Waikato Regional Council Technical Report 2020/08

# Wharekawa Coast 2120: Natural hazard risk assessment

www.waikatoregion.govt.nz
ISSN 2230-4363 (Online)

Prepared by:
Sophie Marsh, Whitney Mills, Phil Mourot, Terry Hume, Rick Liefting, Stephen Hunt

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

June 2022

Document #: 16353817

| | | |
|---|---|---|
| Peer reviewed by:<br>Scott Thompson | Date | March 2022 |
| Approved for release by:<br>Rick Liefting | Date | May 2022 |

# Acknowledgments

The completion of this report has been made possible by the contributions from a wide range of technical experts and members of the community.

Thank you to Alec Wild, Marje Russ and Richard Reinen-Hamill from Tonkin and Taylor for assisting with the quantitative risk assessment methodology, providing a “sounding board” for ideas, and for feedback on report. Thank you also to members of the Wharekawa Coast 2120 Technical Advisory Group for review and feedback on the draft report.

Thank you to NIWA and GNS Science for the use of RiskScape, and particularly to Ryan Paulik and Ben Popovich for assistance with the setting up and use of RiskScape.

Thank you to the many members of the community, technical experts and staff members who provided information to help understand the impacts of previous natural hazard events and impacts that may occur in the future:

a. Members of the Wharekawa community, particularly Keith Woodley (Pūkorokoro Miranda Shorebird Centre), Justin Johnstone, Eddie Johnson, John Waata, Ria Brejaart (EcoQuest), Janine Archer (Kaiaua School) and Lynn Harvey (owner of Pink Shop)
b. Adrian Brocksopp and Tim Russell from Ravensdown
c. Tony Schischka from Ministry for Primary Industries (MPI)
d. John Bubb and Wanda Leadbeater from Rural Support Trust
e. Vikus Joubert and David Greig from NZ Transport Agency (NZTA)
f. Nina Murphy, Lukas de Haast, Ethan Hohneck, Marina van Steenbergen, Joel Hogan, Brett Otto, Gert van Eeden, EJ Wentzel, David Varcoe and Peter Thom from Hauraki District Council
g. Matthew Taylor, Yanbin Deng, Bruno David, Gary Talbot and Irving Young from Waikato Regional Council

Thank you to the Wharekawa Coast 2120 community panel for your assistance designing the community risk thresholds exercise, for leading this exercise with the community, and for providing feedback on the results.

Thank you also to the attendees of the risk threshold workshops held for stakeholders with level of service responsibilities in the project area.

Thank you to Scott Thompson from Waikato Regional Council for independent peer review of this report.

Your contributions are greatly valued and appreciated.

# Table of Contents

# Figures

# Tables

# Abstract

Wharekawa Coast 2120 aims to bring the Wharekawa communities together to define their path for the future, while enabling flexibility to respond to changing conditions such as projected climate change. This natural hazard risk assessment is part of this process, with the purpose to enable the community panel to understand and evaluate the most significant natural hazard risks to the project area, and compare the risks across compartments and impact categories. The results will predominantly inform community panel workshops, an exercise with the wider community to assess community risk thresholds and a stakeholder workshop on risk thresholds. To achieve this purpose; information was collated on the impacts of recent significant historical natural hazard events, qualitative (coastal erosion and freshwater flooding) and quantitative (coastal inundation and Hauarahi Stream flooding) risk assessments were undertaken, additional information on potential impacts was collated, and vulnerability was assessed.

The results show that in terms of potential impacts, coastal inundation is the most significant natural hazard to the project area, with exposure and estimated damage costs being greatest in sub-compartments 1a (Pūkorokoro Miranda) and 2a (Kaiaua township). Hauarahi Stream flooding is a significant natural hazard for sub-compartment 2a, but events are likely to have lesser impacts than coastal inundation. The impacts of coastal erosion are not significant for most of the Wharekawa Coast currently; however, they may be in the future, with shoreline retreat likely to be primarily driven by coastal inundation and sea level rise. For the five streams assessed qualitatively for freshwater flooding risk, impacts are generally expected to be low, with the exception of Whakatiwai Stream if the stopbanks breach or overtop. When determining community risk thresholds, vulnerability should also be considered as it has the potential to influence when intolerable thresholds may be reached. Characteristics and vulnerability factors have been assessed for the project area, with any spatial variations described. It is considered that this risk assessment achieves its purpose, but it is recognised that more detailed assessment may be required to evaluate potential adaptation options; this will occur later in the process.

# Executive summary

**Introduction and Purpose**

The Wharekawa Coast 2120 project will look at a wide range of issues within the project area to provide for a resilient and prosperous future, with one of the focuses being on climate change and natural hazards. To understand the impacts of climate change and natural hazards in the Wharekawa Coast 2120 project area several reports have been compiled. This natural hazard risk assessment is informed by relevant information from these reports, as well as additional information and data to assess natural hazard risk to the project area. The purpose of this assessment is to:

1. Work with and enable the community panel (Panel) to understand the most significant natural hazard risks to the Wharekawa Coast 2120 project area.
2. Enable the Panel and wider community to evaluate the risk posed by these hazards by determining community risk thresholds for the impacts of each hazard scenario.
3. Compare the relative risk of these hazards across different compartments and impact categories, to inform the development of adaptation actions and pathways.

The results of this risk assessment will be used to inform Panel workshops, and an exercise with the wider community and workshop with key stakeholders (such as asset managers and emergency services) where initial risk thresholds will be determined. The process applied will generally follow best practice guidance from the Ministry for the Environment and from Waikato Regional Council's Risk Assessment Framework.

This risk assessment is an initial evaluation and comparison of the risk posed by different natural hazards, rather than a detailed assessment to evaluate specific adaptation options, which may be required later in the process.

**Project compartments**

For the purposes of this risk assessment and the wider project, the Wharekawa Coast 2120 project area has been divided into 5 compartments, which include 5 coastal sub-compartments and 5 inland sub-compartments (Figure 3). Exposure, damage costs and resident displacement days have been assessed for each sub-compartment that is exposed to the hazard scenarios.

**Hazard scenarios**

This risk assessment considers the following natural hazard scenarios:

1. Coastal erosion – qualitative risk assessment for current and long-term risk
2. Freshwater flooding – qualitative risk assessment
3. Coastal inundation – quantitative risk assessment of a moderate (RL2.4m (MVD-53); between a 5 and 10% AEP) and major (RL3.0m (MVD-53); <0.5% AEP) event
4. Hauarahi Stream flooding - quantitative risk assessment of a moderate (Qp39; 20% AEP) and major (Qp81; 1% AEP) event

These natural hazards have been chosen as natural hazard assessment work and (natural hazard) expert knowledge demonstrates that they are the most significant natural hazard risks for the Wharekawa Coast. Climate change event scenarios have not been assessed, as present-day events already have a significant impact. Climate change will result in these impacts occurring more frequently.

**Elements potentially exposed to natural hazard risk (elements)**

Elements have been identified from existing regional and district council data and data collected at community workshops. This data has been categorised into five impact categories of: buildings and properties; lifelines; services, recreation and tourism; cultural; and ecological. Information on community values has also been considered, with the results incorporated into the categories listed above, rather than being presented separately.

**Historical event information**

Natural hazard events that have occurred in the past will often happen again; thus, historical event information can be incredibly useful. The known impacts of the following recent significant historical events are presented:

1. January 2018 storm tide event
2. March 2017 flood event (Tasman Tempest)
3. April 2017 flood event (Ex-Tropical Cyclone Debbie)

This information will be incorporated with the risk assessment results when presenting information to the Panel and other stakeholders to assist with determining thresholds.

**Qualitative risk assessment (coastal erosion)**

Coastal erosion risk has been assessed qualitatively due to the uncertainty associated with the available hazard information and the lower hazard (and risk), when compared to coastal inundation. Currently the potential impacts of coastal erosion are very low for most of the project area, with low potential impacts in sub-compartment 2a, and the southern and northern ends of sub-compartments 3a and 1a respectively. However, in the long term with the projected effects of climate change, the impacts of coastal erosion have the potential to be significant for all coastal sub-compartments, albeit as a result of shoreline retreat primarily driven by coastal inundation and sea level rise.

**Qualitative risk assessment (freshwater flooding)**

For five streams (excluding Hauarahi Stream), freshwater flooding risk has been assessed qualitatively due to the lower hazard (and risk) when compared to coastal inundation and Hauarahi Stream flooding, and the lack of available hazard information. For these streams, impacts are expected to be very low to low where stopbanks are present and flood events do not exceed stopbank design. Even for events that overtop or breach stopbanks, impacts from Pūkorokoro, Miranda and Taramarie Streams are still expected to be low as rural land is the main element exposed. However, the potential impacts of a stopbank breach or overtopping at Whakatiwai Stream are high, as much of the village could be flooded (as was seen in the 1960s). Waharau Stream does not have stopbanks and flooding could cause moderate impacts.

**Quantitative risk assessment (coastal inundation and Hauarahi Stream flooding)**

A quantitative risk assessment was carried out for coastal inundation and Hauarahi Stream flooding comprising two parts; exposure, and estimated damage cost and resident displacement (when residents are unable to live in their homes while repairs are made).

<u>Exposure</u>

Exposure has been assessed using ArcGIS, by overlaying flood depth data with data representing elements to determine whether the element is exposed (or not), and the degree of exposure of each element (defined by the depth of flooding).

Exposure to coastal inundation is greater than for Hauarahi Stream flooding, including when assessing sub-compartment 2a individually. For coastal inundation, exposure is greatest in sub-compartment 1a in the south and reduces towards the north as the land becomes more elevated. The elements with the greatest percentage exposed to coastal inundation for the project area are; recreation, business and residential land, stormwater infrastructure, bridges, Department of Conservation public conservation areas, Hauraki Rail Trail, service, recreation and tourism elements and Pūkorokoro Miranda Wetland. For Hauarahi Stream flooding, the elements with the greatest percentage exposed are recreation, business and residential land, stormwater infrastructure, bridges, infrastructure associated with the Hauraki Rail Trail, and service, recreation and tourism elements.

<u>Damage costs and resident displacement</u>

Damage costs for buildings and roads were estimated with RiskScape, and rural pasture land with ArcGIS, by using fragility functions to calculate damage ratios for each element, and then multiplying this by cost information. Resident displacement days were estimated using RiskScape and a fragility function based on building damage ratio, and the number of residents displaced was calculated using the average household size from Census data.

For coastal inundation, the estimated damage costs for buildings are significantly greater than those for rural pasture land, which are greater again than those for roads. The estimated damage costs are greatest in sub-compartment 2a, due to the high exposure and large number of buildings. Damage costs are also high in sub-compartment 1a, due to the high exposure and large areas of pasture land, as well as significant costs to buildings and roads. Estimated damage costs to sub-compartments 3a, 4a and 5a from coastal inundation are less but still significant. For Hauarahi Stream flooding, estimated damage costs are much lower, with some costs resulting from damage to roads and buildings in sub-compartment 2a.

For coastal inundation, the estimated resident displacement time ranges from two weeks to two months, with the greatest number of residents displaced in sub-compartment 2a. For Hauarahi Stream flooding, the estimated number of residents displaced is much lower, and for a period of two weeks only.

**Additional information on potential impacts**

Quantitative information alone is not enough to fully understand risk. Thus, information has been collated from Wharekawa Coast 2120 project reports, historical event information, technical experts, staff and community members to add value to the results of the quantitative risk assessment, by describing potential impacts and influencing factors.

**Vulnerability**

The vulnerability section provides a qualitative assessment of the capacity of the community to effectively cope and adapt to natural hazard events, based on characteristics of the community and project area which were collated from Wharekawa Coast 2120 project reports. There are many characteristics that influence vulnerability in the project area. Some, characteristics such as limited road access and a relatively high socioeconomic deprivation rating can result in increased vulnerability, whereas others such as an ability to muck in and get things done (for example cleaning up following the January 2018 storm tide event), can result in increased resilience (and reduced vulnerability). Other characteristics vary spatially, such as the predominance of pasture land in sub-compartment 1a which is exposed to flooding, and result in vulnerability varying across the project area. These vulnerability factors may affect when impacts from natural hazard events become intolerable, and as such should be considered when determining thresholds.

# Glossary

The following definitions are those used in the context of this report[1]:

AEP - Annual exceedance probability, or the chance of an event happening in any one year, expressed as a percentage. A 1% AEP is equivalent to a 100-year average return period (ARP).

ArcGIS - A geographic information system (GIS) for working with maps and geographic information maintained by the Environmental Systems Research Institute (Esri).

Bathtub model - Hydrodynamic modelling of coastal inundation that does not include the dynamic or transient effects of waves or storm tide flooding of land; essentially transfers the coastal water level inland until that land elevation is reached (Ministry for the Environment, 2017). A simpler definition, is that it means treating the ocean like a bathtub, that fills up the same way that a tub does when you add water – the lower part fills up first, and the water rises at the same level everywhere.

Capital Value – The amount that a property is likely to have sold for at the date of the local council's last general revaluation, excluding chattels (Quotable Value, n.d.). The Capital Value is also known as Government Valuation (GV) or Rating Valuation (RV).

Community risk threshold – The point at which the community can no longer tolerate the impacts of a natural hazard event. Adaptation actions or pathways should be implemented prior to a community risk threshold being reached. Community risk thresholds are equivalent to 'adaptation thresholds' that are described in the 2017 MfE Guidance.

Damage ratio – The proportion of damage (expressed as a decimal) that is estimated to occur to an element at risk (e.g. building, road), calculated using a fragility function.

Datum – A fixed vertical elevation or level used as a reference point.

Degree of exposure – The depth of flooding, i.e. <0.5m, 0.5-1m, 1-2m, >2m, that an element is exposed to.

Exposure - People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses (Rovins, et al., 2015).

Fragility function - Fragility functions typically relate the proportion of damage (damage ratio) for a variety of elements such as buildings and roads to flood characteristics such as inundation depth, velocity or duration (adapted from Reese & Ramsay, 2010).

Impact category – The grouping of similar elements potentially exposed to natural hazard risk, in order to assess impacts and present results coherently.

Land Value - The most likely selling price of the bare land at the date of the local council's last general revaluation (Quotable Value, n.d.)

MVD-53 – Moturiki Vertical Datum 1953

[1]Defined terms are *italicised* the first time they are used in this report.

Natural hazard – A natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (Rovins, et al., 2015)[2].

Primary Hazard Zone - An area in which the risk to life, property or the environment from natural hazards is intolerable (Waikato Regional Policy Statement 2016).

Qp – Peak flow

Qualitative risk assessment - A qualitative risk assessment uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur (Quality Planning, 2017).

Quantitative risk assessment - A quantitative risk assessment uses numerical values for both consequences and likelihood using data from a variety of sources (Quality Planning, 2017).

Resident displacement days - The average time that residents are unable to live in their home while repairs are made to the building due to damage from a natural hazard event.

Risk - Effect of uncertainty on objectives (AS/NZS ISO 31000:2009, Risk management standard). Risk is often expressed in terms of a combination of consequences of an event (including changes in circumstances) and the associated likelihood of occurrence (Ministry for the Environment, 2017).

RiskScape - A loss modelling tool in development by NIWA and GNS Science to support evidence-based risk assessments for natural hazards. It draws on decades of natural hazards research to model how assets (e.g. buildings and infrastructure) can be impacted by hazards, using technical vulnerability information.

RCP – Representative Concentration Pathway. Four scenarios of future radiative forcings from greenhouse gases (Ministry for the Environment, 2017).

RL – Reduced level, meaning that the elevation value provided is relative to a specific datum. E.g. RL3.0 m (MVD-53), means that the elevation is 3.0 m relative to Moturiki Vertical Datum 1953.

Signals - Derived indicator values, monitoring changes in physical, social, cultural, economic, and risk attributes, which provide early warning to signal that a trigger (decision point) is approaching in the near to medium term and should prompt thinking and initial engagement processes on the next steps or any changes to the trigger (Ministry for the Environment, 2017).

Trigger - A derived indicator value(s), which when reached, provides sufficient lead time to cover community engagement, consenting, construction and funding arrangements, to ensure a new pathway or adaptation action can be implemented before the risk threshold is reached (adapted from Ministry for the Environment, 2017).

Ūrupa - A Māori cemetery or burial site.

Vulnerability – The predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including exposure, sensitivity or susceptibility to harm or damage, and lack of capacity to cope and adapt (adaptive capacity) (Ministry for the Environment, 2017). In this assessment two broad types of vulnerability are considered:

[2] This definition is used as it is simple, clear and consistent with the Resource Management Act 1991 (RMA) definition, which is: "natural hazard means any atmospheric or earth or water related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire, or flooding) the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment" (RMA).

1. For the physical elements of buildings, roads and rural pasture land, the estimated fragility (see fragility function definition) of each element is used to estimate the proportion of damage that will occur for a given hazard exposure, based on the physical integrity of each element.
2. Additionally, numerous other characteristics of a community (which are often difficult to quantify) can affect the adaptive capacity of a community. These include social and economic characteristics, as well as characteristics caused by the location of communities, e.g. road access, and are described qualitatively.

Wāhi tapu - a sacred place or sacred site subject to long-term ritual restrictions on access or use, e.g. a burial ground, a battle site or a place where tapu (sacred, restricted) objects were placed.

# 1 Introduction

## 1.1 Wharekawa Coast 2120

The Wharekawa Coast 2120 project aims to bring the Wharekawa communities together to define their path for the future, while enabling flexibility to respond to changing conditions (such as those caused by projected climate change). Wharekawa Coast 2120 will look at a wide range of issues within the project area, to provide for a resilient and prosperous future, with a focus on:

a. climate change and *natural hazards*;
b. future development and land use;
c. economic opportunities; and
d. community infrastructure.

To understand the impacts of climate change and natural hazards in the Wharekawa Coast 2120 project area, the following suite of reports have been compiled:

a. Community Overview
b. Economic Profile
c. Coastal Processes and Hazards (coastal inundation, coastal erosion and tsunami)
d. Rapid flood hazard assessment of Hauarahi Stream
e. Wider River Flood Assessment
f. Ecological Values Impact Assessment
g. Natural Hazards Social Impact Assessment for Wharekawa; and
h. Natural Hazard Risk Assessment (this report).

This risk assessment is informed by relevant information from the above reports, as well as additional information and data, to assess *risk* to the Wharekawa Coast project area from coastal inundation and erosion, and freshwater flooding, particularly in Hauarahi Stream (identified as the most significant natural hazard risks for the project area).

The results of this risk assessment will be used to inform the community panel (Panel) workshop on 'Natural Hazard Risk Assessment', and will also assist with the workshops following. The objective of the risk assessment workshop is: "Natural hazard risks are identified, evaluated and understood by the Panel". The results will also inform an exercise with the wider community to assess community risk thresholds.

This report will enable the Panel to identify and understand the most significant natural hazard risks to the Wharekawa Coast. Section 3.9 of this report documents the process to enable the Panel and wider community to evaluate risk, i.e. to determine *community risk thresholds* (thresholds).

Council asset managers, lifeline utility providers, Civil Defence Emergency Management (CDEM) and emergency services will also provide information on risk thresholds for their assets and responsibilities (section 3.9.1).

The process of determining thresholds will generally follow best practice guidance from the Ministry for the Environment on coastal hazards and climate change (MfE Guidance) (Ministry for the Environment, 2017) and from Waikato Regional Council's (WRC) Risk Assessment Framework (Framework).

## 1.2 WRC Risk Assessment Framework

The Waikato Regional Council Risk Assessment Framework (Framework) has been developed to support implementation of the Waikato Regional Policy Statement (WRPS) natural hazard provisions. It provides a simple process that can be used to identify, assess and understand risk associated with natural hazards. The Framework is based on the key concepts and principles of ISO 31000:2018 - Risk management – Guidelines, and also considers the MfE Guidance (where the overall approach and process are consistent with ISO 31000:2018). The Framework is yet to be tested, and as such has not been finalised so that refinements can be made as required. Wharekawa Coast 2120 is the first project to use the Framework.

The Framework comprises a Risk Assessment Process Flow Chart (Figure 1) and associated set of key questions, some explanatory text and supporting template tools. This report primarily covers the 'Analyse' step of the Risk Assessment, in that it presents (for identified natural hazard scenarios) the analysis of the *exposure* of and impacts to elements potentially exposed to natural hazard risk. The report also documents the reasoning behind the work completed for the 'Identify' step (level of detail of natural hazard reports and hazard scenarios chosen to analyse) (Section 3.2), and the proposed process for the 'Evaluate' step which will be undertaken with the Panel and relevant experts (Section 3.9).

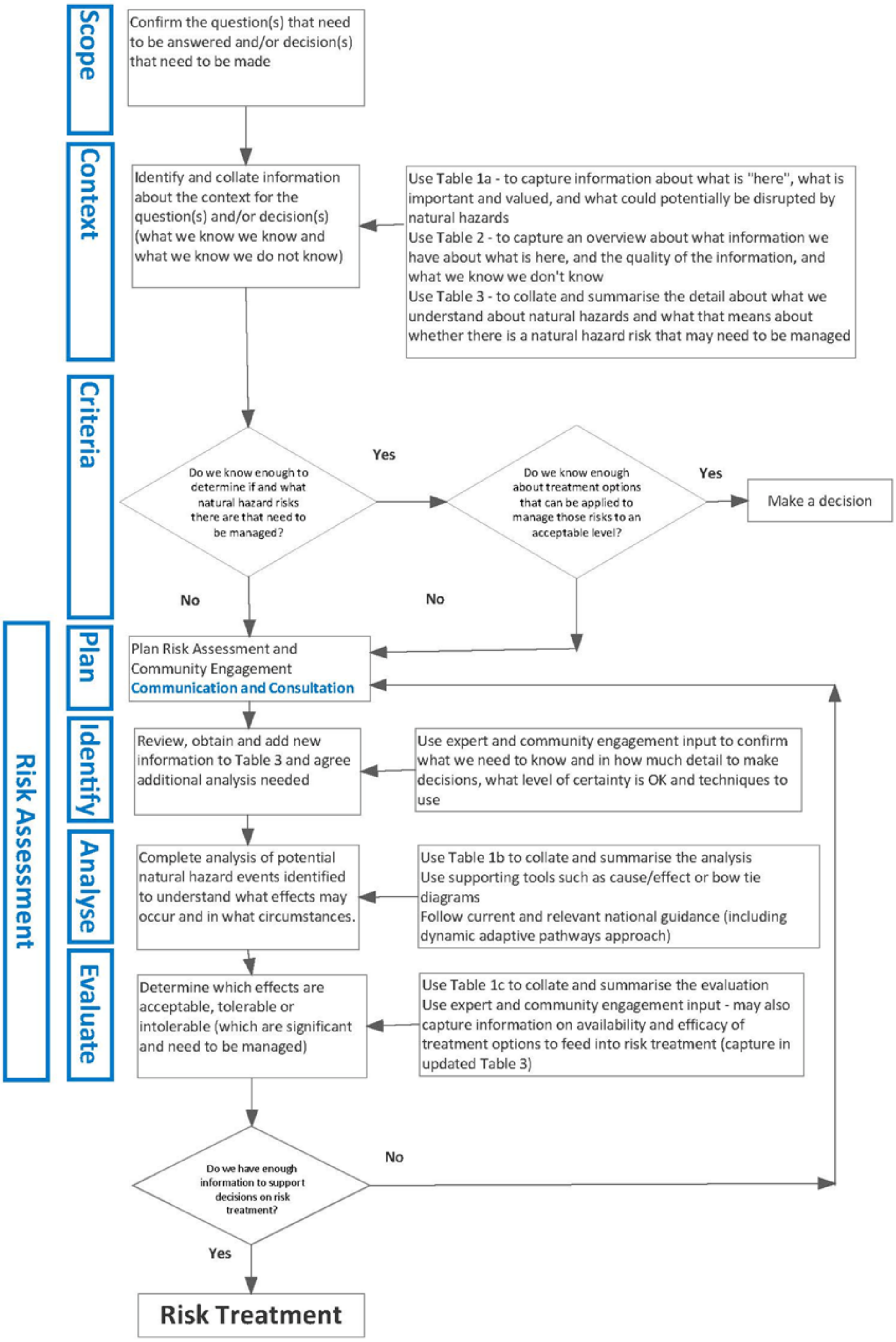



**Figure 1** **Risk Assessment Process Flowchart (WRC Risk Assessment Framework)**

## 1.3 Purpose

The purpose of this risk assessment is to:

1. Work with and enable the Panel to understand the most significant natural hazard risks to the Wharekawa Coast 2120 project area.
2. Enable the Panel and wider community to evaluate the risk posed by these hazards by determining initial thresholds for the impacts of each hazard scenario.
3. Compare the relative risk of these hazards across different compartments and impact categories, to inform the development of adaptation actions and pathways.

## 1.4 Scope

This risk assessment is intended to provide information on the consequences of significant natural hazards (i.e. the effects of coastal erosion, coastal inundation, and freshwater flooding events – detailed in section Hazard scenarios3.2) on elements potentially exposed in the study area. The spatial extent of the study area is the Wharekawa Coast 2120 project area (**Error! Reference source not found.**).

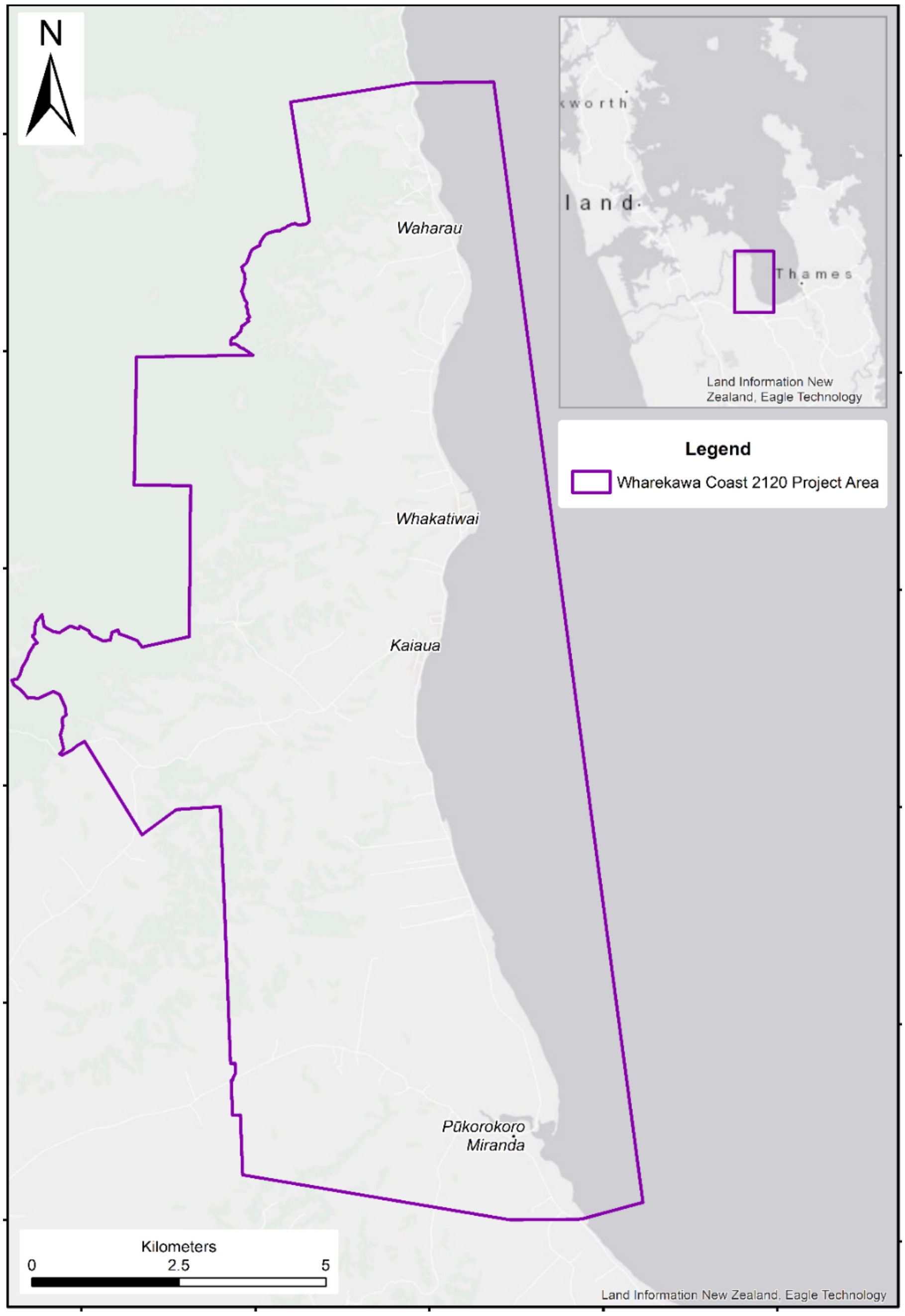



**Figure 2 Wharekawa Coast 2120 project area**

The information presented in this risk assessment comprises four parts:

1. Information collated from the community, Hauraki District Council (HDC) and WRC on the impacts of historical natural hazard events in the area;
2. *Qualitative risk assessment* informed by experts for coastal erosion and freshwater flooding (excluding Hauarahi Stream);
3. *Quantitative risk assessment* carried out using *RiskScape* Core Engine v.0.7.1 (a risk modelling software in development by NIWA and GNS Science) and *ArcGIS* (developed by Esri) for coastal inundation and Hauarahi Stream flooding; and
4. Additional information on the potential impacts of natural hazard events and on the *vulnerability* of the community to natural hazard events, informed by natural hazard experts and Wharekawa Coast 2120 project reports.

This assessment provides a level of detail suitable to be used for an initial evaluation and comparison of the risk posed by significant natural hazards (refer to section 3.2.1). Adaptation options and pathways will be evaluated at a later stage in this process; more detailed assessment may be required to inform this.

## 1.5 Limitations

The broad limitations and assumptions of this risk assessment include (further specific limitations are detailed in Section 3):

1. Limited information on the specific impacts (losses, costs) of historical natural hazard events, particularly those that occurred prior to the inclusion of the project area into the Waikato Region and Hauraki District (from the Auckland Region and Franklin District) in 2010.
2. Limitations that are carried over from the reports and modelling undertaken to assess coastal hazards and freshwater flooding – these are detailed in the relevant reports.
3. This risk assessment considers coastal inundation and Hauarahi Stream flooding events individually, but does not assess the impacts from a combined coastal inundation and Hauarahi Stream flooding event. Such an event is relatively rare but will likely result in greater impacts to the project area.
4. Data representing the elements potentially exposed to natural hazard risk is considered to be reasonably complete and up to date, however it is unlikely to represent exactly what is present within the project area. Additionally:
    a. Privately owned utility infrastructure including power and telecommunications has not been included in this study as this information is not readily available.
    b. The damage cost of buildings on non-rateable land (for example, some conservation and local authority land) has not been accounted for.
    c. For cultural elements, only elements that are known to HDC have been assessed. It is recognised that there are likely to be valued elements, particularly of archaeological/spiritual values, which are unknown and therefore not included.
5. Uncertainty is inherent in any quantitative or qualitative natural hazard risk assessment, as it is impossible to predict the exact impacts of any natural hazard event.
6. Loss estimates (which inform damage costs) are made using *fragility functions* derived from research and historical event observations. Fragility functions will not accurately predict the way that each individual element responds to flooding. However, when assessing elements collectively, the use of fragility functions should provide a reasonable estimate.
7. Damage cost estimates are unlikely to represent actual repair/replacement/re-establishment costs following an event; however, they provide a means to estimate and compare these costs across compartments and for different hazard and event scenarios. Costs have only been estimated for elements where fragility (physical vulnerability) and cost information is readily available.

8. In any natural hazard event, the resulting impacts vary depending on a large number of characteristics ranging from insurance coverage, to road access, to the socio-economics of an area. These characteristics and their resulting vulnerability factors have been considered in Section 7, but many factors and their dependencies will not be realised until an event occurs, and will vary hugely from event to event.
9. The outputs of this risk assessment will be used to assist the community to assess thresholds for the Wharekawa Coast. These thresholds will provide a guide to community scale risk tolerance; actual tolerance at a property scale will vary from person to person, and it is difficult to know what will be intolerable until it occurs.

*Regarding the use of RiskScape Core Engine v.0.7.1 software, NIWA makes no representations or warranties regarding the accuracy or completeness of the Software, the use to which Data may be put, or the results which may be obtained from using the Software, and NIWA accepts no liability for any loss or damage (whether direct or indirect) incurred by any person through the use of or reliance on the Software.*

# 2 Setting the scene: Community values

As set out in the Framework, an important part of any risk assessment is setting the context (Figure 1). A key part of setting the context is determining what is present in the project area that is valued. This knowledge can then be used to determine if the valued elements could be disrupted by natural hazards.

For this risk assessment, information about what is valued has been collated from community workshops and the Wharekawa Coast 2120 project reports.

A community workshop was held on 30 November 2019, which saw approximately 40 community members come together to hear from technical experts and share what matters most to them. Participants were asked to share their thoughts on the following:

- I love/value
- I want to see/see more of
- I don't want to see/see less of
- I'm concerned about

A summary of the knowledge gained from the workshop is that the community loves the project area most because of its peaceful and relaxing atmosphere, small community feel, wild and natural spaces, and its unique features including marae, shorebirds, and hot pools. The wetlands, trees, natural features and wild spaces are especially important. The community doesn't want to see over-commercialisation, pests, or erosion, but they would like to see more playgrounds, kerbing and footpaths, stopbanks, and services like drain clearing and grass cutting. They are particularly concerned about flooding, lack of work opportunities, and how they will be able to afford options to address the effects of climate change.

For this risk assessment, the information on what the community loves and values has been used to determine if the valued elements are potentially exposed to natural hazard risk.

The information gathered for the Social Impact Assessment (SIA) reiterates the workshop findings, and builds on these with the reasons for why people like the project area as a place to live (page 21 of SIA). These reasons are more generalised statements which provide context, but cannot be tied directly to elements potentially exposed.

# 3 Methodology

## 3.1 Project compartments

For the purposes of this risk assessment and the wider project, the Wharekawa Coast 2120 project area has been divided into 5 compartments, which include 5 coastal sub-compartments and 5 inland sub-compartments (Figure 3). Compartments are used to allow for the alignment of information and management options within similar river and coastal environments.

The 5 compartments were derived using river catchment boundaries, with smaller catchments grouped together to create a manageable number of compartments. The division between inland and coastal compartments is at the (simplified) *RL* 5.0 metre (m) contour (relative to *MVD-53*), as coastal processes do not occur above this elevation. The coastal sub-compartments were designed to fit with the inland catchment boundaries, but also to align with areas of similar coastal processes and the main communities along the coast. The location of the coastal sub-compartments also takes into account the original coastal compartments from the Kaiaua/Wharekawa Coastal Compartment Management Plan (Tonkin & Taylor, 2010a), but with modifications to better align with the Wharekawa Coast 2120 project.

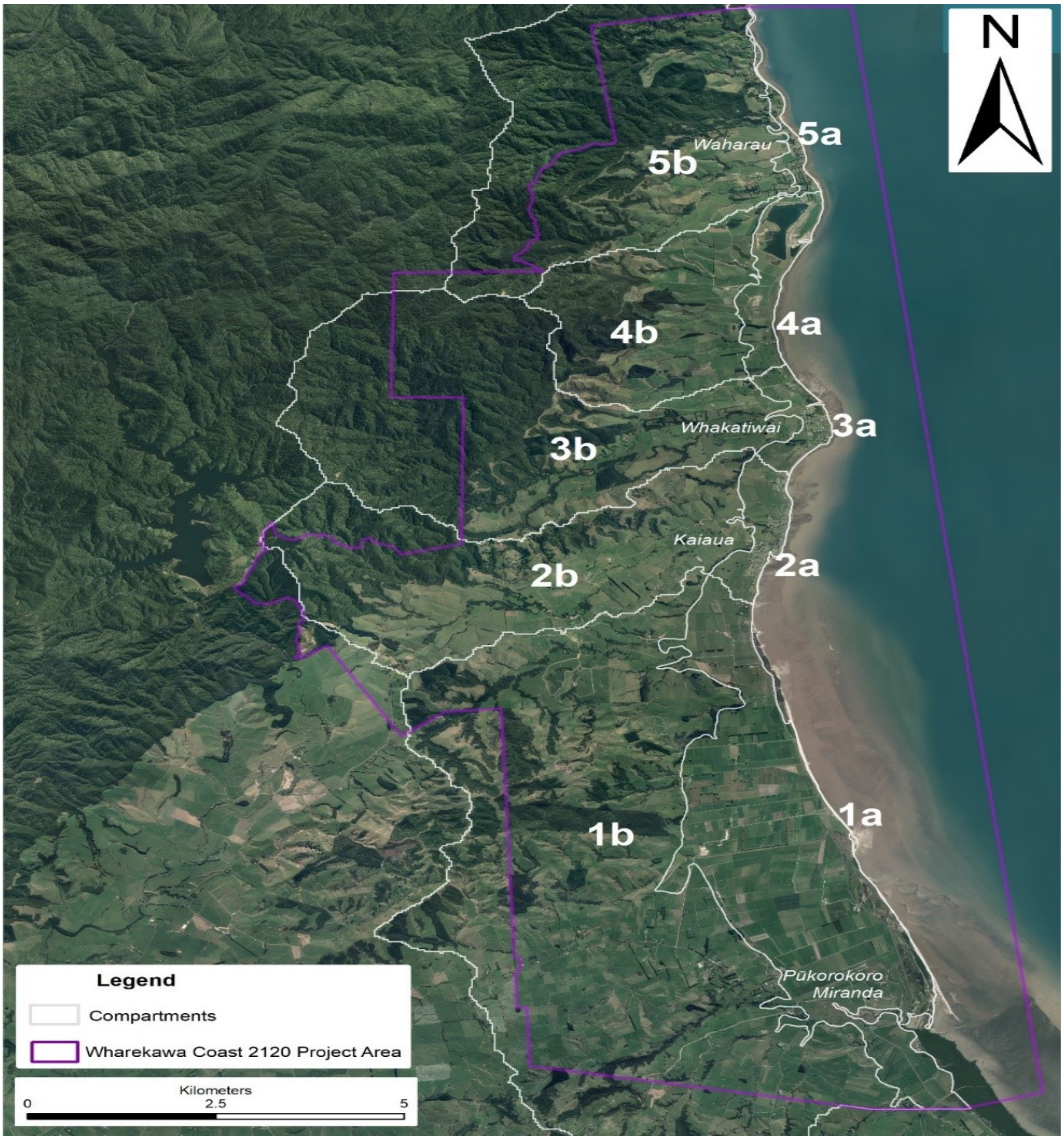



**Figure 3** **Wharekawa Coast 2120 project compartments and sub-compartments, where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 2b Kaiaua inland; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

Not all compartments are exposed to significant risk from natural hazards. As such, the coastal sub-compartments (1a to 5a) will be assessed for coastal inundation and coastal erosion, and the Kaiaua sub-compartments (2a and 2b) will be assessed for Hauarahi Stream flood risk. The remainder of the sub-compartments will not be explicitly assessed as part of this risk assessment (although some contain the upper reaches of streams that are qualitatively assessed) but may be at a later stage in the project, for example, when considering adaptation options.

