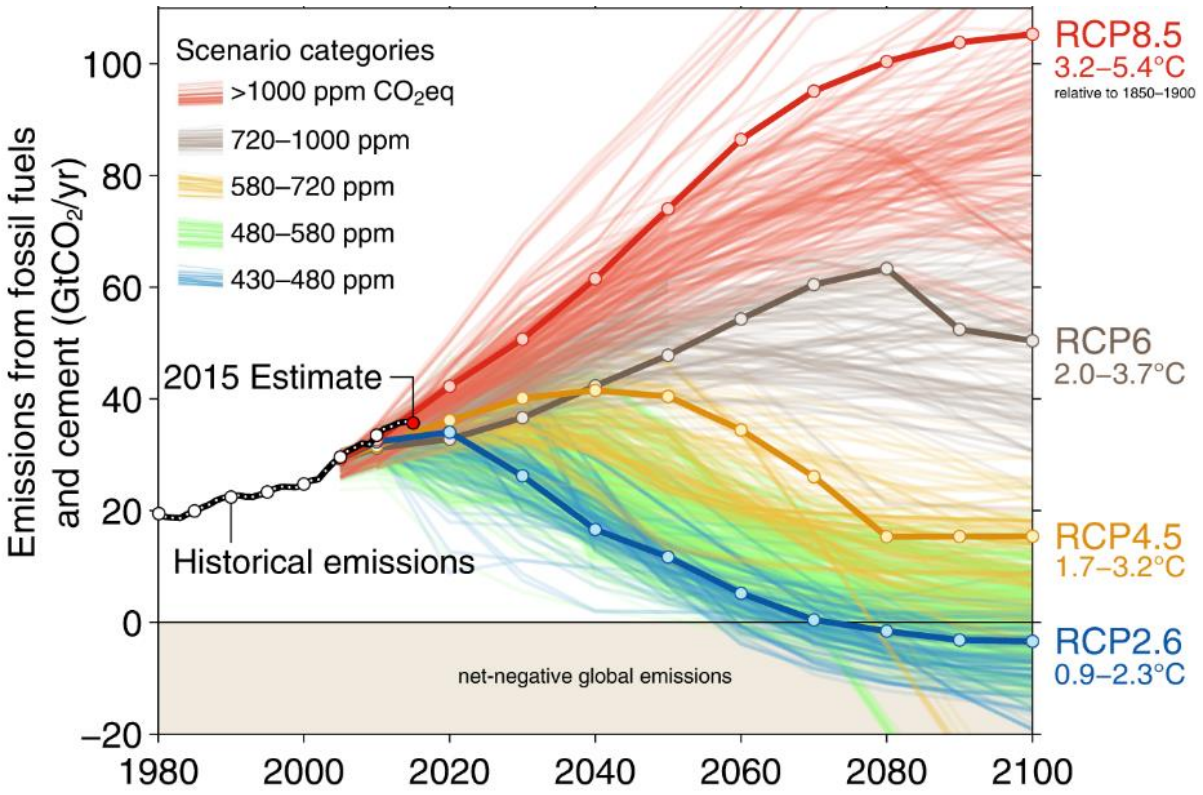


Figure 5. RCP scenarios showing annual emissions per year. Source: Fuss et al (2014).

The IPCC's 6th Assessment Report (AR6), released in 2021/2022, presents a modified set of scenarios titled Shared Socioeconomic Pathways (SSPs). SSPs build on the RCP scenarios by considering a number of different climate policy pathways. Climate information relevant for the scale of this assessment using updated SSP scenarios has not yet been developed for New Zealand. However, investigations indicate the

differences between RCP and equivalent SSP climate projections are not significant (Bodeker et al., 2022):

> *"… overall future regional projections using CMIP6 [IPCC AR6] global projections over New Zealand, excluding extremes, are expected to be similar to previous versions, but perhaps with areas of improved confidence and clarity. The projections detailed in MfE (2018) can therefore likely be used with reasonable confidence that the improved knowledge represented in the AR6 report do not fundamentally change key findings."*

As such, RCP scenarios are considered appropriate for this assessment but could be updated when downscaled SSP projections become more available as a future piece of work.

Scenarios - Physical Risks and Opportunities Assessment

We propose using two RCP scenarios for the physical risk and opportunities assessment:

RCP 4.5 – This is a lower mid-range scenario, where greenhouse gas emissions are stabilised. It leads to a range of mean annual temperature projected across New Zealand of 0.5-1.0°C by 2031–2050 and 0.7-1.7°C by 2081–2100 (NIWA, 2017a). The RCP 4.5 scenario is useful to identify risks under a more realistic ambitious reduction pathway, where emissions peak around 2040 and then decline.

RCP 8.5 – This is a 'high-end' emissions scenario with high global emissions. It leads to a range of mean annual temperature projected across New Zealand of 0.6-1.2°C by 2031–2050 and 2.0-3.2°C by 2081–2100 (NIWA, 2017a). The RCP 8.5 scenario is useful to identify the most significant risks if warming continues unabated. The RCP 8.5 'high-end' scenario is a worst-case assumption for a risk assessment (Hausfather, 2019).

We acknowledge the usefulness of the other RCP scenarios (2.6 and 6). Points that were considered in the decision to use only on RCP 4.5 and RCP 8.5 for the physical climate risk assessment include:

- **Data availability**. Not all climate hazards are assessed with the full range of RCPs (e.g. WCC Draft District Plan mapping for coastal hazards with climate change used RCP8.5 (median) and RCP8.5 (83rd percentile) for sea level rise projections, as per MfE guidance (MfE 2017).

- **Feasibility**. RCP2.6 is a very stringent pathway which requires that carbon dioxide (CO_2) emissions start declining by 2020 and go to zero by 2100 (IPCC, 2014). This is considered ambitious based on the latest IPCC AR6 report (IPCC, 2021), latest emissions reductions pathways and Paris Accord promises. It is therefore considered to be an unrealistic scenario for the purposes of a physical climate risk assessment and for informing adaptation planning.

- **Efficiency.** The proposed qualitative assessment methodology involves workshopping with domain experts and council representatives on the climate hazard exposure. To add RCP2.6 (dramatic emissions reduction) and RCP6.6 (mid-range emissions reductions) would increase workshop assessment time for not much gain in climate risk resolution.

- **Consistency**. MfE (2021) guidance recommends the use of RCP4.5 and 8.5. These RCPs were used by neighbouring *Manawatū-Whanganui Regional Climate Change Risk Assessment* (Horizons, 2021). The use of these scenarios promotes consistency in how regional risks have been assessed.

Scenarios - Transition Risks and Opportunities Assessment

For the transition risk assessment, we recommend using RCP4.5 and 8.5, plus and additional 'swift transition' scenario (RCP2.6).

RCP2.6 – this scenario represents a swift transition to a carbon-neutral economy, with strict policy changes to reduce emissions that lead to net-negative global emissions by 2070. Mean annual temperature increases in the Wellington area are limited to 0.4-0.9°C by 2031-2050 and 0.2-1.0°C by 2081-2100 (MfE, 2018). This scenario represents the extreme in transition risk and is used to test an organisation's transition resilience.

1.1.2 Recommended Timeframes

Three main timeframes are recommended for assessing risks (and opportunities) from climate change. There is a fourth for coastal hazard risks resulting from rising sea levels (MfE, 2021).

Present day (1986-2005): The impacts already occurring from climate change are a starting point for considering the urgency of the risks identified. This is also a useful starting point when seeking feedback, before considering future impacts.

Mid-century (2031-2050): This covers the next few cycles of council long-term plans, and 30 years is the planning timeframe for local government infrastructure strategies (Local Government Act 2002, section 101B) and asset management plans. It also aligns with the longer terms granted for resource consents (up to 35 years).

End-century (2081-2100): Typically used as the juncture for detailed climate change projections. A limitation of this timescale is that some decisions (e.g. land-use planning) require at least 100-year timeframes. However, this timeframe enables projections for a wide range of climate variables without the need for extrapolation.

2150: For coastal hazard risks related to sea-level rise, given that:

- The *New Zealand Coastal Policy Statement 2010* has a requirement to assess coastal hazard risks (including climate change) to "at least 100 years".
- A set of New Zealand-specific sea-level rise projections to 2150 is available in the *Coastal Hazards and Climate Change Guidance for Local Government* (MfE, 2017, p 105, Figure 27).
- Regional coastal flooding risk exposure mapping has been completed for coastal areas with up to five-metres of sea-level rise (GWRC, 2021).
- The NZSeaRise results were recently released (May 2022) providing vertical land motion and sea-level rise projections around the New Zealand coast (NZSeaRise, 2022). MfE guidance (2017) recommends accounting for vertical land motions in future projections.

1.2 Identify Climate Hazards

Climate hazards and the associated climate related variables (or drivers) have been pulled from the NCCRA assessment to align with the national approach. The relative importance of each hazard, and the way they combine to create compounding risks, will be determined in the risk screening and scoring process. **Table 4** presents the climate hazards that will be considered in the WRCCIA.

Table 4. Key categories of hazards arising from climate change most likely to result in substantial risks to include in the WRCCIA. Source: NCCRA method report appendix: Table B1-2.

Hazard (arising from climate change)	Primary climate-related variables	Secondary climate-related variables
Higher mean temperatures: air and water	• Higher day and night temperatures • Higher mean water (freshwater and marine) temperatures	• More heatwaves and warm spells • Fewer frosts or cold days
Heatwaves: increasing persistence, frequency and magnitude	• Higher day and night temperatures • Increase in persistence of maximum daily temperatures above 25°C	• Changes in seasonal winds • Humidity changes from changes in cloudiness

Hazard (arising from climate change)	Primary climate-related variables	Secondary climate-related variables
More and longer **dry spells** and **drought**	• Low seasonal rainfall • Change in seasonal wind patterns • Interannual variability (eg, ENSO)	• Higher day and night temperatures
Changes in climate seasonality with longer summers and shorter winters	• Fewer frosts or cold days • Higher day and night temperatures • Changes in seasonal rainfall	• Changes in seasonal wind
Increasing **fire–weather** conditions: harsher, prolonged season	• Low seasonal rainfall • Change in seasonal wind patterns • Increase in persistence of maximum daily temperatures above 25°C • Humidity changes from changes in cloudiness	• Higher day and night temperatures • Interannual variability (e.g., ENSO)
Increased **storminess and extreme winds**	• Increase in storminess (frequency, intensity) including tropical cyclones • Changes in extreme wind speed	• Changes in wind seasonality • Interannual variability (e.g., ENSO) • Increase in convective weather events (tornadoes, lightning)
Change in **mean annual rainfall**	• Higher or lower mean annual rainfall in sub-national climate zones • Changes in seasonal winds	• Humidity changes from changes in cloudiness
Reducing **snow and ice cover**	• Higher day and night temperatures • Changes in rainfall seasonality • Change in seasonal wind patterns • Receding snowline • Reduced snow and glacier cover • Earlier snow melt	• Increase in avalanches • Interannual variability (e.g., ENSO)
Increasing **hail** severity or frequency	• Increase in hail severity or frequency • Increase in convective weather events (tornadoes, lightning)	• Humidity changes from changes in cloudiness
River and pluvial flooding: changes in frequency and magnitude in rural and urban areas	• Changes in extremes: high intensity and persistence of rainfall • Increase in hail severity or frequency • Interannual variability (e.g., ENSO) • Increased storminess and wind • Relative sea-level rise (including land movement) • Rising groundwater from sea-level rise	• Humidity changes from changes in cloudiness • Changes in rainfall seasonality • Change in seasonal wind patterns • More and longer dry spells and droughts (antecedent conditions)
Coastal and estuarine flooding: increasing persistence, frequency and magnitude	• Relative sea-level rise (including land movement) • Change in tidal range or increased water depth • Permanent increase in spring high-tide inundation • Rising groundwater from sea-level rise • Changes in extremes: high intensity and persistence of rainfall • Increase in storminess (frequency, intensity) including tropical cyclones	• Changes in waves and swell • Changes in extreme wind speed • Changes in sedimentation (estuaries and harbours)