The official names of the sub-compartments assessed in this risk assessment have been provided by the community panel and are as follows:

1a: Pūkorokoro Miranda
2a: Kaiaua township
2b: Kaiaua inland
3a: Whakatiwai
4a: Waihihi (formerly known as Pukekereru, thus some documents may use this name)
5a: Waharau

## 3.2 Hazard scenarios

This risk assessment considers the following natural hazards:

1. Coastal erosion
2. Coastal inundation
3. Freshwater flooding, particularly Hauarahi Stream

These have been chosen as previously completed natural hazard assessment work and expert knowledge demonstrates that they present the most significant natural hazard risks for the Wharekawa Coast. The natural hazard scenarios that are assessed in this report are described in Table 1, with the hazard scenarios for the quantitative risk assessment presented in Figure 4.

**Table 1 Natural hazard scenarios included in risk assessment**

| Natural hazard | Scenarios (all quantitative scenarios are present day) |
|---|---|
| Coastal erosion | Qualitative assessment for current and long-term risk |
| Freshwater flooding | Qualitative assessment for five streams |
| Coastal inundation | Moderate event - RL2.4m (MVD-53); between a 5 and 10% *AEP*<br>Major event - RL3.0m (MVD-53); <0.5% AEP |
| Hauarahi Stream flooding | Moderate event - *Qp*39; 20% AEP<br>Major event - Qp81; 1% AEP |

For coastal erosion, a qualitative risk assessment was considered appropriate because coastal erosion is not expected to be a major hazard in either the short or long term when compared with coastal inundation (Hume, 2020). There are also insufficient numerical data and modelling of future coastal processes to carry out an accurate quantitative risk assessment. Furthermore, there is considerable uncertainty associated with the potential response of the coastal sedimentary system to climate change and sea level rise, particularly as predictions are pushed out to 2120.

For freshwater flooding, a qualitative risk assessment was considered appropriate (with the exception of Hauarahi Stream) because the flooding generally does not impact homes or key services. This means it presents a lower hazard than coastal inundation and Hauarahi stream flooding, thus is less likely to result in intolerable risk. Additionally, there are numerous smaller streams in the project area and there is not sufficient resource or numerical data available to complete flood modelling for all of them. The streams that have been qualitatively assessed for freshwater flood risk are presented in Figure 5.

For coastal inundation, *bathtub modelling* has been undertaken to present approximate inundation extents and depths for different sea levels (relative to Moturiki Vertical *Datum* 1953) (Waikato Regional Council, 2019), and analysis by NIWA (Stephens, et al., 2015) has determined the frequency at which these sea levels are likely to occur (at present day). For this risk assessment, the sea levels of RL 3.0m and RL 2.4m will be assessed. This allows the risk to be assessed for a major coastal inundation (storm) event (RL3.0m) that is also approximately equivalent to the January 2018 storm tide event (thus providing additional knowledge and experience), and a moderate event (RL 2.4m), the impacts of which may still become intolerable with increasing frequencies.

For coastal hazards, Ministry for the Environment (2017) recommends that risk be assessed for the range of New Zealand-wide sea level rise scenarios (*RCP* scenarios) provided in the MfE Guidance, in order to consider a range of futures that are not implausible. However, for this assessment it was decided to not assess coastal inundation risk with future climate sea levels, because the relatively flat and low-lying nature of the Wharekawa Coast means a large part of the project area is already significantly impacted by present day events. Given this, it is expected that the increasing frequency of such events, rather than the increasing magnitude, will be more of a factor when determining thresholds. This thinking is further expanded on in section 3.9.3. Note that areas of indirect inundation (i.e. areas that are below the sea level but may have no direct flow path to the sea) have not been included in the assessment (shown in green in Figure 4). These areas may still be affected by coastal inundation in some way, e.g. via groundwater.

For Hauarahi Stream flooding, a rapid flood hazard assessment has been completed to produce hazard maps showing the approximate extent and depths of different frequency events (Grant, et al., 2020). For this risk assessment, the Qp39 (moderate) and Qp81 (major) events will be assessed. The reasoning for this is similar to coastal flooding, except that a higher frequency event is assessed (Qp39), as this higher frequency event (approximately a 20% AEP) already produces significant impacts for Kaiaua. It was decided not to assess river flooding risk with the effects of climate change, because with sea level rise, the impacts of coastal inundation will eclipse the impacts of river flooding.

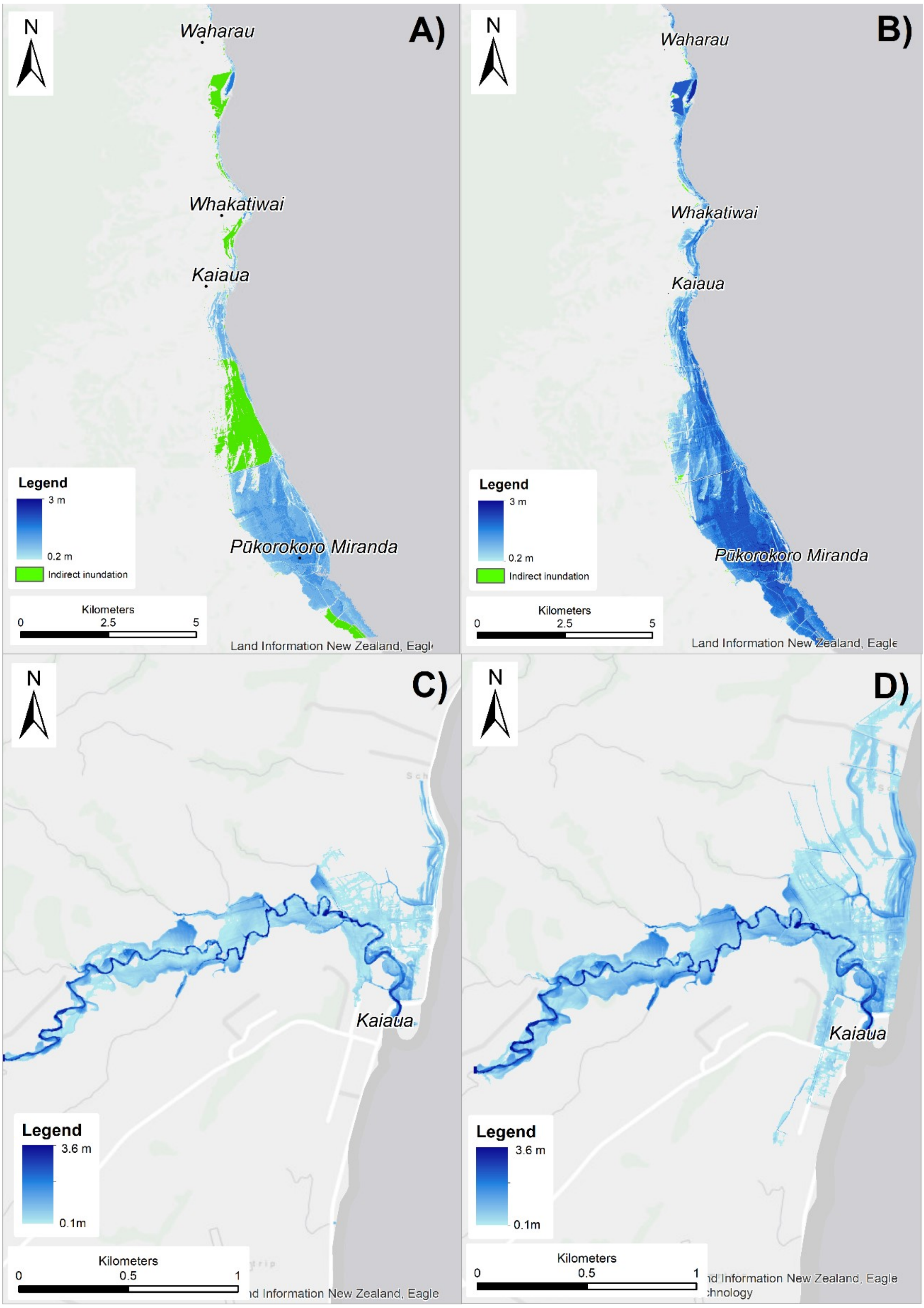



**Figure 4** **Natural hazard scenarios for the quantitative risk assessment: A) coastal inundation – moderate; B) coastal inundation – major; C) Hauarahi Stream flooding – moderate; D) Hauarahi Stream flooding – major**

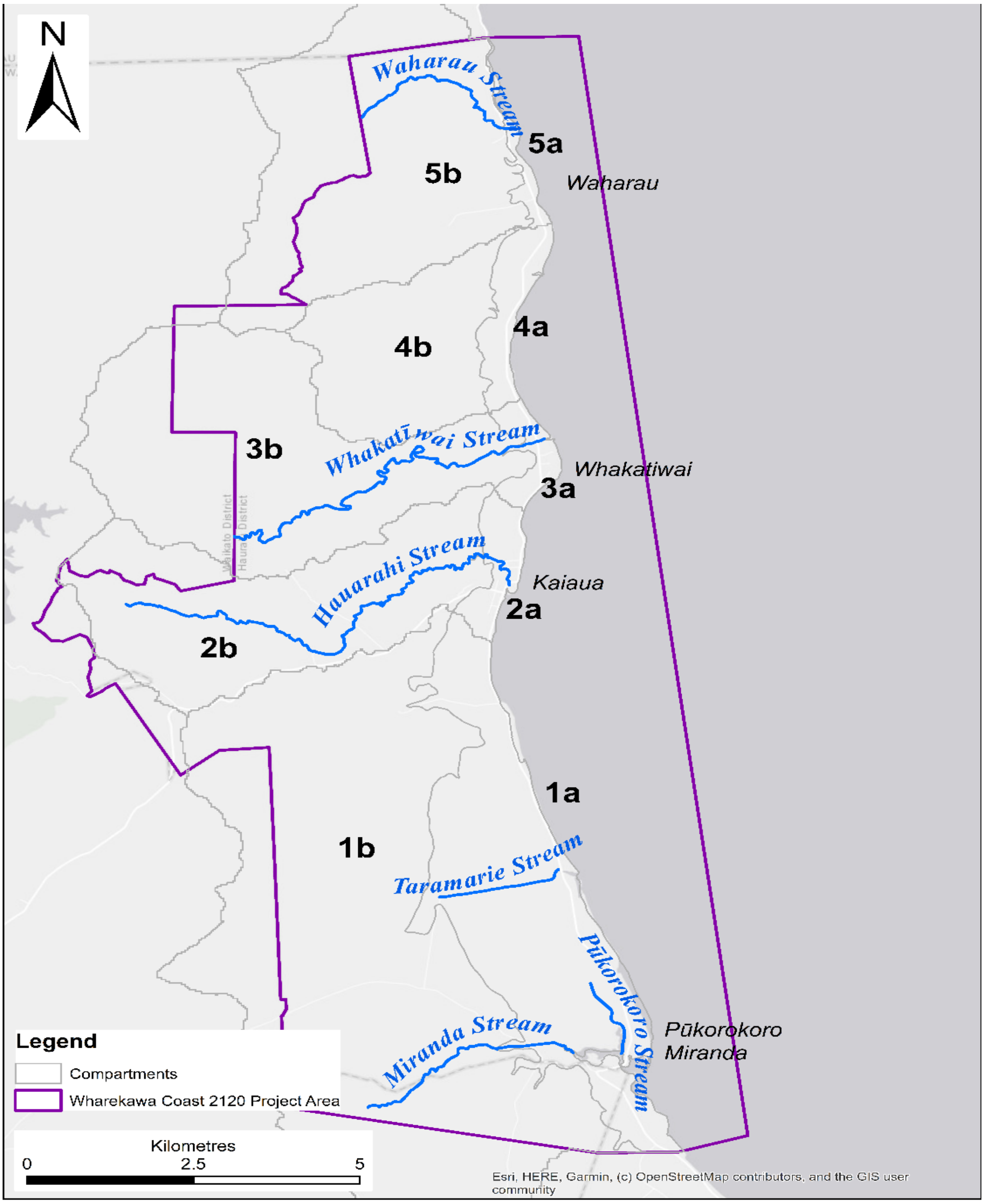



**Figure 5** **Streams that have been qualitatively assessed for freshwater flood risk (excluding Hauarahi Stream) in relation to sub-compartment locations**

### 3.2.1 Level of detail of hazard data

For both coastal inundation and Hauarahi Stream flooding, the risk assessment is based on modelled hazard scenarios. A key consideration here is the level of detail required to inform the risk assessment.

We consider that both the bathtub model for coastal inundation and the Rapid Flood Hazard Assessment for Hauarahi Stream flooding provide hazard data that is fit for purpose. This risk assessment is an initial evaluation and comparison of the risk posed by different natural hazards (step 4 of the MfE 10-step decision cycle - Figure 6), rather than a detailed assessment to evaluate specific adaptation options (which may come later in the process; step 6 of MfE 10-step decision cycle).

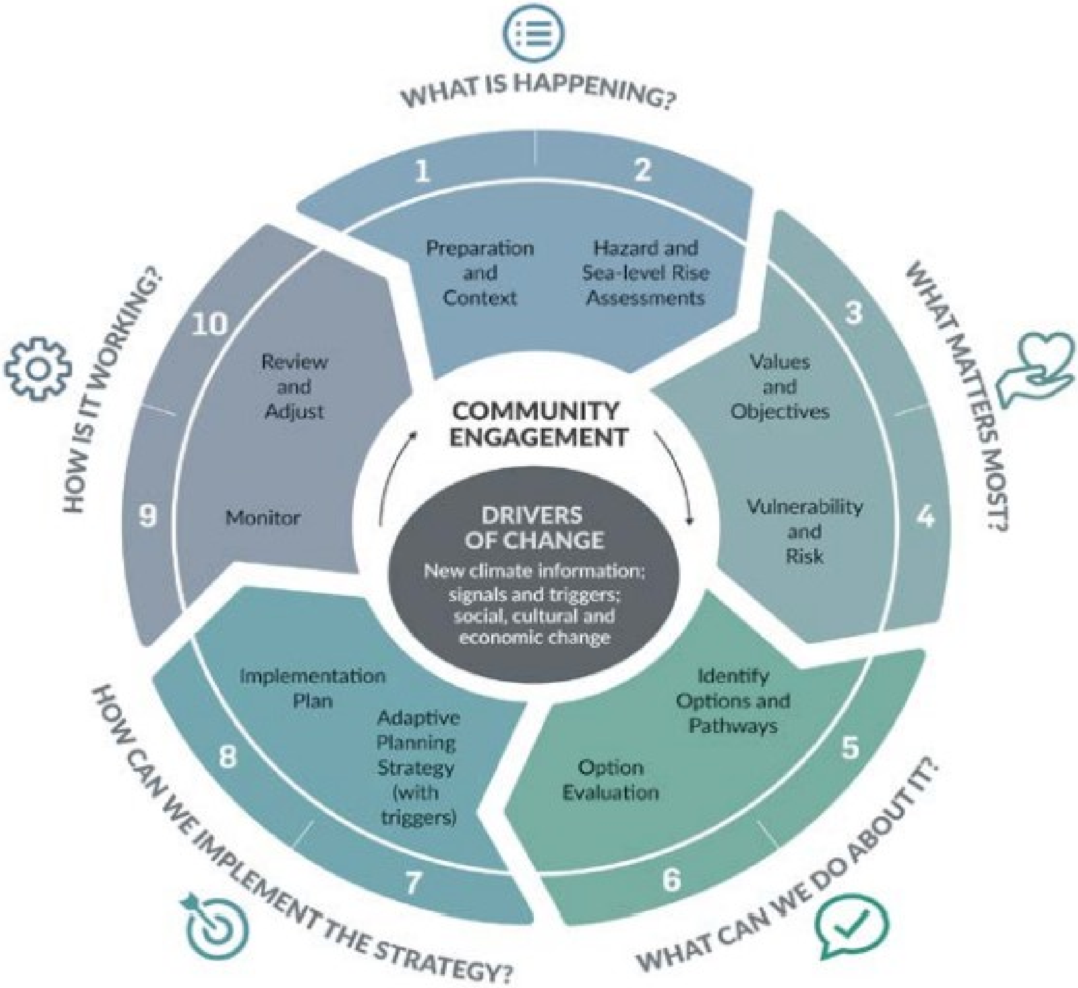



**Figure 6** **MfE Guidance 10-step decision cycle, grouped around five questions (Ministry for the Environment, 2017)**

It is also worth mentioning that uncertainty is inherent in any natural hazard risk assessment. There are so many factors that affect risk, some of which are not well known or understood, that a simplified approach (as has been applied here) is often the most practical.

## 3.3 Elements potentially exposed to natural hazard risk

The elements that are potentially exposed to natural hazard risk (elements) have been identified from existing HDC and WRC data and data collected at community workshops. This data has been categorised into five *impact categories* (with additional information on community values) to allow the risks to which similar elements are exposed to be presented and evaluated together. The impact categories and the data (source and date last edited/downloaded in brackets) that they are comprised of is presented in Table 2.

**Table 2** **Impact categories and data for risk assessment**

| Impact category and data name | Data name |
|---|---|
| Buildings and properties | Building footprints *(HDC, August 2016 – edited and joined to property data (WRC, May 2020))* |
| | Land use type *(HDC, October 2013 – edited from zone data)* |
| | Rural pasture land *(HDC, October 2013 – edited from zone and vegetation data)* |
| | Population data *(Stats NZ, June 2020)* |
| Lifelines | Road centre lines *(LINZ, January 2020)* |
| | Bridges *(HDC, September 2017 – created from Community points)* |
| | Stormwater lines *(HDC, January 2020)* |
| | Stormwater points *(HDC, January 2020)* |

| | |
|---|---|
| | Stopbanks *(HDC, June 2016)* |
| | Surface water takes *(WRC, May 2020)* |
| | Groundwater takes *(WRC, May 2020)* |
| Services, recreation and tourism | Community points *(HDC, December 2018 – edited)* |
| | Hauraki Rail Trail *(digitised from HDC plans, May 2020)* |
| | Rail Trail features *(digitised from HDC plans, May 2020)* |
| | Department of Conservation (DOC) public conservation areas *(HDC, December 2019 - edited)* |
| Cultural | Archaeological sites *(HDC, June 2016)* |
| | Māori pa *(HDC, December 2019)* |
| | Marae *(HDC, June 2016)* |
| | Māori land blocks *(Ministry of Justice and Ministry for Primary Industries, May 2017)* |
| Ecological | Native vegetation *(HDC, October 2013)* |
| | Regional Parks *(HDC, October 2013)* |
| | Pūkorokoro Miranda wetland (Ramsar site) *(DOC, May 2020 - edited)* |
| *Community values* | *Values data (HDC, February 2020 – digitised from community workshop - edited)* |

Many of the data sets have been edited in some way to make them fit for purpose for this risk assessment. This, along with the content of each data set is outlined below for each impact category.

### 3.3.1 Buildings and properties

Land use type (polygon) data for the project area shows that land use is dominated by rural (Figure 7, Figure 8), with some areas of forest conservation in the hill country. There are lesser areas of residential and recreation land near the coast, and a smaller area again that is used for business.

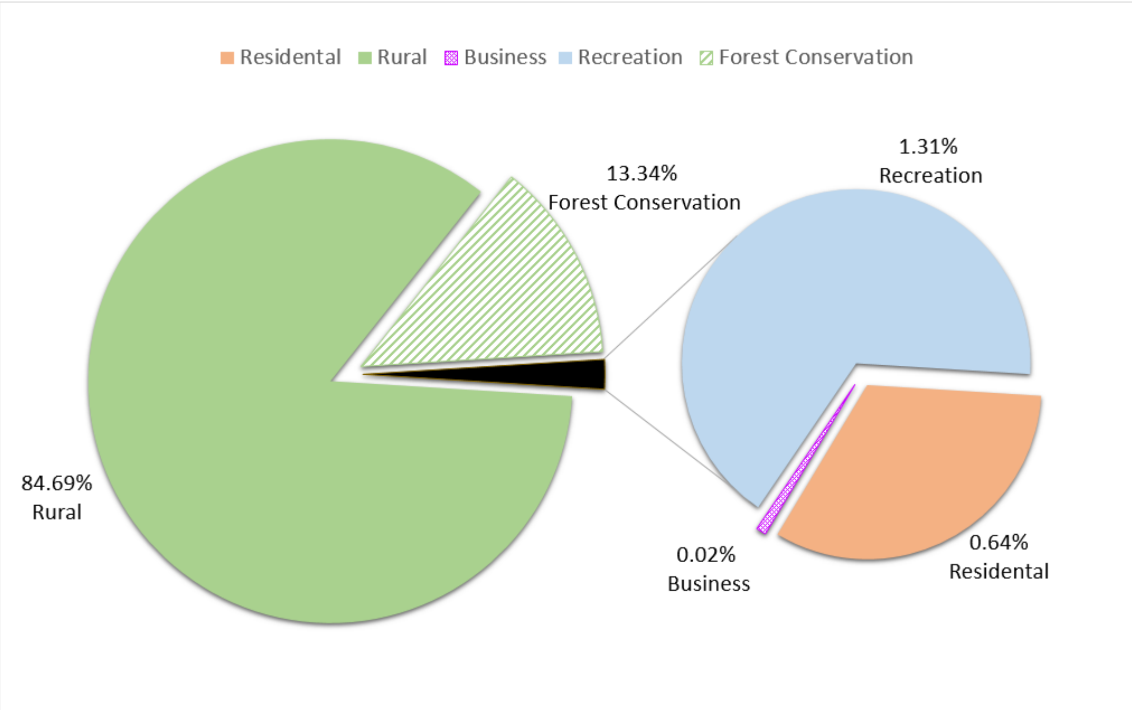



**Figure 7 Proportion of each land use type in Wharekawa Coast 2120 project area**

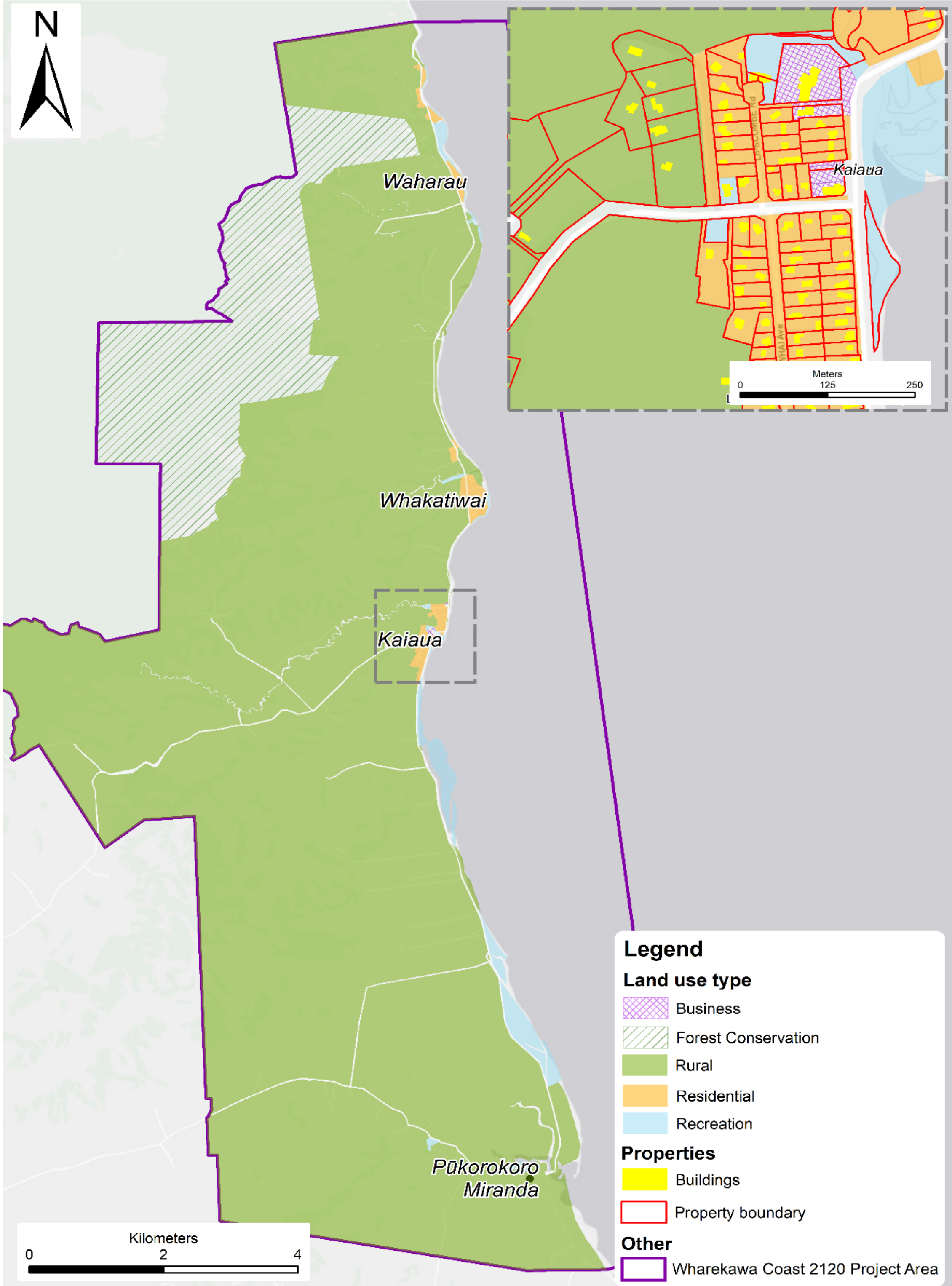



**Figure 8** **Land use types in the Wharekawa Coast 2120 project area**

The land use type data is derived from Franklin District Plan (Plan Change 14; operative 21 October 2013) zone data, where zones have been re-classed as land use types that are more fit for purpose (Table 3). An additional 'rural' polygon was added at the southern extent of the project area where the zone data was incomplete.

**Table 3 Re-classification of zones to land use types**

| Zone | Land use type |
|---|---|
| Coastal | Rural (except for known recreation land, which was re-classed to Recreation) |
| Forest Conservation | Forest Conservation |
| Recreation | Recreation |
| Rural | Rural |
| Village | Residential |
| Village – business | Business |

An additional data set, 'rural pasture land' has been created to estimate the area of rural land that is pasture (used predominantly for dairying) (Appendix 1). This was created by removing areas of known native and exotic vegetation (provided as data from HDC) from areas of rural land use type.

The building footprints are polygon data, with each polygon representing the floor area of a building, including small sheds and garages, etc. There are a small proportion of building footprints missing, likely due to the data set being slightly out of date, but this will not significantly affect the results. The data has been edited to remove all buildings except the main building for each property (reducing the number of footprints from approximately 1500 to 500). The main building was identified as the footprint with the largest area for residential, business and recreation land uses, and identified as the main dwelling using aerial imagery for rural land uses. The building footprint data has also been joined with the property data to attribute each main building with property land and *capital value* information. Property improvement value was calculated (capital minus *land value*).

The population data used in this assessment is the average household size for the Kaiaua meshblock (equivalent to the Miranda-Pūkorokoro Statistical Area in the 2018 Census), which according to the 2013 Census (statistic not available for the 2018 Census) is 2.3 people (Stats NZ, 2013).

Note that septic tank data is available, but information from HDC staff suggests that most properties use a septic tank, thus the potential impacts to septic tanks can be described as sub-set of buildings (section 7.1.1).

### 3.3.2 Lifelines

The data within the lifelines categories comprises point and line data which represents assets that provide essential infrastructure services to the community (Figure 9). Table 4 expands on the assets that are included in each data set. Note that the surface and groundwater take data is derived from WRC resource consent information, thus the locations may not be exact.

**Table 4 Descriptions of lifelines data**

| Data name (and source) | Data description |
|---|---|
| Road centre lines (LINZ) | Road centre lines for all public roads, including East Coast Road, Kaiaua Road and smaller local roads (line data) |
| Bridges (HDC – created from community points) | Road bridges (point data) |
| Stormwater lines (HDC) | Stormwater pipes and open drains (line data) |
| Stormwater points (HDC) | Stormwater catchpits, inlets and manholes (point data) |
| Stopbanks (HDC) | HDC-managed stopbanks at Whakatiwai and Taramaire Streams (line data) |
| Surface water takes (WRC) | Approximate location (and use) of active consented surface water takes (point data) |
| Groundwater takes (WRC) | Approximate location (and use) of active consented groundwater takes (point data) |

Although it is recognised that the majority of properties use rainwater tanks for water supply (particularly in residential areas), surface and groundwater takes have been included due to their susceptibility to flooding events, particularly coastal inundation (due to salinity), and as they often supply water for agricultural uses.

Additional data that could be assessed within this category includes power and communications data, however it was too difficult to source and gain permission to use this data within the timeframes of the project. Additionally, fragility information on these asset types is limited.

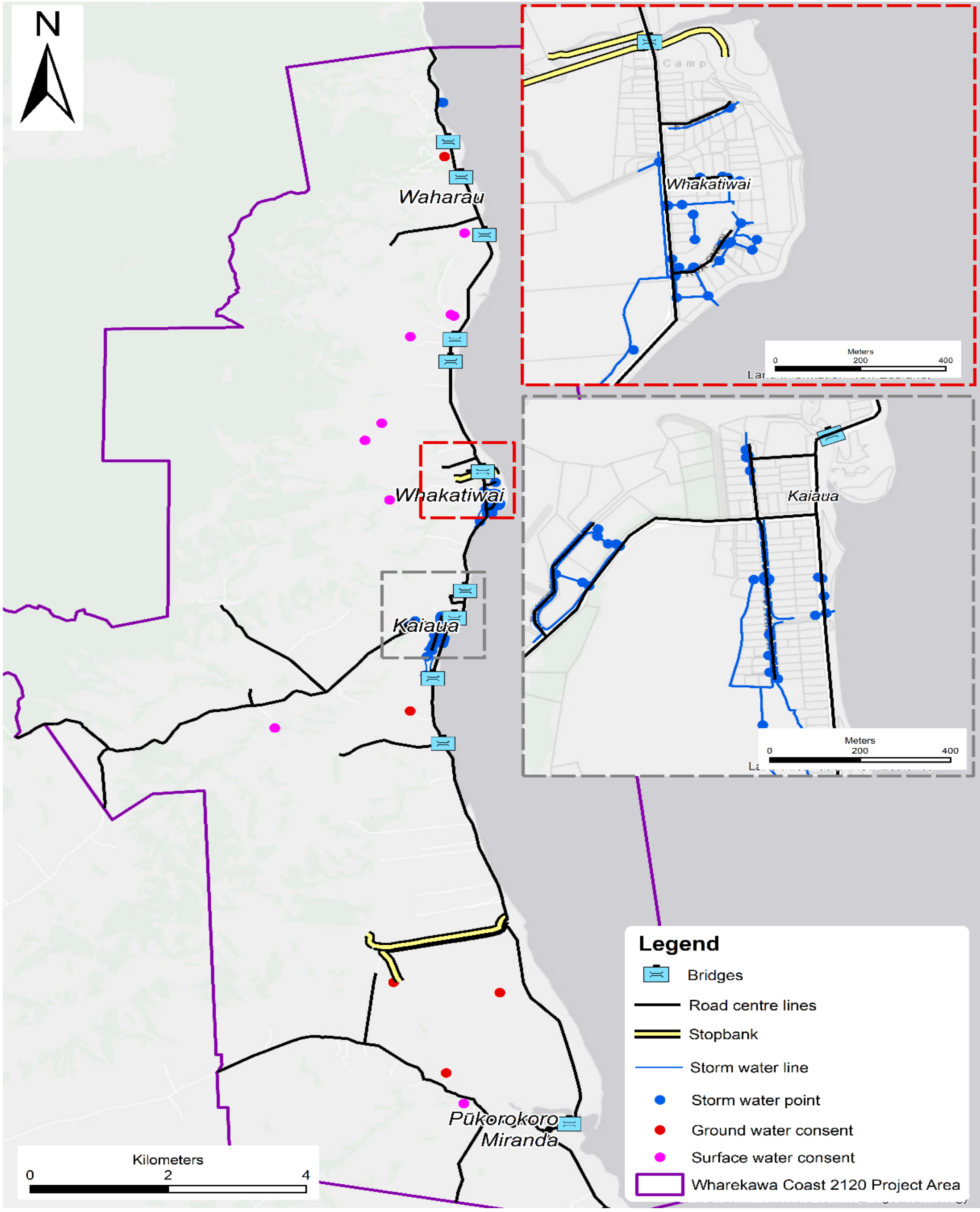



**Figure 9 Lifelines data for the Wharekawa Coast 2120 project area**

## 3.3.3 Services, recreation and tourism

The data within this category comprises point and line data which represent a variety of elements that contribute to services, recreation or tourism within the project area (Figure 10). Some of these features are buildings, thus are also assessed in the Buildings and Properties impact category. However, they are included here as their value to the community is often more than that of a typical building. Table 5 expands on the elements that are included in each data set.

**Table 5 Description of services, recreation and tourism data**

| Data name (and source) | Data description |
|---|---|
| Community points – services (HDC – edited) | Sub-set of community points. Includes G.A.S station, pink shop, public toilets, dump station, medical centre, Kaiaua School, fire station, etc. (point data) |
| Community points – recreation and tourism (HDC – edited) | Sub-set of community points. Includes tourist accommodation, bowling club, playgrounds, campsites, Pūkorokoro Miranda Shorebird Centre, etc. (point data) |
| Hauraki Rail Trail (digitised from HDC plans) | The existing and proposed sections of the Hauraki Rail Trail as at May 2020 (line data) |
| Rail Trail features (digitised from HDC plans) | Proposed public toilets and overnight camping area associated with the rail trail as at May 2020 (point data) |
| DOC public conservation areas (HDC – edited) | Miranda Stream Conservation Area, East Coast Road Scenic Reserve and Miranda Taramaire Wildlife Management Reserve |

The community points data is a compilation of three data sets from HDC (Points of interest, Community points and Asset areas) with the data edited as required, to remove duplications, classify points as either a service or a recreation and tourism element, and create a separate dataset for bridges (in Lifelines impact category). For the exposure analysis, the DOC public conservation areas data has been edited to remove areas that are seaward of the mean high water coastline (LINZ NZ Coastlines and Islands Polygons (Topo 1:50k), 2019).

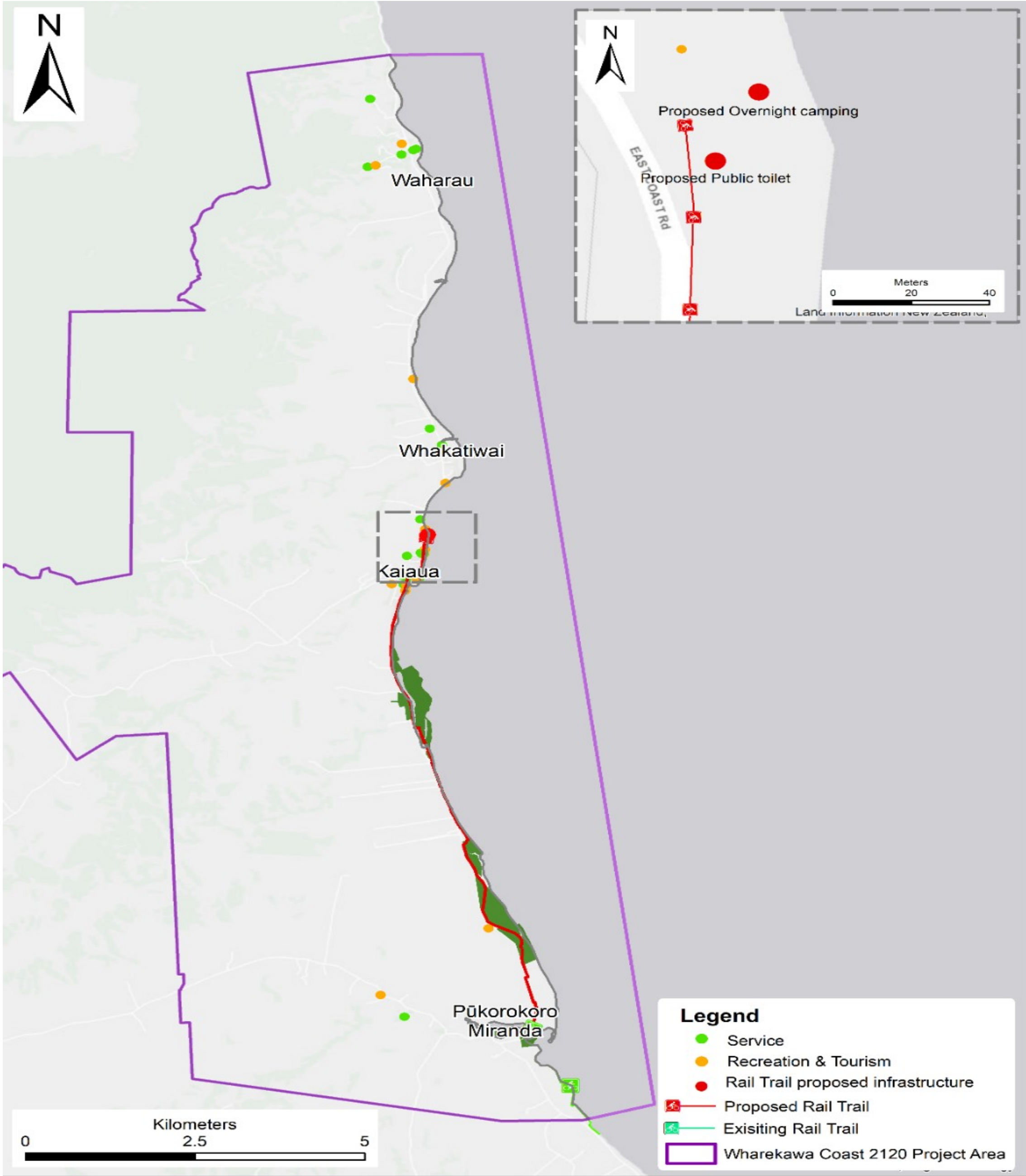



**Figure 10  Services, recreation and tourism data for the Wharekawa Coast 2120 project area**

### 3.3.4 Cultural

The data within this category comprises point data (sourced from HDC) which represents known elements of cultural significance to Māori, with a few sites with significance to the wider population (Figure 11). These are marae, pā sites and archaeological sites. Approximately 95% of archaeological sites are of Māori origin, including *Ūrupa*, middens and pa sites, with the remaining sites comprising historical house and building sites and the Guy C Goss and HMNZS HINAU shipwrecks. This category also includes polygon data which represents Māori-owned land blocks. This data was sourced from HDC, but was validated using information provided by the community panel (John Waata via Justin Johnstone, personal communication, 19/06/20).

It is recognised that there are likely to be elements of value that are not mapped or identified, so this information provides an indication of the elements affected, but cannot be considered a comprehensive assessment.

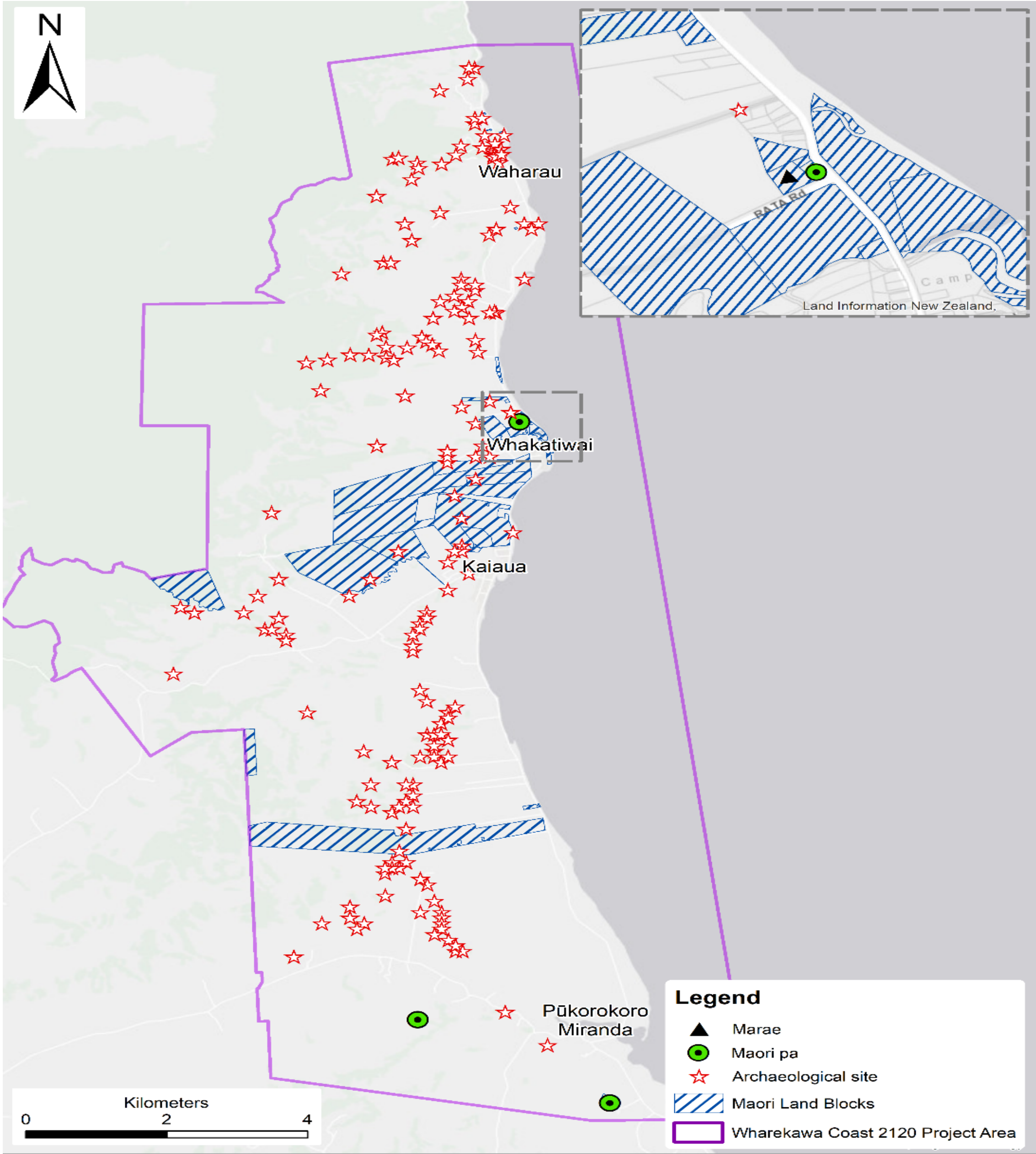



**Figure 11** **Cultural data for the Wharekawa Coast 2120 project area**

### 3.3.5 Ecological

The data within this category comprises polygon data (sourced from HDC and DOC) which represents land with key ecological value (Figure 12). Table 6 expands on the elements that are included in each data set.

**Table 6** **Description of ecological data**

| **Data name (and source)** | **Data description** (all polygon data) |
|---|---|
| Pūkorokoro Miranda wetland (Ramsar site) (DOC, supplied 2020 - edited) | The site is a wetland of international significance. The Chenier plain (shell banks) between Miranda and Kaiaua is a unique landform that is rare globally. These shell banks, as well as grass flats, are used as high tide roosts by many birds. |
| Regional Parks (HDC) | Waharau and Whakatiwai Regional Parks |
| Native vegetation (HDC) | Land covered by native bush |

The Pūkorokoro Miranda wetland data has been edited to only include the area inside the Wharekawa Coast 2120 project area; for the exposure analysis, it was edited to remove areas that are seaward of the mean high water coastline (LINZ NZ Coastlines and Islands Polygons (Topo 1:50k), 2019).

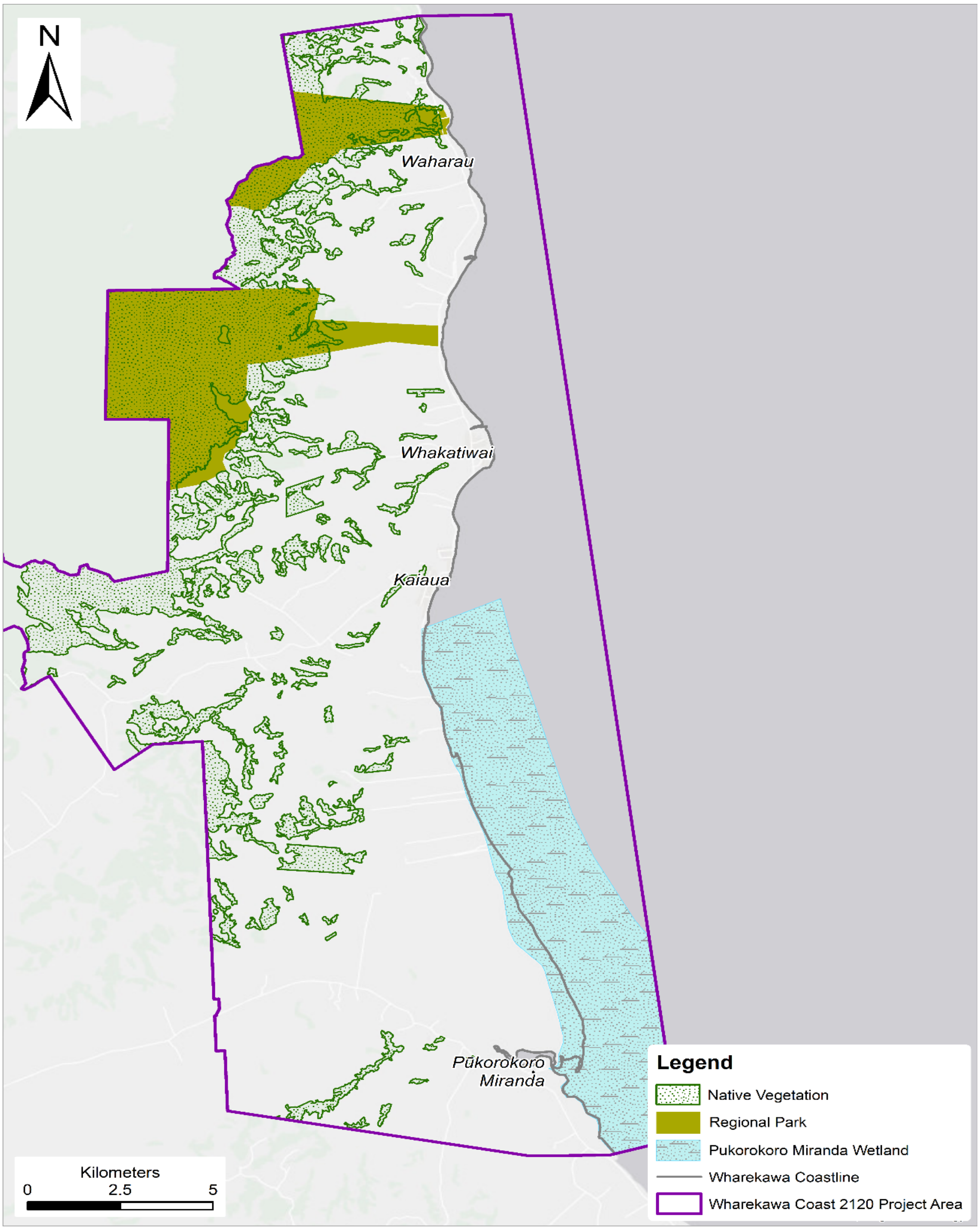



**Figure 12 Ecological data for the Wharekawa Coast 2120 project area**

Further information on ecological values that are not explicitly represented by spatial data is provided in section **Error! Reference source not found.**.

### 3.3.6 Community Values

This information comprises point data that was digitised from the outputs of the community workshop on 30 November 2019. It was then refined to only include points that referred to elements that are valued, i.e. the answers to the question, "what do you love/value" and to remove double ups and Miranda Hot Springs (outside project area) (Figure 13). Additionally, valued elements that do not have a specific location have not been included; these are:

- The bird life and bird roosts at high tide
- Sea life/fishing
- Areas where vehicles are restricted from the beach
- Kaimoana
- The whole area, coastline and the coastal road

- Relaxed beach atmosphere
- Community looking after community
- Getting the basics (service station, pub and boating)

Analysis of the data confirmed that most of the valued elements (with a specific location) are already represented by the data in the above categories. Because of this the community value results will not be presented separately, instead valued elements will be highlighted when presenting the results of each impact category.


**Figure 13** **Community values data for the Wharekawa Coast 2120 project area**

## 3.4 Historical event information

Information has been collated on the impacts of the following historical natural hazard events, which represent the most recent significant events for the project area:

1. January 2018 storm tide event
2. March 2017 flood event (Tasman Tempest)
3. April 2017 flood event (Ex-Tropical Cyclone Debbie)

Information was collated from the following sources:

1. Regional event summary: Storm surge event, 4-6 January 2018, Waikato Regional Council Internal Series 2018/25 (Craig & O'Shaughnessy, 2018)
2. Regional flood summary: Rainfall event 7 to 12 March 2017, Waikato Regional Council Technical Report 2017/21 (Craig, 2017)
3. Regional flood summary: Ex-Tropical Cyclone Debbie (4-6 April), Tasman Low (11-13), and Ex-Tropical Cyclone Cook (13-14 April), Waikato Regional Council Technical Report 2017/20 (Craig, et al., 2017)
4. HDC staff (data and information on asset repair cost, etc.)
5. The community – information was received via a Google Forms questionnaire (Appendix 2) that was sent to Panel members, emails and from conversations with community members.

## 3.5 Qualitative risk assessment – coastal erosion and freshwater flooding

A qualitative risk assessment uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur (Quality Planning, 2017).

Qualitative risk assessments are generally less detailed than quantitative risk assessments. As stated in section 3.2, they are considered appropriate to use for coastal erosion and freshwater flooding (excluding Hauarahi stream) due to the lower hazard, lack of detailed hazard information and uncertainty associated with that information.

### 3.5.1 Coastal erosion

A qualitative risk assessment was undertaken for each of the 5 coastal sub-compartments using the following information:

1. Measurements of coastal erosion, or the shoreward retreat of the shoreline, as derived from the Tonkin & Taylor (2010b) historical rates (1944 to 2002) of shoreline change, where the shoreline was mapped as the edge of vegetation;
2. Google Earth imagery;
3. Data on elements (described in section 3.3); and
4. Knowledge from previous site visits by coastal science experts.

The results of this assessment are provided in Table 9 (section 5.1), with the 5 columns in the table describing:

1. The 5 coastal sub-compartments.
2. Current coastal erosion/shoreline retreat, which is the average rate of coastal erosion in each sub-compartment based on Tonkin & Taylor (2010b). An assumption made is that the historical average rate for 1944 to 2002 is a measure of the existing (short term) rate.
3. Long term coastal erosion/shoreline retreat, which is an estimate of the relative degree of erosion/shoreline retreat in the long term due to changes in coastal processes (e.g., higher sea levels, storm tides, wave climate, sediment supply) caused by climate change and sea level rise. This is primarily driven by coastal inundation rather than coastal erosion.
4. Qualitative risk to elements potentially exposed to the current erosion rate.

5. Qualitative risk to elements potentially exposed to coastal erosion/shoreline retreat in the long term.

Appendix 3 provides further background and considerations for the approach taken for this qualitative risk assessment. It also summarises the previous work on coastal erosion risk undertaken by Opus (2015), and briefly details why a different approach was taken here.

### 3.5.2 Freshwater flooding (excluding Hauarahi Stream)

A qualitative risk assessment was undertaken for 5 streams in the project area. These streams were selected for the following reasons:

1. They are in more populated locations, increasing the risk;
2. a larger number of historical events with impacts have been documented; and
3. each of these streams (except for Waharau) have stopbanks which provide a level of protection, but also have the potential for failure or overtopping.

The risk assessment was carried out using hazard and historical impact information from the Wider River Flood Assessment Report, data on elements (described in section 3.3) and expert knowledge.

The results of this assessment are provided in Table 10 (section 5.2), with the 4 columns in the table describing:

1. The streams and the sub-compartment they are located in
2. Flood hazard information for each stream, including historical event impact information
3. Qualitative risk to elements potentially exposed during events that do not exceed the design of the stopbanks
4. Qualitative risk to elements potentially exposed during events that overtop or breach the stopbanks

Note that Hauarahi Stream is not included as the flood risk from Hauarahi Stream has been assessed quantitatively. Also, there are several additional small streams/drains in the project area that are not assessed here but are identified in the Wider River Flood Assessment.

## 3.6 Quantitative risk assessment – Coastal inundation and Hauarahi Stream flooding

The data available for coastal inundation and Hauarahi Stream flooding is suitably accurate to be used in a quantitative risk assessment, which provides more detailed results than those from a qualitative risk assessment.

A quantitative risk assessment uses numerical values for both consequences and likelihood using data from a variety of sources (Quality Planning, 2017). The quality of the analysis depends on the accuracy and completeness of the numerical values and the validity of the models used.

This assessment will focus on quantifying the consequences (i.e. the impacts) of natural hazard event scenarios that are known to have a given likelihood of occurring (on average) in any one year, i.e. a deterministic risk assessment. The results can then be used to determine at what frequency these impacts may become intolerable.

A combination of RiskScape Core Engine v.0.7.1 and ArcGIS have been used for this assessment.

### 3.6.1 Exposure

Exposure to the hazard is measured by the extent and the depth of flooding (note that for sections 3.6.1 and 3.6.2, ‘flooding’ and ‘flood depth’ generally refer to both coastal inundation and Hauarahi Stream flooding). Data representing elements have been overlaid with flood depth data from coastal inundation and Hauarahi Stream flood modelling to determine whether each element is exposed (or not), and the *degree of exposure* of each element. The degree of exposure is defined by the depth of flooding, i.e. <0.5m, 0.5-1m, 1-2m, >2m.

It is important to note that exposure simply measures whether flooding is present (and to what depth) at each element. It does not measure the loss or cost associated with this exposure (this is assessed for certain elements, as described in Section **Error! Reference source not found.**).

### 3.6.2 Estimated damage costs and resident displacement

Damage costs have been estimated for three elements; buildings, roads (excludes bridges) and rural pasture land. These elements have been chosen as they are the elements likely to have some of the largest direct damage costs associated, and they also have the most readily available information on fragility (physical vulnerability) and value/replacement cost. In addition, *resident displacement days* (the average time that residents are unable to live in their homes while clean up and repairs are undertaken) and the number of residents displaced has been estimated to provide an indication of the level of disruption to households. The methods used to calculate damage costs and resident displacement is summarised in **Error! Reference source not found.** (and expanded on in the sections below). RiskScape was used for buildings, resident displacement and roads. ArcGIS was used for rural pasture land.

**Table 7 Summary of method to calculate damage costs and resident displacement (* means 'multiplied by')**

| Element | Exposure method | Loss method | Fragility function | Cost/*displacement* method |
|---|---|---|---|---|
| Building footprints | Flood depth at centre point of building | Exposure result * fragility function | Reese & Ramsay, 2010 | Loss result * property improvement value |
| *Resident displacement days* | - | - | *Reese & Ramsay, 2010* | *Building footprints loss result * fragility function* |
| *Residents displaced* | - | - | - | *Displacement result (where displacement days > 0 only) * average household size (2.3 people)* |
| Road centre lines | Flood depth at each flood model grid cell ($2m^2$) | Exposure result * fragility function | Green et al., 2011 | Loss result * roading depreciated replacement cost |
| Rural pasture land | Area of land exposed to flooding | River: Exposure result * 0<br><br>Coastal: Exposure result * 0.66 | Factors derived from Jan 2018 event data and NZ-specific info | Loss result * pasture establishment cost |

Human casualties are not assessed as they are assumed to be zero, as warning time for coastal inundation and river flooding events is generally sufficient to allow for evacuation when required, and these hazards are less likely to result in casualties (than for example tsunami or earthquakes). In addition, there is always significant uncertainty associated with estimating these losses.

Building contents replacement and clean-up cost and resident displacement cost have also not been estimated due to a lack of area-specific information and the significant uncertainty associated with estimating these losses.

#### 3.6.2.1 Fragility functions

Fragility functions can be considered to represent the physical vulnerability of an element (additional elements of vulnerability are considered in section 8). They have been used to estimate the losses (*damage ratio*) of certain elements for varying flood depths, and resident displacement days (as a function of damage ratio). A range of fragility functions have been considered for each element and the most appropriate function selected based on expert judgement (

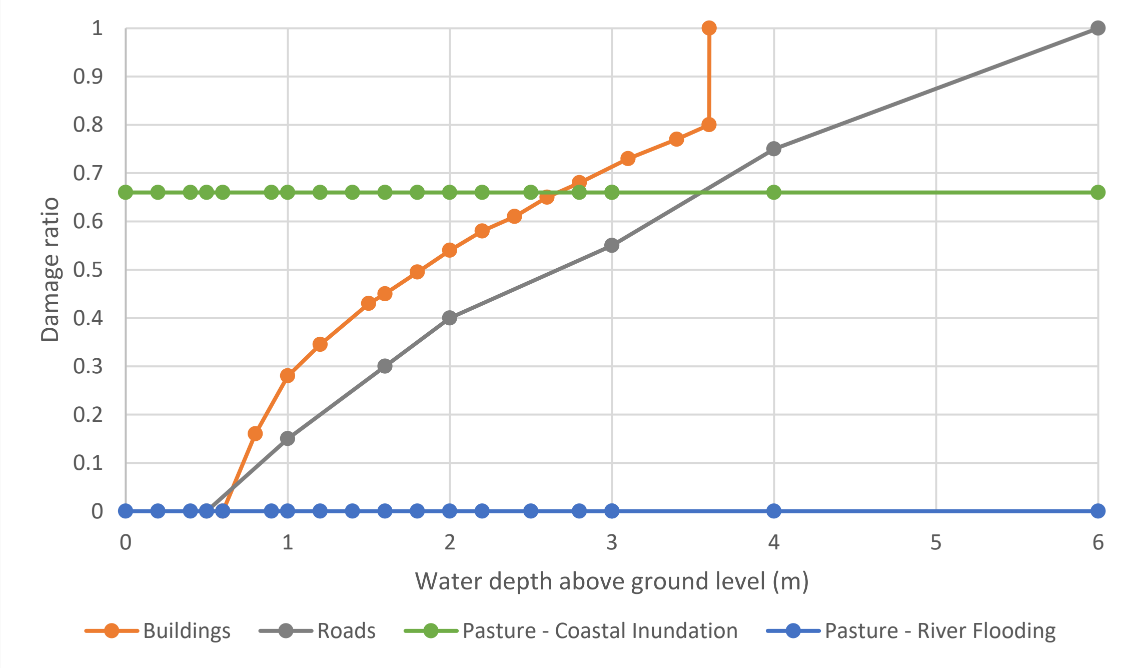



Figure 14 and Figure 15). The fragility functions considered include FEMA (2015), Green et al. (2011), Mason et al. (2012), Prahl et al. (2018) and Reese & Ramsay (2010), as well as New Zealand-specific information and data from the January 2018 storm tide event.

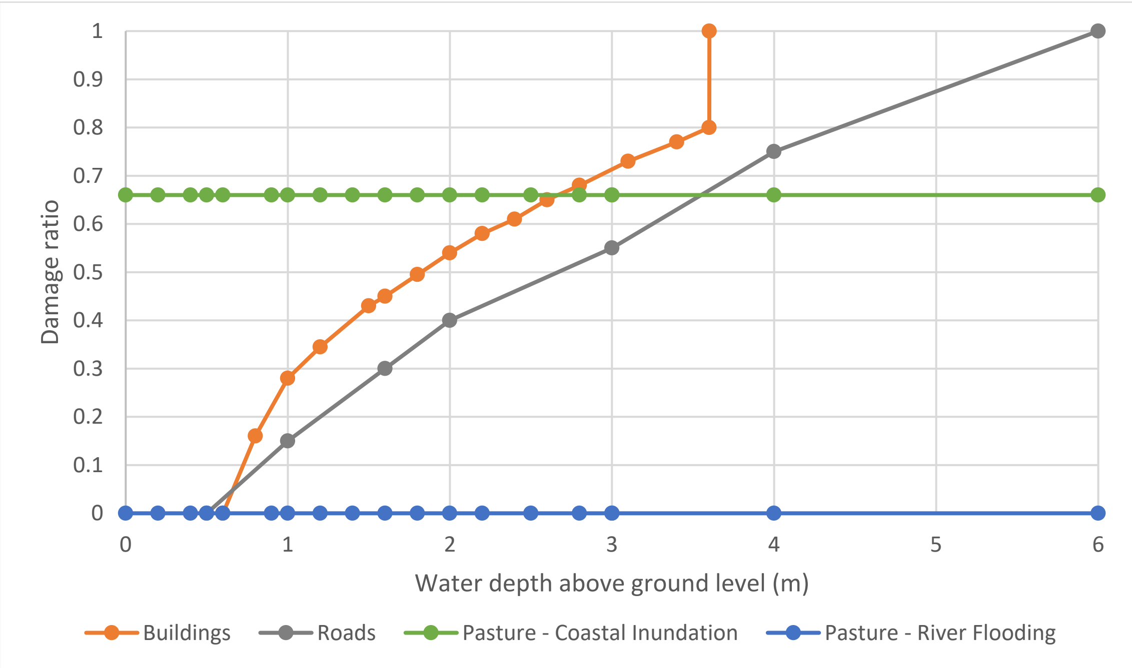



**Figure 14** **Fragility functions used to estimate losses (damage ratio) in this quantitative risk assessment (note: buildings function has been moved along the x-axis by 0.6 m to account for building floor levels – see below)**

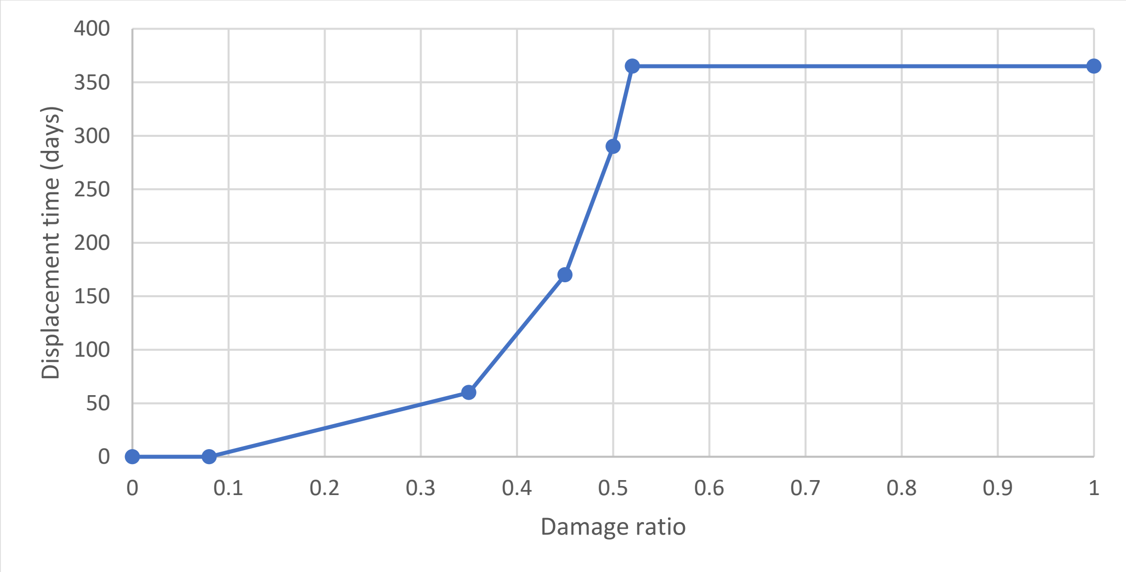



**Figure 15** **Fragility function used to estimate resident displacement days in this quantitative risk assessment**

**Buildings:**

The fragility function selected for assessing building losses is from Reese & Ramsay (2010) as these are appropriate for New Zealand building stock. Reese & Ramsay (2010) developed a suite of fragility functions for residential buildings based on construction type, number of storeys and age (as a proxy for floor type) (Figure 16). The fragility function selected to estimate the damage of buildings is "timber – one storey – 1960-80". This selection was made for the following reasons:

1. The predominant construction type in the project area is timber or fibre board, with most on piles (HDC, personal communication, 06/05/20).
2. A desktop review of coastal settlements in the project area using google street view suggests that the majority of buildings (approximately 80%) are one-storey.
3. Building permits for the project area suggests buildings have been constructed from the 1960s onwards; F Lowry Road appears to be 1980s; Mylindas Road and Rua One Place (around 1999/2001) seem to be the most recent subdivisions of any scale (HDC, personal communication, 05/05/20).
4. This fragility function is the most conservative (i.e. more likely to overestimate than underestimate losses).

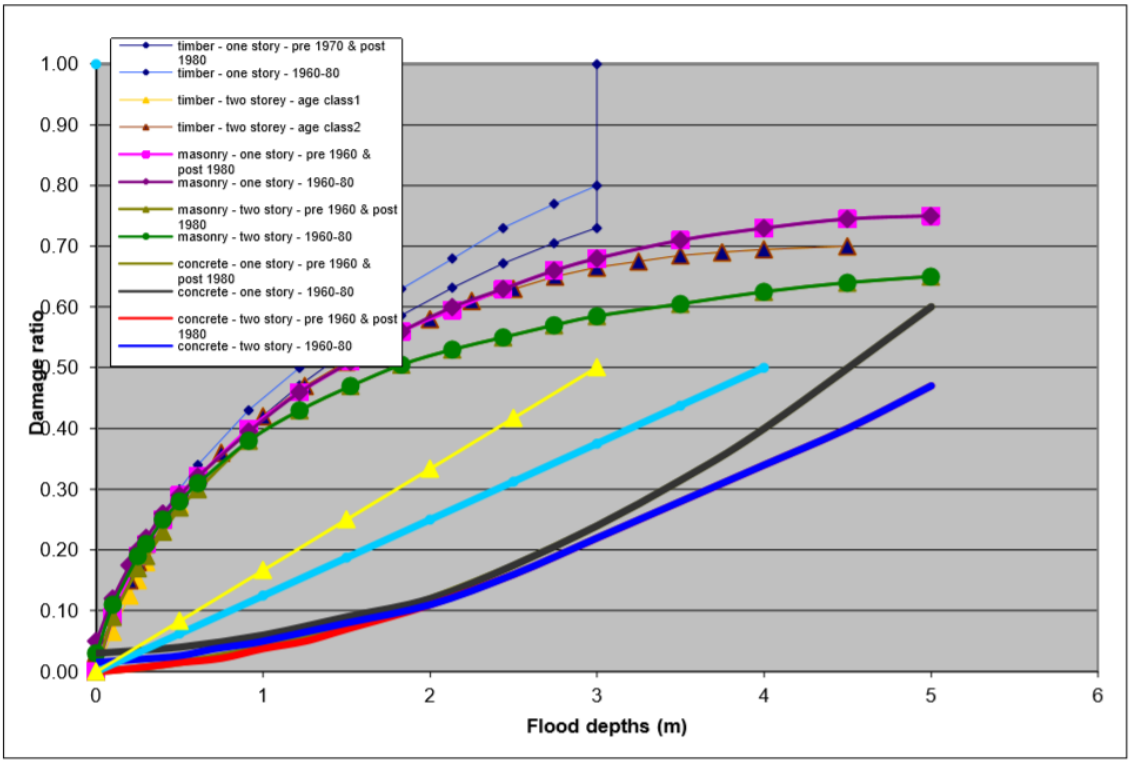



**Figure 16 Flood fragility curves for various building types, with flood depth being depth above floor level (Reese & Ramsay, 2010)**

Note that the fragility functions in Reese & Ramsay (2010) use flood depth above floor level, whereas this assessment uses the raw flood depths, i.e. above ground level (as detailed floor level information is not available for the project area). To account for this, the fragility function was moved along the x-axis by 0.6 m to represent flooding above floor level. 0.6 m was chosen as a representative floor level as:

1. the desktop review of coastal settlements suggests flood levels are approximately 0.5 m above ground on average (though it is recognised that many are lower, and some newer buildings and those raised post-January 2018 are significantly higher); and
2. Reese & Ramsay (2010) uses building age (assumed to be predominantly 1960-80) as a proxy for floor height above ground. The typical floor height for a building constructed in 1960-80 is 0.63 m (Reese & Ramsay, 2010).

This fragility function has been used for all buildings, regardless of land use type for the following reasons:

1. Commercial buildings such as offices, schools, etc., normally have a similar structure and use similar materials to residential buildings (Reese & Ramsay, 2010). This is backed up by observations of typical commercial (business and recreation land use types) buildings in the project area.
2. For rural properties, there are often multiple sheds and barns as well as the main dwelling. However, as there is no way to accurately split the property improvement value across the different buildings, damage has been assessed at the main dwelling only (assumed to hold most of the value). Additionally, the fragility function for residential and industrial buildings is reasonably similar (the largest difference in damage ratio at any given depth is ~0.15) (Mason, et al., 2012) (Reese & Ramsay, 2010).

**Roads:**

There is less available information on road damage fragility functions. The fragility function selected for assessing roading losses is from Green et al. (2012) (excludes bridges), which is deemed to be the most appropriate. The Hauraki District Council roading manager has reviewed this fragility function and confirmed its applicability to the project area (Hauraki District Council, personal communication, 25/06/20).

It should be noted that this fragility function is based on flood depth, whereas in reality most structural damage occurs as  result of high flow velocities or wave activity, and depends on the shoulder/embankment material and geometry (Reese & Ramsay, 2010). However, much of this data is not available and an assessment to this level of detail is outside the scope of this report.

**Rural pasture land:**

There are a limited number of fragility functions for agriculture, but none that are specific to New Zealand. Fragility functions that are available from overseas often do not document whether they are for fresh or saltwater flooding, or whether they are for crops (and which type) or pasture (major factors in determining damage). For these reasons, instead of using an overseas fragility function it was decided to use New Zealand-specific information for river flooding and real data from the January 2018 storm tide event for coastal inundation.

For this assessment permanent damage to rural pasture land from Hauarahi Stream flooding is assumed to be zero, for the following reasons:

1. Following the Taranaki and Horizons regions storm in 2015 (freshwater flooding), most of the pasture on inundated farms remained alive as the water receded within six days. Where pasture needed to be re-established, this was often as a result of silt deposition (Ministry for Primary Industries, 2015).
2. Dairy NZ states that in cold weather pasture can survive for 10-12 days in clean water and 4-10 days in silted water (Dairy NZ, n.d.).
3. Flood waters from the Hauarahi Stream are expected to drain relatively quickly (the majority within 4 days), and are not expected to deposit large volumes of silt (according to modelling and historical event knowledge).

Thus, any pasture renewal required is expected to be minimal, though it is recognised that growth may be restricted in the short to medium term.

For coastal inundation, damage to pasture is often extensive due to the drying out of pasture from the salt content of seawater. Research conducted by WRC soil scientists following the January 2018 storm tide event showed that ryegrass pasture was killed after flooding for 36 hours, but was able to survive for flooding of 24 hours or less. The research also showed that due to the soil types in the area, salt water infiltration was poor (impact only seen in top 2 cm of soils), and that salt content in that top 2 cm reduced significantly following the first rainfall (35 mm) post-event (Taylor & Kruger, 2018).

Following the 2018 event, aerial imagery was flown which captured the extent of the dead pasture. This extent was digitised and can be viewed in the Waikato Regional Hazards Portal (Portal) – coastal hazards tab – "apparent inundation extent of Jan 2018 storm". During the 2018 event, sea level at the Tararu tide gauge in the Firth of Thames was recorded at a maximum of 2.98 m (MVD-53) (Hume, 2020). Thus, the 3.0 m (MVD-53) coastal inundation layer (available in the coastal inundation tab of the Portal) is considered a good representation of the inundation that occurred in the 2018 event. This data enables the comparison of the area inundated with the area of dead pasture that resulted (calculated from the southern project area boundary to just south of Kaiaua township), producing a factor of 0.66. Due to the low-lying and flat nature of the inundated areas, it is considered this factor is appropriate to use for both the moderate and major coastal inundation event scenarios.

#### 3.6.2.2 Damage cost information

**Buildings:**

Building damage cost has been estimated using property improvement value, which is derived by subtracting the Land Value from the Capital Value. Property improvement value is not (and is likely to be lower than) the replacement cost of buildings and services on a property, but it is the best readily available information on the value of buildings in the project area.

HDC, like the majority of territorial authorities, use Quotable Value NZ to do their valuations (HDC, personal communication, 12/05/20). Rating valuations are usually carried out once every three years and are based on the likely selling price (market value) of a property (excluding chattels such as carpets, drapes, light fittings and other removable items) at the time of the valuation (Quotable Value, n.d.). Rating values are unlikely to pick up structures/improvements that have not required a building consent.

To assess the relevance of using valuation data, the Capital Value of properties were compared to the asking price for fifteen recently sold or currently for sale properties (comparison on 29/05/20). Although the Capital Value was on average 10% lower than the asking price, this is considered to be within an acceptable level of uncertainty, particularly given the difference between asking and selling price, and that it is generally the land that is increasing in value rather than the house.

Note that for this assessment, the loss and cost of buildings has only been assessed for the main dwelling (or largest building footprint) on the property (generally assumed to represent most of the property improvement value). This is a limitation, particularly for rural properties where buildings that contribute to the property improvement value (some significantly, e.g. milking sheds) are spread out and exposed to different flood depths.