Hazard (arising from climate change)	Primary climate-related variables	Secondary climate-related variables
Sea-level rise and salinity stresses on brackish and aquifer systems and coastal lowland rivers	• Relative sea-level rise (including land movement) • Permanent and episodic (low river flow) saline intrusion • Low seasonal rainfall • Rising groundwater from sea-level rise • Permanent increase in spring high-tide inundation	• Changes in sedimentation (estuaries and harbours) • Interannual variability (eg, ENSO)
Increasing **coastal erosion:** cliffs and beaches	• Relative sea-level rise (including land movement) • Changes in waves and swell • Changes in extreme rainfall: high intensity and persistence • Changes in sedimentation from catchment run-off • Increased storminess and extreme winds • Interannual variability (eg, ENSO)	• Rising groundwater from sea-level rise • Changes in rainfall seasonality • Change in seasonal wind patterns
Increasing **landslides and soil erosion**	• Changes in extreme rainfall: high intensity and persistence • Changes in rainfall seasonality • More and longer dry spells and droughts (antecedent conditions)	• Interannual variability (eg, ENSO)
Marine heatwaves: more persistent high summer sea temperatures	• Higher mean ocean temperatures • Increase in persistence of maximum daily temperatures e.g. above 25°C • Change in seasonal wind patterns • Ocean circulation changes	• Interannual variability (eg, ENSO) • Changes in waves and swell
Ocean chemistry changes: nutrient cycling and pH changes	• Changes in ocean nutrient cycling – upwelling and carbon • Ocean acidification (pH decreasing) • Higher mean surface-water temperatures • Change in seasonal wind patterns	• Ocean circulation changes • Interannual variability (eg, ENSO)
International influences from climate change and greenhouse gas mitigation preferences	• Immigration • Markets (pricing, preferences) • Pacific Island countries (disaster responses, development)	

1.3 Organising Themes

1.3.1 Domains

The NCCRA framework draws on the Treasury's He Ara Waiora framework and the National Disaster Resilience Strategy. It was developed to gain an understanding of risk across five value domains (natural, human, built, economy, and governance). Here we have embedded the NCCRA domains within the Te Taiao Narrative drawing on the singular Māori lens and name for "The Environment" to shape the assessment (refer **Part A**).

The organising themes are presented in **Table 5**.

Table 5. Organising themes - Te Taiao and five value domains

Te Taiao	Domain	Description
Oranga Whenua	**Natural Environment**	All aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), indigenous & taonga species**,** and the ecosystems in terrestrial, freshwater and marine environments.
Koiora (Communities) **Whairawa**	**Economy**	The set and arrangement of inter-related production, distribution, trade, and consumption that allocate scarce resources.
Koiora (Communities) **Whare Tangata**	**Built Environment**	The set and configuration of physical infrastructure, transport, and buildings sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications, waste and coastal defences.
Koiora (Communities) **Oranga Tangata**	**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).
Kawanatanga	**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.

1.3.2 Elements at Risk

The following elements have been identified from a review of the NCCRA and discussions with the Council Project Team. This list is adaptable as the risks become more defined in the early stages of the assessment.

Table 6. Elements at risk domains. Adapted from NCCRA (2020).

Domain	Element
Natural Environment Oranga Whenua 	Indigenous & Taonga Species
	Forest Ecosystems, Services and Processes
	Wetland Ecosystems, Services and Processes
	Coastal Ecosystems, Services and Processes
	Freshwater Ecosystems, Services and Processes
Economy Koiora – Whairawa 	Forestry
	Horticulture
	Viticulture
	Pastoral Farming
	Tourism
	Public Services (including government, scientific research, and education)
	Insurance coverage and credit provision
	Māori Enterprise
	Information technology and creative industries
Built Koiora – Whare Tangata 	Airports and Seaports
	Buildings and Facilities (public and private)
	Energy
	Flood and Coastal Defences
	Transport (Road and Rail)
	Solid Waste Management
	Communications
	Drinking water
	Stormwater infrastructure
	Wastewater infrastructure
	Marae and cultural sites
Human Koiora – Oranga Tangata 	Human health
	Social cohesion and community wellbeing
	Existing inequities
	Social infrastructure and amenities
	Cultural heritage
	Sports and recreation
Governance Kawanatanga 	Partnership Strategy and Framework with Mana Whenua
	All governing and institutional systems
	Legislation and Policy
	Climate related Litigation
	Emergency Management

Phase 1 - Qualitative Assessment

The qualitative assessment methodology has been informed by, and builds on:

- The MfE's *National climate change risk assessment for New Zealand* (NCCRA) (2020).
- The MfE's *A guide to local climate change risk assessments* (2021).
- ISO 14091:2021: *Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment* (2021).
- Manaaki Whenua *He huringa āhuarangi, he huringa ao: a changing climate, a changing world* (2021).

The IPCC risks assessment framework outlines the elements of hazard, exposure and vulnerability, with the overlap being the risk. Vulnerability is related to the sensitivity and adaptive capacity of the element at risk. This framework is indicated in **Figure** below.

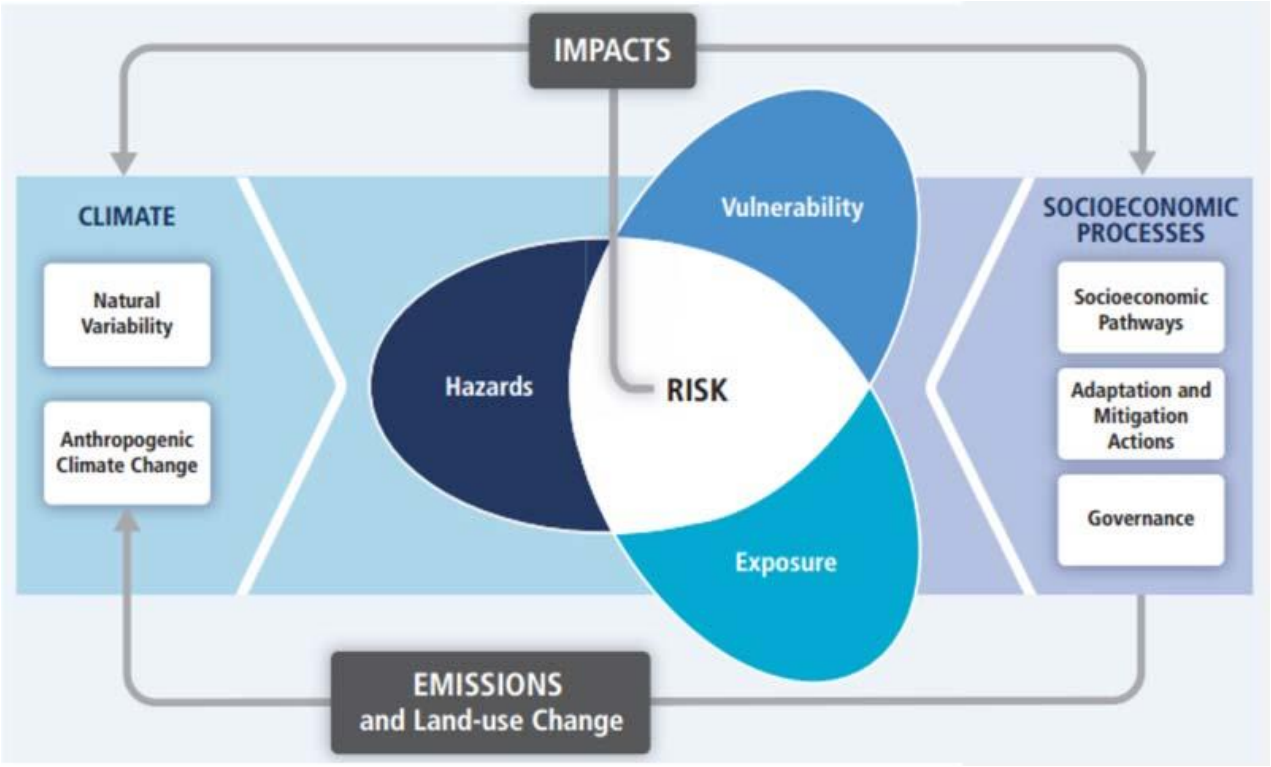


Figure 6. Schematic of risk equation based on exposure, sensitivity and adaptive capacity. Source: IPCC AR5.

The high-level steps for undertaking the qualitative assessment are:

- Identification and classification of risks (direct, indirect, compounding, cascading and transition) and opportunities – through a number of different methods across a series of workshops.
- Assessment of identified risks through scoring of exposure, sensitivity and adaptive capacity to generate a risk score. This stage will be supported by a GIS web-viewer tool where possible.
- Assessment of consequence and uncertainty to generate a priority classification.

The following sections outline the above steps in more detail.

2 Risk Screening and Identification

2.1 Screening of Direct Risks and Opportunities

WRCCIA Step	Aim	Considerations	Output
2.1 – Identification of direct risks and opportunities	Identification of notable direct risks and opportunities, along with identification of indirect and compounding risks.	**Activity lead: Domain leads** Subject matter experts (SMEs) review the influence of each climate hazard on each element at risk under an RCP8.5 scenario at 2100.	Risk screening matrix and risk register.

2.1.1 Risk Screening

The purpose of the initial high-level risk screen is to identify whether or not elements at risk will be impacted by the climate hazards and therefore whether they are to be included in the assessment. Impact will be determined as a binary (i.e. 'yes' or 'no'). The initial screen will assume hypothetical full exposure to a climate hazard under a 2100 worst case climate projection (RCP8.5). Both direct and indirect risks will be considered to inform this initial binary screen.

Opportunities can also be drawn from this stage (green). Although not scored in Step 3, opportunities can be recorded, investigated and detailed in the final report.