**Roads:**
Roading damage cost has been estimated using the average depreciated replacement cost of $313,000 per kilometre (km) (excludes bridges). This value has been calculated for the roads in the project area by HDC roading manager, Lukas De Haast (HDC, personal communication, 06/07/2020), based on information from the HDC valuation of roading assets as at 01 July 2019 (WSP, 2020).

The depreciated replacement cost is the cost to replace the roads at their current value (rather than as new). This value therefore provides an estimate of the damage cost (or value lost), rather than the cost to repair or replace the roads to an 'as new' standard.

**Rural pasture land:**
For this assessment, only direct damage costs are estimated, which is interpreted to be the cost to re-establish pasture that has died as a result of flooding (pasture establishment cost). However, it is noted that other costs will result, including from loss of production, additional feed requirements, relocation of or reducing stock numbers and damage to equipment.

Pasture establishment cost information has been sourced from Ravensdown and MPI. Ravensdown Principal Consultants who were involved in recovery following the January 2018 storm tide event provided the following estimate of pasture re-establishment cost (though also noted that individual farm situations will differ, and additional estimated costs of up to $305/hectare (ha) may be incurred for spraying and cultivation) (Adrian Brocksopp & Tim Russell, personal communication, 17/06/20):

| | | |
|---|---|---|
| *Drilling cost $145 / ha* | | *$145* |
| *Seed cost 20kg/ha @ $15ha* | *$300* | |
| *DAP applied at drill 200kg/ha @ 820/t* | | *$164* |
| *Nitrogen at 8 wks at 65kg/ha N protect at $650/t* | *$42* | |
| *Spreading at $10/ha* | *$10* | |
| ***Total*** | | ***$661/ha*** |

For the Taranaki and Horizons Regions storm in 2015, MPI (2015) estimated a total pasture renewal cost of $900,000 for 1100 ha of pasture that required renewal, i.e. an average of $818/ha. This is higher than the Ravensdown estimate, which could be due to any number of reasons including differences in pasture quality, or differences in contractor and seed costs.

The pasture establishment cost used for this assessment is the Ravensdown estimate as it was provided specifically for this risk assessment, but rounded up to $700/ha to provide some allowance for additional spraying and cultivation costs.

## 3.7 Additional information on potential impacts

This section provides additional information on the potential impacts of coastal inundation and river flooding. This is information that is not explicitly covered by the results of the quantitative risk assessment, but adds value to these results. It is derived from a number of sources, including historical event information (sources detailed in Section 3.4), technical experts, staff members and community members. Additionally, relevant information has been collated from two Wharekawa Coast 2120 reports:

1. Natural Hazards Social Impact Assessment for Wharekawa
2. Ecological Values Impact Assessment

## 3.8 Vulnerability

This section provides a qualitative assessment of the capacity of the community to effectively cope and adapt to natural hazard events, based on characteristics of the community and project area. Note that physical vulnerability, also known as fragility, is assessed separately for buildings, roads and rural pasture land (section 3.6.2.1).

Information on characteristics of the community and project area that may affect vulnerability was collated from the following Wharekawa Coast 2120 project reports:

1. Community Overview
2. Economic Profile
3. Natural Hazards Social Impact Assessment for Wharekawa

These characteristics were summarised, and factors that may influence vulnerability as a result of each characteristic were identified. This was carried out for the project area as a whole (rather than for the constituent communities) as most factors affect the entire project area equally (or information is only available at the project area scale). However, some factors affect some areas more than others, and these have been identified and expanded on.

The approach used to assess vulnerability is potentially not as detailed as that recommended in the MfE Guidance, partly due to the small size of the project area (covered by just one NZ Census Statistical Area (SA2)). Vulnerability does not appear to vary significantly along the Wharekawa Coast, therefore it is not as useful as an input for ranking or prioritising areas, as suggested in the Guidance. Rather, it is more useful as an input to be considered when determining thresholds (as is also suggested in the Guidance) – the approach taken is considered to be of sufficient detail for this purpose.

## 3.9 Process to determine risk thresholds

This report defines community risk thresholds as the point at which the community can no longer tolerate the impacts of a natural hazard event. This point is defined by frequency, i.e. how often can a given set of impacts occur before they are no longer tolerable.

Adaptation actions or pathways should be implemented prior to a community risk threshold being reached, to reduce the risk to an acceptable or tolerable level. To achieve this, we need to be able to assess what the thresholds are, and have an idea of when they might be reached. This section describes how this was achieved for Wharekawa Coast 2120 and how the results will be used for the next steps of the project.

### 3.9.1 Risk thresholds for stakeholders with level of service responsibilities

Thresholds for most impact categories and elements have been determined by the Panel (section 3.9.2). However, there are several stakeholders with level of service responsibilities in the project area, including HDC asset managers, New Zealand Transport Agency (NZTA), utility providers (power and communications), Civil Defence Emergency Management (CDEM) and emergency services. Thus, these stakeholders have informed thresholds for elements and services that they are responsible for servicing or providing.

To achieve this, two workshops were held. The workshop attendees, process and outcomes are detailed in Appendix 4.

### 3.9.2 Community risk thresholds

The method to assess community risk thresholds initially proposed to the Panel by the project technical advisory group was similar to that used for the main stakeholder risk threshold workshop. Except that the exercise would be completed by the Panel members individually and then together as a Panel for all the sub-compartments and the relevant impact categories.
However, feedback from the Panel highlighted two key concerns:

1. The Panel members did not feel comfortable assessing thresholds for sub-compartments where they do not live; and
2. The Panel members did not feel comfortable assessing thresholds on behalf of the community.

The Panel instead suggested that the exercise be completed by the wider community. Due to limitations on large gatherings because of Covid-19, the Panel members volunteered to each lead the exercise in the sub-compartment where they live. They visited members of the community in their sub-compartment with community risk threshold booklets to be filled out, explained the exercise and answered any questions, and then collected the booklets at the end to provide to the project team.

The community risk threshold booklets were individual to each sub-compartment and included:

1. an overview of Wharekawa Coast 2120 and the community risk thresholds exercise
2. instructions to complete the exercise
3. qualitative and quantitative impact information (from the risk assessment) for each of the impact categories, and information from the stakeholder risk thresholds workshops
4. tables to mark their thresholds and space to write any comments

The community risk threshold booklets can be viewed under Resources on the Wharekawa Coast 2120 website.

The results were collated and analysed and presented back to the Panel for feedback during a Panel workshop. The feedback received has been incorporated into the final Risk threshold results report, which also includes a summary of the comments received. To share the results with the wider community, posters were created for each sub-compartment and also published under Resources on the project website.

The co-designed approach led by the Panel did increase the potential for error in the results, which could be caused by community members not understanding the exercise correctly or from Panel members inadvertently influencing responses. To reduce this risk, a workshop was held with the Panel to assist with their understanding of the exercise, and Panel members were also provided with a cheat sheet with key messages.

On the positive side, this approach resulted in a great level of community engagement, and provided a much better representation across the whole community and project area than what would have been achieved with the method originally proposed.

### 3.9.3 Next steps

For coastal inundation, the risk threshold results were used to determine the rise in sea level required for the thresholds to be reached, using analysis by Stephens (2019). This then enabled the estimation of how much time is available to implement adaptation options, using the four sea level rise scenarios from the MfE Guidance (Figure 17). The estimated time available before a threshold is reached is therefore a range, with the minimum time representing the RCP8.5 H+ scenario, and the maximum time representing the RCP2.6 M scenario.

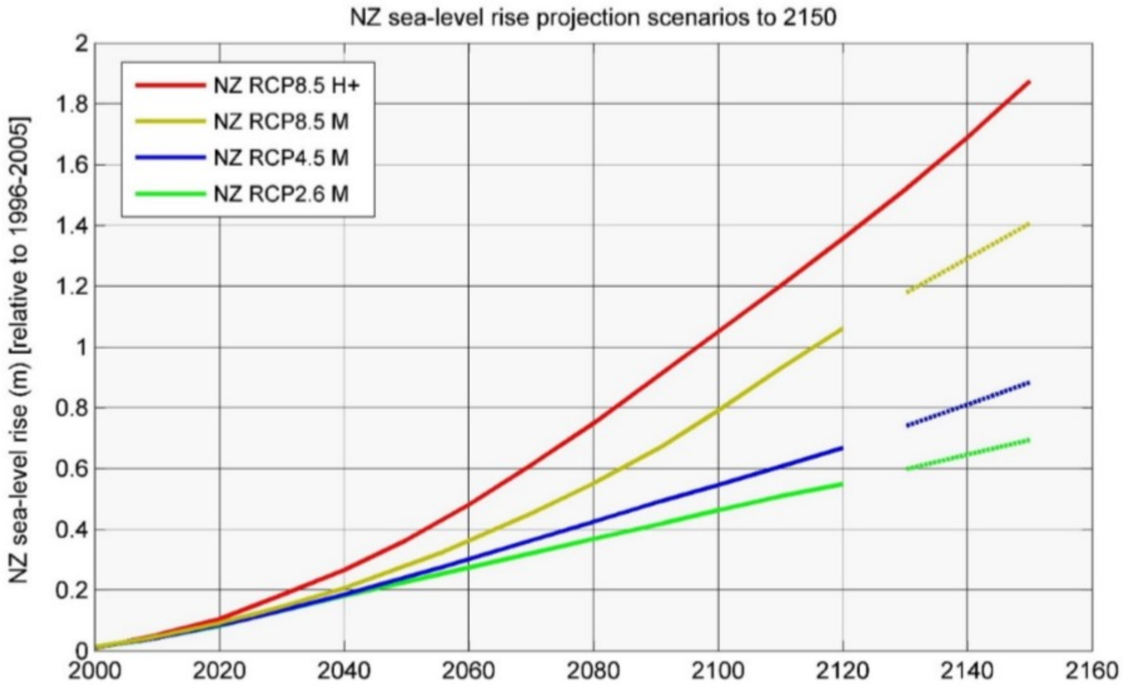



**Figure 17 Four scenarios of New Zealand-wide regional sea level rise projections for use with MfE Guidance (Ministry for the Environment, 2017)**

For Hauarahi Stream flooding, the results were reviewed to see if any thresholds are currently being reached. If so, adaptation measures will be required to reduce this risk to a tolerable or acceptable level. If not, specific river flooding adaptation options are unlikely to be required.

The above results will be used to provide additional context when investigating adaptation options and pathways, in terms of how much time is available and which sub-compartments and impact categories may need to be prioritised (Figure 18). These thresholds can then be refined (if required) following the identification and evaluation of adaptation options and pathways, and will form the basis for determining *signals* and *triggers* (used to determine when implementation of an adaptive pathway is required in order to avoid reaching a threshold).

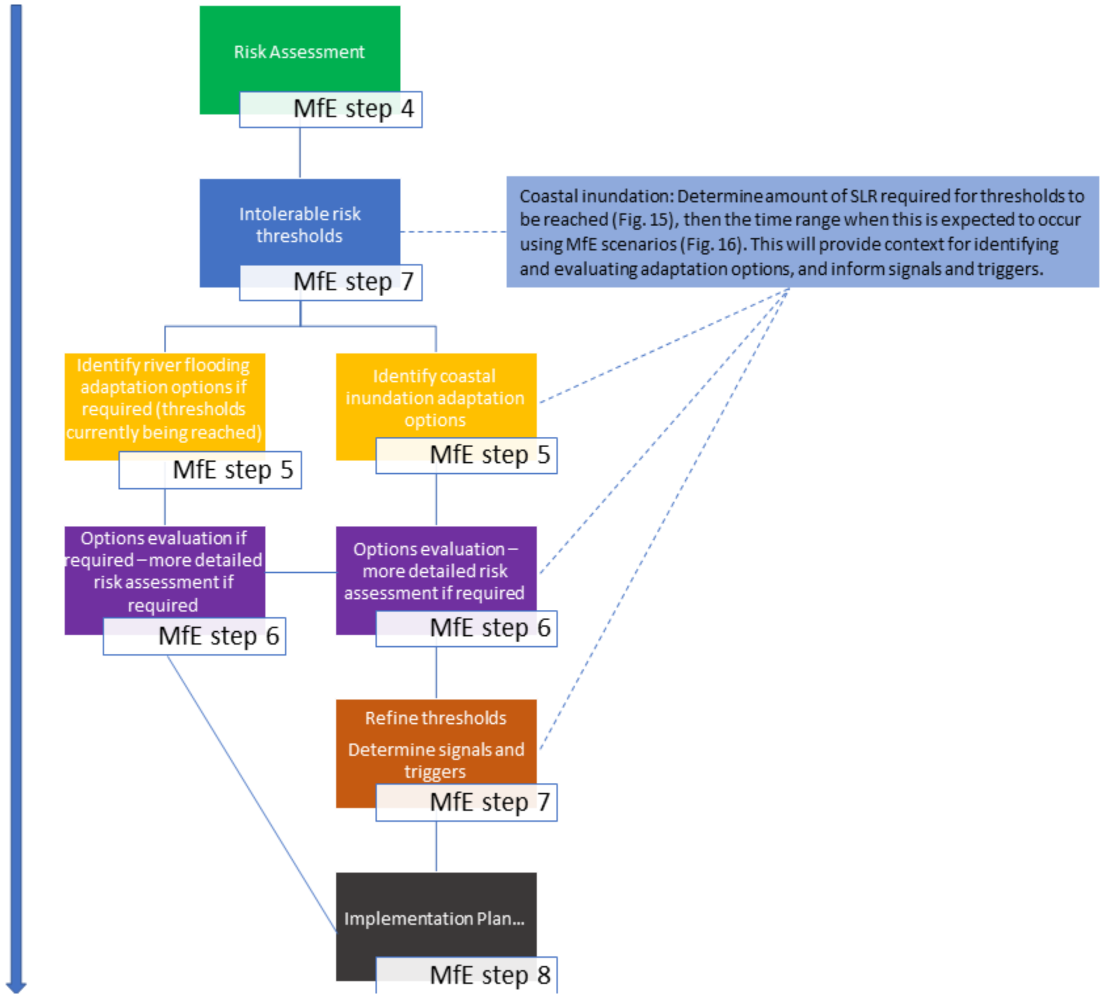



**Figure 18** **Process to use the outputs of this risk assessment for the Wharekawa Coast 2120 process, and how it relates to the MfE guidance 10-step decision cycle**

It should be noted that the order of this proposed process differs from that presented in the MfE Guidance (Figure 6), in that initial thresholds are determined prior to investigating options and pathways, and as a separate step to signals and triggers. However, it is in line with WRC's Framework, where risk is evaluated prior to determining risk treatment. This is proposed as determining thresholds first will provide context to the Panel when identifying and evaluating adaptation options, in terms of what the options are aiming to avoid, and how much time might be available to implement them. Additionally, signals and triggers (which come later) are much more technical, thus will be informed by experts, rather than the Panel.

### 3.9.4 Risk threshold considerations

It is recognised that frequency is just one determinant of tolerance, and that factors such as the time of year of an event and existing conditions (e.g. drought or waterlogged soil) will also affect tolerance. However, there are too many variables to attempt to take these factors into account.

Thresholds were determined for each impact category (with categories further refined to achieve more detail) and as a whole. This is because if a threshold is reached for a certain category before it is reached for others, it may be the case that risk can be mitigated for just that category initially. However, risk must still be considered as a whole due to cumulative impacts of more than one category being affected. For example, local businesses being closed may be more intolerable if East Coast Road is also closed for an extended period, the school being closed may be more intolerable if some homes are uninhabitable. It also made the exercise more achievable by breaking the information into manageable chunks.

It may be the case that not all intolerable risk (where a threshold is reached) will be able to be reduced to an acceptable or tolerable level, for example due to consenting, engineering or funding limitations. In this case, prioritisation of the most severe risks will be required.

The Panel should be aware that a possible outcome of determining an area as being exposed to intolerable risk (because a threshold has been met) is that it may be identified as a "*Primary Hazard Zone*", as set out in the WRPS (Method 13.1.2), during either the upcoming Regional Plan Review or a public plan change process. The plan review and plan change processes involve public consultation under the Resource Management Act 1991. The implications of being identified as a 'Primary Hazard Zone" is that Regional Plans assume control of structures to reduce the risk from natural hazards to an acceptable level over time. To reduce intolerable risk to an acceptable level, adaptation options including managed retreat will be considered.

# 4 Historical event risk information

Historical event information is incredibly valuable in informing risk assessments, as what has happened in the past will often happen again in the future. The Wharekawa Coast 2120 project area has experienced multiple natural hazard events, notably coastal inundation and river flooding. The knowledge gained from this lived experience will prove invaluable to the community when developing thresholds.

## 4.1 January 2018 storm tide event

On 5 January 2018 a significant storm tide event resulted in the coastal inundation of large portions of the townships of Kaiaua, Waharau and Whakatiwai and the wider Pūkorokoro/Miranda coastal area. This inundation resulted in significant impacts to the Wharekawa Coast 2120 project area, including building damage, disruption to drinking water, wastewater and power, septic tank overflows, road closures and significant damage to farmland (Craig & O'Shaughnessy, 2018). Table 8 summarises the known information on these impacts.

**Table 8 Summary of known impacts to the Wharekawa Coast 2120 project area from the January 2018 storm tide event**

| Impact Category | Impact description |
|---|---|
| **Buildings and properties** | Extensive wastewater contamination of land and buildings occurred due to septic tank overflow (HDC Information Report from 22/01/18 received via HDC, personal communication, 26/03/20)<br><br><u>Residential dwellings:</u><br>243 assessed; 162 with light (relatively superficial)/no damage; 72 with moderate (may include some structural) damage; 9 with heavy (uninhabitable) damage (Craig & O'Shaughnessy, 2018).<br><br>8 confirmed uninsured; 87 confirmed insured; remaining unknown if insured (as at 12 Jan 2018) (HDC Information Report from 22/01/18 received via HDC, personal communication, 26/03/20).<br><br>81 septic tanks were emptied/cleaned via HDC (HDC, "civildefenseseptictank" dataset, created 08/01/18).<br>Some septic tanks were not used for 3 weeks because of needing to be pumped out (Ria Brejaart, Google Form questionnaire, 19 May 2020). |

*Kaiaua township immediately after high tide on 5 Jan* (Craig & O'Shaughnessy, 2018)

*Inundation of Kaumatua flat garages (dwellings were not flooded above floor level) located at northern end of Kaiaua Primary School – inundation may have been exacerbated as a result of debris obstruction of culvert (John Waata, personal communication, 12/05/20)*

<u>Rural dwellings:</u>
26 assessed; 22 with light/no damage; 0 with moderate damage; 4 with heavy damage (Craig & O'Shaughnessy, 2018).

<u>Rural pasture land:</u>
Significant impacts to agriculture are ongoing due to saltwater inundation causing pasture to become 'burnt' and die (Craig & O'Shaughnessy, 2018).

Estimated area of dead pasture is 805 ha (WRC, "previous event apparent extent" dataset, created from aerial imagery taken post-event, created 2019).

For some farms, it took 2 seasons before pasture quality returned to pre-event levels, one farm at a cost of $110,000 (local farmers via Eddie Johnson, personal communication, 08/06/20).

<table>
<tr>
<td></td>
<td><br><br>Inundation of rural land around Miranda (John Bubb, personal communication, 21/05/20) (Craig & O'Shaughnessy, 2018)<br><br>Salt burnt pasture due to coastal inundation (Craig & O'Shaughnessy, 2018)</td>
</tr>
<tr>
<td>Lifelines</td>
<td><u>Roads:</u><br>Local road closures between Kaiaua and Miranda during high tide on morning of 5 Jan (Craig & O'Shaughnessy, 2018).<br><br>Front Miranda Rd and East Coast Rd to Waharau Regional Park opened on 6 Jan; north of Waharau Regional Park restricted to priority traffic until 7 Jan, then opened to one lane (Craig & O'Shaughnessy, 2018).<br><br>Roading repair cost (includes road bridges) to date (costs are ongoing due to resource consent work) is $768,480 (HDC, personal communication, 08/05/20).</td>
</tr>
</table>

*Damage to East Coast Rd, Anarau Bay (HDC, personal communication, 07/07/20)*


*Sediment and debris on East Coast Rd, Kaiaua (photo credit: Jason Oxenham, taken from [NZ Herald article](#) from 23/12/18)*

*Underslip at northern Hauraki District boundary (initial slip occurred due to March/April 2017 rainfall events, but regressed further due to January 2018 event)* (Ngawhika, 2018)

| | |
|---|---|
| | <u>Three waters:</u><br>Drinking water supply is generally by rainwater tanks, but pumps were ruined by saltwater inundation and were out for several days (Ria Brejaart, Google Form questionnaire, 19 May 2020).<br><br>Disruption to water and wastewater in Kaiaua from 5-7 Jan (Craig & O'Shaughnessy, 2018).<br><br>Stormwater repair/clean-up costs were within existing budgets (HDC, personal communication, 18/05/20).<br><br><u>Power:</u><br>Disruption to power in Kaiaua from 5-7 Jan (Craig & O'Shaughnessy, 2018). Counties Power prioritised restoring the main feeds, followed by individual customers; 80% of power was restored within 24 to 36 hours, with 100% restored within five days (Waikato Lifeline Utilities Group Forum, personal communication, 04/09/20). |
| **Services, recreation and tourism** | Service, recreation and tourism elements were inundated, including the Pink Shop which was closed for about a week for clean-up and repairs (Lynn Harvey, personal communication, 03/08/20).<br><br>*The Pink Shop (Photo credit: Justin Johnstone)*<br><br>Bayview Hotel, Kaiaua Fisheries and the GAS station did not get flooded inside the buildings and did not need to close (Lynn Harvey, personal communication, 03/08/20).<br><br><u>Kaiaua School:</u> (Janine Archer, personal communication, 06/08/20)<br>The grounds were flooded but no water entered the buildings and there was no physical damage. Debris was deposited on the gates, fence, driveway, carpark and front grassed area, and was cleaned up by locals with a loader and by hand. The back field was flooded and bark from the playground was washed onto the grass.<br><br>The event occurred during school holidays, so no closure was required.<br><br><u>EcoQuest Education Foundation:</u> (Ria Brejaart, Google Form questionnaire, 19/05/20)<br>9 out of 13 cabins, two teaching areas, the ablutions block, sheds and storage spaces were all inundated by 0.6 m of seawater. 3 passenger vehicles, pumps and equipment were destroyed. Food gardens and ornamental trees died off as a result of saltwater inundation. |


*EcoQuest on 05/01/18 (photo credit: Ria Brejaart)*

Recreation areas:
The beach at Whakatiwai was accessible but littered with inundated caravans which stayed “in a jumble for months”; eventually some were taken away and others dried out (Ria Brejaart, Google Form questionnaire, 19 May 2020).

The beach at Waharau was accessible by foot and 4WD. The picnic area was covered in rocks and debris (Ria Brejaart, Google Form questionnaire, 19 May 2020).

*Beach at Whakatiwai on 05/01/18 (photo credit: Ria Brejaart)*

The Pirate Ship playground was intact, except that the bark needed to be replaced (completed quickly). Rocks and debris were deposited on the reserve area in Kaiaua and were not cleared for a long time – this has been an ongoing issue for maintenance as the rocks prevent the grass being mown (Lynn Harvey, personal communication, 03/08/20).

Hauraki Rail Trail:
Rail Trail closed from Thames to Miranda from 5-16 Jan. Rail Trail opened to Miranda Holiday Park on 16 Jan, except for 2 km section to the bird hide which remained closed indefinitely due to damage (Craig & O'Shaughnessy, 2018).

Pūkorokoro Miranda Shorebird Centre: (Woodley, 2018)
Impacts included pumps being taken out, flooding of garage and storeroom, die off of trees and shrubs, a large section of boardwalk shifted 70 m (though remained intact), minor damage to bird hides, damage to trails and interpretation panels.
The majority of clean up and repairs were completed within a week. The remaining trail and boardwalk repairs were planned to be completed within a month.

| | |
|---|---|
| | 8 people, including 4 guests sheltered in place (unable to evacuate due to flooding of road).<br><br>*Pūkorokoro Miranda Shorebird Centre - the storm swept away the boardwalk to the Godwit Hide (photo credit: Chelsea Rails)* |
| **Cultural** | No known information |
| **Ecological** | Impacts to some species of birds, particularly the white-fronted tern (New Zealand threat ranking): At Risk) and black-billed gull (threat ranking: Nationally Critical), which were nesting in colonies on the outer shell spit which was completely inundated (Keith Woodley, personal communication, 13/07/20). Refer to section 7.5.1 for further information.<br><br>*Top - Birds take refuge from the storm in the car park; Bottom - Black-billed Gulls quickly return to their roost on the shellbank (photo credit: Chelsea Ralls, Ray Buckmaster)* |
| **Other** | <u>Direct welfare costs:</u><br>HDC spent ~$112,000 on direct welfare costs (not incl. staff time), incl. emptying septic tanks, providing skip bins & disposing of rubbish, providing drinking water and portaloos. $43,000 was provided to 19 families from the Disaster Relief Fund. (HDC, personal communication, 26/05/20)<br><br><u>Emergency response:</u><br>The Thames-Valley Emergency Operating Area activated an emergency operations centre (EOC) in response to impacts in the Hauraki and Thames-Coromandel Districts. The response phase continued until 9 Jan; a State of Emergency was not declared. (HDC Information Report from 22 January 2018 received via HDC, personal communication, 26/03/20) |

Additional impact information that is outside the Wharekawa Coast 2120 project area but provides useful context has been provided by NZTA (Vikus Joubert, personal communication, 02/06/20). The total cost for rebuilding the entire 43 km of SH 25 between Thames and Coromandel (typically an 8 m wide carriage way, including shoulders) which was largely washed away was $18.9 million. This equates to an average replacement cost of ~$440,000 per lineal km (or ~$55 per m$^2$). This cost includes the replacement of all roading related infrastructure, including culverts, channels, retaining structures and pavement build up. It is of a similar order of magnitude to the estimated roading damage cost outlined in section 3.6.2.2 and used in the quantitative risk assessment ($313,000 per km).

## 4.2 March 2017 rainfall event – Hauarahi Stream flooding

The Hauarahi Stream at Kaiaua has a history of significant flood events, with the most recent occurring in March 2017 (colloquially known as the Tasman Tempest) (Figure 19). The event caused a significant amount of disruption to infrastructure such as roading, power networks and water supplies. Kaiaua was isolated due to flooding on roads from the early hours of the morning until just before midday on 8 March (Craig, 2017). The flooding resulted in damage to 8 houses in the township, as well as to farmland (Craig, 2017). The Pink Shop was also flooded and was required to close for about a week for clean-up and repairs (Lynn Harvey, personal communication, 03/08/20). Minor flooding of the school grounds occurred but the buildings were not affected (Janine Archer, personal communication, 06/08/20).

HDC assisted residents with sandbagging to protect properties from flood water, and WRC staff were sent to investigate the situation (Figure 20). Some of the flooding originated from the Hauarahi Stream where the channel capacity was reduced because of mangrove growth (Craig, 2017). WRC does not currently have any channel clearance agreements in place here, although HDC recently completed some routine river management work to improve water flow and stability of the main channel.

**Figure 19 Flooding of Kaiaua township from Hauarahi Stream during March 2017 event (photo credit: Justin Johnstone)**

**Figure 20 Floodwaters and farmland damage left); mangroves encroaching Hauarahi Stream (right) on 8 March (Craig, 2017)**

## 4.3 Ex-Tropical Cyclone Debbie, April 2017

Two ex-tropical cyclones and a low pressure system, (Ex-Tropical Cyclone Debbie, Tasman low, and Ex-Tropical Cyclone Cook) made landfall in New Zealand on 4 April, 11 April, and 13 April respectively; these events followed an earlier period of intense rainfall in parts of the Waikato region during March 2017 (Craig, et al., 2017).

Ex-Tropical Cyclone Debbie caused heavy rainfall across the Waikato Region, however was relatively short-lived with heavy rainfall easing by the early hours of 6 April (Craig, et al., 2017). Despite the short-lived nature of the event, it resulted in lasting impacts for the community of Waharau which was isolated (by road) due to the closure of Waharau Bridge for safety reasons (due to floodwaters eroding bridge abutments - Figure 21) and a landslide blocking East Coast Rd to the north (Craig, et al., 2017). Prior to the bridge closure, residents were given time to self-evacuate (to avoid isolation), with many taking this option. Repairs to the bridge were estimated to take two weeks, and clearing the landslide was estimated to take up to a month (Bryant, 10/04/17).

The cost to HDC to reinstate the bridge abutment was (at least) $47,617, which includes costs for project management, flood damage inspection and bridge scour remedial works (Joel Hogan, personal communication, 02/09/20).

**Figure 21 Eroded bridge abutments at Waharau Bridge, April 2017 (photo credit: Ruwade Bryant/Fairfax NZ)**

This bridge closure had implications for emergency services to the area, with the following information provided by Tess Watts (Deputy Chief Fire Officer, Kaiaua Voluntary Rural Fire Force (KVRFF)) via Justin Johnstone (personal communication, 05/05/20):

*The KVRFF had to have a stationary emergency vehicle situated on the north side of the bridge. This was kitted out with medical supplies, a basic portable pump and basic firefighting equipment, but would not be sufficient in a large scrub or structure fire. Closure of the bridge also meant that neighbouring brigades who know the area and terrain well, such as Mangatangi and Ngatea would be unable to provide backup crews if required. The bridge closure was a risk to KVRFF and to other emergency services. In a large-scale vegetation or house fire KVRFF could not provide an effective initial attack, meaning the fire could get out of control very quickly, putting community and crew at risk. In a medical emergency it could have meant the difference between saving someone's life or not.*

*From an emergency services point of view, it is important that with one way in and out, that access via Waharau bridge is maintained at all times given access via East Coast Rd north of the bridge to Orere Point is often limited or unavailable due to slips and coastal erosion.*

Additionally, a number of enquiries were received by WRC regarding flooding and damage in the Wharekawa Coast 2120 project area, however staff were unable to attend due to other areas requiring priority (from Hauraki Zone Situation Report at 1545 hrs 05/04/17).

# 5 Qualitative risk assessment results (coastal erosion and freshwater flooding)

The risk assessments for coastal erosion and freshwater flooding use an exposure classification to qualitatively assess risk. This exposure classification is as follows:

1. Very Low: No or minimal elements are exposed to flooding
2. Low: A small proportion of elements are exposed to flooding and impacts are likely to be minimal
3. Moderate: A medium proportion of elements are exposed and impacts may be significant
4. High: A large proportion of elements are exposed and impacts may be severe

## 5.1 Coastal erosion

This assessment describes the elements potentially exposed to coastal erosion in the next 100 years, taking into account the potential effects of climate change and sea level rise on coastal processes, while understanding that there is significant uncertainty in climate change projections at long time scales (Table 9). Elements potentially exposed to coastal erosion and shoreline retreat in the long term include rural and residential property, Kaiaua School, Wharekawa Marae, roading, council reserves and boating facilities.

**Table 9** **Changes in shoreline position and qualitative assessment of elements potentially exposed to coastal erosion/shoreline retreat for each coastal sub-compartment of the Wharekawa Coast. Note: At long time scales the exposure is classified as moderate to high because there will be significant landward movement of the shoreline, albeit primarily driven by coastal inundation rather than coastal erosion.**

| | **Coastal erosion/shoreline retreat** | | **Qualitative risk assessment** | |
|---|---|---|---|---|
| **Sub-compartment** | **Current (short term)** | **Long term (to 2120)** | **At current erosion rate** | **Long term (to 2120)** |
| **Pūkorokoro Miranda (1a)**<br><br>Pūkorokoro Miranda to Kaiaua (9.5 km) | Northern 2.5 km (south of Kaiaua): Erosion (-0.4 to -2.73 m/yr).<br><br>Little or no shoreline movement in centre.<br><br>Southern 4.5km (north of Miranda): Accretion (0 to +2.5 m/yr). | Significant erosion and shoreline retreat predicted because coastal plain is low and will be inundated by sea level rise | Northern 2.5 km:<br>*Exposure: Low*<br>Potential loss of Reserve area, possible impacts on East Coast Rd and Rail Trail (continued maintenance of existing erosion structures). Possible impact on drainage structures (flood gates, culverts)<br><br>Southern 7 km of sub-compartment:<br>*Exposure: Very low*<br>No elements are exposed | *Exposure: Moderate/High*<br>Potential for significant impacts on; Reserve areas, loss of existing Chenier ridges, East Coast Road and Hauraki Rail Trail, stopbank and drainage structures, rural land, residential and rural buildings |
| **Kaiaua township (2a)**<br><br>Kaiaua (1.9 km) | Little or no shoreline movement with localised shoreline retreat occurring between 1944 and 1980. From 1980 to 2002 the shoreline has stabilised. Mostly accretion +0.39 to -0.4 m/yr with localised accretion (0.99 to 1.49 m/yr) north of the river mouth and localised erosion (-0.41 to -1.0 m/yr) south of the river mouth.<br>Shoreline movements affected by river mouth. | Some erosion but landward movement of shoreline offset by supply of sand from the river and by high ground in the central area. Where coastal plain is low it will be inundated by sea level rise. | *Exposure: Low*<br>Potential loss of reserve area (carparking), continued maintenance of erosion protection structures (some unconsented), possible impact on East Coast Road | *Exposure: High*<br>Potential for significant impact on; Reserve areas (carparking, boat ramp, moorings), East Coast Road (including culverts, bridge), residential and business buildings, stormwater assets, rural land |

| | | | | |
|---|---|---|---|---|
| **Whakatiwai (3a)**<br><br>Whakatiwai delta<br>(2.9 km) | Majority of compartment:<br>Little or no shoreline movement with localised erosion and accretion as sand banks forming delta at stream mouth shift in position.<br><br>Southern 500 m of compartment:<br>Localised accretion in the very south at shoreline promontory.<br>Accretion +0.39 to -0.4 m/yr erosion with erosion (-0.41 to -1.00 m/yr) and accretion (0.99 to 0.40 m/yr) in places. | More localised erosion in future but offset to some degree by sediment supply from the stream. Where coastal plain is low it will be inundated by sea level rise. | Majority of compartment:<br>*Exposure: Very low*<br>No elements are exposed<br><br>Southern 500 m of compartment:<br>*Exposure: Low*<br>Potential impact on East Coast Road (existing erosion protection structures) including culverts. | *Exposure: High*<br>Potential for significant impact on; East Coast Road (including bridge), stopbanks, Reserve area, residential and rural buildings, Wharekawa Marae, Kaiaua School, stormwater assets, rural land |
| **Waihihi (4a)**<br><br>Stevenson's Quarry to Whakatiwai<br>(3.2 km) | Little or no shoreline movement south of the quarry.<br>Some accretion north of quarry in vicinity stream mouths. | Shoreline retreat as coastal plain here is lower, wider and further from sediment source. Where coastal plain is low it will be inundated by sea level rise. | *Exposure: Very low*<br>No elements are exposed | *Exposure: Moderate/High*<br>Potential for significant impact on; East Coast Road, rural land, Regional Park, residential and rural buildings, business/industrial area (Quarry), man-made lakes |
| **Waharau (5a)**<br><br>Auwharewhare to Stevenson's Quarry<br>(3.3 km) | Accretion +0.39 to -0.40 m/yr erosion.<br>Some places with greater accretion (+0.99 to +0.40 m/yr). | A small amount of shoreline retreat only as sub-compartment close to sediment supply and ground level higher than in the south | *Exposure: Very low*<br>No elements are exposed | *Exposure: Moderate/High*<br>Potential for significant impact on; East Coast Road (including culverts and bridges), residential buildings |

## 5.2 Freshwater flooding

This assessment describes the flood hazard and elements potentially exposed to flooding from five key streams in the project area (Table 10). Elements potentially exposed to flooding include rural and residential property, Wharekawa Marae, EcoQuest, roading, stopbanks and floodgates.