The number of intersections an element at risk has to the list of climate hazards (e.g. increased fire-weather, drought and coastal flooding = 3) will inform the development of compounding risk descriptions and scenarios for that element.

Figure 7 provides an example of how the high-level screen will be conducted, with element-hazard combinations assigned a binary 'impact' / 'no impact' rating based on the assumptions outlined above.

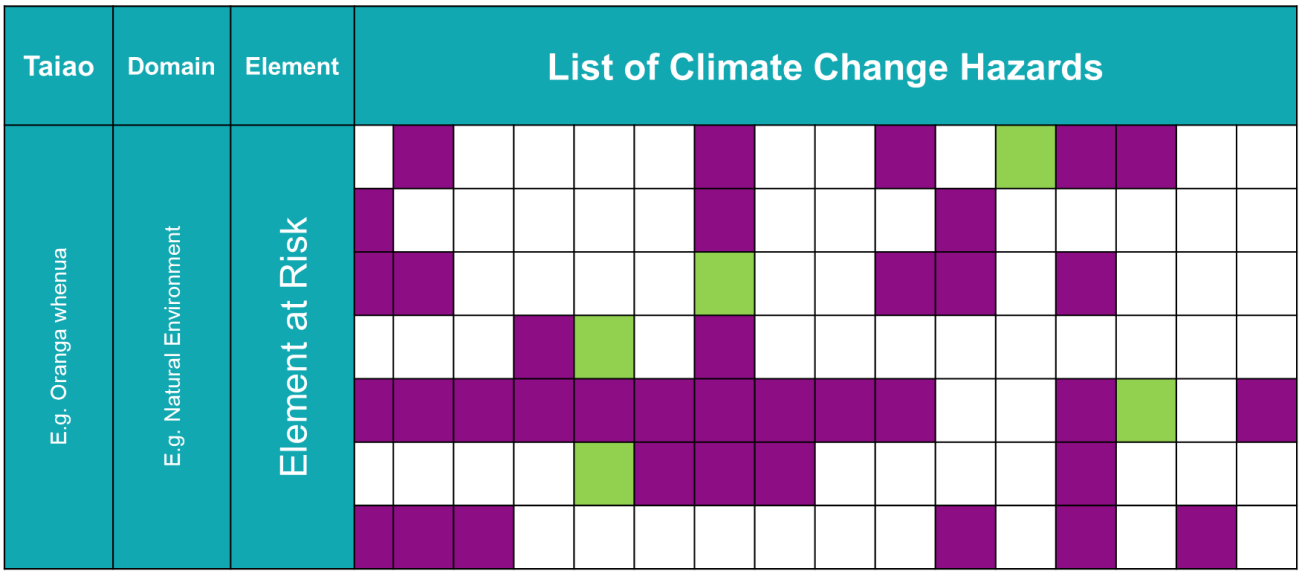


Figure 7. Example table for high-level screen. Purple indicates where 'impact' is identified, green indicates where 'opportunity' is identified, white indicates 'no impact'.

2.1.2 Risk Descriptions

All notable element-hazard combinations (i.e. those denoted as 'yes' to potential impact) will be taken forward to develop a list of regional risk descriptions. These risk descriptions will be used to populate the regional risk register, as per the example in **Table 7**.

Table 7. Example of risk descriptions developed from high-level risk screen

Risk ID	Hazard	Element at Risk	Domain	Taiao	Description
#1	*Sea Level Rise*	*Airports*	*Built Environment*	*Koiora – Whare Tangata*	*Risk to airports located near the coast due to sea level rise and coastal flooding.*

The identified risks will form the foundation of the qualitative regional climate change risk register (Appendix A).

2.2 Identification of Governance Risks

WRCCIA Step	Aim	Considerations	Output
2.2 – Identification of governance risks	Workshops to identify and understand key governance risks that are not captured in the risk screening approach	**Activity Lead: Judy Lawrence** Review of governance material alongside key regional agencies (Central Govt, Waka Kotahi, etc.) to assess the key governance risks	Recommendations for how these risks might be reduced through additional governance actions and by whom

2.2.1 Context

Governance-related climate risks are distinct from those in the other Taiao/domains because they are cross-cutting and indirect, emerging from and influencing other domain risks. In particular, they have the effect of reducing or enhancing the ability of parties to address risks in the other domains by reducing adaptive capacity (Lawrence et al., 2018). Governance risks are considered to represent significant barriers to or enablers of climate mitigation and adaptation action relevant to all domains. Given this, the elements at risk from the governance domain will be assessed differently.

The purpose of the governance risk assessment is to identify and assess the most significant governance risks and opportunities for councils in the Wellington Region. The governance risk assessment will be undertaken via two workshops, supported by review of the existing governance frameworks and mechanisms.

2.2.2 Identification of Governance Risks

The first workshop will inform the data gathering phase and cover the following set of questions:

- Do the councils have a risk management system to monitor emerging climate risks and present ones? If so, are the roles and responsibilities clearly defined?
- Does the council have a mechanism for partnering with iwi/Māori?
- Are the relationships and systems with iwi/Māori effective?
- Are there coordinating mechanisms between councils and key agencies (e.g. Waka Kotahi, DoC) across the region to address changing risk? Do these mechanisms function effectively?
- How are climate emergencies managed where interconnectivity is interrupted? (Emergency Management Plan and Lifelines Group Terms of Reference and Regional CEO Group Terms of Reference). Do these mechanisms function effectively?
- Are climate emergency impacts just cleaned up or is there a process to decide whether replacement *in situ* happens or are other options examined?
- What triggers a change in management/governance operations?
- How are different council functions integrated within and across councils?
- What elements are missing to enable integrated risk management and climate change adaptation?

The material elicited from the first governance workshop will be used to identify if the governance of climate risks is adequate and if not, how it can be built on and improved.

2.2.3 Assessment of Governance Risks

A set of adequacy criteria will be developed and used to assess governance risks. Elements would include:

- The ability of the current governance system to address uncertainty and changing risk
- The ability of the community to understand the scale and scope of the climate risks
- The ability of the current institutional system to reduce emerging and cascading risks and not create new risks through decision making
- The ability to build strong and new relationships across the community and to work with communities towards sustainable and flexible decision-making systems that reduce climate risks
- The ability of councils to work across time-inconsistent barriers leading complex and changing risk across scales and functions.

The second workshop will test the veracity of the assessment results and the recommendations (adaptation entry points). The entry points for addressing the governance risks would emerge from the risk assessment, and its implications described. This will enable the councils to take the overall risk assessment methodology and apply it at different scales across the region and develop entry points for adaptive actions within the governance architecture. High-level governance actions might include, for example:

- Coordinating mechanisms for planning and responses
- Effective partnership arrangements with iwi/Māori
- Revised Long Term Plans and Asset Management Plans
- New regional funding instruments
- Partnering with central government

2.2.4 Outputs

A shortlist of governance risks with the highest scores will be included in the risk register and detailed in a WRCCIA report section. This will include the key governance risks across the region and high-level recommendations for how to manage these risks through additional governance actions.

2.3 Identification of Cascading Risks

WRCCIA Step	Aim	Considerations	Output
2.3 – Identification of cascading risks	Workshops to identify and understand key cascading risk archetypes	**Activity Lead: Paula Blackett** Develop, assess causal links to consider cascading and cross-cutting risks at a community and higher level of detail	• Illustrative maps of impact interdependencies • Illustrative spatial map of nodes of impacts across the region with some standout examples

2.3.1 Context

The Intergovernmental Panel on Climate Change Sixth Assessment Report (AR6) *Climate Change 2022: Impacts, Adaptation and Vulnerability, the working Group II contribution* (IPCC, 2022), highlights indirect and cascading risks as having the greatest potential impacts on people, places, and spaces.

The identification of cascading risks is complex given the interconnected nature of risks across multiple spatial and temporal domains, with multiple individual organisations involved but unable to solve these

challenges on their own. This reflects how organisations are part of a complex network, responding to complex climate futures. Cascading risks are therefore not conducive to a traditional 'linear' or 'compartmentalised' risk assessment and require a different approach to the assessment of direct risks (as opposed to using the domain approach).

To identify cascading risks, we propose a 'places and spaces' approach, whereby different climate drivers and scenarios can be played out to identify cascades. Recognising the multiple different potential cascading risk chains, locations and connectedness of the Wellington region, we have suggested an approach that involves the development of 'archetypes'. By selecting typical archetypes that cover key potential cascading risks relevant to the region, more-specific cascading risks can be developed for specific areas using the same methodological approach in future studies.

This approach is novel, building on research from specialists within the Beca-led team to start identifying cascading risks for the Wellington Region. This process is, by necessity, experimental. An experimental approach aligns with one of the key goals and outcomes of this process: to develop capability in council partners and stakeholders through workshops, where guided critical thinking is used to identify cascading risks.

2.3.2 Defining the Archetypes

The assessment of cascading risks will include:

- Identification of three to five risk archetypes that are specific and relevant to numerous locations across the region (e.g. coastal communities affected by sea-level rise).
- Identify exogenous impacts that cascade from outside the region and from afar (e.g. external supply chains/movement of people/ports and airports).

These cascading risk archetypes will provide both an example of the types of cascade risks that might exist at numerous locations across the region and a method for future investigation of those cascading risks. Both of these can be used for knowledge generation and capacity building for councils at a more granular level.

The cascading risks will be identified and developed via workshops. The purpose of the first cascading risk workshop will be to determine what archetypes are of value to the councils and for what climate driver (**Figure 8**). This information will give us the starting point for each cascade (e.g. what are the cascading impacts on the built environment due to sea level rise?)

At the end of the workshop, up to five archetypes will be agreed. These archetypes will need to be relevant to numerous locations across the region so will need to explore common issues.