**Table 10 Flood hazard and qualitative risk assessment for five key streams in the Wharekawa Coast 2120 project area (Note: the locations of the streams are shown in Figure 5; ECR = East Coast Road)**

<table>
<tr><th rowspan="2">Stream name and sub-compartment</th><th rowspan="2">Flood hazard</th><th colspan="2">Qualitative risk assessment</th></tr>
<tr><th>For events that do not exceed stopbank design</th><th>For events that overtop or breach stopbanks</th></tr>
<tr><td>Pūkorokoro and Miranda Streams (1a and 1b)<br><br>Pūkorokoro and Miranda Streams have been considered together as they confluence upstream of the ECR bridge.</td><td>Both streams have stopbanks owned and managed by DOC, providing some protection to nearby farmland. They are in the Living Waters Project area.<br><br>The streams drain two separate catchments; Miranda Stream drains a 1780ha catchment and Pūkorokoro Stream drains a 204ha flat rural land catchment.<br><br>Following construction of the Miranda Stream stopbanks, a build-up of mangroves and sediment in the lower reaches of Miranda Stream increased local bed levels. It is unknown if bed levels have reduced post mangrove removal.<br><br>Documented historical event information (which event is unknown) states that a storm surge event corresponding with high flows in Miranda Stream overtopped the stopbanks and ECR, inundating farmland for several days and depositing silt and debris. It was suggested that this flooding may have resulted from the increased bed levels post stopbank construction.</td><td>Exposure: Very Low/Low<br><br><u>Downstream of stopbanks:</u><br>Very little or no exposure of rural land or buildings to flooding. The height of the ECR bridge is unknown, therefore it is possible that it may be exposed to flooding and cause road closure.<br>The freshwater ecosystem and sensitive coastal environment at the mouth of the stream will be exposed.<br><br><u>Upstream of stopbanks:</u><br>Along both streams, rural land may be impacted if the flow exceeds the capacity of the stream. Farm buildings (e.g. sheds) located along Miranda Road that are close to the drains/culverts that flow into Miranda Stream may also be impacted.</td><td>Exposure: Low<br><br><u>Downstream of stopbanks:</u><br>Potential for impacts to rural land, including properties on the corner of ECR and Miranda Road, and ECR (including the bridge) which may cause road closure.<br><br><u>Upstream of stopbanks:</u><br>No additional impacts.<br><br>Any increased bed levels of Miranda Stream will result in an increased potential for stopbank overtopping.</td></tr>
</table>

| | | | |
|---|---|---|---|
| **Taramarie Stream (1a)** | Taramarie Stream is in the Taramarie Drainage District (TDD), managed by HDC. The Taramarie Stream is serviced by 5km of stopbanks and 10 flood gates which provide some flood protection to surrounding farmland.<br><br>Past confusion around ownership and maintenance responsibilities limited the effectiveness of this infrastructure. Prior to 2014, approximately 50ha of productive farmland was exposed to both freshwater flooding/ponding and coastal inundation two to three times a year. Information from the community suggests this was due to the ineffectiveness of the floodgates and high tide not allowing water to be discharged.<br><br>However, with the formal establishment of the TDD, the infrastructure is now regularly maintained by HDC, reducing the occurrence of flooding. | *Exposure: Very Low/Low*<br><br>No exposure of rural land or buildings to flooding. The height of the ECR bridge is unknown, therefore it is possible that it may be exposed to flooding and cause road closure. | *Exposure: Low*<br><br>Potential for impacts to rural land, farm buildings and ECR (including the bridge) which may cause road closure. There is also a privately owned bridge located at the upstream end of the stopbanks that may be impacted as the bridge travels over the stopbank.<br><br>The TDD floodgates may also be impacted. |
| **Whakatīwai Stream (3a and 3b)** | Whakatīwai Stream drains a large catchment of 1670ha which extends up into the Hunua Rangers.<br><br>The downstream section of the Whakatīwai Stream through the village was straightened for the construction of stopbanks following damaging flood events in the 1960s. HDC now own these stopbanks; however, there is no ratings system in place for maintenance of the stopbanks or stream management.<br><br>The 1966 and 1967 river flood events flooded a large proportion of the village with significant impacts to the majority of houses in the Whakatīwai settlement, the Whakatīwai village general store, four cabins at the campsite (now EcoQuest) and rural land including stock loss.<br><br>Since stopbank construction, Whakatiwai has not experienced any flooding from Whakatiwai Stream, only from drains and overland flow paths during heavy rainfall. | *Exposure: Low*<br><br><u>Downstream of stopbanks:</u><br>No exposure of rural land or buildings to flooding. The height of the ECR bridge is unknown, therefore it is possible that it may be exposed to flooding and cause road closure. Further erosion of the stopbanks and bridge abutments may also occur.<br><br><u>Upstream of stopbanks:</u><br>Rural land, including on Maori Land Blocks, may be impacted if the flow exceeds the capacity of the stream. Farm buildings (e.g. sheds) may also be impacted, but no residential buildings are exposed. There are several archaeological sites in the upper reaches of the stream that may be exposed. | *Exposure: High*<br><br><u>Downstream of stopbanks:</u><br>Potential for impacts to a large proportion of properties and associated infrastructure in Whakatīwai village, including EcoQuest, and ECR (including the bridge) which may cause road closure and further erosion of the stopbanks and bridge abutments. There is also potential for impacts to Wharekawa Marae, Maori Land Blocks and an archaeological site.<br><br><u>Upstream of stopbanks:</u><br>No additional impacts. |

| | | | |
|---|---|---|---|
| | The January 2011 event caused lateral erosion of the stopbanks upstream and downstream of the bridge, and erosion surrounding the bridge abutments. Following this event, HDC completed some work on the stopbanks and channel, but they consider that the performance of the stopbanks have been reduced. | | *Due to the damage caused by the January 2011 event there is now an increased likelihood of stopbank failure.* |
| **Waharau Stream (5a and 5b)** | Waharau Stream drains a smaller catchment of 410ha which extents up into the Hunua Ranges and includes the Waharau Regional Park. It does not have any stopbanks.<br><br>The downstream reach of the stream through the village was straightened when Waharau Bridge was constructed, resulting in a long history of throughout the stream.<br><br>As described in section 4.3, Waharau Stream experienced flooding in April 2017 which eroded the abutments of Waharau Bridge and resulted in road closure while repairs were made. This may have also been contributed to by a previous flood event in March 2017. These flood events also resulted in inundation of rural land and deposition of silt and debris. | *Exposure: Moderate/High*<br><br>Potential for impacts to several properties and buildings, rural land upstream of the village, two archaeological sites upstream of ECR, and ECR (including the bridge) which may cause road closure and erosion of the bridge abutments<br><br>ECR and the Waharau bridge is exposed to flooding during high flow events, which can result in further impacts similar to the 2017 flooding event, resulting in longer term impacts that may occur during large flooding events. Consequently, this will result in the Waharau residents becoming cut off from Kaiaua and its services. | |

# 6 Quantitative risk assessment results (coastal inundation and Hauarahi Stream flooding)

## 6.1 Exposure

The results of the exposure assessment are, for each hazard type and sub-compartment, presented by impact category and event scenario (major and moderate). The results quantify the exposure to hazards (by degree of exposure) in terms of number (or length or area) and percentage of elements exposed. Note that that exposure results for the Cultural impact category are not presented by sub-compartment (only for the project area as a whole) as the Cultural Values Assessment has not yet been completed, thus thresholds cannot yet be determined for this category. Additionally, the exposure of known cultural elements to coastal inundation and Hauarahi Stream flooding is relatively low.

Due to the complex nature of the results it is not appropriate to simply combine elements to summarise risk across impact categories. For example, the potential impacts from a stormwater manhole being exposed are less than the potential impacts from a bridge being exposed. It is also not appropriate to use percentage elements exposed alone as a proxy for risk, as the potential impacts depend on both the number (or length or area) of elements exposed and the percentage, e.g. 10% of 100 buildings exposed has a greater potential impact than 10% of 10 buildings. Similarly, only reporting on the number of elements exposed does not provide the whole picture. For this reason, the only comparison made of the exposure across sub-compartments is for land area exposed (for the major event scenario) (section Overall6.1.3.3).

### 6.1.1 Coastal Inundation

#### 6.1.1.1 Pūkorokoro Miranda (sub-compartment 1a)

Figure 22 to Figure 25 show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, Services, Recreation and Tourism and Ecological.

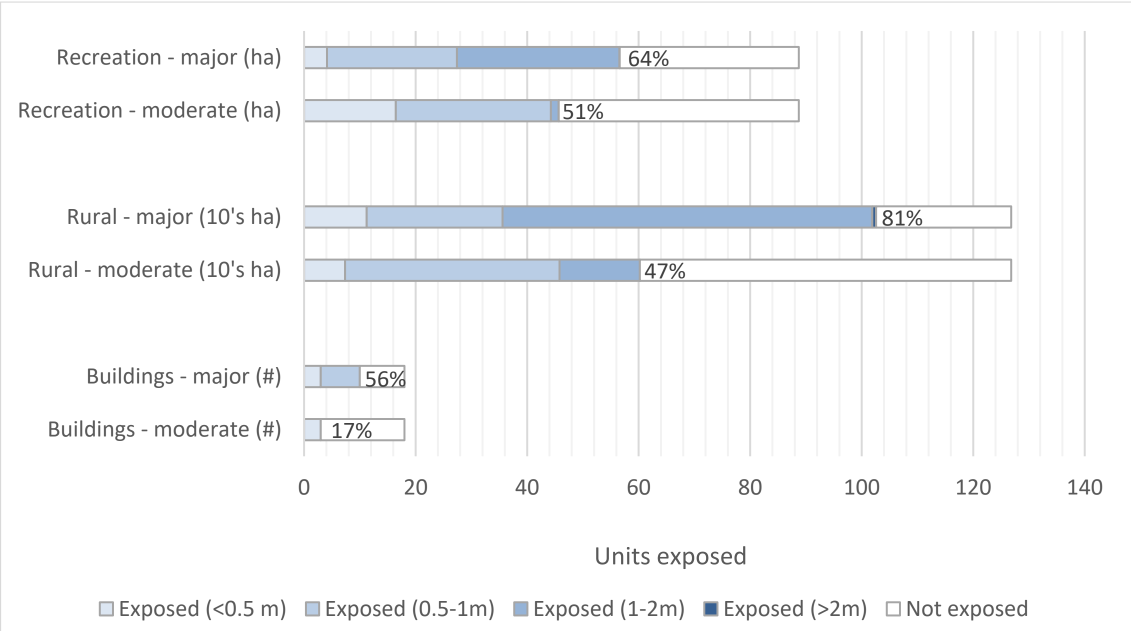



**Figure 22 Exposure of buildings and land use types to coastal inundation in sub-compartment 1a (note: percentages refer to total % exposed; rural land is shown in 10's of ha)**

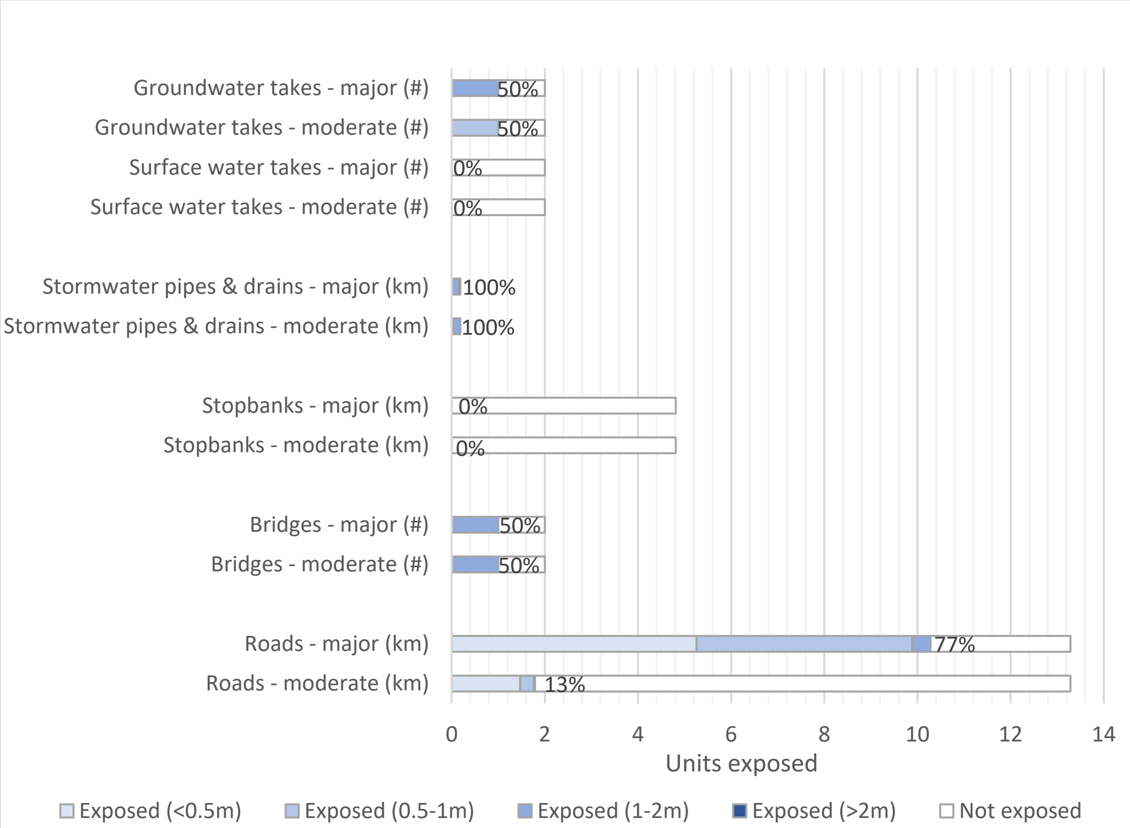



**Figure 23** **Exposure of lifeline elements to coastal inundation in sub-compartment 1a (note: percentages refer to total % exposed)**

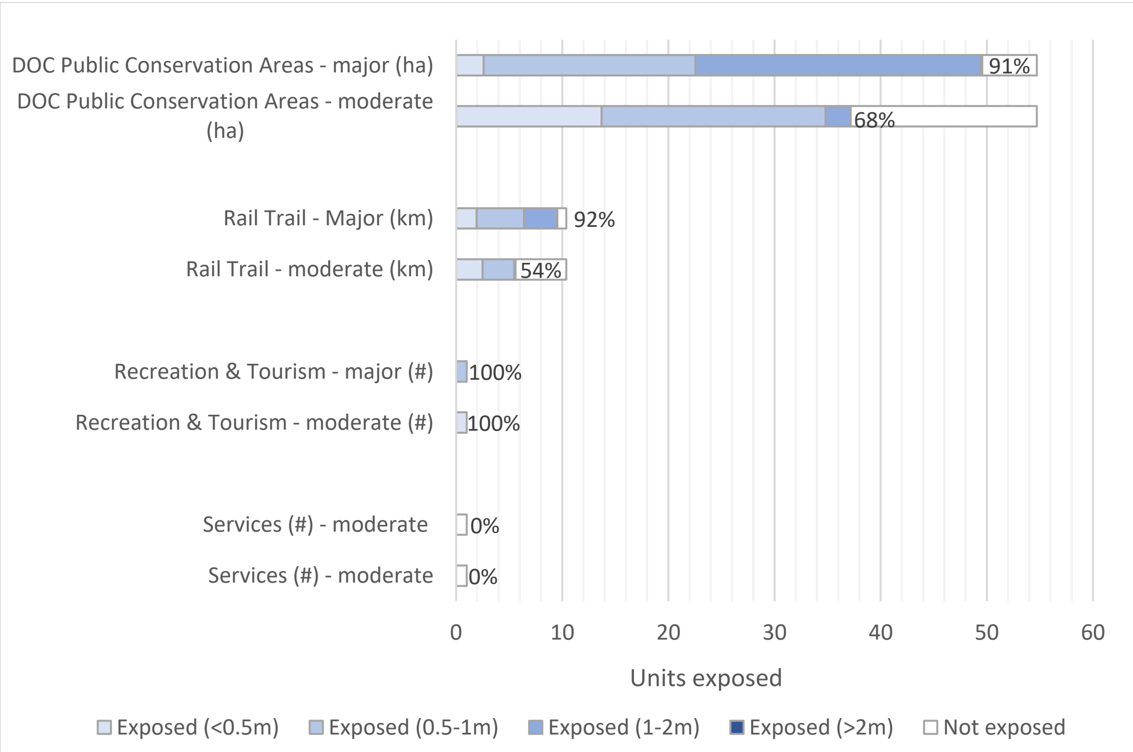



**Figure 24** **Exposure of recreation and tourism elements to coastal inundation in sub-compartment 1a (note: percentages refer to total % exposed)**

The recreation and tourism element shown in Figure 24 is Pūkorokoro Miranda Shorebird Centre, which is particularly valued by the community (who also value the shorebirds themselves and the potential tourism development opportunities they offer). Additionally, Rays Rest is valued by the community, and is exposed to 0.5-1 m of coastal inundation in the major event scenario (not exposed in the moderate). The service element shown in Figure 24 is Miranda Cemetery.

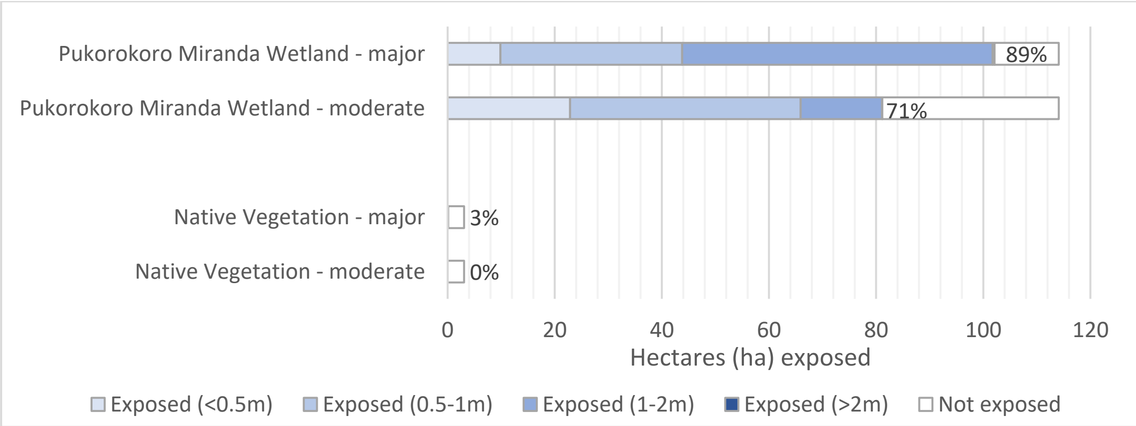



**Figure 25** **Exposure of ecological elements to coastal inundation in sub-compartment 1a (note: percentages refer to total % exposed)**

Sub-compartment 1a is the most low-lying out of all of the sub-compartments in the project area. As such, the majority of elements present are highly exposed to coastal inundation, particularly rural land, roads, DOC public conservation areas, Hauraki Rail Trail, Pūkorokoro Miranda Wetland and Shorebird Centre, and Rays Rest.

#### 6.1.1.2 Kaiaua township (sub-compartment 2a)

Figure 26 to Figure 28 and **Error! Reference source not found.** show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, and Services, Recreation and Tourism. There are no ecological elements in this sub-compartment, except for 1.2 ha of native vegetation which is not exposed in either scenario (major or moderate).

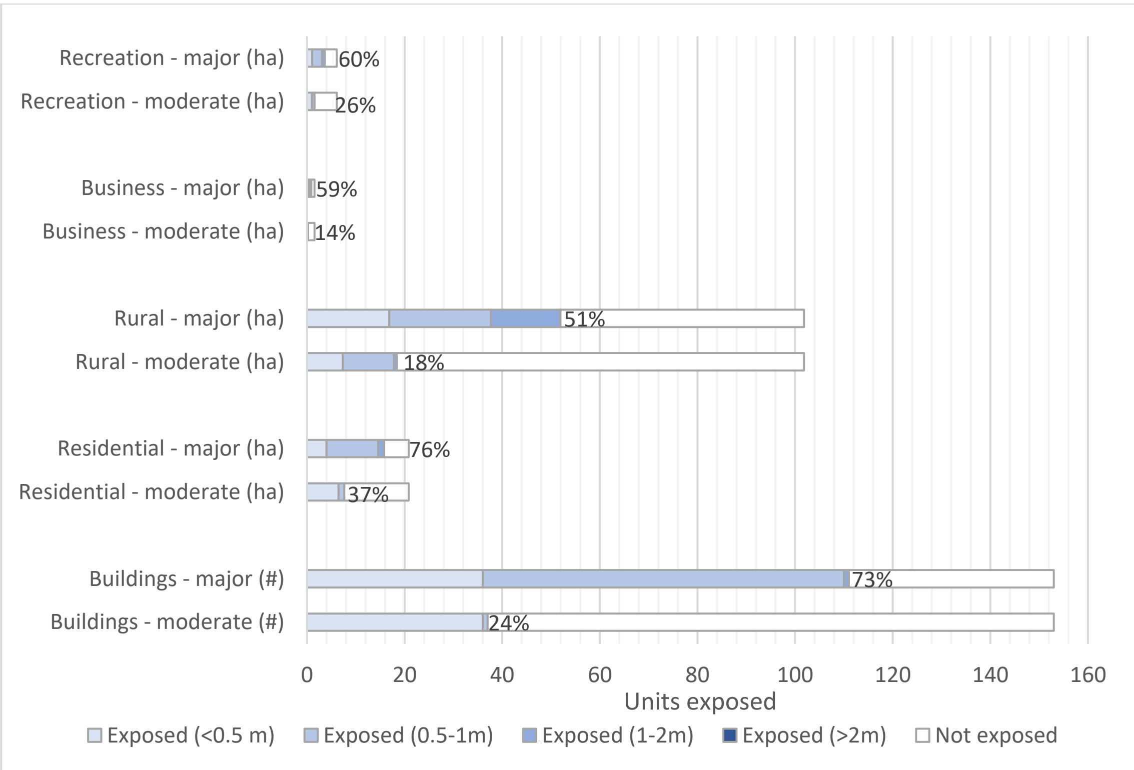



**Figure 26** **Exposure of buildings and land use types to coastal inundation in sub-compartment 2a (note: percentages refer to total % exposed)**

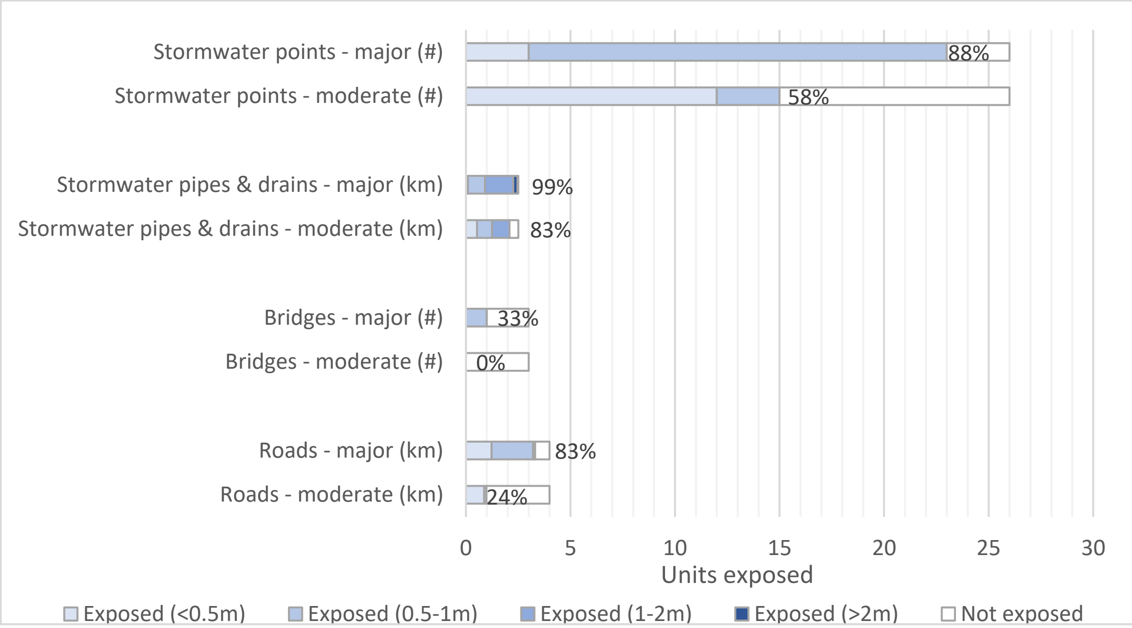



**Figure 27 Exposure of lifeline elements to coastal inundation in sub-compartment 2a (note: percentages refer to total % exposed)**

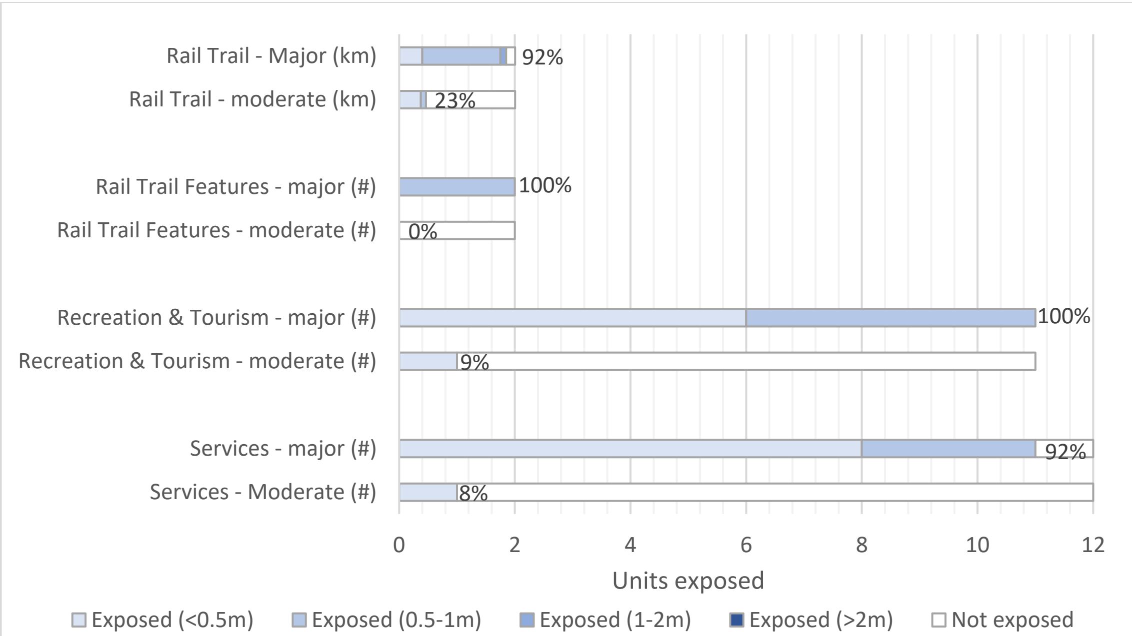



**Figure 28 Exposure of recreation and tourism elements to coastal inundation in sub-compartment 2a (note: percentages refer to total % exposed)**

**Table 11 Exposure of key service, recreation and tourism elements to coastal inundation in sub-compartment 2a (note: elements valued by the community are highlighted grey)**

| Key service, recreation and tourism elements | Event scenario | Exposed (<0.5 m) | Exposed (0.5-1m) | Exposed (1-2m) | Exposed (>2m) | Not Exposed |
|---|---|---|---|---|---|---|
| Kaiaua Seaside Store (Pink Shop) | major | | x | | | |
| | moderate | | | | | x |
| Kaiaua Fisheries | major | x | | | | |
| | moderate | | | | | x |
| Kaiaua School | major | | x | | | |
| | moderate | | | | | x |
| Kaiaua Rural Fire Station | major | | | | | x |
| | moderate | | | | | x |
| Kaiaua Medical Centre | major | x | | | | |
| | moderate | | | | | x |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Ambulance Station** | major | x | | | | |
| | moderate | | | | | x |
| **Kaiaua Bowling Club** | major | x | | | | |
| | moderate | | | | | x |
| **Bayview Hotel** | major | | x | | | |
| | moderate | | | | | x |
| **Kaiaua Motors** | major | x | | | | |
| | moderate | | | | | x |
| **GAS Kaiaua** | major | x | | | | |
| | moderate | | | | | x |
| **Pirate Ship Playground** | major | x | | | | |
| | moderate | | | | | x |
| **Information centre (information board)** | major | | x | | | |
| | moderate | x | | | | |

Additionally, the boat ramp at Kaiaua is particularly valued by the community and is exposed to coastal inundation.

Sub-compartment 2a includes the township of Kaiaua, meaning that the majority of services, recreation and tourism elements are located in this sub-compartment. It is also relatively low-lying, resulting in a high exposure to coastal inundation, particularly for the major event scenario. Elements that are highly exposed to coastal inundation include buildings, all land use types, stormwater infrastructure, roads, Hauraki Rail Trail and associated infrastructure, and service, recreation and tourism elements particularly the Pink Shop, Kaiaua School, Bayview Hotel, the Information Centre (information board) and Kaiaua boat ramp.

#### 6.1.1.3 Whakatiwai (sub-compartment 3a)

Figure 29, Figure 30 and **Error! Reference source not found.** show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, and Services, Recreation and Tourism. There are no ecological elements in this sub-compartment, except for 1.3 ha of native vegetation of which 19% is exposed in the major event scenario (not exposed in the moderate event scenario).

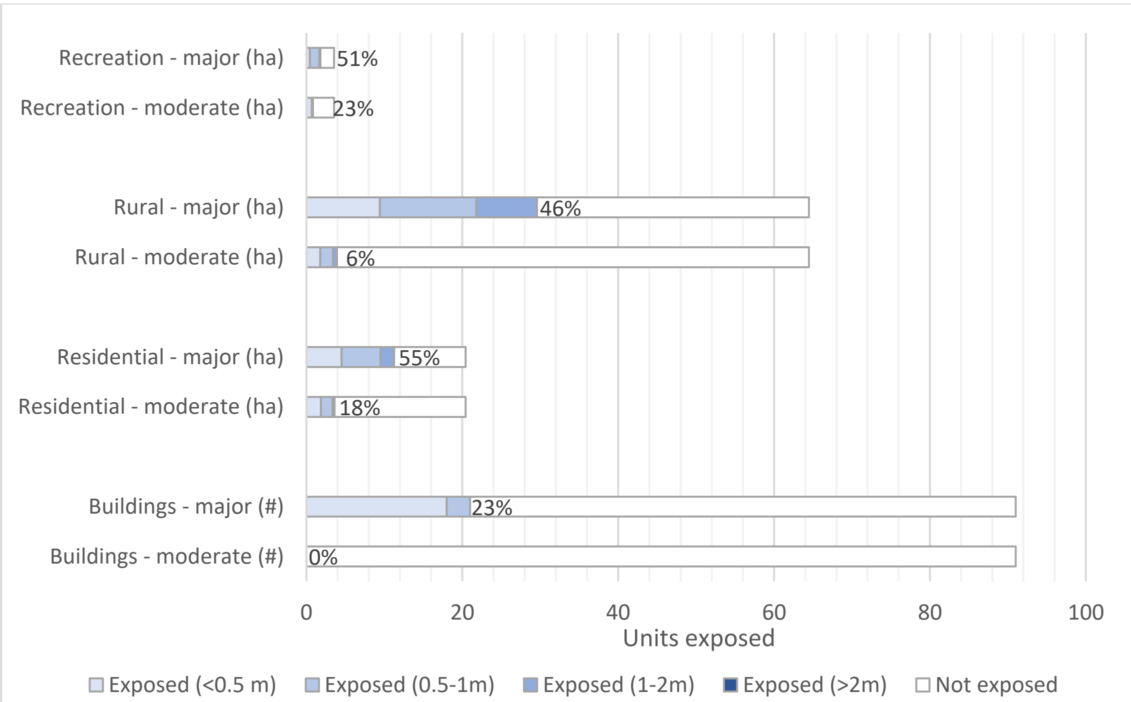


**Figure 29 Exposure of buildings and land use types to coastal inundation in sub-compartment 3a (note: percentages refer to total % exposed)**

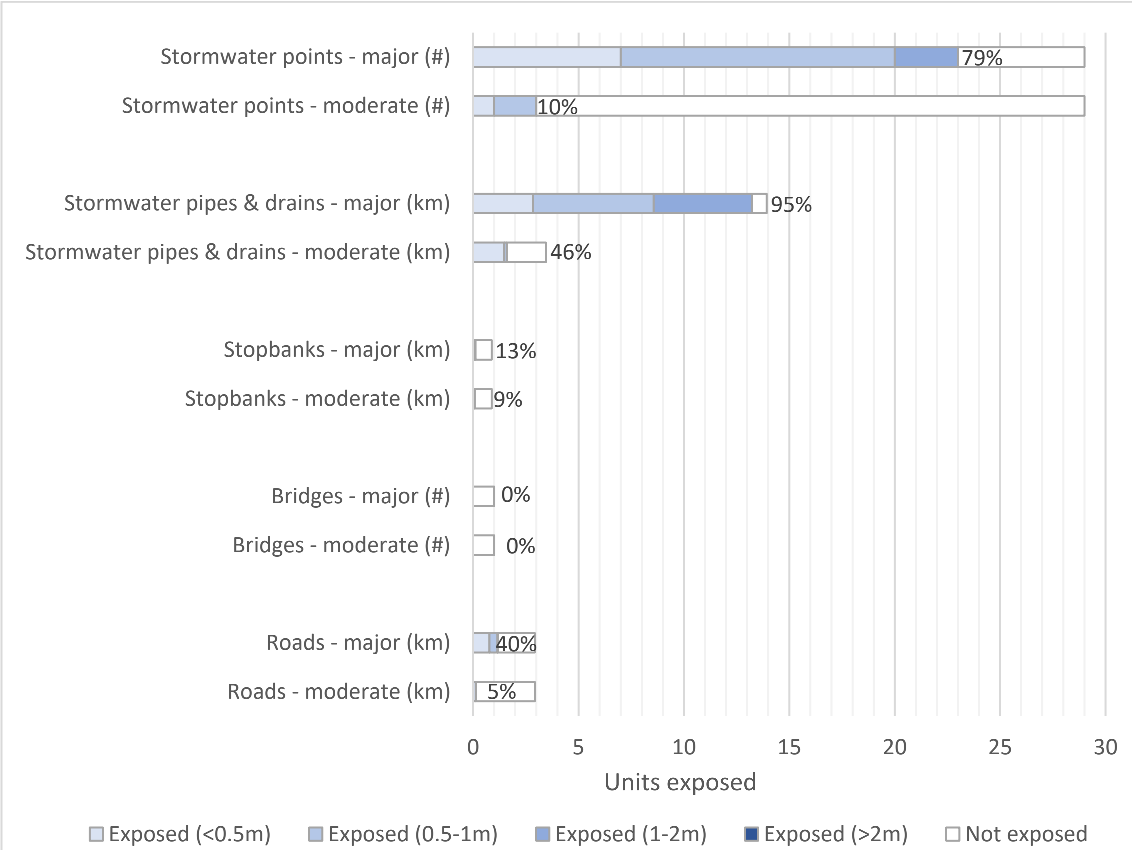



**Figure 30 Exposure of lifeline elements to coastal inundation in sub-compartment 3a (note: percentages refer to total % exposed)**

**Table 12 Exposure of key service elements to coastal inundation in sub-compartment 3a**

| Key service elements | Scenario | Exposed (<0.5 m) | Exposed (0.5-1m) | Exposed (1-2m) | Exposed (>2m) | Not Exposed |
|---|---|---|---|---|---|---|
| **Eco quest Education Foundation Centre** | major | x | | | | |
| | moderate | | | | | x |
| **Te Kohanga Reo O Whare Kawa** | major | | | | | x |
| | moderate | | | | | x |

There is one recreation & tourism element exposed to 1-2 m of coastal inundation in the major event scenario (but not exposed in the moderate), which is a picnic site.

Additionally, the community has identified Wharekawa Marae, Ūrupa and Māori-owned land as being particularly valued elements. Based on the locations provided by the community, the Ūrupa is exposed to <0.5 m of coastal inundation in the major event scenario (not exposed in the moderate). Wharekawa Marae is not expected to be exposed in either event. The exposure of Māori land blocks is presented in section 586.1.3.

Sub-compartment 3a is less low-lying than 1a and 2a, resulting in a lower exposure of elements to coastal inundation. However, rural, residential and recreation land is still significantly exposed, as is stormwater infrastructure, roads, Ecoquest Education Foundation Centre and an Ūrupa.

#### 6.1.1.4 Waihihi (sub-compartment 4a)

Figure 31 to Figure 33 show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines and Ecological. There are no services in this sub-compartment and only one recreation and tourism element (Kaiaua Seaside Lodge) which is exposed to <0.5 m of coastal inundation for the major event scenario and not exposed for the moderate. There is also a boat ramp which is particularly valued by the community and is exposed to coastal inundation.