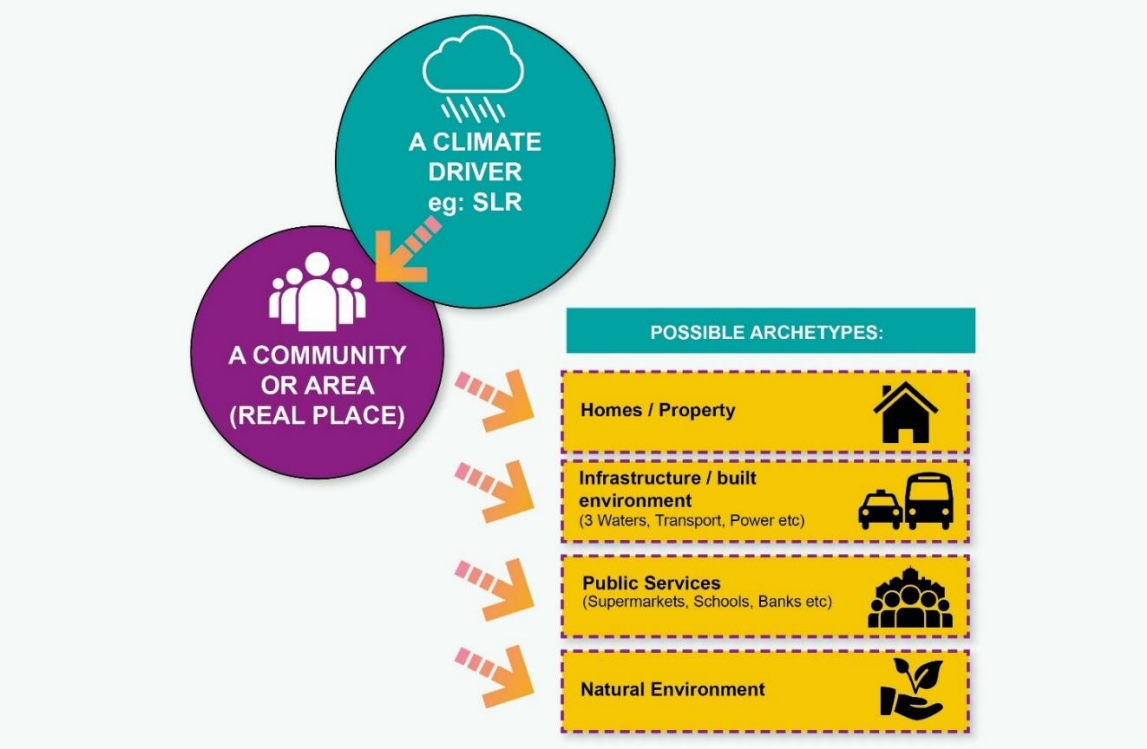


Figure 8. Cascading assessment – Workshop to identify possible archetypes.

2.3.3 Development of Cascading Risks

The next stage will develop an understanding of propagating impacts from the primary climate driver and where they go across domains i.e. supply chains / essential public services / most affected areas spatially and over time. We note that the cascading risks will have both localised, regional and potentially national links.

Working through each archetype in a half day workshop, beginning with the maps used in the qualitative domain-specific workshop, the participants will be asked 3 sets of questions:

1. *What could happen if [the climate driver] affects [domain]*? What is the first thing that will happen across other domains with a direction of the effect - i.e. if 'A' increase then 'B' decreases. For example, what could happen when sea-level rise increases and local roading infrastructure is compromised?

    i. What will happen next? e.g. the communities accessed by the roads experience loss of service with access interrupted

    ii. What will happen after that, and after that, and after that? e.g. the people and businesses are unable to get to their place of work, those businesses may be critical services to the region like hospitals, affecting public health services in the region, etc.

These questions can be used to draw up multiple chains of links between different parts of the system and different domains. The links won't go on forever, they will have a natural end point, or they will connect with another archetype/domain. Use of these and other elicitation questions will build an understanding of the complex and interdependent relations between systems, even within the context of a relatively data poor environment.

2. *How will the cascading risks move outside this spatial area and into the rest of the region/country? Where (spatially) might the effects be experienced* (map). Be mindful of exogenous impacts and cross council impacts.

3. *What risks might cascade from outside the defined area – where might they come from other councils, national or international*? Be mindful of exogenous impacts and cross council impacts

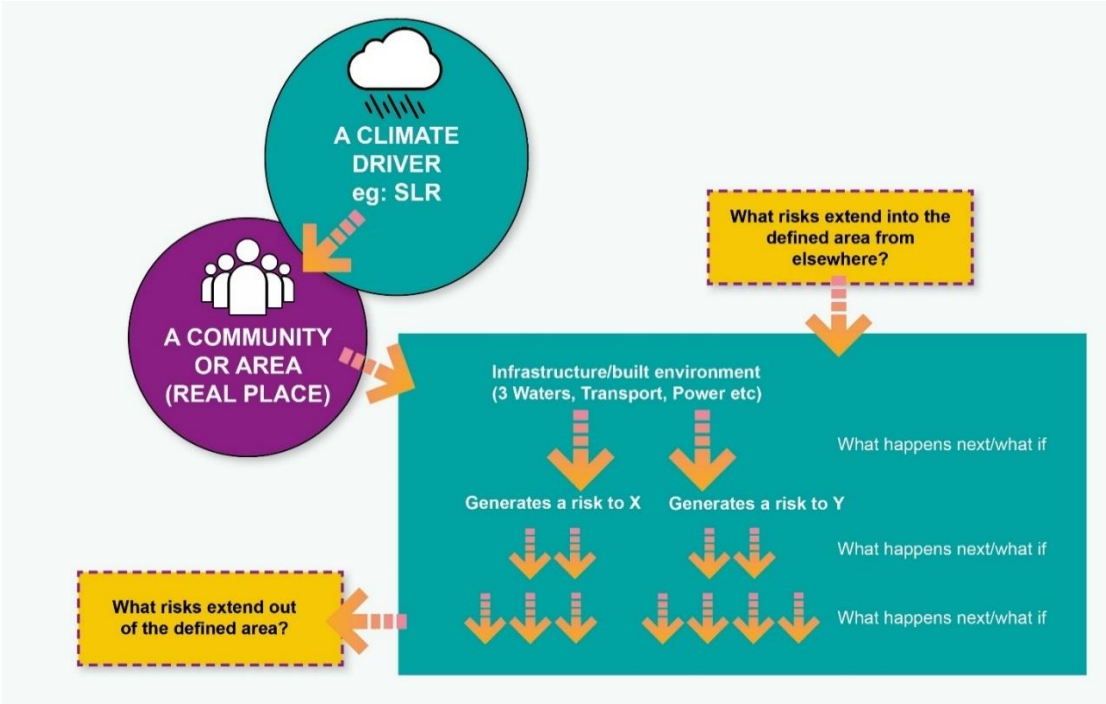


Figure 9. Cascading assessment – Workshop to assess archetypes.

Once all the archetypes are complete for that climate driver, participants will be asked to consider:

If the archetype was another climate driver, how would it be different? E.g., flood rather than sea level rise?

Once the 3 questions (above) have been addressed and considered for other climate drivers, workshop participants will be asked to look over the cascading risks and identify the most significant cascades. This will be done by prioritising the interdependencies and scale of impact and timing. The outcome of this exercise will be a qualitative rating of cascading risks and identification of where they may exist.

Assessment of the cascading impacts in the Wellington Region will be undertaken with specific regard to the methodology principles (Part A). This will ensure meaningful and considered outputs that can be used to identify areas of higher impact at the community level.

2.3.4 Outputs

The three to five archetypes of cascading risks in the Wellington region will be appended to the comprehensive risk register and detailed in a WRCCIA report section.

The cascading risk archetypes and examples within the Wellington region will sit below the risk register as a presentation of a number of linked risks (drawing on the other risk assessment steps). A qualitative rating for each archetype (identified in the workshops) will be presented.

For the 5 archetypes, the outputs for the cascading risks will include:

- Illustrative maps of impact interdependencies (e.g. causal loop diagrams) and impact nodes.
- Production of representative archetypes that can be used and replicated in different spatial areas.
- An example narrative with preliminary thinking on cascading risks of significance and implications for the Wellington region.

2.4 Identification of Transition Risks and Opportunities

WRCCIA Step	Aim	Considerations	Output
2.4 – Identification of transition risks and opportunities	Account for key transition risks and opportunities as part of the risk assessment process	**Activity Lead: Matt Raeburn** Align with the Task-force for Climate-related Financial Disclosures (TCFD) framework and the requirements of the Zero Carbon Act.	A shortlist of transition risks and opportunities with the highest materiality scores for inclusion in risk prioritisation workshop.

2.4.1 Context

Transition risks differ from physical risks from climate change. They occur due to a swift transition to a net zero carbon economy and may entail extensive policy, legal, technology, and market changes. Depending on the nature, speed, and focus of these changes, transition risks pose varying levels of financial and reputational risk to the councils (TCFD, 2017).

The integration of transition risks in this assessment will align with the Task-force for Climate-related Financial Disclosures (TCFD) framework and the requirements of the Climate Change Response (Zero Carbon) Amendment Act 2019. The Zero Carbon Act requires councils to report climate-related information to the Minister for Climate Change and the independent Climate Change Commission (MfE, 2019b).

The TCFD framework is international best practice in disclosing climate-related financial risks and opportunities to shareholders, stakeholders and investors. There are eleven disclosures under the TCFD framework that fall under the categories of strategy, risk management, governance and metrics & targets. Climate scenario analysis is the key strategic component of the TCFD. It requires consideration of both physical and transition risks when testing an organisation's resilience to climate change.

Transition risks in this assessment will be informed by the previous risk identification workshops and be considered in connection with physical risk. Guidance from the UN Environment Programme Finance Initiative includes the following matrix for connecting transition to physical risks (**Table**), which serves as a template for organisations to start illustrating how physical risks impact transition risk drivers (CISL, 2022).

For example, physical climate changes like increased wildfires and drought can make land-based carbon offsetting projects needed for the transition to a low carbon economy increasingly vulnerable and difficult to measure and verify.

Table 8. Example matrix for accounting for the interdependencies between physical and transition risk.

		CHRONIC PHYSICAL RISKS				ACUTE PHYSICAL RISKS
Transition indicators	Impact	Temperature change	Changes in precipitation / water availability	Wind	Sea level rise	Changes in intensity, frequency, and location of extreme weather events
Transition drivers that are prompted or influenced by physical hazards.	Direct	Impact on the operation side.				
	Indirect	Impact on the wider contextual factors, including the natural resource availability along the supply chain and market demand.				

2.4.2 Identification of Transition Risks and Opportunities

Our subject matter specialists will identify a preliminary list of transition risks that are relevant to the councils under the categories established by the TCFD framework (**Table**). Notably, the TCFD framework includes

several categories of opportunities related to the transition to a low emissions economy, including resource efficiency, diversification of energy source, products/services, markets and resilience.

Table 9. Transition risk categories and example risks and opportunities

Risk	Examples
Policy and Legal	• *Risk:* Exposure to litigation from councils' decisions around managed retreat • *Risk:* Higher compliance costs of emissions reporting obligations
Market	• *Risk:* Increased cost of raw materials due to strict regulations • *Opportunity:* Central government subsidies or funding programmes for regional climate mitigation or adaptation projects (e.g. renewable energy or transition plans)
Reputation	• *Risk:* Increased resident and stakeholder concern for council response to climate change and quickly developing national policies • *Risk:* Financial impact from loss of ratepayers, due to resident departures • *Opportunity:* Shift in resident preferences for regions that prioritise climate mitigation and adaptation leading to an increase in ratepayers
Technology	• *Risk:* Costs associated with the transition to lower emissions technology • *Risk:* Stranded assets and early retirement of existing, carbon emitting infrastructure • *Opportunity:* Adoption of more efficient modes of transport and reduced operating costs • *Opportunity:* Use of lower emissiosn sources of energy and reduced exposure to future fossil fuel price increases • *Opportunity:* Returns on investment in low-emissions technology
Resilience	• *Opportunity:* Investment in ecosystem restoration due to mitigation needs leading to broader positive biodiversity, resilience and social outcomes • *Opportunity:* Increased market valuation through resilience planning

2.4.3 Workshop

The transition risks will be identified and confirmed in a workshop in collaboration with the council participants. The workshop will consist of an abbreviated climate scenario analysis exercise focused on transition risks associated with RCP 2.6. RCP 2.6 represents the extreme in transition risk and is therefore best suited to testing the council's transition resilience (**Table 10**).

Table 10. Comparison of transition and physical risks under RCP 2.6, 4.5 and 8.5. Only RCP2.6 will be used in the transition risk assessment.

IPCC Scenario	Global mean temperature increase[6]	Transition Risk Severity	Physical Risk Severity	Description
RCP 2.6	0.9 – 2.3 °C	High	Moderate	RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.
RCP 4.5	1.7 – 3.2 °C	Moderate	High	Warming is more likely than not to exceed 2°C for RCP4.5 (medium confidence).
RCP 8.5	3.2 – 5.4 °C	Low	Extreme	Warming is likely to exceed 2°C for RCP8.5 (high confidence).

[6] Relative to a 1850-1900 baseline

During the workshop, the transition risks will be assigned a materiality rating based on how significant the risk or opportunity is considered to be, with a particular focus on financial impacts.

2.4.4 Outputs

A shortlist of six to seven transition risks and opportunities with the highest materiality scores will be included in the risk register and detailed in a WRCCIA report section on transition risks.

3 Qualitative Risk Assessment

WRCCIA Step	Aim	Considerations	Output
3 – Qualitative Risk Assessment	Qualitative score of exposure, sensitivity and adaptive capacity for direct and indirect risks identified in step 2.1	**Activity lead: Domain leads** Use of GIS hazard/element viewer to understand exposure, along with subject matter experts and literature to inform sensitivtiy and adaptive capacity	Completed register of climate risks

The initial qualitative assessment will take place through a series of five structured workshops (one workshop per domain). This will allow relevant Subject Matter Experts (SMEs) from each council to attend the relevant domain to their area of speciality. The initial first pass screening of exposure of elements at risk to climate hazards will identify 'hazard-element at risk' combinations to carry forward into the qualitative assessment.

The qualitative assessment will consider climate hazard-element at risk combinations for:

- Exposure at each RCP scenario and timeframes
- Vulnerability (interplay of sensitivity and adaptive capacity)

Governance, cascading and transitional risks will be scored in their own workshops (as per Section 2).

3.1.1 Assessing Exposure

The qualitative assessment of exposure scoring will use the MfE (2021) framework. The MfE Guidance defines '**exposure'** as "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by natural hazards and climate change."

In other words, elements (e.g., people, buildings, infrastructure, environments, primary production and critical facilities) are **exposed** to climate change hazards if they are spatially located within an area affected by a climate-related hazard.

Exposure will be assessed using projections (e.g. Ministry for the Environment (2018) maps, GWRC online viewer layers, and NIWA descriptors of climate projections) or other available hazard-exposure layers (e.g. coastal flooding with sea-level rise scenarios). The exposure score will be input to the risk register whilst using a GIS viewer that will display available spatial data for the element at risk with climate hazards overlayed. The viewer will not calculate any risk exposure as its purpose will be to inform qualitative and subjective assessment of the exposure by SMEs.

Exposure ratings will be qualitatively determined, for each timeframe and RCP scenario, using the MfE (2021) scoring framework on a four-point scale, from low to extreme, as indicated in **Table 11**.

Table 11. Proposed qualitative exposure scoring for qualitative assessment

Score	Exposure	Description
Extreme	>75% of sector/element is exposed to the hazard	Significant and widespread exposure of elements to the hazard
High	50-75% of sector/element is exposed to the hazard	High exposure of elements to the hazard
Moderate	25-50% of sector/element is exposed to the hazard	Moderate exposure of elements to the hazard
Low	5-25% of sector/element is exposed to the hazard	Isolated elements are exposed to the hazard

In a workshop, the domain specialists and council representatives will need to agree on a qualitative score for each element exposed to each hazard.

3.1.2 Assessing Vulnerability

As per the MfE Guidance (2021), the vulnerability of elements to climate change hazards is to be qualitatively assessed as the interplay of the **sensitivity** of the element to climate hazards and its **adaptive capacity**.

The assessment methodology assumes vulnerability (as defined by sensitivity and adaptive capacity) is constant across timeframes.

Sensitivity: Refers to the degree to which an element at risk is affected, either adversely or beneficially, by climate variability or change (IPCC, 2014a). Sensitivity relates to how the element will fare when exposed to a hazard, which is a function of its properties or characteristics (MfE, 2021). A sensitivity score will be qualitatively assigned at a high level to each element-hazard combination on a scale from 1 – 'low' to 4 - 'extreme,' as indicated in **Table 12**.

Table 12. Proposed qualitative sensitivity scoring of elements to a given climate hazard

Sensitivity Level	Code	Definition
Extreme	4	Extreme sensitivity to a given climate hazard
High	3	High sensitivity to a given climate hazard
Moderate	2	Moderate sensitivity to a given climate hazard
Low	1	Little to no sensitivity

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC (2021). An adaptive capacity score will be assigned to each element-hazard combination on a scale from 1 – 'high' to 4 – 'very low,' as indicated in **Table 13**. Note the adaptive capacity scores are reverse coded, as higher adaptive capacity will contribute to a lower overall risk score.

Table 13. Proposed qualitative scoring adaptive capacity of elements to a given climate hazard

Adaptive capacity	Definition	Score
High	High capacity to adapt	1
Medium	Medium capacity to adapt	2
Low	Low capacity to adapt	3
Very low	Very low capacity to adapt	4

For each element-hazard combination carried through to the qualitative assessment, an overall vulnerability score will be calculated. The overall vulnerability score will be determined by combining the sensitivity and adaptive capacity scores, as per **Table** and **Table 15**.

Table 14. Proposed vulnerability framework combining the assessments of Sensitivity and Adaptive Capacity.

Vulnerability			Sensitivity			
			Low	Moderate	High	Extreme
			1	2	3	4
Adaptive capacity	Very low	VL	VL1	VL2	VL3	VL4
	Low	L	L1	L2	L3	L4
	Medium	M	M1	M2	M3	M4
	High	H	H1	H2	H3	H4

Table 15. Proposed vulnerability calculation for Sensitivity and Adaptive Capacity.

Vulnerability score	Combined Adaptive Capacity and Sensitivity indicators
Extreme	VL3, VL4, L4
High	VL2, L3, M3, M4
Moderate	VL1, L2, M2, H3, H4
Low	L1, M1, H1, H2

We recognise that some risks may not suit assessment and subsequent rating of exposure and vulnerability, such as those risks associated with governance matters. To account for this, we propose to provide a rating of overall risk, based on its magnitude. This will be qualitative and elicited during engagement activities, without specifically using the relationships of exposure and vulnerability.

3.1.3 Risk Rating

For each element-hazard combination an overall risk score will be determined. The overall risk score is based on the combination of the exposure and vulnerability scores (**Table 16**). Risk scores will be compiled into the risk register table.

Table 16. Proposed risk framework combining the assessments of Exposure and Vulnerability.

Risk			Exposure			
			Low	Moderate	High	Extreme
			L	M	H	E
Vulnerability	Extreme	4	L4	M4	H4	E4
	High	3	L3	M3	H3	E3
	Moderate	2	L2	M2	H2	E2
	Low	1	L1	M1	H1	E1

Table 5. Proposed risk scoring framework combining the assessments of Exposure and Vulnerability

Risk level	Combination
Extreme (4)	H4, E4, E3
High (3)	M4, H3, H2, E2
Moderate (2)	L4, M3, M2, H1, E1
Low (1)	L3, L2, L1, M1

3.1.4 Assessment of Compounding Risks

Compounding impacts will be assessed across **Elements at Risk** by considering the multiple occurrences of the climate hazards together.

For this assessment ***compound risks*** are defined as risks that "arise from the interaction of hazards, which can be characterized by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors" (IPCC, 2019).

The compounding risk assessment will combine the risk scores from the workshop-informed qualitative risk assessment (Section 3.1.3) across multiple climate hazards for each element at risk within a domain.

The compounding assessment is intended to illustrate how specific elements at risk within a district are exposed to multiple climate change hazards. Compounding risks do not signal the overlapping occurrence of the hazards (e.g., drought and floods cannot occur in the same place at the same time). Rather, compounding risk identifies the degree to which an element is exposed to multiple climate change hazards, which could compound the effects on the element at risk over the assessment timeframes (e.g., drought followed by intense flooding).

We propose to assess the compounding risk for each element at risk by combining the assessed scores (Low to Extreme risk), and presenting how many individual hazards that element is exposed to (e.g., *element x* is exposed to 5 compounding risks). The scored compounding risk for each element will be added to the risk register table.

The purpose of the compounding risk calculation is to assess which elements at risk are exposed to the greatest number of climate change hazards e.g. a hot-spot for risks, and the overall multi-hazard risk scoring for that element.

The compounding risk score will be useful to inform the identification and prioritisation of specific risks and elements. This also supports the selection of cascading risk assessment archetypes where the multiple hazards can be explored together.

3.2 Qualitative Risk Register

A comprehensive risk register will be produced and populated with the results of Steps 2 and 3. The risk register will include direct, indirect, compounding and transition risks. Each risk will be assigned a Risk ID based on the risk type and domain. Indirect risks will be linked to their direct risk description where applicable. For risks that are not scored based on exposure and vulnerability, a final risk score will be assigned based on their assigned method of scoring (See Governance, Cascading and Transition risk sections 2.2 to 2.4).

Cascading risks will not sit within the comprehensive risk register as they are a holistic investigation of links between the identified risks and are not scored on the same risk scale (Low to Extreme). The Archetype Cascades will be described qualitatively and link to Risk IDs in the risk register where relevant.

The comprehensive risk register is intended to be a living document that can be updated regularly as councils continue to monitor climate risk and introduce adaptation measures, thus altering scores of exposure and vulnerability. An example risk register is presented in **Appendix A**.

4 Prioritisation

WRCCIA Step	Aim	Considerations	Output
4 – Prioritisation	Develop list of prioritised risks to inform adaptation efforts and identify top risks to put through to detailed (quantitative where possible) assessment	**Activity lead: Consultant Methodology Team** Assessment of consequence and uncertainty The data available and nature of risk to be able to quantitatively assess the risk (using geospatial methods) Whether pre-existing hazard studies are available and assessments do not need repeating	Prioritised register of climate risks

To assist with prioritisation and selection of risks for detailed assessment (Phase 2 of the methodology), an assessment of consequence and uncertainty will be undertaken ahead of a Priority Risks selection workshop. Consequence and uncertainty considerations will be included as a column in the comprehensive risk register.