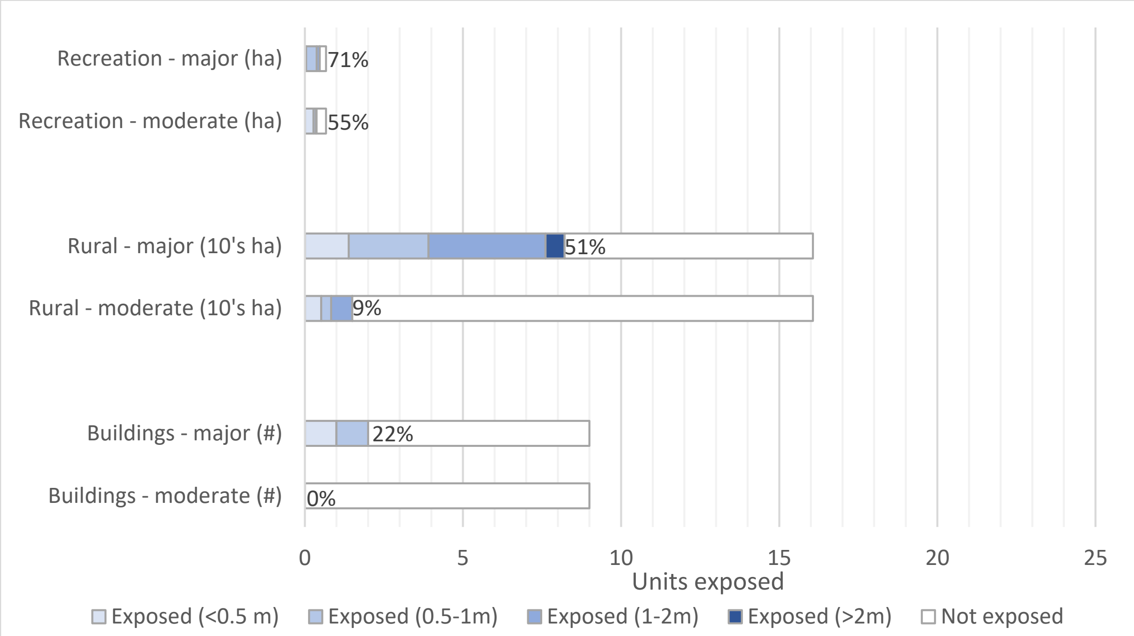



**Figure 31** **Exposure of buildings and land use types to coastal inundation in sub-compartment 4a (note: rural land is shown in 10's of ha)**

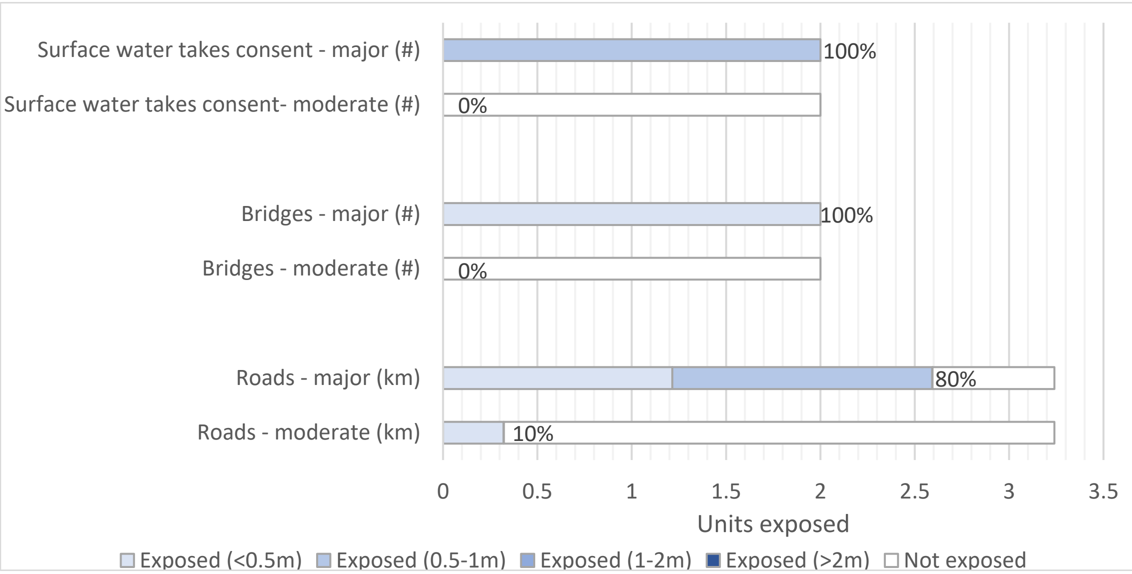



**Figure 32** **Exposure of lifeline elements to coastal inundation in sub-compartment 4a (note: percentages refer to total % exposed)**

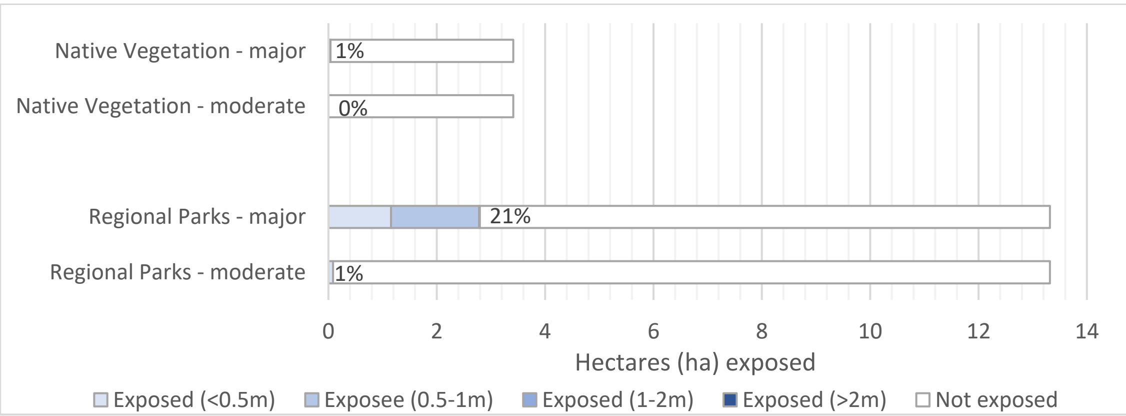



**Figure 33** **Exposure of ecological elements to coastal inundation in sub-compartment 4a (note: percentages refer to total % exposed)**

Whakatiwai Regional park is particularly valued by the community.

Again, sub-compartment 4a is less low-lying than 1a and 2a, resulting in a lower exposure of elements to coastal inundation. However, rural and recreation land is still significantly exposed, as are bridges, roads and the boat ramp.

#### 6.1.1.5 Waharau (sub-compartment 5a)

Figure 34 to Figure 36 show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines and Ecological. There are no recreation and tourism elements in this sub-compartment, and only two services; a public toilet which is not exposed and a sanitary dump station which is exposed to <0.5 m of coastal inundation for the major event scenario and not exposed for the moderate. Waharau Park and beach camp area, and beach access is particularly valued by the community and is exposed to coastal inundation.

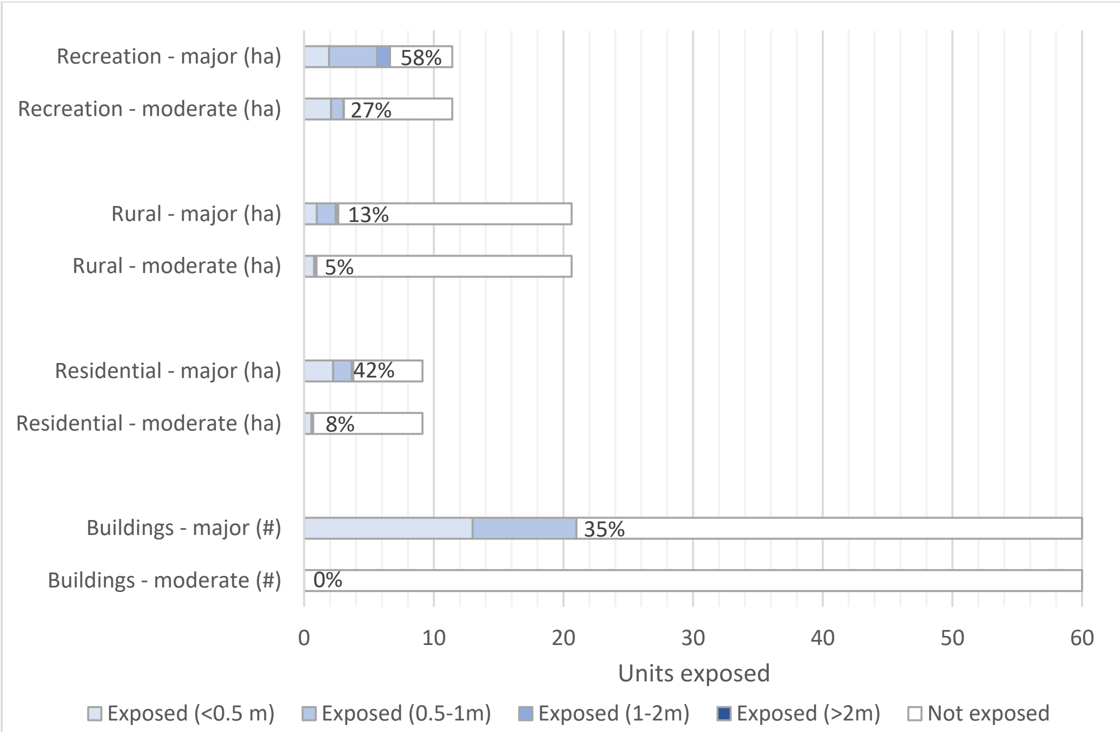



**Figure 34** **Exposure of buildings and land use types to coastal inundation in sub-compartment 5a (note: percentages refer to total % exposed)**

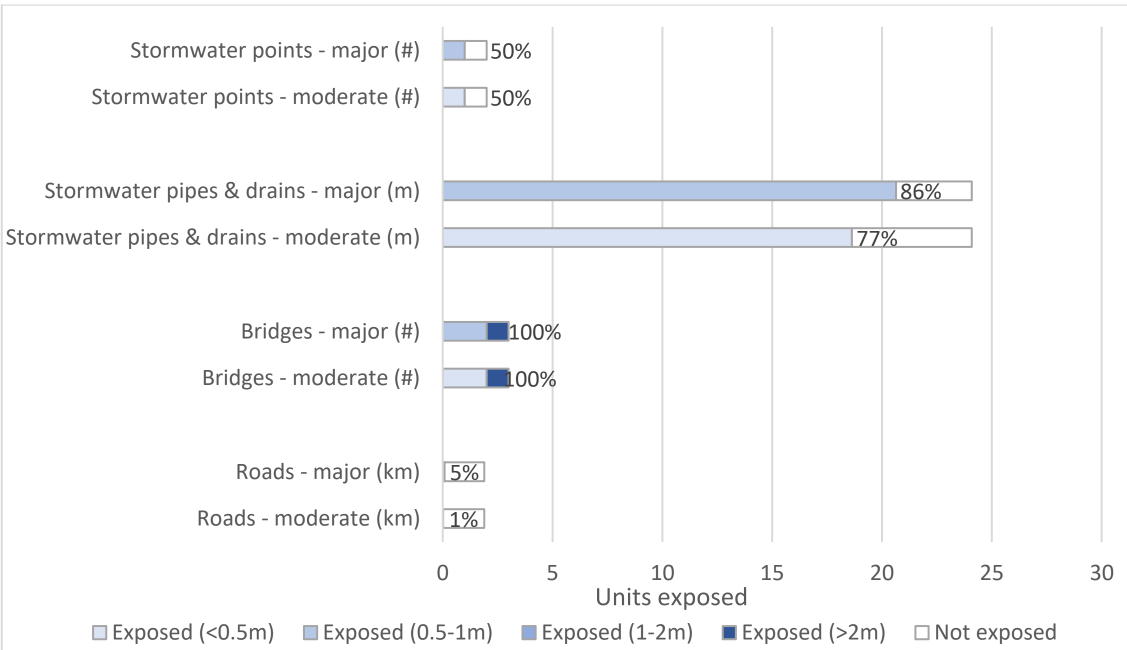


**Figure 35 Exposure of lifeline elements to coastal inundation in sub-compartment 5a (note: percentages refer to total % exposed)**

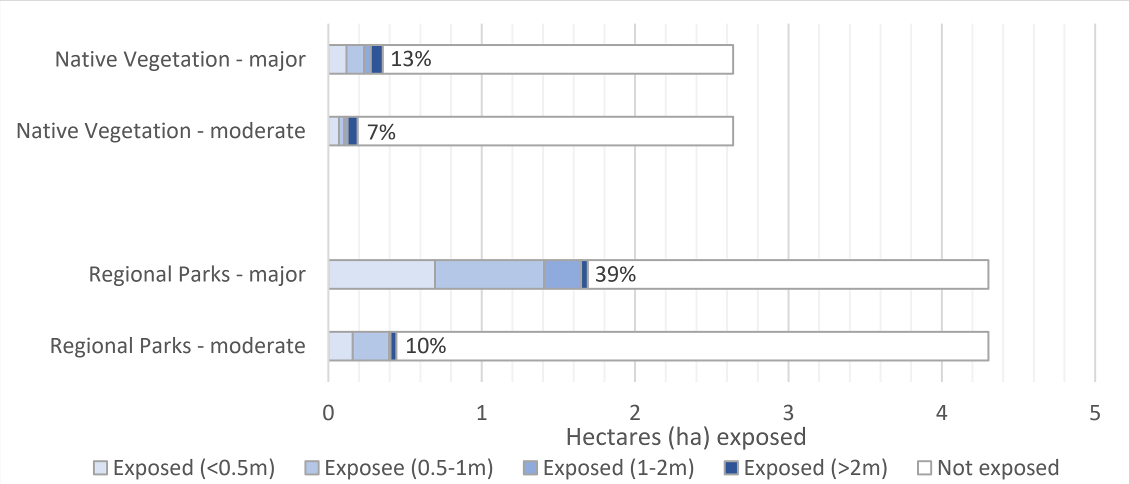



**Figure 36 Exposure of ecological elements to coastal inundation in sub-compartment 5a (note: percentages refer to total % exposed)**

Waharau Regional park is particularly valued by the community.

Sub-compartment 5a is the most elevated of the coastal sub-compartments, resulting in a lower exposure of elements to coastal inundation. However, residential and recreation land is still significantly exposed, as are stormwater infrastructure, bridges, Waharau Regional Park and beach camp area. Buildings are also relatively exposed to the major event scenario.

### 6.1.2 Hauarahi Stream flooding

#### 6.1.2.1 Kaiaua townsip (sub-compartment 2a)

Figure 37 to Figure 39 and **Error! Reference source not found.** show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, and Services, Recreation and Tourism. There are no ecological elements in this sub-compartment, except for 1.2 ha of native vegetation which is not exposed in either scenario (major or moderate).

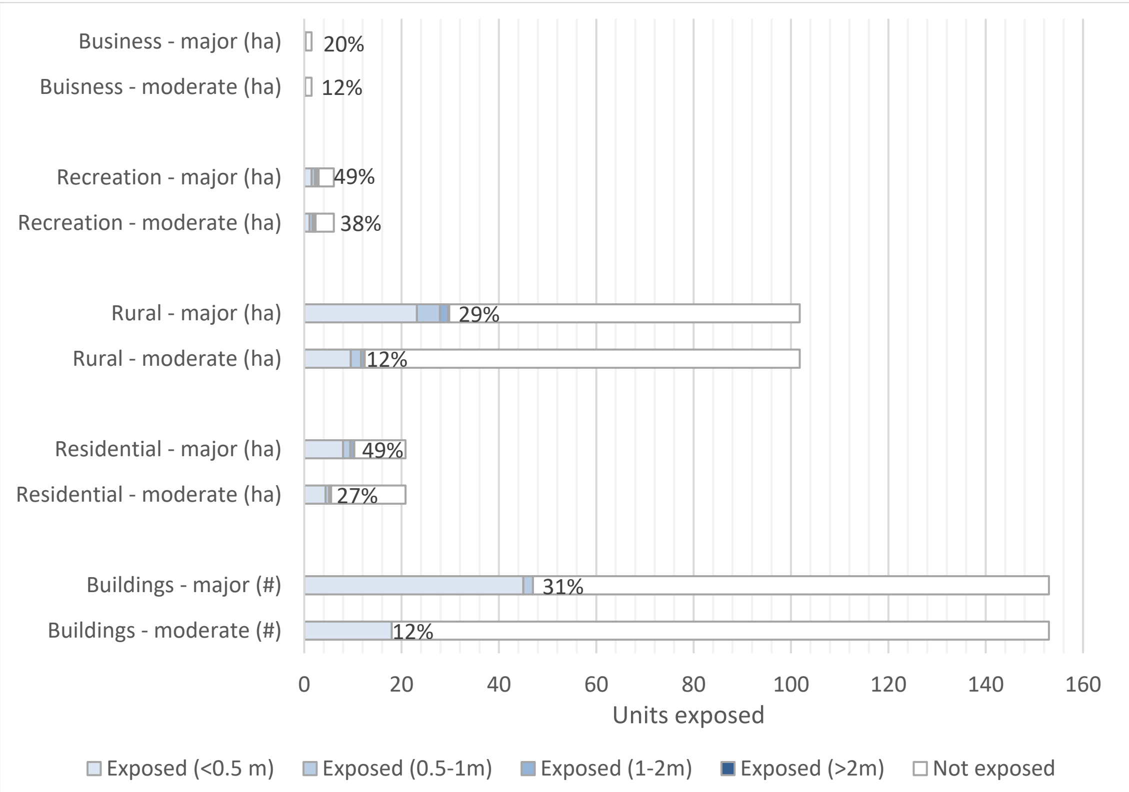


**Figure 37 Exposure of buildings and land use types to Hauarahi Stream flooding in sub-compartment 2a (note: percentages refer to total % exposed)**

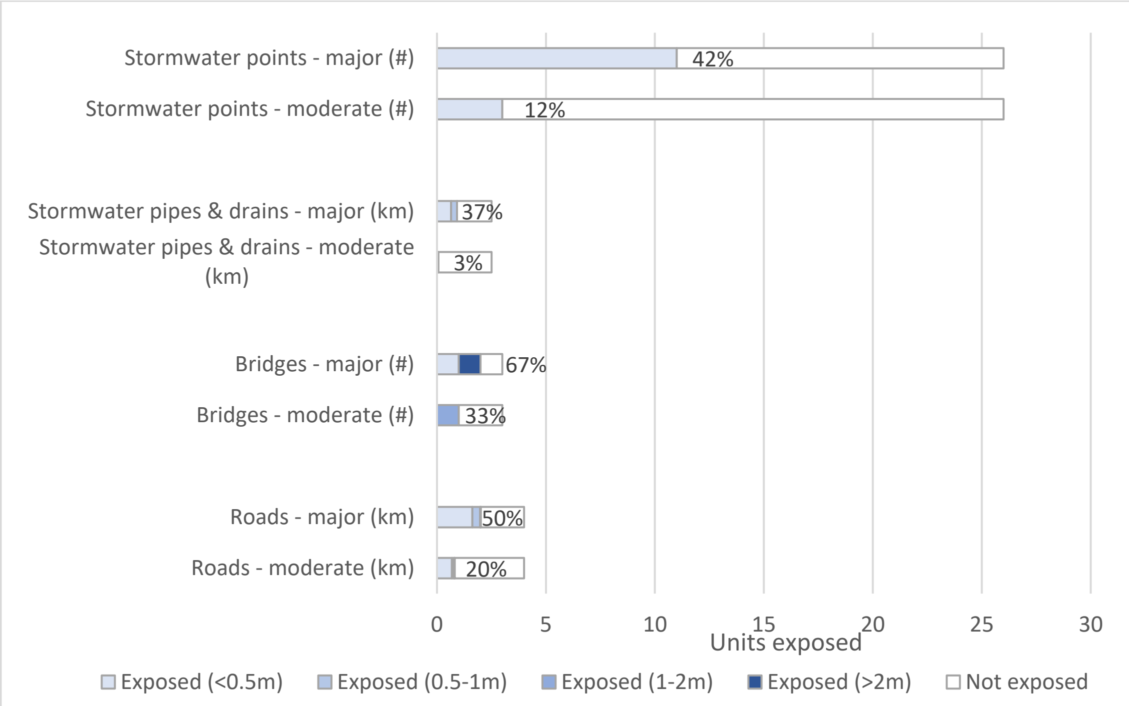



**Figure 38 Exposure of lifeline elements to Hauarahi Stream flooding in sub-compartment 2a (note: percentages refer to total % exposed)**

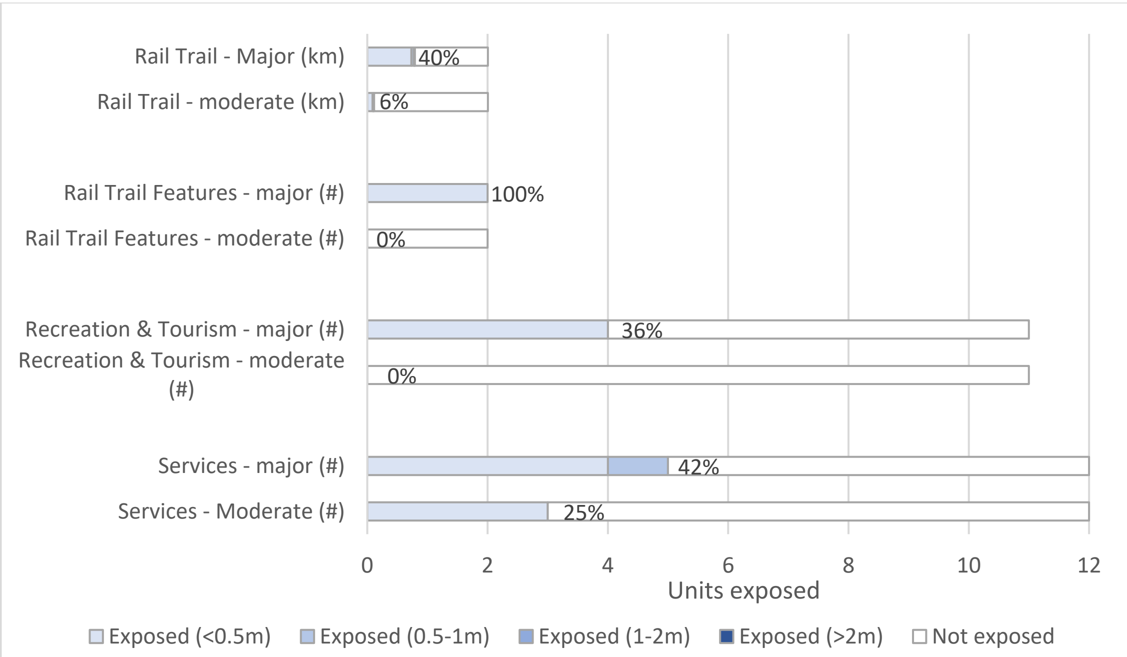



**Figure 39 Exposure of recreation and tourism elements to Hauarahi Stream flooding in sub-compartment 2a (note: percentages refer to total % exposed)**

**Table 13 Exposure of key service, recreation and tourism elements to Hauarahi Stream flooding sub-compartment 2a (note: elements valued by the community are highlighted grey)**

| Key service, recreation and tourism elements | Event scenario | Exposed (<0.5 m) | Exposed (0.5-1m) | Exposed (1-2m) | Exposed (>2m) | Not Exposed |
|---|---|---|---|---|---|---|
| Kaiaua Seaside Store (Pink Shop) | major | x | | | | |
| | moderate | | | | | x |
| Kaiaua Fisheries | major | | | | | x |
| | moderate | | | | | x |
| Kaiaua School | major | x | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | moderate | | | | | x |
| **Kaiaua Rural Fire Station** | major | x | | | | |
| | moderate | x | | | | |
| **Kaiaua Medical Centre** | major | x | | | | |
| | moderate | x | | | | |
| **Ambulance Station** | major | | | | | x |
| | moderate | | | | | x |
| **Kaiaua Bowling Club** | major | x | | | | |
| | moderate | | | | | x |
| **Bayview Hotel** | major | | | | | x |
| | moderate | | | | | x |
| **Kaiaua Motors** | major | | | | | x |
| | moderate | | | | | x |
| **GAS Kaiaua** | major | | | | | x |
| | moderate | | | | | x |
| **Pirate Ship Playground** | major | x | | | | |
| | moderate | | | | | x |
| **Information centre (information board)** | major | | | | | x |
| | moderate | | | | | x |

Additionally, the boat ramp at Kaiaua is particularly valued by the community and is exposed to Hauarahi Stream flooding.

Sub-compartment 2a includes the township of Kaiaua, meaning that the majority of services, recreation and tourism elements are located in this sub-compartment. The township is highly exposed to Hauarahi Stream flooding, particularly to the north of the stream. Elements that are particularly exposed to stream flooding include residential and recreation land, stormwater infrastructure, roads, bridges, Hauraki Rail Trail and associated infrastructure and service elements. Buildings and recreation and tourism elements are also relatively exposed.

#### 6.1.2.2 Kaiaua inland (sub-compartment 2b)

Figure 40 shows the exposure of elements for the Buildings and Properties impact category. There are lifeline elements in this sub-compartment (roads and stormwater infrastructure) but none are exposed in either scenario (major or moderate). There are no service, recreation or tourism elements located in this sub-compartment. There are no ecological elements in this sub-compartment, except for 335.8 ha of native vegetation which is not exposed in either scenario (major or moderate).

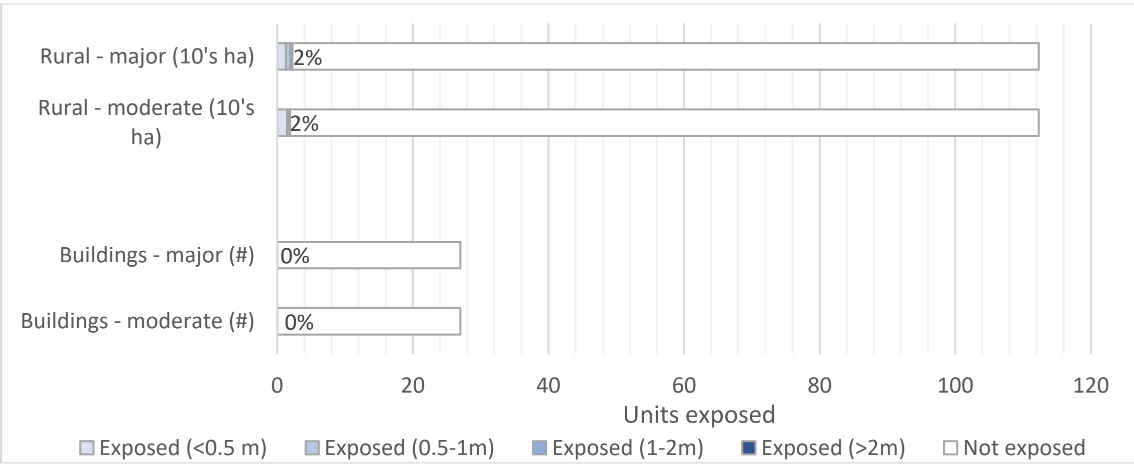



**Figure 40 Exposure of buildings and land use types to Hauarahi Stream flooding in sub-compartment 2b (note: percentages refer to total % exposed)**

The only element exposed to Hauarahi Stream flooding in sub-compartment 2b is rural land, and only 2% of this land is exposed for both the major and moderate event scenarios.

### 6.1.3 Wharekawa Coast 2120 project area – overall results

#### 6.1.3.1 Coastal Inundation

Figure 41 to Figure 46 Figure 45show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, Services, Recreation and Tourism, Ecological and Cultural for the Wharekawa Coast 2120 project area as a whole. These results include the inland sub-compartments which are not exposed to coastal inundation, thus the percentage of elements exposed is generally lower than that for each sub-compartment.

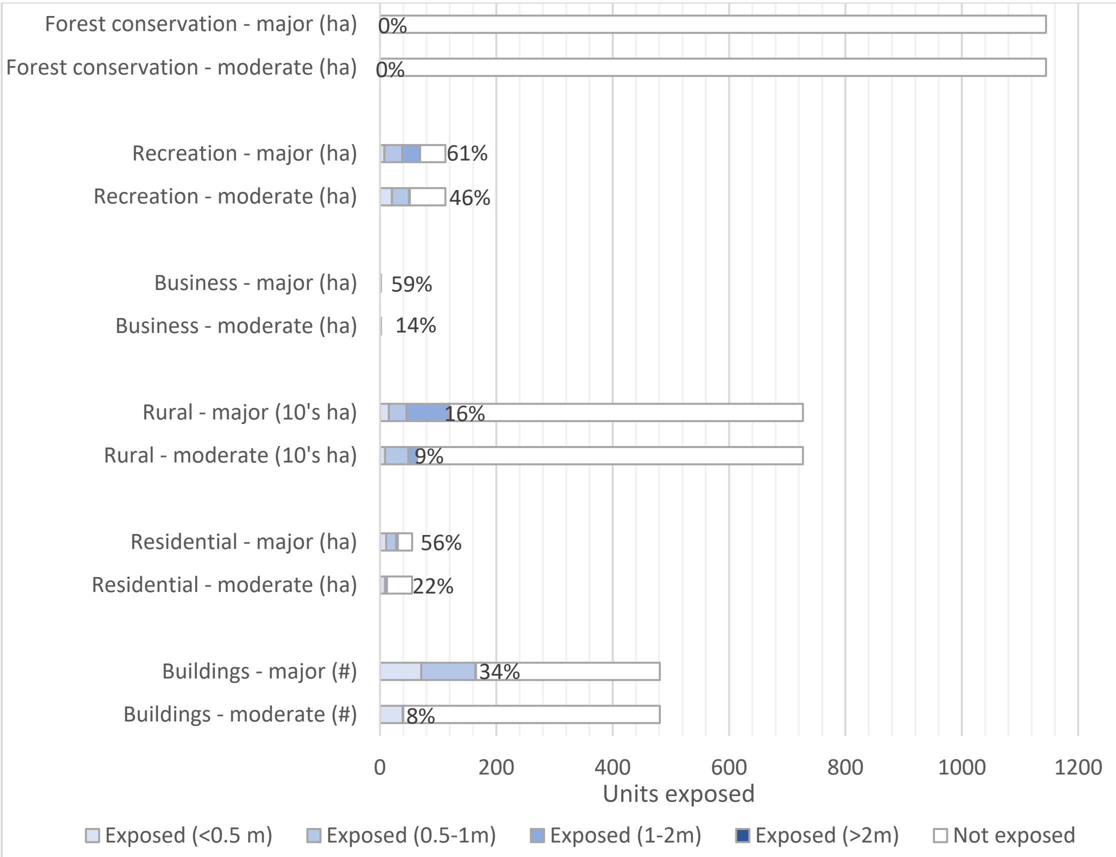



**Figure 41 Exposure of buildings and land use types to coastal inundation in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed; rural land is shown in 10's of ha)**

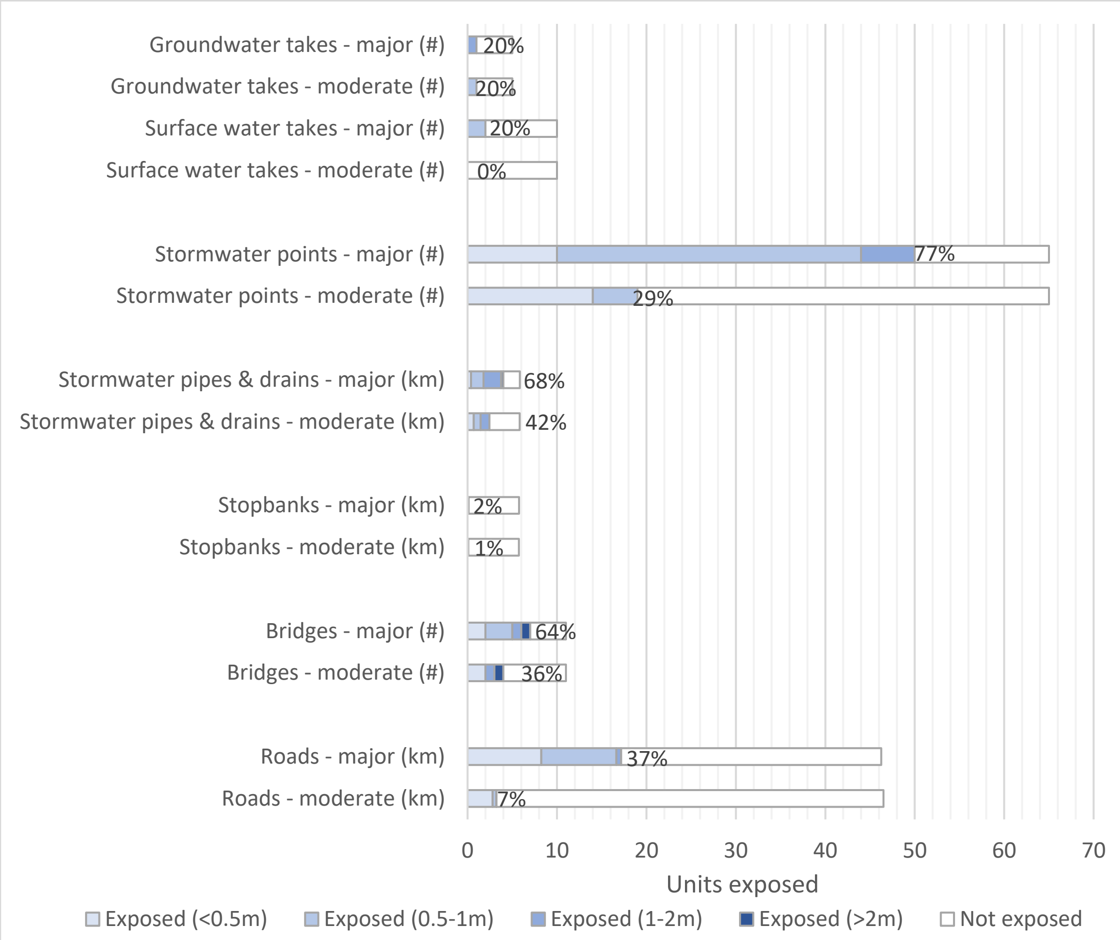



**Figure 42** **Exposure of lifeline elements to coastal inundation in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)**

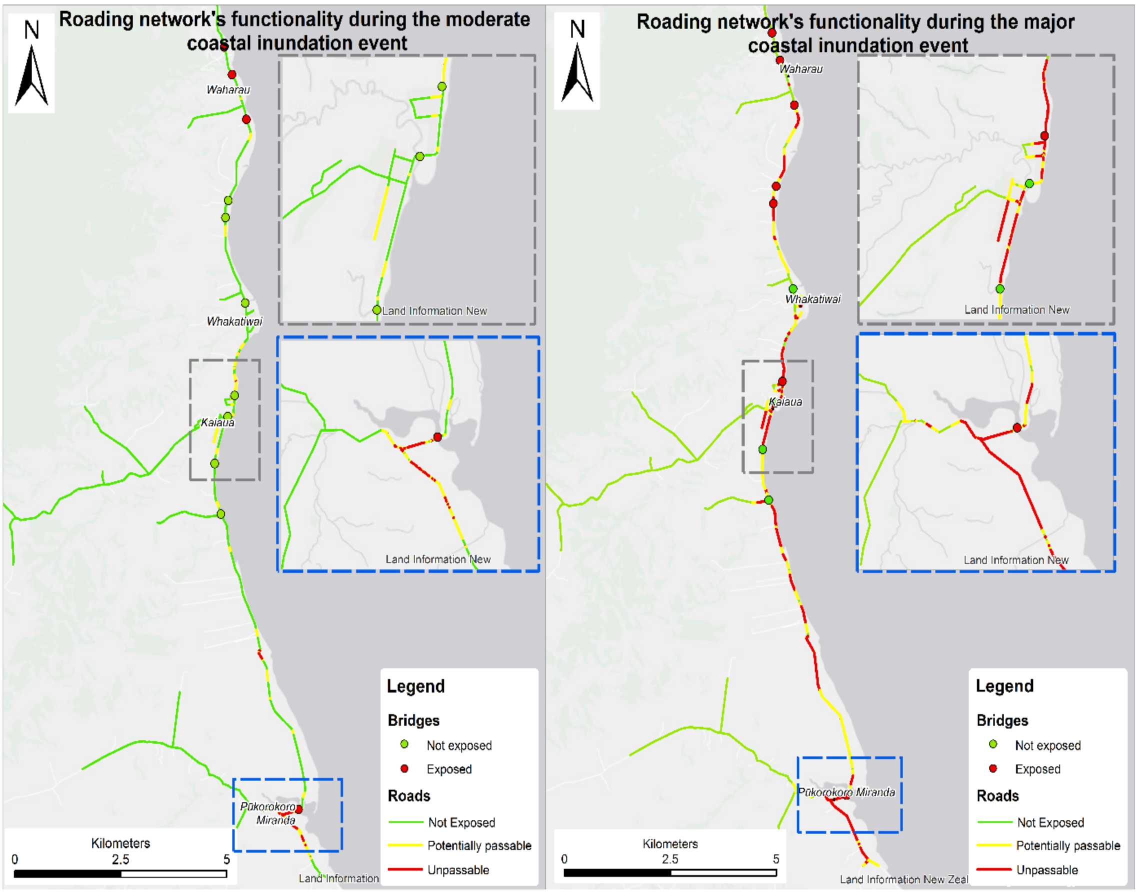



**Figure 43** **Exposure of roads and bridges to coastal inundation (note: potentially passable is <0.5 m flood depth; unpassable is >0.5 m flood depth)**

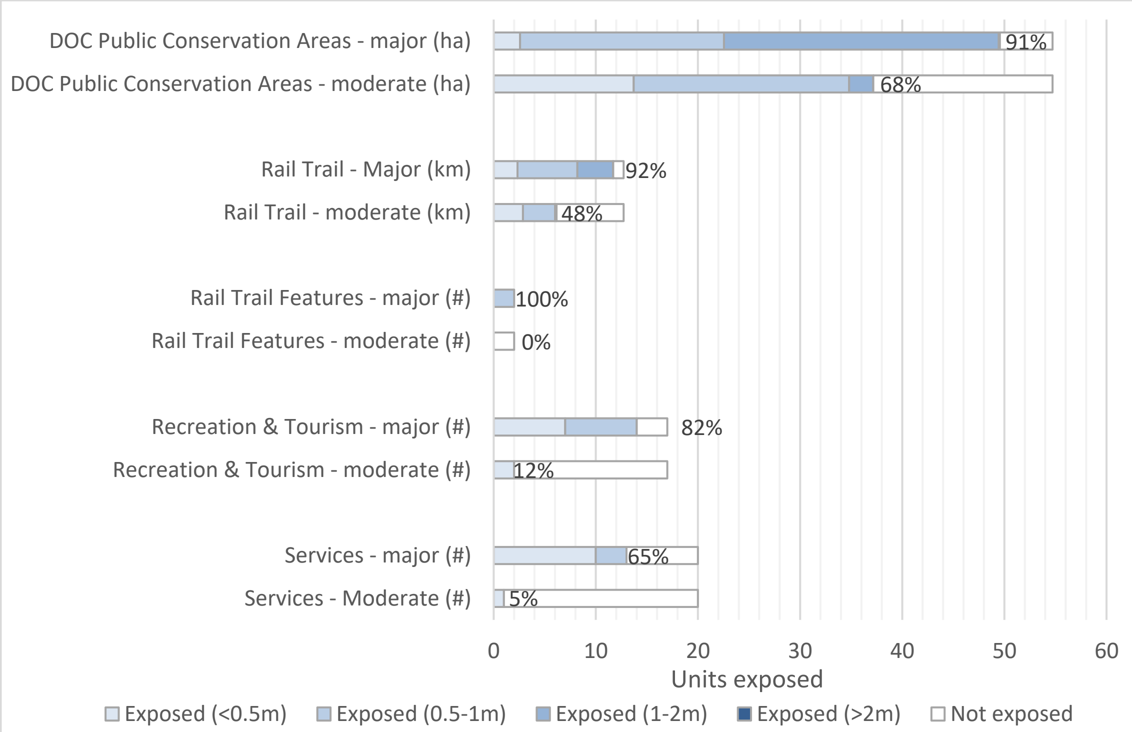



**Figure 44** **Exposure of recreation and tourism elements to coastal inundation in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)**

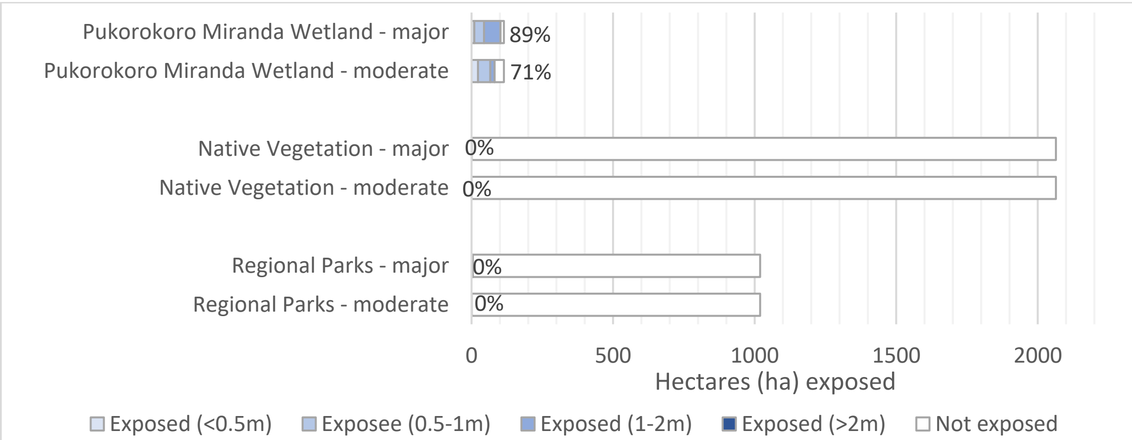



**Figure 45** **Exposure of ecological elements to coastal inundation in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed; there is some exposure of native vegetation and Regional Parks but it is less than 0.5%)**

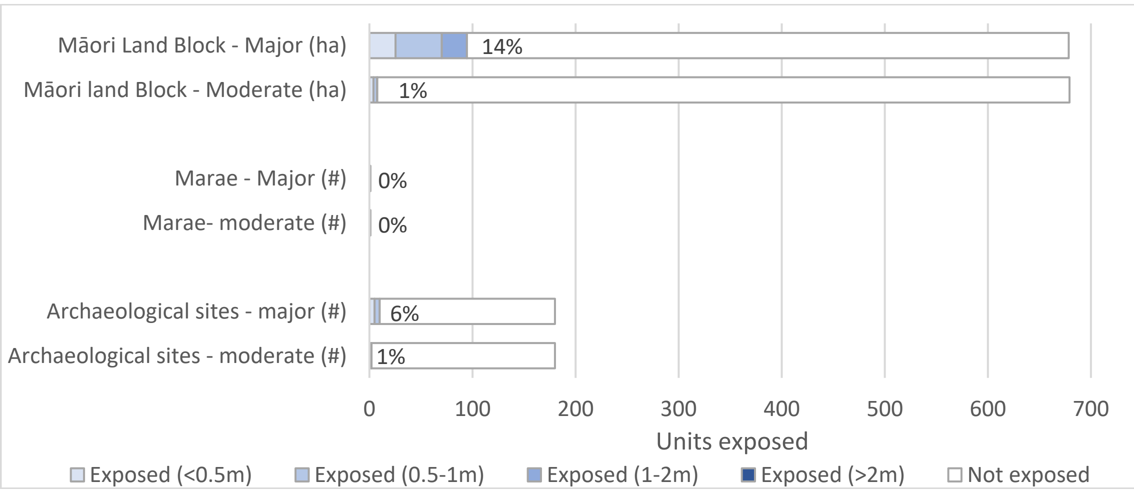



**Figure 46** **Exposure of cultural elements to coastal inundation in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)**

The elements with the greatest percentage exposed to coastal inundation for the whole project area are recreation, business and residential land, stormwater infrastructure, bridges, DOC public conservation areas, Hauraki Rail Trail, service, recreation and tourism elements and Pūkorokoro Miranda Wetland.