4.1.1 Consequence Rating

Consequence is defined as the outcome of an event that may result from a hazard. It will be scored semi-quantitatively by category across different value categories. **Table 18** presents an example consequence scoring table (adapted from MfE Guidance) which can be further adapted or replaced to align with existing council risk scoring processes.

Table 18. Example consequence scoring table

Rating	Consequence/criteria				
	Koiora I Whairawa – Economy	Koiora I Oranga Tangata – Community and lifestyle	Oranga Whenua – Environment and sustainability	Kāwanatanga – Public government	Koiora I Whare Tangata – Built
Catastrophic	Regional decline leading to widespread business failure, loss of employment, and hardship	The region would be seen as very unattractive, moribund, and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective	Service restoration takes >1 month or major prosecution
Major	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen in danger of failing completely	Service restoration within 1 month or minor prosecution

Rating	Consequence/criteria				
	Koiora I Whairawa – Economy	Koiora I Oranga Tangata – Community and lifestyle	Oranga Whenua – Environment and sustainability	Kāwanatanga – Public government	Koiora I Whare Tangata – Built
Moderate	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts	Service restoration within 2-3 weeks or infringement notice
Minor	Individually significant but isolated areas of reduction in economic performance relative to current forecasts	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure	Service restoration within 1 week or consent compliance notice

4.1.2 Uncertainty Rating

Uncertainty relates to the type, amount, quality and consistency of evidence along with the degree of scientific agreement as it relates to a specific risk. An assessment of uncertainty will be undertaken prior to the Priority Risks selection workshop to determine where a risk, despite being significant, has been extensively investigated and is therefore less appropriate for the detailed assessment.

Table 19. Uncertainty scoring table

Uncertainty Rating	
Certain	High agreement, robust evidence
Uncertain	Low agreement, limited evidence

4.1.3 Selection for Phase 2

A Priority Risk selection workshop will follow the delivery of a draft risk register that details the outputs of the qualitative risk scoring process. An example of the risk register output is provided in **Appendix A**. The purpose of the workshop will be to select ten direct risks and ten other risks (indirect, compounding, transition, cascading) that will be carried through into the detailed assessment stage. Selection of the risks requires balancing many factors in combination with the qualitative risk assessment ratings.

Factors that will need be considered in the Priority Risk selection workshop include:

- Primary risk rating (exposure, vulnerability) in relation to timeframe.
- Consequence of the risk, reflecting local values.
- Level of uncertainty, against risks with higher extreme consequences with high certainty.
- Specific location/community inequities or vulnerabilities that may drive a higher priority.
- The proclivity for that risk to be assessed using quantitative and geospatial methods.
- Whether pre-existing hazard studies are available and assessments do not need repeating.

The level of detail of the assessment for selected risks will be dependent on the data available (i.e. whether it can be quantitatively assessed). A critical consideration to this risk selection is whether there is sufficient information within existing datasets to underpin the detailed risk assessment. Where data is found to be insufficient, recommendations will be made for future investigations and development of datasets.

5 Phase 2 – Detailed Risk Assessment

The second phase of the methodology is a detailed assessment of the risks identified in the Priory Risk selection workshop. Noting that a detailed risk assessment of every identified risk will not be possible within the scope and programme of this project, a detailed assessment of the following will be undertaken:

- 10 direct physical risks (e.g. sea-level rise exposure to airports/seaports), and
- 10 indirect, cascading, compounding or transitional risks

There is a large potential range of risks that may be selected for this detailed analysis, with each risk analysis requiring a nuanced approach to produce appropriate outputs.

The intention for a detailed assessment is to further quantify the risk. Using GIS as a foundation, risks can be identified, evaluated, aggregated and displayed for a more targeted assessment (within data availability limitations). The use of GIS may also enable property level risks to be extrapolated.

However, this will not always possible where, for example, the assessment of the risk is based in qualitative interpretation (such as cascading risks), is based in a non-spatial environment (e.g. governance risks), or does not have robust information at a regional or district scale (e.g. insufficient GIS information).

We anticipate that the 10 direct physical risks will be able to be investigated using quantitative analysis. The other risks will be investigated through quantitative analysis where possible or else will be assessed by way of descriptions and narrative.

Where applicable, the quantitative assessment will use the same available downscaled climate change hazard projections (refer Section 1), district and city hazard and exposure modelling (where appropriate), and vulnerability indicators to assess risks (refer data gaps report).

WRCCIA Step	Aim	Considerations	Output
5 – Detailed Assessment supported by geospatial analysis	Detailed assessment of risk. Assessed by building geospatial relationships between GIS layers of selected risks where possible.	**Activity lead: Consultant Geospatial Team** • Data availability and scale of reporting • Informed relationships between elements and hazards	The results will be incorporated into a GIS reporting tool (see below) displaying the results of the detailed assessment across the pre-determined climate/RCP scenarios.

5.1 Detailed Assessment

The detailed analysis will be based on the well-established principles of risk quantification as visualised in Figure and expressed as:

$$R = fC(Hi, E, Vi)$$

where risk (R) is a function (fC) of the consequences from a hazard event (H) impacting an exposure (E) (i.e. element at risk). Consequences are determined from the exposures vulnerability (V) to an impact type and magnitude in response to either a single or, in the case of compounding risks, multiple hazard events (i) (Paulik et al., 2022).

This equation can be implemented geospatially and requires detailed understanding for each component of the selected risk R, the data and metadata supporting H_i, E and V_i, the relationship between the hazard event (i) and the element at risk (E).

Geospatial and quantitative analysis will be most beneficial where this information is clearly defined, such as where data from geospatial models can be combined with geospatial asset layers with a known vulnerability of the asset to the hazard. This could enable:

- a detailed assessment of exposure in various hazard scenarios (e.g. for flooding this can be for various events with different average recurrence intervals)
- a detailed assessment of element at risk sensitivity based on data attributes (e.g. for infrastructure this may be related to the age, condition, or material of a network)
- an assessment of exposure to vulnerable populations (species, demographics), which can be integrated with available vulnerability data, for a more granular view of risk.

Critically relevant to this WRCCIA phase is the material within existing datasets to underpin the detailed assessment. The level of detail in the risk assessment will be compromised if there is insufficient data available on *H*, *E* or *V* to support *each* step of the assessment for *each* of the selected risks *R*. For example, if the selected risk is regional then it is critical that *region-wide* data is available at a sufficient level of detail (i.e. consistent resolution). The selection step (see Section 4.1.3) will require an iterative process to account for this.

5.1.1 Assessment Process

The process of undertaking a detailed assessment of each risk *R* involves:

- Select risk, noting dependencies
- Review data layers and identify limitations
- Determine target outputs and aggregation level
- Prepare input layers
- Determine hazard-vulnerability-risk relationship model
- Undertake analysis (using RiskScape®)
- Provide to GIS Tool to visualise and interact with risk analysis

Table 20 further indicates the process that we will follow for each of the identified risks. The example provided is intended to help explain the risk assessment steps and concepts and is theoretical only.

Table 20. Indicative process and decision making for undertaking a detailed assessment of the selected risk.

Step	Description	Example for illustration only
1	Select risk to take through from Phase 1. • Note dependencies on data and existing risk information *What risk do we want to assess?* *What risks already have sufficient information and do not need reanalysis?*	• Risk to coastal wetland ecosystem habitat from increased drought (heatwaves) prevalence and intensity.
2	Review data for *H*, *E*, *V* and event *i*. • Determine whether there is sufficient information to support detailed analysis and create meaningful outputs. Iterate where necessary. • Acknowledge data uncertainties and limitations for downstream outputs. *Are the risks sensible for quantitative assessment and aligned to available information?*	• Polygons are available for coastal wetland locations throughout the region. • Change in drought intensity available as raster layers from NIWA/GWRC • Metadata is available on ecosystem composition

Step	Description	Example for illustration only
3	Determine target *R* outputs and metrics. • Consider information availability for climate hazards, timelines and exposure • Determine an appropriate lowest aggregation scale (highest level of detail) for the risk (i.e. results to suburb or district or regional) • Determine level of data to use in the assessment *What do we want to quantify in relation to this risk?* *What level of detail should each risk report?*	• Hectares of wetlands at risk, their location, timing of exposure • Value of ecosystem services exposed, their location • Species exposed • Hectares of wetlands exposed to droughts is less relevant at suburb level as wetlands often span multiple suburbs, and hence risk is relevant to report at district and regional scale.
4	Prepare quantitative inputs. • Compile layers and information for *H, E, V, i* • Including attribute data to carry through to output • Address timeframes and RCP scenarios	• Find ecosystem data from source • Geospatial *H* (drought) data from NIWA for RCP 4.5 and RCP 8.5 for each timeframe. • Hazard events *i* = drought duration
5	Identify the exposure relationship *E* for hazard *H* • Use literature or subject matter experts • Test relationship for geospatial implementation • May include several relationships between multiple hazard layers and elements at risks	• Exposure of coastal wetlands to drought is a function of % drought change and area of wetland. E.g. *5 ha exposed to 2% drought change* *10 ha exposed to 5% drought change*
6	Identify the vulnerability *V* (combining sensitivity and adaptive capacity) of the element at risk to the hazard. • Informed by quantitative data where possible. • May refer to qualitative assessment phase or SME judgement.	• Linear relationship between % change in drought frequency and coastal wetland ecosystem diversity at habitat scale. 1% drought increase = 5 % loss in ecosystem species diversity 5% = 20% loss 10% = 50% loss
7	Identify risk scoring for outputs • Consider how GIS tool will display outputs *What metrics of risk are useful, and what metrics can be made from the available data?*	5% loss of diversity = minor 20% loss = severe 50% loss = catastrophic
8	Develop matrix or decision tree framed around steps 4-7. Consider: • format of the data • exposure, vulnerability data • aggregated output format.	See example in Figure 10. Example of decision tree process to be developed for each Figure 10 below.
8	Compile aggregation of risk at appropriate scale as per agreed outputs	• Hectares at risk of minor, severe, extreme risk across region • Ecosystem services value at risk in each district
9	Translate matrix or decision tree into RiskScape®/GIS model.	

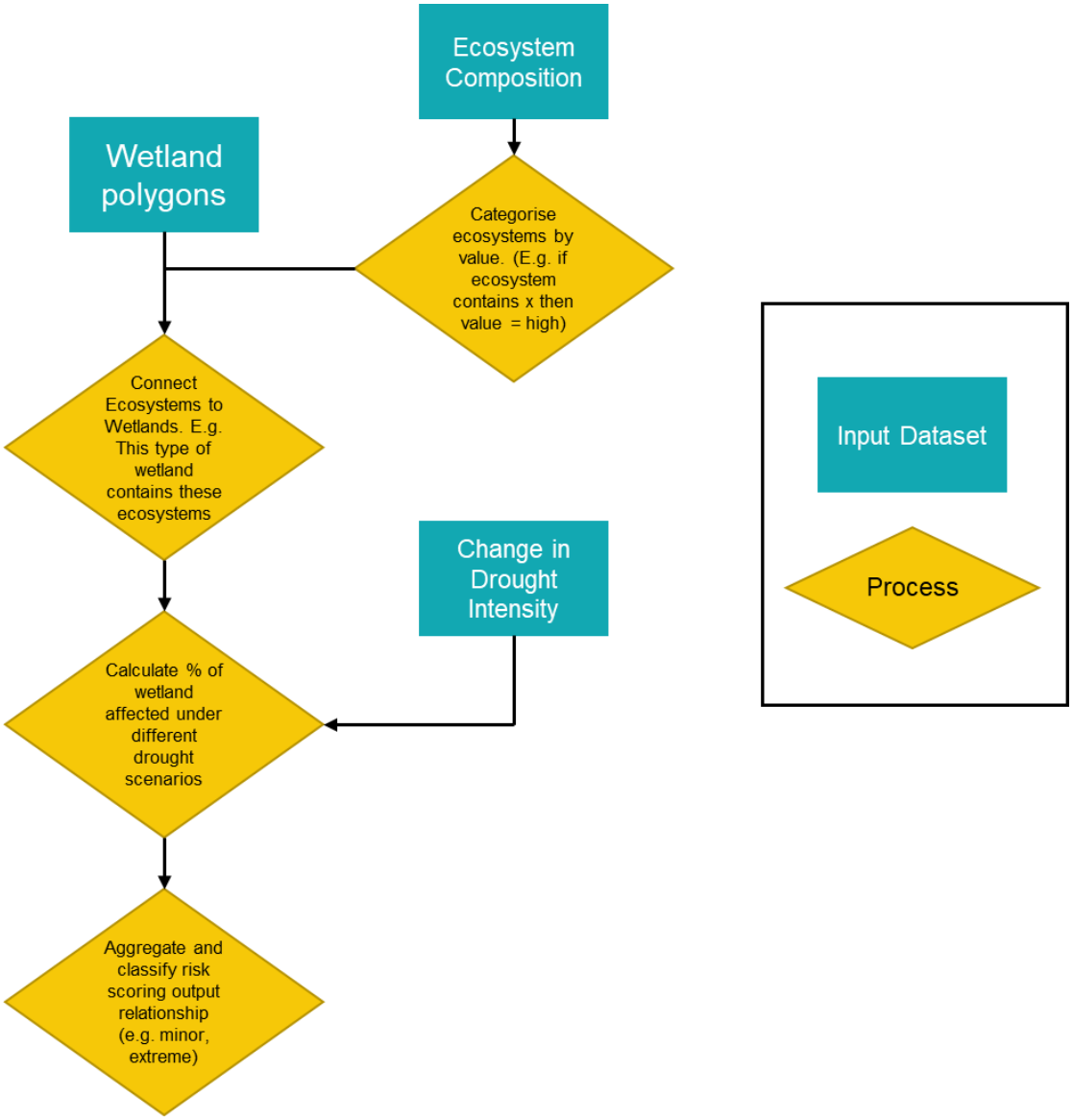


Figure 10. Example of decision tree process to be developed for each risk.

The above approach will require a nuanced response to each selected risk to best target relevant outputs. Each of these steps may involve judgement of relevant thresholds for effects (e.g. choosing to use 0.3 m as the damage threshold for flood water depth beneath the building footprint). We will document the steps in each and highlight where judgement has been applied.

5.1.2 Data Gaps

Data deficiency and suitability for region-wide risk scoring is noted as a significant risk for this stage of the assessment. High level data gaps were assessed in the early phases of the study to inform the qualitative scoring of exposure and have been catalogued in the working web-viewer tool. This understanding of data availability and data quality will be used iteratively to inform selection of suitable candidates for the detailed risk analysis (Section 4).

Where data gaps are noted and deemed vital for further quantification of selected risks, SMEs will consider whether data can be inferred from existing knowledge or literature. For example, there may not be specific data on the social impacts

of a particular hazard (e.g., social impact of increased landsliding from increased rainfall intensity). However, SMEs may identify obvious constraints for an area because it has only one entry/exit point (e.g. Wainuiomata, Castlepoint, Ngawi or Mataikona), therefore if the road is compromised, then all those communities will be affected because there may not be full services in those locations (e.g. supermarket, schools, medical). The project team will therefore need to make assumptions about critical needs (e.g. hospitals, schooling, employment) and social impact from that climate hazard. We will document the steps in each case and highlight where judgement has been applied.

If data cannot be inferred to enable a quantification of risk then some risks may need to be recorded in the final report as recommended next steps for adaptation planning (e.g. further research required).

5.2 Geospatial Tool

The purpose of the GIS reporting tool is to display the results of the qualitative assessment (the risk register) and the detailed risk assessment (completed using the steps above and utilising RiskScape®) across the pre-determined climate/RCP scenarios. It will not enable a 'live' recalculation of risk but will spatially display identified risks and enable risks to be viewed/interrogated in different ways.

Development of the reporting tool for viewing the detailed risks requires:

- Understanding the risk assessment and accompanying risk register to be able to view the qualitative risk assessment scores by district, rōhe, or suburb level
- Presentation of detailed assessment of risks with associated quantitative information.

Detailed Functional Requirements for the tool will need to be developed after the detailed assessment has been completed and a better understanding of each of the desired outputs has been established (as per Table 21). At this point we will take the feedback on the use of the tool provided as part of the methodology development workshop to develop a Minimum Viable Product (MVP) with input from the project team's domain experts. Some of this high-level feedback thus far includes support for:

- An ESRI ArcGIS solution
- The ability for council GIS teams to leverage model outputs to use within their own environment.
- The ability to update as new information is made available or every 3-5 years (e.g. climate change projection downscaling by NIWA)
- Providing a visualisation as an evidence base for key decisions to stakeholders.

The MVP will be presented and tested with the council project team for feedback and ongoing development will be undertaken in an iterative manner.

5.2.1 Council Inputs

In developing the detailed assessment and the GIS tool for each of the selected risks, we will need input from council end-users. This is because the purpose of the GIS reporting tool will drive its end functionality. For example, we are aware that the tool is likely to be used in stakeholder engagement so features that may be important to include the ability to select particular assets, properties, sites of significance and see what risk information is available.

5.2.2 Recommendation for Data Hosting Arrangements

An assessment of options for hosting of the GIS reporting tool has been undertaken. However this is a recommendation only as it is noted that this is ultimately a decision for the councils involved in this project.

Based on our assessment, we recommend a new dedicated project AGOL is established for the hosting of the GIS reporting tool through the AEC subscription model (**Figure 11**). As the detailed assessment and requirements of the tool are still to be developed, this solution allows for a relatively quick configuration and deployment with minimal barriers for the project team to trial and test prototypes. The 1-year timeframe for

licencing allows time to review who will use the tool and how it will be used, while still being in a format which is compatible with council GIS systems for future handover and maintenance. The cost of this option (around $2-3,000 per year) is a worthwhile investment to give the flexibility and functionality that is likely to be required.

Table 21 summarizes the key considerations from geospatial data tool hosting arrangements. More detail is provided in section 5.2.3.

Table 21. Key considerations for data hosting arrangements

Consideration	AGOL in Council GIS	Enterprise in Council GIS	New dedicated project AEC AGOL
Process and Access	High Complexity	High Complexity	Low Complexity
Licensing & Versioning	Moderate Complexity	Unknown	Moderate Complexity
Licensing Cost	Moderate Complexity	Unknown	Moderate Complexity
Integration	Moderate Complexity	Low Complexity	Moderate Complexity
Impact on Timeframes	Moderate Complexity	High Complexity	Low Complexity
Handover & ongoing management	Low Complexity	Low Complexity	Moderate Complexity
Collaboration	Moderate Complexity	High Complexity	Low Complexity

5.2.3 Reporting Tool Hosting Options

This section summarises the options for hosting of the GIS reporting tool along with some of the key considerations for each.