#### 6.1.3.2 Hauarahi Stream flooding

Figure 47 to Figure 52 Figure 45show the exposure of elements for the impact categories of; Buildings and Properties, Lifelines, Services, Recreation and Tourism, Ecological and Cultural for the Wharekawa Coast 2120 project area as a whole. These results include the compartments which are not exposed to Hauarahi Stream flooding (1, 3, 4 and 5), thus the percentage of elements exposed is generally much lower. This is useful to compare the exposure of elements to Hauarahi Stream flooding against coastal inundation.

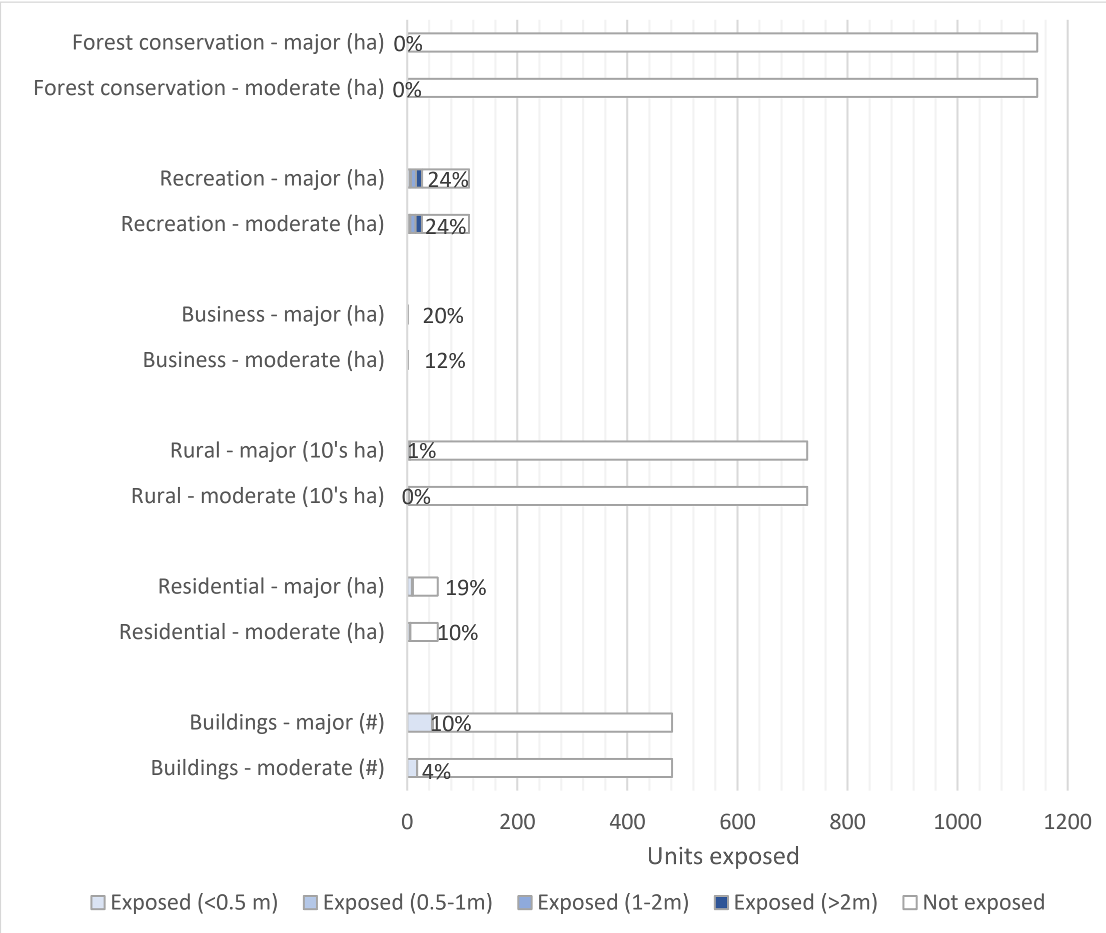



**Figure 47 Exposure of buildings and land use types to Hauarahi Stream flooding in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed; rural land is shown in 10's of ha)**

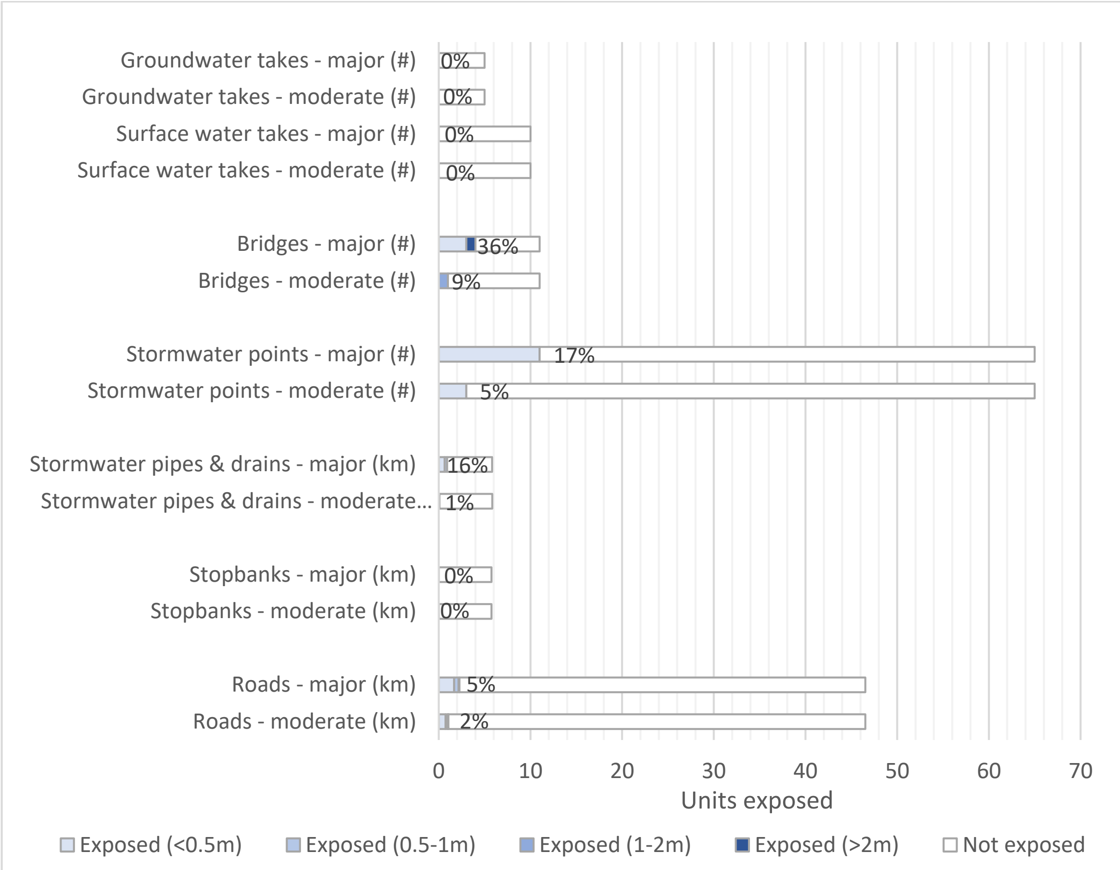



**Figure 48** Exposure of lifeline elements to Hauarahi Stream flooding in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)


**Figure 49** Exposure of roads and bridges to Hauarahi Stream flooding in compartment 2 (note: potentially passable is <0.5 m flood depth; unpassable is >0.5 m flood depth)

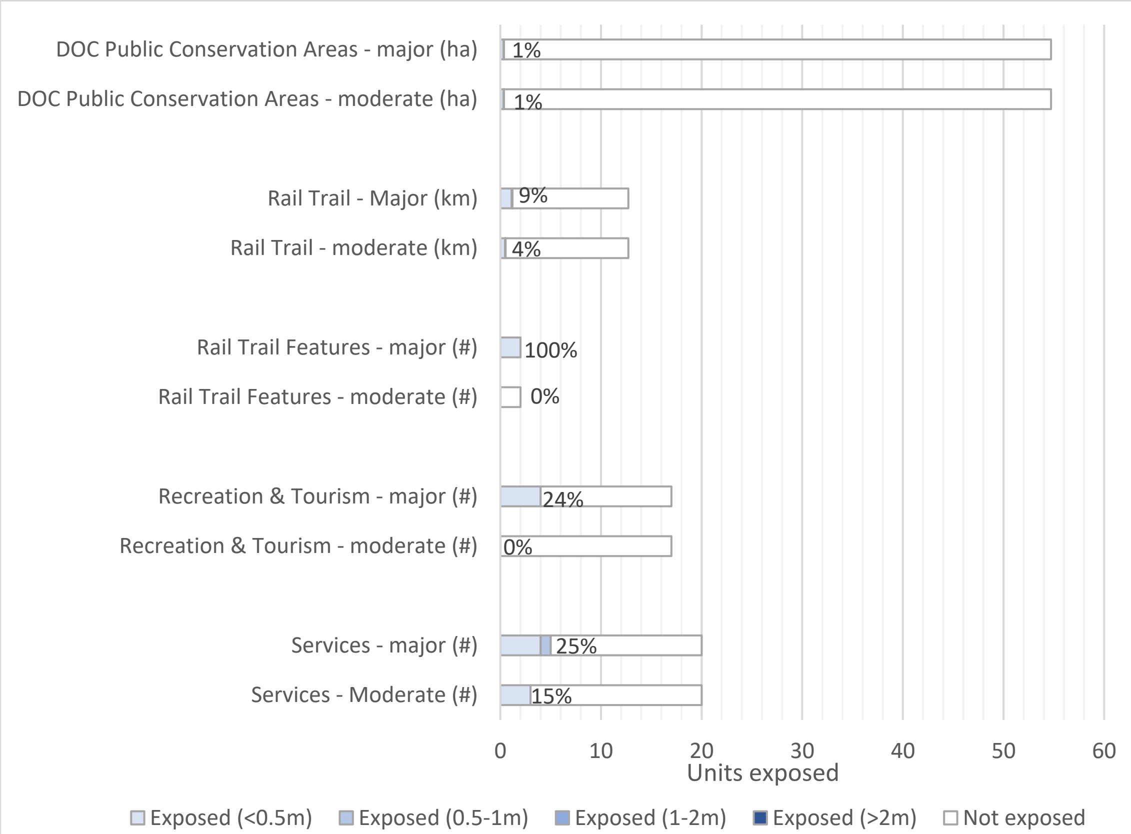



**Figure 50** **Exposure of recreation and tourism elements to Hauarahi Stream flooding in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)**

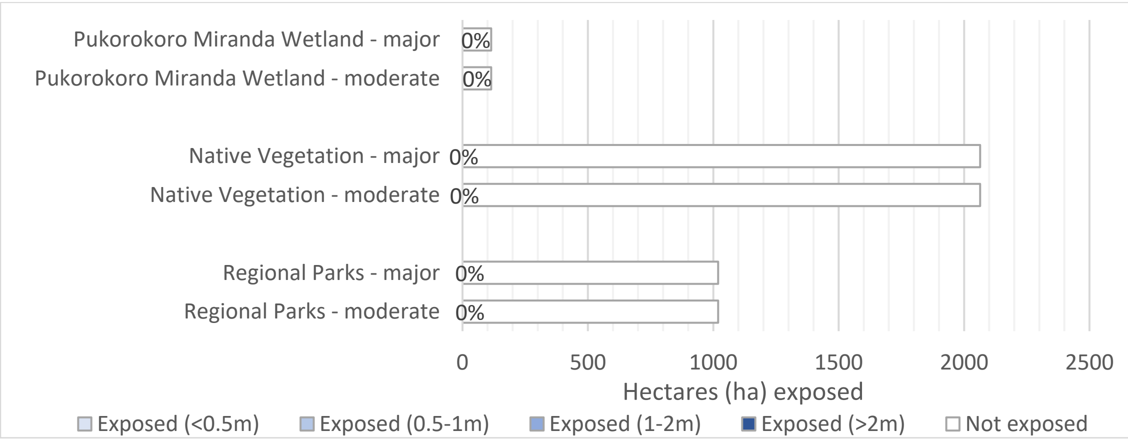



**Figure 51** **Exposure of ecological elements to Hauarahi Stream flooding in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed; there is some exposure of native vegetation and Regional Parks but it is less than 0.5%)**

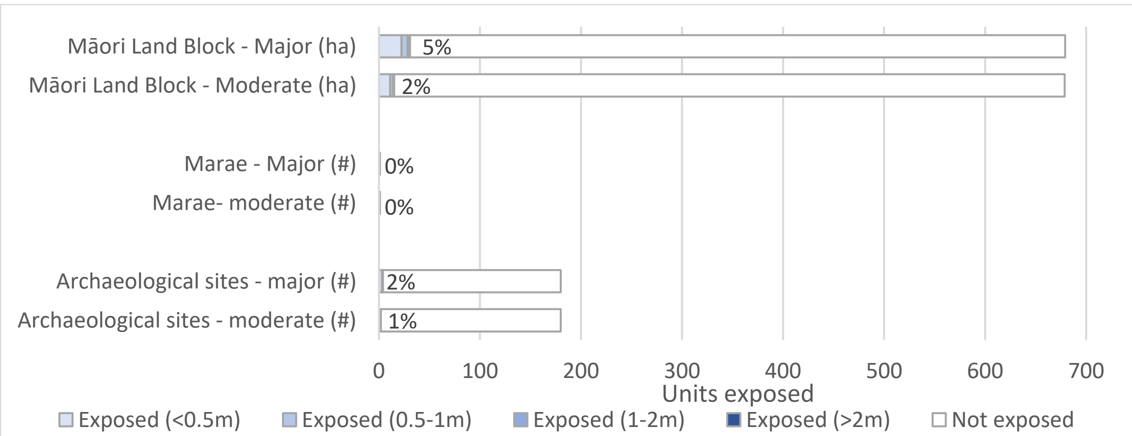



**Figure 52** **Exposure of cultural elements to Hauarahi Stream flooding in the Wharekawa Coast 2120 project area (note: percentages refer to total % exposed)**

For the whole project area, the percentage of elements exposed to Hauarahi Stream flooding is relatively low for all impact categories. The elements with the greatest percentage exposed are recreation, business and residential land, stormwater infrastructure, bridges, infrastructure associated with the Hauraki Rail Trail, and service, recreation and tourism elements.

#### 6.1.3.3 Overall

Figure 53 simply shows the relative exposure of land area to coastal inundation and Hauarahi Stream flooding for each sub-compartment that is exposed (major event scenarios).

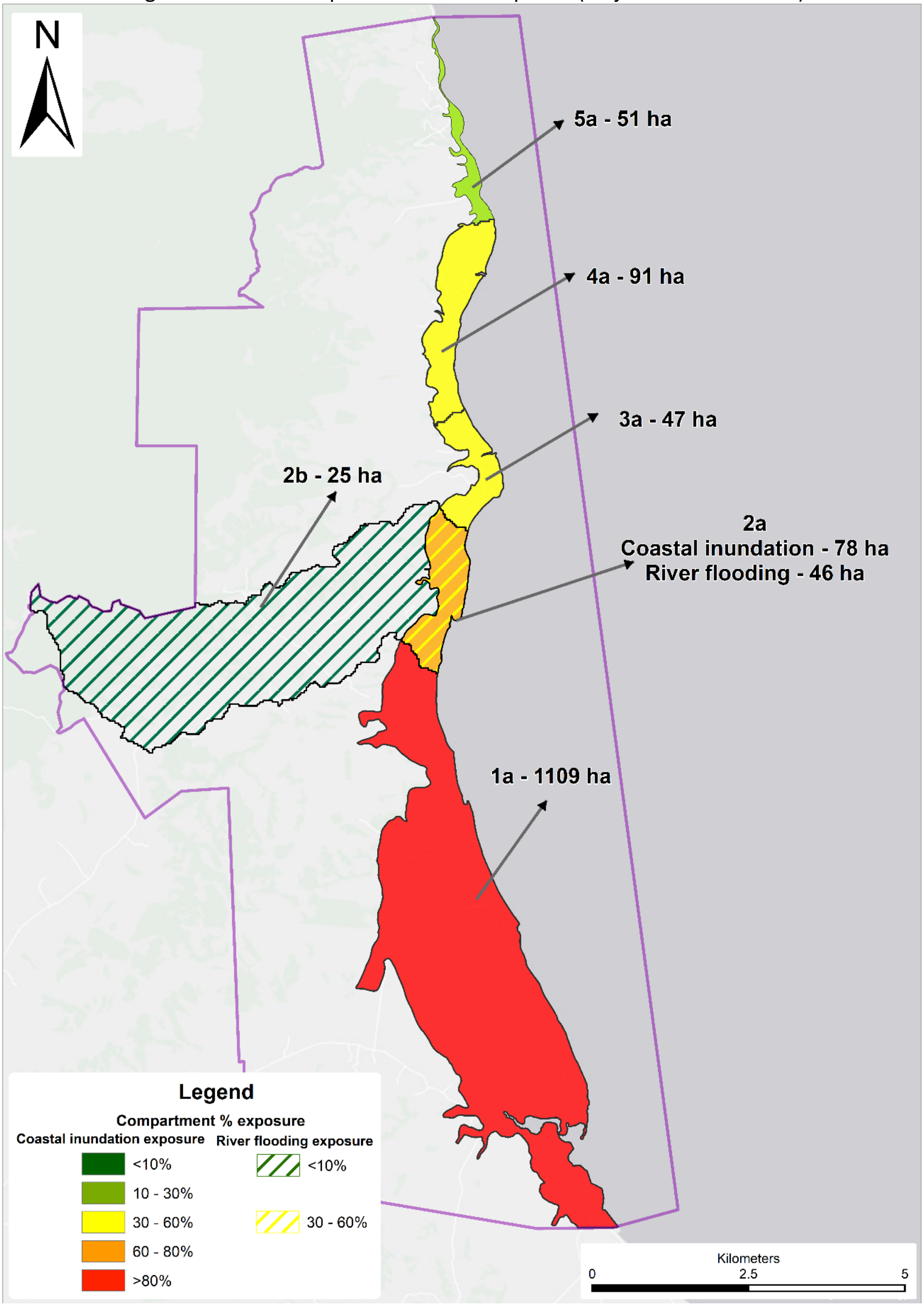



**Figure 53 Relative exposure of land area to coastal inundation and Hauarahi Stream flooding by sub-compartment (major event scenarios) (note: labels show land area exposed), where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

The highest percentage of land is exposed in the south of the project area, and decreases to the north as land becomes more elevated. For the major event scenarios, a higher percentage of land is exposed to coastal inundation than Hauarahi Stream flooding in both for sub-compartment 2a and the whole project area.

## 6.2 Estimated damage cost and resident displacement

The results for damage cost and resident displacement are, for each hazard type and element, presented by sub-compartment and event scenario, and quantify the estimated damage cost and resident displacement for each. Because the estimated damage cost results are in the same unit, i.e. $, they are suitable to add together to compare the sum of estimated damage costs across compartments (presented for the major event scenario) (section **Error! Reference source not found.**), though it should be noted that limitations in the accuracy of the results are likely to vary for the different elements.

### 6.2.1 Coastal inundation

Figure 54 to Figure 56 shows the estimated cost of damage to buildings, roads, and rural pasture land from coastal inundation for each sub-compartment. Figure 57 shows the estimated number of residents displaced for different time periods for the major event scenario.

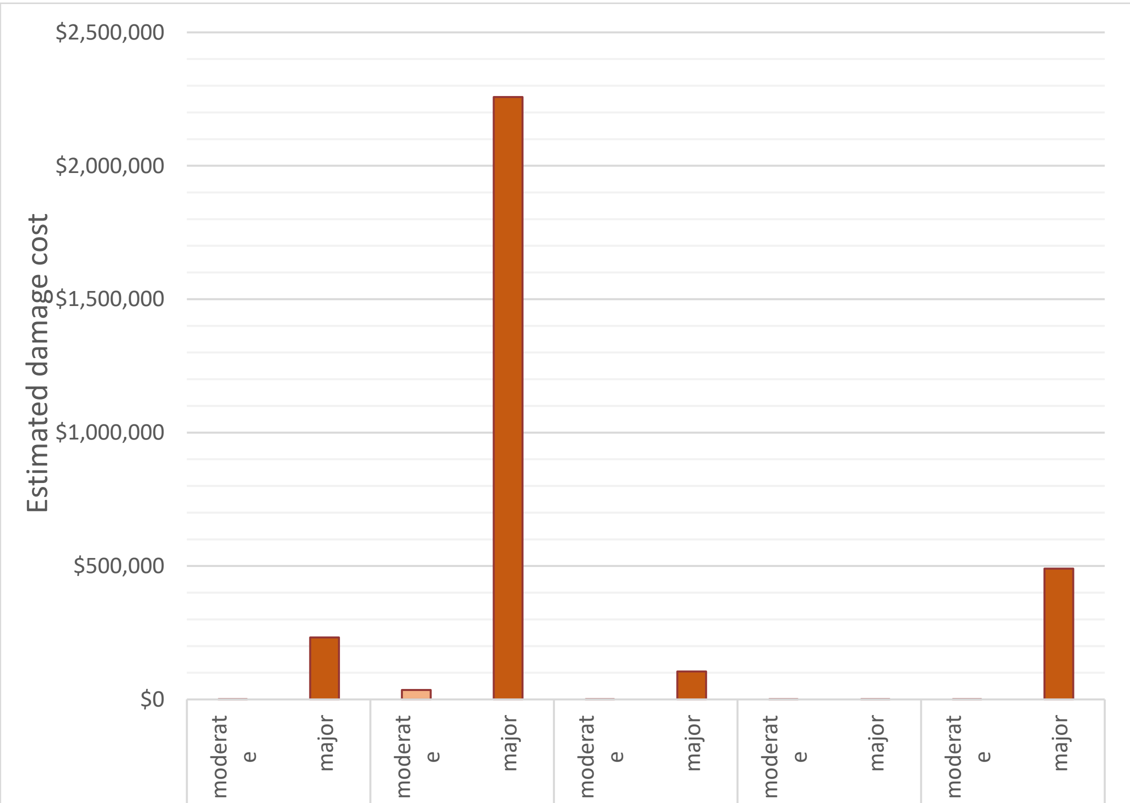



**Figure 54 Estimated cost of damage to buildings from coastal inundation by sub-compartment, where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

The total estimated cost of damage to buildings for the Wharekawa Coast 2120 project area from coastal inundation is $35,000 (2 significant figures (sf)) and $3,100,000 (2 sf) for the moderate and major events respectively.

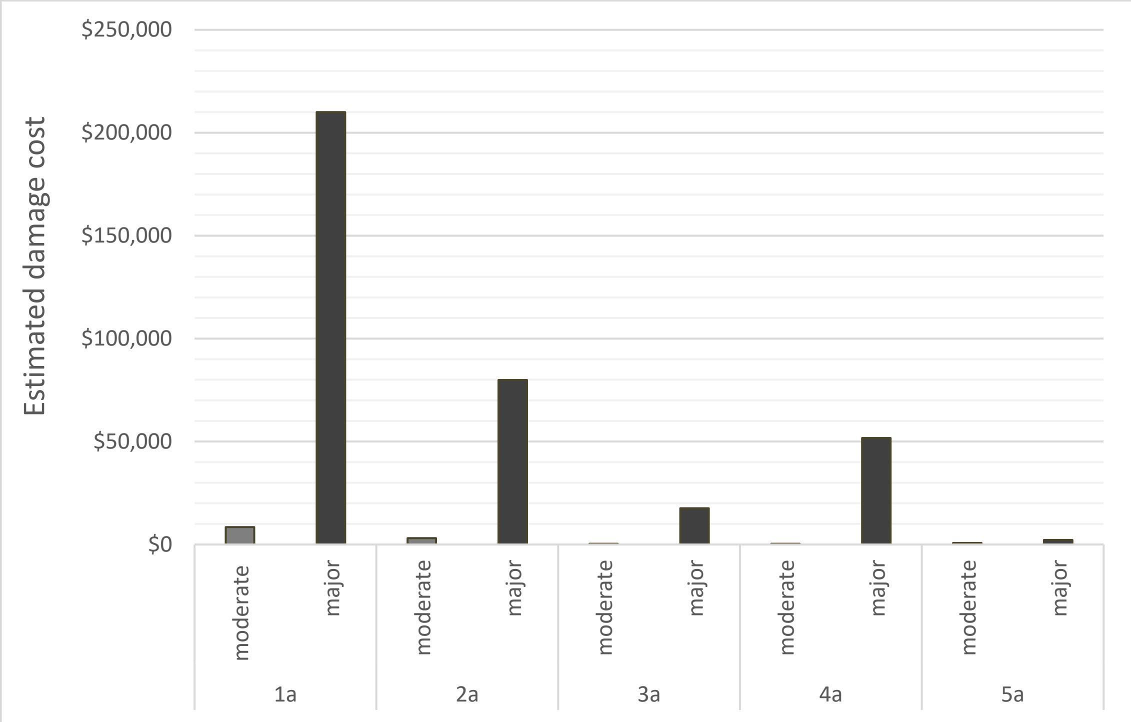



**Figure 55** **Estimated cost of damage to roads from coastal inundation by sub-compartment, where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

The total estimated cost of damage to roads for the Wharekawa Coast 2120 project area from coastal inundation is $12,000 (2 sf) and $360,000 (2 sf) for the moderate and major events respectively.

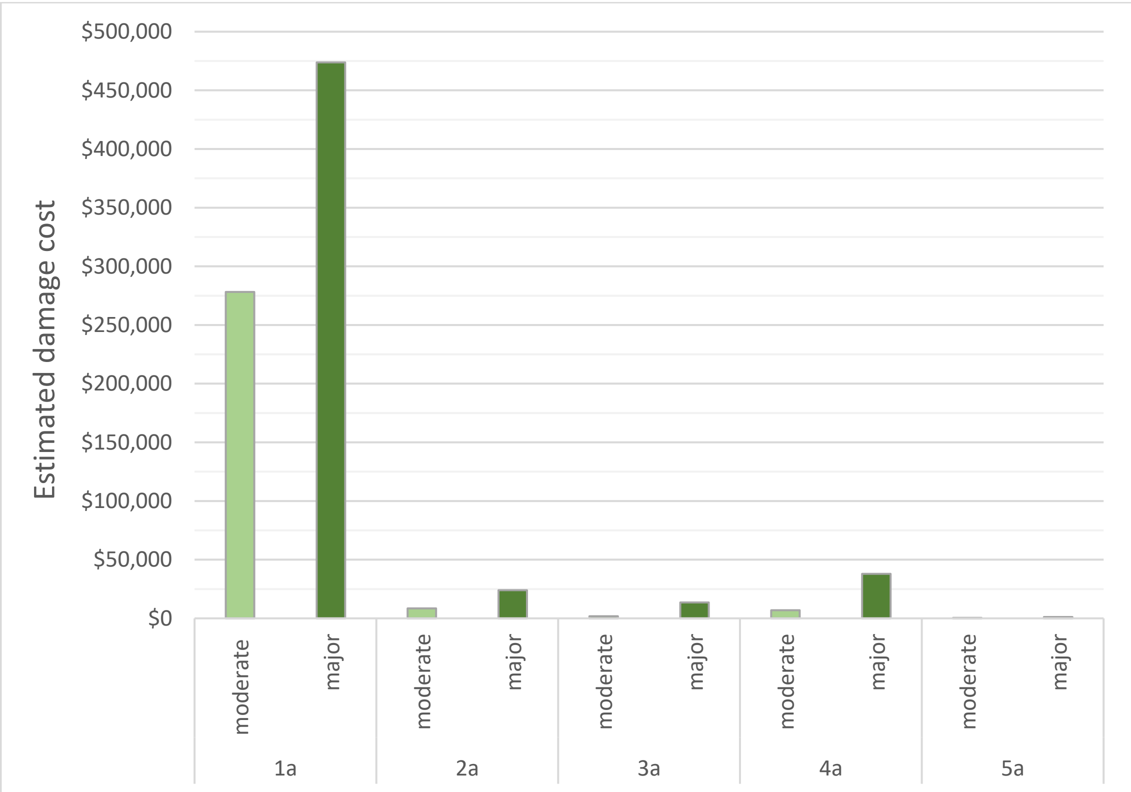



**Figure 56** **Estimated cost of damage to rural pasture land from coastal inundation by sub-compartment, where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

The total estimated cost of direct damage to pasture for the Wharekawa Coast 2120 project area from coastal inundation is $3000,000 (2 sf) and $550,000 (2 sf) for the moderate and major events respectively.

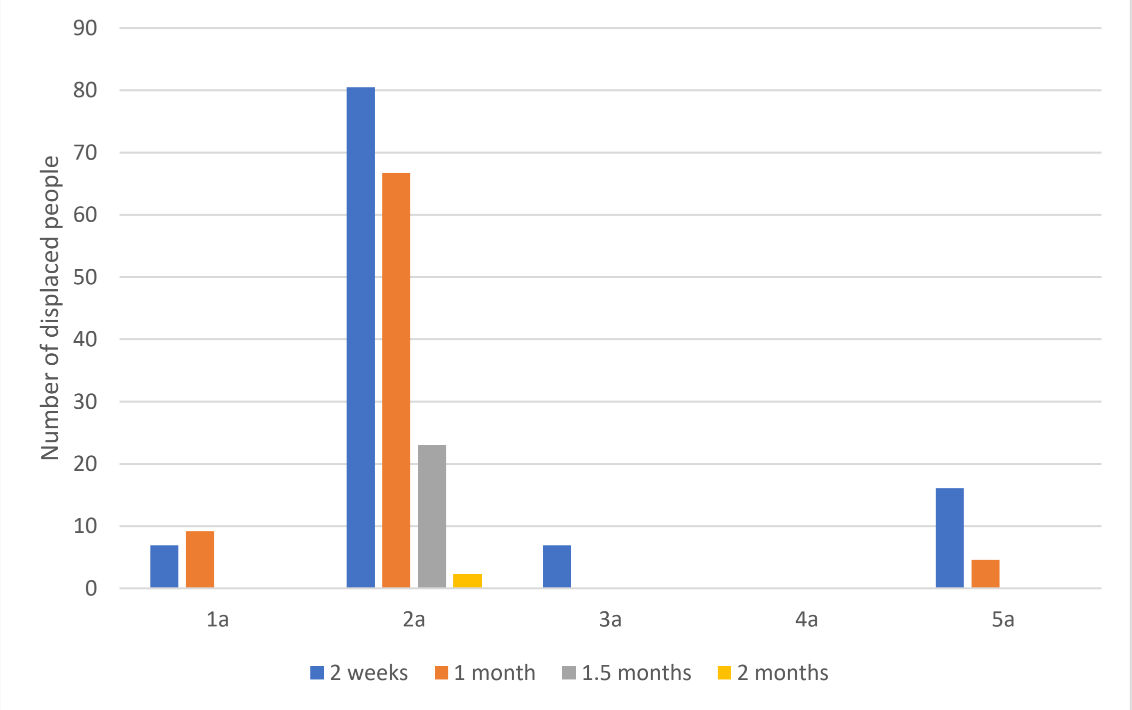



**Figure 57 Estimated number of residents displaced from the coastal inundation major event scenario by sub-compartment, where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

For the major event scenario, the total estimated number of residents displaced is 216 people, with the estimated displacement time for each person ranging from two weeks to two months.

For the moderate event, only one building (2 people) (in sub-compartment 2a) is expected to result in residents being displaced, and for a period of two weeks.

### 6.2.2 Hauarahi Stream flooding

For buildings, the damage cost resulting from Hauarahi Stream flooding is estimated to be low, with damage costs only resulting in sub-compartment 2a (Kaiaua township) and from the major event scenario – the estimated damage cost here is $68,000 (2 sf). The estimated damage cost from the moderate event scenario is $0 (as buildings are not expected to flood above floor level based on the assumptions made), and the estimated damage cost for sub-compartment 2b (Kaiaua inland) is $0 (as there are no buildings exposed). The resulting number of residents displaced for sub-compartment 2a from the major event is estimated at 5 people for a period of two weeks.

Figure 58 shows the estimated cost of damage to roads from Hauarahi Stream flooding for each sub-compartment that is exposed. The estimated cost for sub-compartment 2b is $0 as no roads are exposed.