Figure 11. Summary of reporting tool hosting – Recommendation

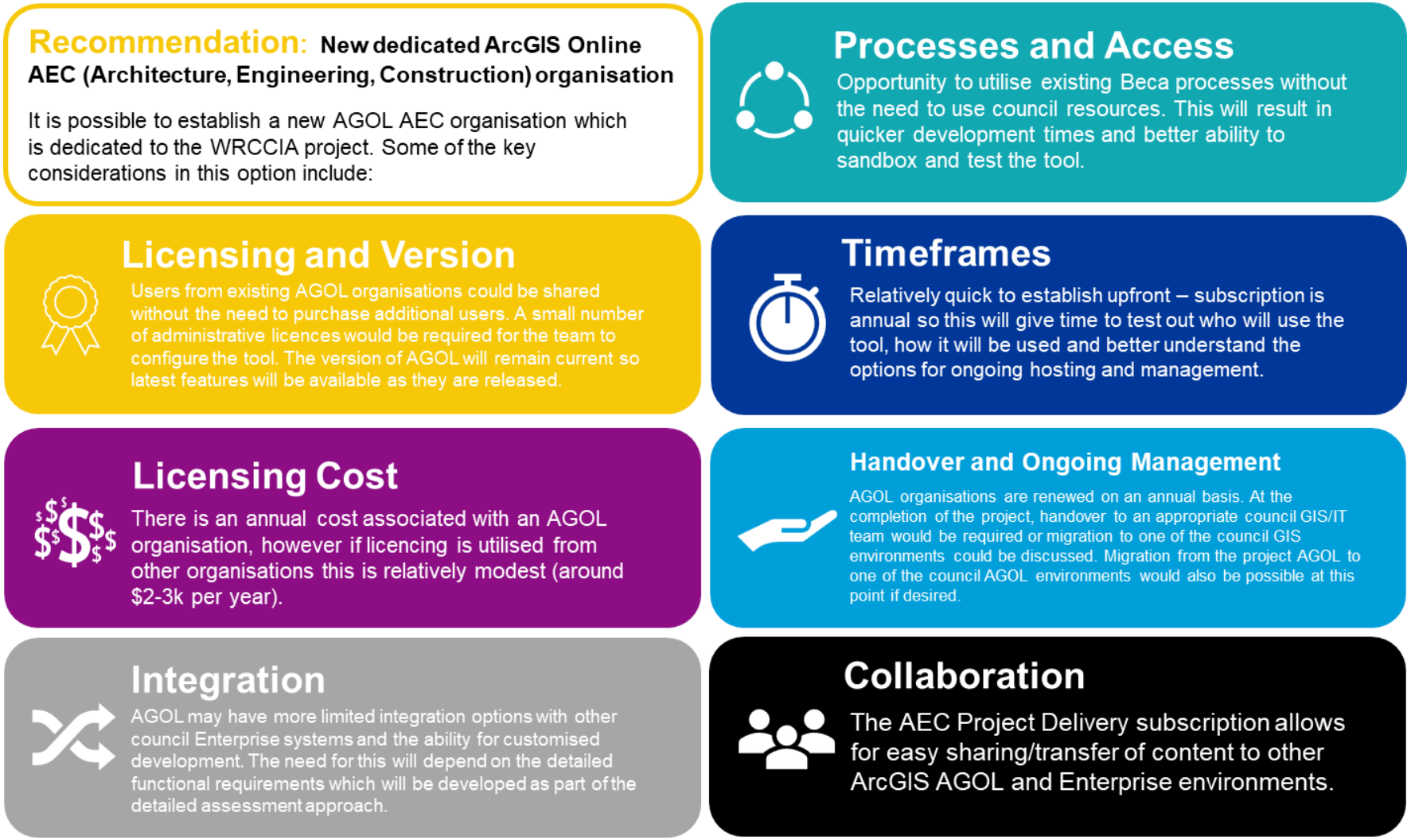


Figure 12. Summary of reporting tool hosting – Consideration 1

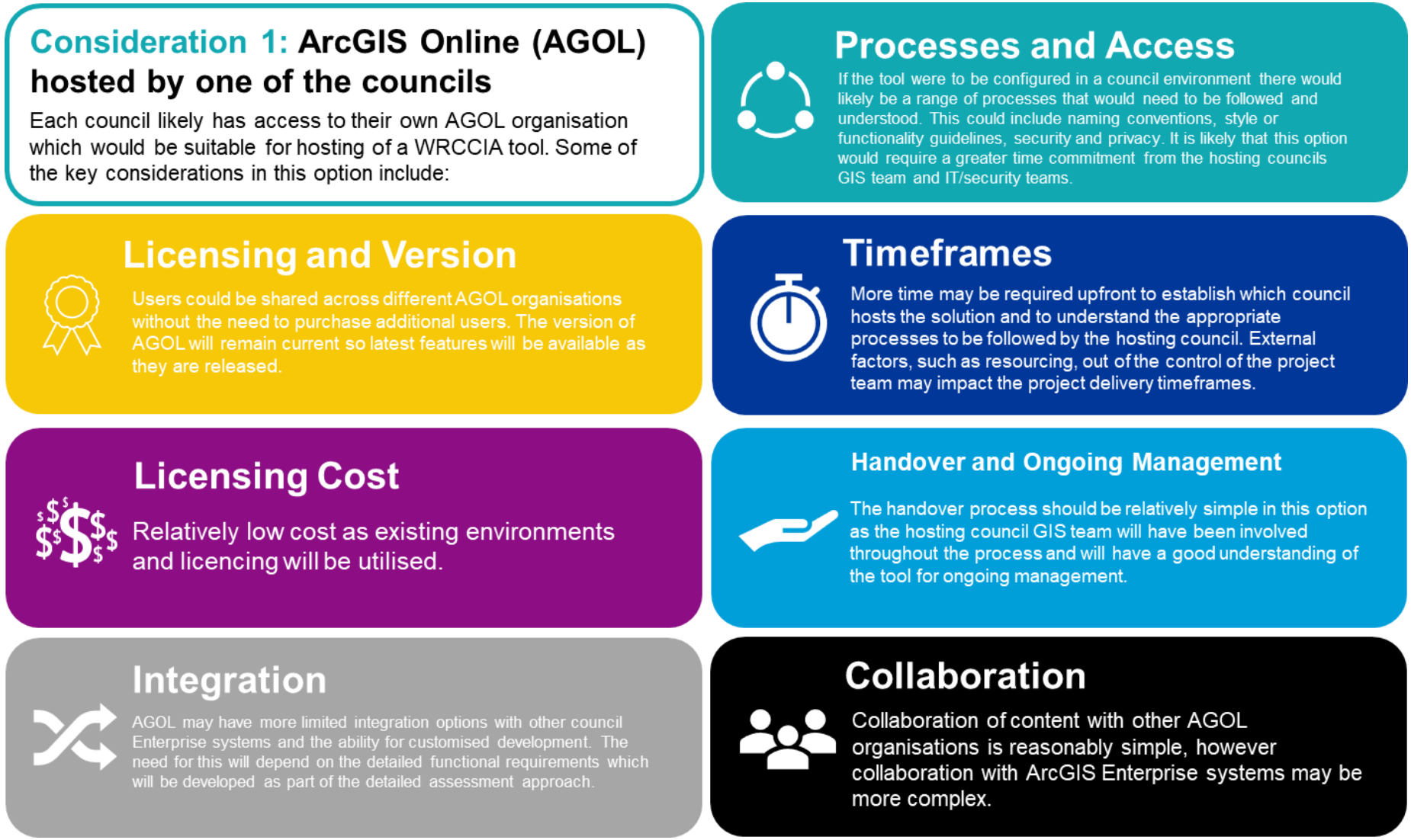
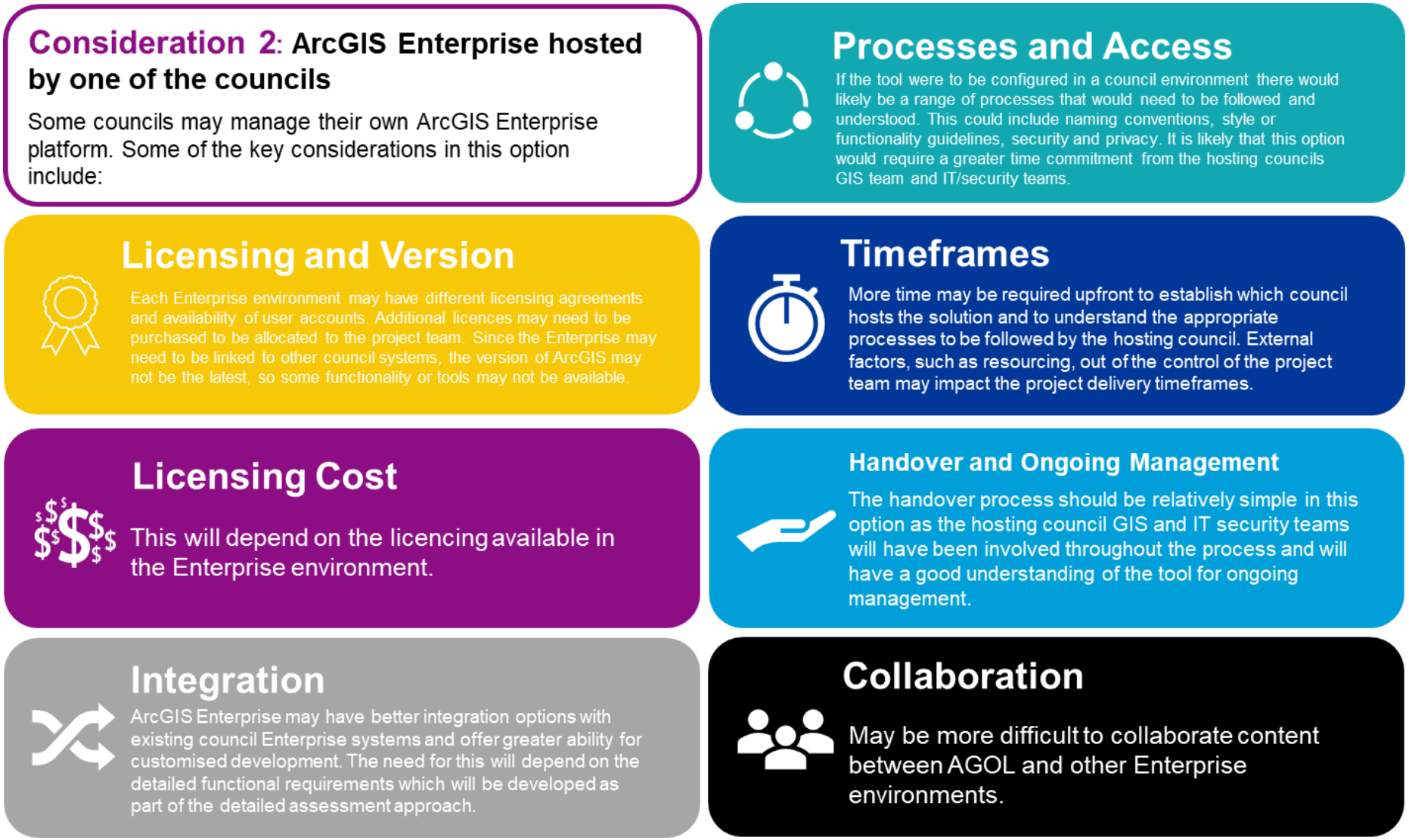


Figure 13. Summary of reporting tool hosting – Consideration 2



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Appendix A – Example Risk Register

Risk ID	Climate hazard	Element at risk	Domain	Extent	Risk Type	Risk statement	Risk description	Potential downstream (indirect) impacts	Exposure					Exposure rating justification / comments	Sensitivity	Sensitivity rating justification / comments	Adaptive capacity	Adaptive capacity rating justification / comments	Vulnerability	Risk				
									Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5							Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5
eg. Domain (Environment), Risk Type (Direct), No. (1) : ED1	*Climate Hazard X*	*Element at Risk Y*	*Domain* *Te Taiao Aspect*	*Region-wide risk or specific to council where exposure is different*	*Direct, Indirect, Transition, Compound*	*Risk to X due to higher Y.*	*Context and description of risk statement*	*'Include text as relevant relating to downstream impacts"*						*Include text as relevant*		*Include text as relevant*		*Include text as relevant*						
BD1	Sea level rise, coastal flooding	State Highway network	Built Koiora I Whare Tangata	Kapiti Coast District	Direct	**Risk to the state highway network due to sea level rise & coastal flooding**	State highway network follows the coast and is at risk from sea level rise which, combined with severe weather and high tides, causing damage and outages.	Impact on regional economy as a significant freight route (Risk IE1)	Moderate	High	Extreme	Extreme	Extreme	Higher exposure for SH roads along Kapiti Coast (compared to region)	Moderate		Very low	Long planning times and high construction cost for any alternate routes	High	Moderate	High	Extreme	Extreme	Extreme
ED1	Sea level rise, coastal flooding	Freight	Economy Whairawa	Wellington Region	Indirect	**Risk to freight network due to sea level rise and coastal flooding affecting state highway network (Risk DB1)**	Important freight nodes including Wellington Port are connected by the State highway network.	NA	Low	Moderate	Moderate	High	Extreme	Alternate routes exist but more areas will be exposed with rising sea levels	High	Majority of freight moves along road	Medium	Rail or Shipping routes available as alternatives	High	Low	Moderate	Moderate	High	Extreme
GI1		Maladaptation	Governance	Wellington Region	Indirect	**Risk of Maladaptation due to practices, processes and tools that do not account for uncertainty and change over long timeframes**			High	High	High	High	High		High		Low		High	High	High	High	High	High