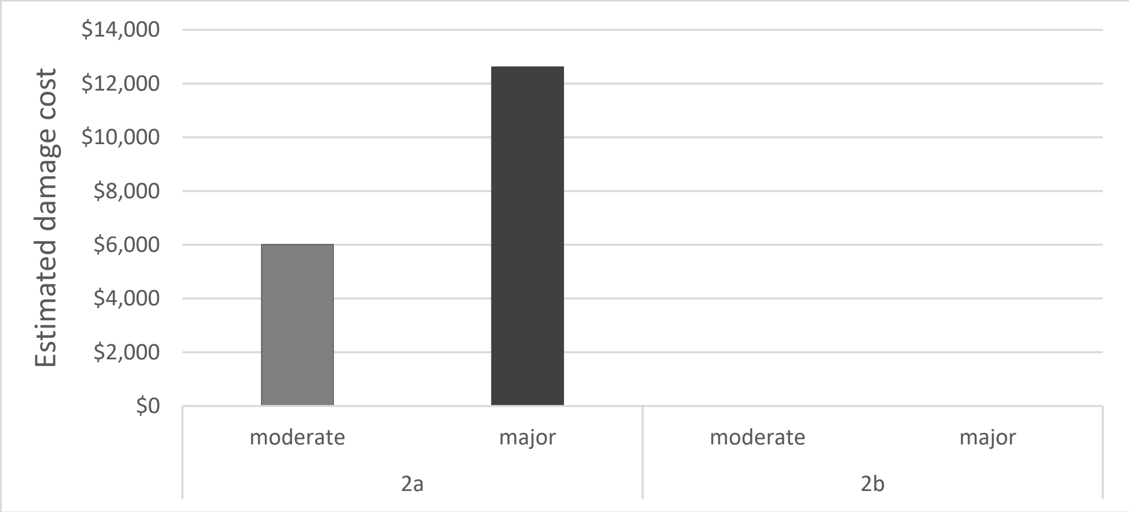



**Figure 58 Estimated cost of damage to roads from Hauarahi Stream flooding by sub-compartment, where sub-compartment names are: 2a Kaiaua township; 2b Kaiaua inland**

The direct damage cost to rural pasture land from Hauarahi Stream flooding is expected to be minimal for the reasons outlined in section 3.6.2.1, thus is not presented here.

### 6.2.3 Sum of estimated damage costs

Figure 59 shows the sum of the estimated cost of damage to buildings, roads and rural pasture land from coastal inundation and Hauarahi Stream flooding for each sub-compartment that is exposed (major event scenarios).

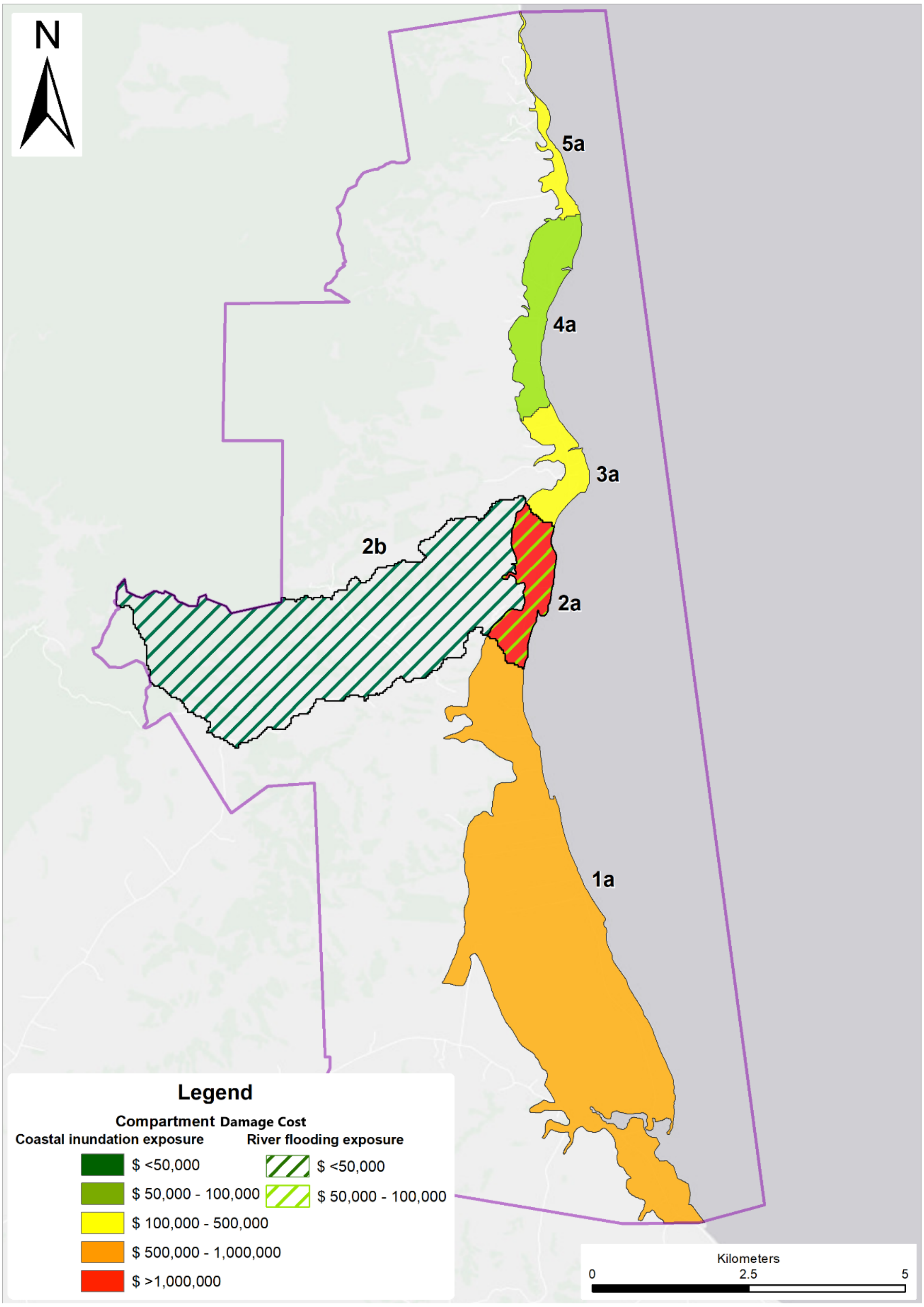



**Figure 59 Sum of estimated cost of damage to buildings, roads and rural pasture land from coastal inundation and Hauarahi Stream flooding by sub-compartment (major event scenarios), where sub-compartment names are: 1a Pūkorokoro Miranda; 2a Kaiaua township; 2b Kaiaua inland; 3a Whakatiwai; 4a Waihihi; 5a Waharau**

The estimated damage costs are the highest by a large margin in sub-compartment 2a, due to the high exposure to coastal inundation and large number of buildings. Estimated damage costs are next highest in sub-compartment 1a (also by a large margin), due to the high exposure to coastal inundation and large area of pasture land, as well as significant costs to buildings and roads. Estimated damage costs to sub-compartments 3a, 4a and 5a from coastal inundation are less but still significant. The estimated damage costs from Hauarahi Stream flooding are much lower than for coastal inundation, both within sub-compartment 2a and for the project area.

# 7 Additional information on potential impacts

Knowing the degree of exposure and estimated damage costs and resident displacement for a given event scenario is useful, but this quantitative information alone is not enough to fully understand the risk. The following section provides additional information on the potential impacts of coastal inundation and river flooding. This is information that is not explicitly covered by the results of the quantitative risk assessment, but adds value to these results.

Also included in this section (7.5.3) is a summary of the key information (related to risk) from the Wharekawa Coast 2120: Ecological Values Impact Assessment report.

## 7.1 Buildings and properties

### 7.1.1 Homes, buildings and disruption to residents

Impacts to homes and other buildings from coastal inundation and river flooding may include:

1. Damage or destruction of homes and other buildings (and their contents), potentially resulting in large repair and clean-up costs (insurance coverage will influence financial impact), loss of sentimental items, residents needing to live elsewhere while clean up and repair works undertaken, and increase in insurance premiums.
2. Failure/overflow of septic tanks, potentially resulting in contamination of land and water and public health risk. Residents may be required to use portaloos and drink only bottled water during this time. Septic tanks will need to be emptied/cleaned out, which may take weeks depending on demand.
3. Power and communications outages.
4. Damage to garages, vehicles and other equipment.
5. Shortage of water available from rain water tanks due increased demand for water to clean up post event (and limited capacity, particularly in summer).

Impacts solely from coastal inundation may include:

1. Disruption to drinking water supply as a result of damage to pumps from saltwater.
2. Gardens (including food gardens) damaged or destroyed, with potential die off due to saltwater.

### 7.1.2 Rural land

In addition to the direct costs resulting from pasture damage (provided in section 6), impacts to rural properties from coastal inundation and river flooding may include:

1. Costs to clear sediment and debris and repair infrastructure (e.g. fences) and equipment (e.g. milking machinery).
2. Loss of pasture productivity, potentially resulting in reduced income, loss of jobs or reduced income, additional feed requirements, relocation of or reducing stock numbers, etc.
3. Costs of spraying out paddocks or weeds and cultivation.
4. Lack of or reduced insurance cover may reduce or eliminate the ability to raise capital for purchasing business assets (EnviroStrat, 2020).

Impacts solely from coastal inundation may include:

1. Saltwater flooding of groundwater and surface water takes, affecting rural water supply and equipment.
2. Ongoing effects with additional drainage and compaction issues caused by the salt (Adrian Brocksopp & Tim Russell, personal communication, 17/06/20).

Note that for Hauarahi Stream flooding, direct costs from pasture damage are expected to be minimal, as most pasture will survive freshwater flooding, unless underwater for at least 4 days or there is considerable silt deposition (not expected for Hauarahi Stream - more detail in section 3.6.2.1).

Another factor to consider is that with the projected effects of climate change there will be a decline in the predictability of weather for farming systems reliant on rainfall and a favourable climate (EnviroStrat, 2020). If farms are already under stress, for example from drought, this is likely to exacerbate any impacts from coastal or river flooding events.

#### 7.1.2.1 Estimated damage costs and January 2018 storm tide event

With respect to the estimated damage costs for rural pasture land (provided in section 6), it should be noted that there is a huge variation in costs to return land to perennial pasture (Adrian Brocksopp & Tim Russell, personal communication, 17/06/20). Following the January 2018 storm tide event, some farmers Ravensdown worked with went straight back into grass clover (as has been assumed to estimate damage costs), but many went through either cropping or annual cycles depending on the feed demand of the farm. There are still ongoing effects with additional drainage and compaction issues caused by the salt and exacerbated by the last two droughts in the area (Adrian Brocksopp & Tim Russell, personal communication, 17/06/20).

It was noted by WRC Scientist, Matthew Taylor (personal communication, 20/05/20) that in general, the farmers least affected were those who allowed for periodic flooding, had a plan to get the water off quickly, had moderate stocking rates and elevated land for their stock while waiting for the water to recede. This is particularly important as the marine clays that dominate the local soils are vulnerable to structural damage during wet conditions (Matthew Taylor, personal communication, 20/05/20).

## 7.2 Lifelines

Impacts to lifelines from coastal inundation and river flooding may include:

1. Road closures, resulting in:
    a. Residents unable to access services and recreation areas or meet for social occasions.
    b. Emergency (and other essential) services may be unable to access Whakatiwai and Waharau.
    c. Travel detours and longer travel times, including for Waharau residents travelling to Auckland (may need to use other service locations such as Ngatea). (EnviroStrat, 2020)
    d. Delay in restoration of the services set out below (electricity, communications, stormwater, stopbanks)
2. Flooding of electricity and communications infrastructure, resulting in a loss of services to residents.
3. Reduced level of service of stormwater assets, resulting in increased flood risk, until assets are cleared/repaired. Damage to stormwater assets is unlikely.
4. Potential damage to stopbanks, resulting in increased flood risk until repairs completed.
5. Damaged council assets, resulting in large repair costs and potentially increased cost to residents through rates (EnviroStrat, 2020).

Impacts solely from coastal inundation may include:

1. Saltwater flooding of groundwater and surface water takes, affecting rural water supply and equipment.

# 7.3 Services, recreation and tourism

## 7.3.1 Services

Impacts to services from coastal inundation and river flooding may include:

1. Damage to or loss of services (may include building and contents) including iconic businesses such as the Pink Shop which also services tourists to the area, and initiatives such as EcoQuest Education Foundation. Private business owners will incur costs to repair damage and clean up. For businesses, a loss of income may result from the downtime required for clean-up and repairs. This may lead to job losses or reduced income.
2. Loss of revenue and reduced ability for businesses to operate if roads are closed for an extended period.
3. Some business owners may not be able to get/afford insurance coverage, eliminating the ability to raise capital for purchasing business assets (EnviroStrat, 2020).

### 7.3.1.1 School

(Janine Archer, personal communication, 06/80/20)

Impacts to Kaiaua School from coastal inundation and river flooding may include:

1. Flooding of the school grounds and deposition of debris. Buildings are unlikely to be flooded above floor level and significant damage is unlikely.
2. Temporary closure of the school while the water recedes and clean up occurs (up to a couple of days if buildings not flooded). School attendance will also be reliant on the roads being open and students being able to travel to school safely.

Kaiaua School is generally less affected by flooding from Hauarahi Stream than coastal inundation, with impacts generally limited to flooding of the back field and carpark (requiring management to keep students away from flooded areas, but generally not school closure), and students being unable to travel to and from school due to road closures. Flooding occurs due to overflow from the drain beside the school.

## 7.3.2 Recreation and tourism

Impacts to recreation and tourism from coastal inundation and river flooding may include:

1. Damage to recreational assets/areas (may include building and contents where relevant) such as the Kaiaua Boat Club, Kaiaua Bowling Club, pirate ship playground and beaches, reducing the recreational and social opportunities in the area, at least in the short term. Asset owners will incur costs to repair damage and clean up.
2. Damage to or loss of tourism infrastructure and initiatives such as the Shorebird Centre, tourist accommodation, and the Hauraki Rail Trail. Private business owners and HDC will incur costs to repair damage and clean up. For businesses, a loss of income may result from the downtime required for clean-up and repairs. This may lead to job losses or reduced income.
   a. The project estimate to construct the Kaiaua to Pūkorokoro Miranda section of the Hauraki Rail Trail (includes trail head development of toilets, carparks, etc. in Kaiaua) is $1.63 million (HDC, personal communication, 11/05/20). Damage/clean-up costs resulting from a large coastal inundation event may be significant.
3. Loss of tourism revenue and reduced ability for businesses to operate if roads (and the Hauraki Rail Trail) are closed for an extended period.
4. Some business owners may not be able to get/afford insurance coverage, eliminating the ability to raise capital for purchasing business assets (EnviroStrat, 2020).

Impacts solely from coastal inundation may include:

1. Damage to DOC conservation areas, for example, inundation with debris, damage to plants.

2. Reduction in aesthetic of beach environment, reducing its popularity an impacting on the visual aesthetic of the area.
3. Long term, the effects of coastal inundation and erosion with projected sea level rise may cause the loss of habitat and the shore birds that rely on it, making the Pūkorokoro Miranda Shore Bird Centre and the branding of the area as the 'The Shorebird Coast' redundant (EnviroStrat, 2020).

# 7.4 Cultural

This section was intended to be informed by a cultural impact assessment, which was planned to be completed as part of Wharekawa Coast 2120. However, due to resourcing and other issues this has not occurred, which is a gap for the project.

# 7.5 Ecological

## 7.5.1 Pūkorokoro Miranda shorebirds

The following information was provided by Keith Woodley of Pūkorokoro Miranda Shorebird Centre (personal communication, 13/07/20) on the impacts to birds from the January 2018 storm tide event:

*The species most impacted at the time were the white-fronted tern (New Zealand threat ranking (TR): At Risk) and black-billed gull (TR: Nationally Critical). Both were nesting in colonies on the outer shell spit which was completely inundated. At the time the gulls had chicks, some well-developed, and many of these appeared to have survived the event itself. I am uncertain about subsequent survival rates over the next few days. The tern colony was still at the egg stage and so all productivity was lost.*

*There would have been two other species breeding on the Wharekawa coastline at the time; northern New Zealand dotterel (TR: Recovering) and variable oystercatcher (TR: Recovering). There is likely to have been a few pairs of each, but we do not know the outcome for these species. However, if any pairs had hatched chicks prior to the event, some may well have survived.*

*The bulk of the shorebird populations on the Firth of Thames are species that breed elsewhere. New Zealand species include pied oystercatcher (TR: At risk: Declining) wrybill (TR: Nationally Vulnerable), pied stilt (TR: Not Threatened) and banded dotterel (TR: Nationally Vulnerable.) The most common Arctic breeding species are bar-tailed godwit (TR: At Risk: Declining) and red knot (TR: Nationally Vulnerable). Most of these birds forage on the intertidal flats during low tide, but require secure roost sites during high tide. The immediate impact of the 2018 event on these species would have been temporary loss of coastal roost sites. However, another potential longer-term impact would be any changes to tidal flat substrates during the event. Benthic animals on which birds feed are finely attuned to conditions such as sediment size, so any movement of sediments (especially fine silty sediments) caused by the surge may negatively impact them. This would then have implications on their availability as bird food. On the other hand, the inter tidal zone is naturally a highly dynamic system, and any effects of the surge may have been temporary in duration. I must qualify this by saying it is, in part, speculative: I am not aware of any specific monitoring for this following the event.*

*We did notice significant changes to more terrestrial species following the event. For instance, spur-winged plovers (TR: Not Threatened) are often associated with pasture areas adjacent to the Shorebird Centre. They were not seen again in these areas until towards the end of 2018. This was presumably because these pastures were inundated with salt water – some for over five days – which likely killed off the terrestrial invertebrates that are their prey. A further observation was that during the winter of 2018 less shorebirds such as pied oystercatchers were using the pastures. Normally during that time of year, especially when the paddocks are wet,* *large flocks of shorebirds are a common sight. Once again, lack of terrestrial invertebrate prey items is the likely reason for this change. Interestingly, ring-necked pheasants (common in the district) that also prey on terrestrial invertebrates as well as vegetable matter were also not recorded in the area until the following year.*

### 7.5.2 Other

Other impacts to ecological elements from coastal inundation and river flooding may include:

1. Drowning of plants and soil organisms. The survival of plants will depend on the time inundated, whether fresh or salt water, and how sensitive the species are to flooding and salt content (Matthew Taylor (WRC scientist), personal communication, 13/07/20).
2. Freshwater fish species are generally well adapted to hydrological changes and often take advantage of flood conditions. However, species like inanga (young are caught as 'whitebait') may be influenced by sea level rise as they spawn in tidal areas where conductivity and vegetation is suitable for egg laying. In the long term, spawning sites may move inland, assuming suitable vegetation is available for laying eggs. However, successful egg development can be impaired if there is excess fine sediment in the water column that may deposit and cake eggs, resulting in their suffocation and ultimately lost viability. (Bruno David (WRC scientist), personal communication, 14/07/20).

Impacts solely from coastal inundation may include:

1. Indirect impacts affecting the native species migration from the coast to the southern Hunua Ranges (a significant natural area (SNA)), reducing the species biodiversity values (Yanbin Deng (WRC scientist), personal communication, 13/07/20).

Impacts solely from river flooding may include:

1. Increased nutrients and sediment entering streams and the Firth of Thames, reducing water quality (EnviroStrat, 2020).

### 7.5.3 Ecological Values Impact Assessment

The Wharekawa Coast 2120 project area has significant ecological values that are not explicitly covered by the data presented in the ecological impact category. To address this information gap, an Ecological Values Impact Assessment was completed for the project area by Hunt & Townsend (2020). This assessment provides information on the ecological values that are present in the project area, and how they could be affected by climate change. The assessment does not cover ecological impacts from individual storm events due to the considerable variation and uncertainty. Because of this, the assessment is more useful when considering adaptation options (to ensure that ecological values are considered) rather than for evaluating risk, but the key information has been summarised in Appendix 5 to provide context.

## 7.6 Overall impacts

Impacts from coastal inundation and river flooding may include all of those provided in each impact category above. When considered together, these impacts may interact in ways that are cumulative, making them less tolerable, such as:

1. If East Coast Road is closed, it may be less tolerable for local services, recreation areas/assets and conservation areas to be closed, because residents are unable to access those outside of their community.
2. If the homes of families with school-aged children are damaged or uninhabitable, it may be less tolerable if the school is also closed, meaning that children must be cared for at home (or elsewhere) during the day.
3. If owners of businesses that benefit from tourists incur large clean-up/repair costs, it may be less tolerable if tourist numbers are also reduced longer-term due to factors such as restricted road access, and damaged tourism and recreation infrastructure.
4. If insurance premiums for homes or businesses have increased due to natural hazard risk, it may be less tolerable if rates also increase (as a result of more frequently damaged council assets).

# 8 Vulnerability

The impacts that result from any given hazard exposure vary depending on a number of factors, ranging from insurance coverage, to the likelihood of being cut off by road, to the socioeconomics of an area. Collectively these factors are known here as vulnerability.

The MfE Guidance refers to vulnerability as both the fragility of assets (covered in section 3.6.2.1 of this report), and the predisposition of a human or biological system to be adversely affected, including the concepts of sensitivity to harm and lack of capacity to effectively cope and adapt (Ministry for the Environment, 2017).

'Sensitivity to harm' is not assessed here as it is generally based on scientific inputs relating to the uncertainty of coastal hazard and climate change scenarios. For Wharekawa Coast 2120, the uncertainty in the projected effects of climate change, particularly sea level rise, will be considered when estimating the time before thresholds are reached, and when determining signals and triggers.

The capacity of the community to effectively cope and adapt is assessed in Table 14 by identifying key characteristics and factors that may affect vulnerability. Most of these factors affect the entire project area relatively equally (or information is only available at the project area scale). However, some factors affect some areas more than others, and these are highlighted purple and numbered and expanded on in section 8.1.

Note that any statistics provided below are derived from the New Zealand 2018 Census for the Miranda-Pūkorokoro SA2. This SA2 covers the majority of the project area, however, at the southern boundary a small area is within the Hauraki Plains North SA2. This portion of the project area is small with very few dwelling this is not considered statistically significant (Murphy, 2020b).

**Table 14 Characteristics and corresponding factors that may affect vulnerability in the Wharekawa Coast 2120 project area**

| | Characteristics | Vulnerability factors |
|---|---|---|
| **Location** | Connection with the coast - the coastal environment is prominent with the main road (East Coast Rd) running close to the sea and the mostly flat terrain giving unimpeded views of the coastline and Firth of Thames (Murphy, 2020a) | The majority of buildings and infrastructure are currently exposed to coastal hazards. If in the future the risk associated with this exposure becomes intolerable, retreating from the coast into the hills (a potential adaptation option) will affect many of the community values that caused people to move to/remain in the area. This may make any retreat option unattractive. |
| | Many properties are only accessible via East Coast Road. (1) | East Coast Road provides the only road access for many properties along the coast, but is also prone to closure due to flooding and/or slips. This increases the vulnerability of residents of these properties (by preventing access to essential services such as food, fuel and medical care), particularly in an emergency. It may also result in a loss of income for residents unable to travel to work for an extended period. |
| | | This potential for isolation also means that many households will be prepared to be cut-off for a few days at a time, more so than in less isolated areas. |
| **Built environment** | The project area is located close to Auckland City but is not considered for large scale residential development. Additionally, the Franklin District Plan aims to direct growth to existing villages and avoid wide dispersal of lots throughout rural and coastal areas. Growth is limited by lack of reticulated services, presence of the Ramsar site, natural hazards, etc. and development has been minimal in the last 20 years. There is some undeveloped land zoned as residential in Whakatiwai where growth may occur. (Murphy, 2020a) | Assets/elements potentially exposed to natural hazards have not increased significantly over the past 20 years, and are unlikely to in the future. This limits the increase in adverse consequences from events. |
| | | Less investment and wealth in the area, therefore less money available for adaptation options and lower cost: benefit ratios. |
| | There is no wastewater network beyond the township of Waitakaruru, thus properties currently have septic tank systems (Murphy, 2020a). | For coastal areas, as the sea level rises the current septic tank systems may become inundated with a corresponding rise of groundwater or seawater and become ineffective. Additionally, failure of septic tanks in flooding events may result in potential health issues and contamination. |
| | There is no reticulated drinking water network, thus most properties have rainfall tanks. | Reticulated drinking water networks are vulnerable to the supply being cut off entirely due to damage. However, water supply from rainwater tanks can also be impacted, with potential for damage to pumps from saltwater (from coastal inundation). Additionally, following natural hazard events there may be a shortage of water |

| | Characteristics | Vulnerability factors |
|---|---|---|
| | | available from rain water tanks due increased demand for water to clean up (and limited capacity, particularly in summer). |
| | The project area generally has a linear lifelines network with power and communication lines mostly following East Coast Road (network is buried, except over bridges where it is aerial). | Communities up and down this corridor are vulnerable to having power and communications (and road access) cut-off if damage to this network occurs. Due to the linear nature, there are limited redundancies - check this at lifelines workshop. |
| | The communities of Pūkorokoro Miranda, Whakatiwai and Waharau do not have any grocery stores, or other essential services such as medical care. Kaiaua township has a small grocery store (Pink Shop), GAS station and Medical Centre, which provide limited services. (2) | Residents are often required to travel outside of the project area (to Ngatea, Auckland, etc.) to access essential (and other) services such as food and medical care. This exacerbates the vulnerability that results from many properties only being accessible via East Coast Road, as residents are generally unable to access services without travelling. However, as noted above, this also means residents are more likely to be prepared to be cut-off from services. |
| | There is currently one drainage district (Taramairie) within the project area, with a further district (Pūkorokoro) being developed north of Miranda Stream. These drainage districts are for freshwater flooding only; unlike flood protection and land drainage in the Hauraki Plains which provide defence against coastal flooding - where these defences end is the southern boundary of the project area (Murphy, 2020a). | The project area is more vulnerable to coastal flooding than the neighbouring Hauraki Plains due to the lack of coastal flooding defences. |
| | There are eight bridges along the East Coast Road within the project area. A number of these bridges are amongst the oldest bridges in the region (EnviroStrat, 2020). | The high number of bridges may result in increased vulnerability of the transport corridor as bridges can be weak points (susceptible to scour, erosion, etc.). This is likely to be particularly the case with older bridges. |
| | Some buildings were raised following the January 2018 event (with consent costs covered by HDC) (Murphy, 2020a). | Buildings with higher floor levels now have a reduced physical vulnerability. |

| | Characteristics | Vulnerability factors |
|---|---|---|
| **Socio-economic** | The Miranda Pūkorokoro area has a 2018 socioeconomic deprivation rating of 7. This is an improvement on the 2013 rating of 8. A value of 10 indicates that an area is in the most deprived 10% of areas in New Zealand and a value of 1 represents the least deprived 10%. (Murphy, 2020a) | A socio-economic deprivation rating of 7 indicates high socio-economic deprivation. Of the nine factors considered in the index (access to internet, income, unemployment, qualification, home ownership, overcrowding, mouldy and damp homes), those leading to the high socio economic deprivation rating in the area include - less access to internet, lower incomes, and more people with no qualifications than NZ as a whole. Positive socio-economic factors include - lower unemployment rate, higher home ownership, lower overcrowding, less damp & mouldy homes than NZ as whole. In general, people who live in more deprived areas are more vulnerable to adverse environmental impacts. They may also have less capacity to cope with these impacts and fewer resources to protect themselves from environmental hazards. See further comments under 'demographics' and 'economic' below. (Atkinson et al., 2019) |
| **Demographics** | There are a number of holiday homes or baches particularly in the coastal part of the area, with around 30 percent of houses recorded as unoccupied dwellings (Murphy, 2020b) | Potentially reduced impacts of natural hazard events, as holiday homeowners have alternate main dwellings thus less reliance on habitability. Holiday homeowners will still be affected by any decrease in property value or insurance affordability/coverage. |
| | | Holiday homeowners may be less connected to the community than permanent residents, increasing their vulnerability in an event. |
| | The population is generally older than New Zealanders as a whole (median age is 54); there is a higher proportion of people not in the labour force (37%), e.g. retired or not seeking work. (Murphy, 2020b) | Retired people are generally less mobile and therefore more physically vulnerable to events. 13% of people aged 65 years and over have one or more activity limitation (have ‘a lot of difficulty’ or ‘cannot do at all’ one or more of the following activities: walking, seeing, hearing, cognition, self-care, and communication), compared with 6% of people aged 30-64 years in Miranda-Pūkorokoro (Stats NZ, 2018). |
| | | Retired people are less vulnerable to events that affect people's income, thus potentially more financially stable. However, retired people (often on a limited fixed income) may be less able to afford rising insurance premiums thus chose not to insure, and may be less likely to have the finances available to move to a new area should natural hazard risk become intolerable, particularly if property values decrease. |

| | Characteristics | Vulnerability factors |
|---|---|---|
| | As at the 2018 census the population of the project area is 849 (an increase from 2013 and 2006) (Murphy, 2020b). | A small population means that when considering adaptation options, the cost: benefit ratios will be lower than for a larger population. |
| | 29% of people have no qualifications which is higher than for New Zealand as a whole (18%). 7% of people have a Bachelors degree and level 7 qualification or higher which is lower than for New Zealand as a whole (15%). (Stats NZ, 2018) | This lower level of qualification may make it more difficult for people to retrain or seek work elsewhere should work in the primary industries and tourism no longer be viable as a result of increasing frequency and severity of natural hazard events. |
| | 68% of households have access to the internet, which is lower than for New Zealand as a whole (86%) (Murphy, 2020a). | Households without internet are likely to be less informed about forecast natural hazard events, and about resilience to natural hazards in general. |
| **Economic** | The median individual income is $28,200, which is lower than for New Zealand as a whole ($31,800) (Murphy, 2020a). | A lower median income may result in less residents being able to afford insurance (see below) and/or adaptation options, while also making it difficult for residents to move out of an area if their thresholds are exceeded. |
| | Some residents experienced large increases in insurance premiums following the January 2018 event (EnviroStrat, 2020). This is likely to increasingly be the case with the projected effects of sea level rise (increasing frequency of events). | Some residents can no longer afford to pay for insurance, thus have opted not to insure their homes. In future natural hazard events, repair costs may be unaffordable without insurance, and residents will be more reliant on external financial support, e.g. funds from mayoral relief, social welfare department. A lack of insurance may also impact wellbeing of residents through the anxiety and concern caused. |
| | Agriculture, forestry and fishing industries employ the most people and have the largest number of businesses. Dairy cattle farming is the largest contributor to GDP for the area ($4.5 million), with sheep, beef and grain farming being the third largest contributor ($2.5 million) (total GDP was estimated at $20.9 million in 2018). (Murphy, 2020b) (3) | Primary industries, particularly agriculture, are often highly vulnerable to impacts from natural hazard events. Agriculture (in New Zealand) is dependent on the presence of pasture (and/or other crops), which are often damaged or killed by flooding, particularly coastal flooding (due to saltwater). In addition, flooding may damage infrastructure and equipment and result in stock losses. A community with a high proportion of work in the primary industries is likely to suffer greater economic impacts than, for example, a community with a high proportion of office-type work. |

| | Characteristics | Vulnerability factors |
|---|---|---|
| | Tourism: The Shorebird Coast has been identified by Destination Coromandel (Regional Tourism Organisation) as a future tourism hotspot. With the Pūkorokoro-Miranda to Kaiaua leg of the Hauraki Rail Trail due to be completed within a year together with the trail from Hunua due to open in late 2020, there are opportunities for this area. The Pūkorokoro Miranda Shorebird Centre is already a popular attraction and has the potential to be one of the key attractions in the Hauraki District. (Murphy, 2020b) (4) | Tourist attractions can be significantly impacted by natural hazard events. Both the Miranda Shorebird Centre and the Hauraki Rail Trail are highly exposed to coastal flooding. Additionally, flooding may impact supporting infrastructure such as campgrounds, reserves and services, and cause road closures, preventing access for tourists. |
| **Ecological** | The Wharekawa Coast is often referred to as the Seabird Coast because of its recognised international importance for birdlife (Murphy, 2020a). | The morphological units that contribute to this bird habitat will be affected by climate change (Hunt & Townsend, 2020), presenting risk to the identity of the Wharekawa Coast and the tourism opportunities that this identity brings. |
| **Community** | During the January 2018 event, the community rallied and helped to clear out the debris using what they had available to them, e.g. machinery from locally owned business (EnviroStrat, 2020). | This indicates a high level of resilience, in that the community are used to looking after themselves and are able to work together well and do what needs to be done. Also, having previous experience of flooding events will generally increase a communities' resilience as they are more likely to understand the potential impacts of future events and how best to mitigate them. |
| | Interviewees of the SIA identified four different categories of residents, depending primarily on how often people had lived in the area and their livelihoods. A number of interviewees also noted that while there is interaction between the different groups, some like to keep to themselves. Further, residents felt that the communities of Waharau, Whakatiwai, Kaiaua and Pūkorokoro – Miranda seem to have little interaction. There is little that brings the community together as a whole or that is celebrated within the broader coastal community. (EnviroStrat, 2020) | The more connected communities are, the greater their resilience, and the lower their vulnerability to hazard events (due to being more likely to assist and look out for each other). This disconnect between different groups may increase the vulnerability of the community as a whole. |
| | The SIA identified the relationship with council (partly due to the 2010 change in administrative boundaries) as a social concern for the area, including that some residents have a lack of confidence in council with regards to reducing risk and responding to hazard events (though other residents have a high level of confidence) (EnviroStrat, 2020). | A lack of confidence in or distrust of council by some residents may lead to conflicting actions taken by those residents and council to try and reduce natural hazard risk. Further, actions taken by individuals to attempt to protect their own property can result in increased impacts to neighbouring properties. If different parties are working against each other, rather than together, this may result in increased vulnerability of the community as a whole to hazard events. |

| | Characteristics | Vulnerability factors |
|---|---|---|
| | The project area currently has limited social gathering places, and many of these, e.g. the Pink Shop and Kaiaua Boating Club are exposed to flooding (EnviroStrat, 2020). (5) | A loss of social gathering places due to natural hazard events may impact the social connectedness of the community. |
| | Many residents have a desire for things to remain as they are (EnviroStrat, 2020). | With increasing frequency of natural hazard events, the community will be required to adapt. A reluctance to change (adapt) may, over time, increase the vulnerability of the community. |
| | Residents perceptions on coastal hazards (and climate change) and the risks they pose vary, from those that believe the risk is significant and will increase with sea level rise, to those that think events only happen once in a lifetime and are sceptical of sea level rise projections (EnviroStrat, 2020). | Residents that believe natural hazard risk is significant (and will increase) are more likely to put adaptive measures in place (e.g. raising floor levels, flood proofing contents, creating a Household Emergency Plan) than those that believe a large event won't happen again. Those residents will be less vulnerable to future events. |
| **Cultural** | Wharekawa, just to the north of Kaiaua, is the site of a Ngāti Pāoa and Ngāti Whanaunga Marae. Whakatiwai is known as the first place that Iwi from Hawaiki entered Hauraki. It is also the site of one of the last large hui of Māori, ~3000 people, which occurred in the area in 1874. There are several *wāhi tapu* sites along the Coast, including a ūrupa site near the beach at Whakatiwai and at Tauwhare Koiora, Kaiaua. The history of the area is tightly bound with the history of the iwi who hold mana whenua in the area. (Murphy, 2020a; EnviroStrat, 2020). | Iwi may have a greater connection with the land; thus, adaptation options may require extra consideration. There may be an unwillingness to retreat if thresholds are reached and/or thresholds may be different than those for other parts of the community. |
| | Only 6% of archaeological sites that are known to HDC are exposed to the major coastal inundation scenario, as most sites are in the hill country (HDC, "archaeological sites" dataset) | Elements of historical cultural value may be less exposed to flooding than other elements (that are predominantly coastal). This may reflect that historically, Māori had only seasonal settlements along the Wharekawa coastline, with more permanent settlements in the hill country. As a result, there may be less attachment to place at the coastline. |

| | Characteristics | Vulnerability factors |
|---|---|---|
| | The population of the area that identify as Māori is increasing at higher rate than non-Māori; 28% are Māori, 87% are European (Murphy, 2020a). There is a higher proportion of Māori in this area than in Hauraki District as a whole (23%). The cohort of Māori that are younger is much larger than for the district as a whole (Stats NZ, 2018). The proportion of Māori land in the project area is 7% (HDC, " Māori land blocks" dataset). | The increasing proportion of the population that is Māori suggests whanau returning to Māori land and papakāinga developments in the area. They are exposed to the increasing natural hazard risks over time to their land and developments. Multiply-owned Māori land has restrictions on abilities to sell the land and this is reflected in the valuation of the land, so they may be financially vulnerable to lower compensation pay-outs, as well as the difficulties of administering compensation with multiply beneficiaries. There is also the cultural significance of the land, as mentioned above. The higher proportion of younger Māori people has implications over the longer term as potentially these younger people will experience the increased risk associated with natural hazards in the future. |

## 8.1 Spatially variable characteristics and factors

1. The northern communities of Whakatiwai and particularly Waharau are more likely to be cut-off by road than Kaiaua and Pūkorokoro Miranda, as they are only accessible by East Coast Road, whereas Kaiaua and Pūkorokoro Miranda are also accessible by Kaiaua Road and Miranda Road (and others). Additionally, the topography along the road is steeper further north, increasing the likelihood of slips. This results in increased vulnerability for residents of Whakatiwai and particularly Waharau for this factor
2. If communities are cut off by road, residents of Kaiaua will be able to access the services within Kaiaua township, whereas residents of the other communities will not. This may result in increased vulnerability for residents outside of Kaiaua for this factor.
3. Of the flat land that is exposed to coastal inundation, farming predominantly occurs in Pūkorokoro Miranda. This results in increased vulnerability (due to greater exposure) for Pūkorokoro Miranda for this factor.
4. The majority of tourism elements are in Pūkorokoro Miranda and Kaiaua, e.g Pūkorokoro Miranda Shorebird Centre and the Hauraki Rail Trail. As a result, these areas are more likely to be impacted by a decrease in tourism following natural hazard events, thus have increased vulnerability for this factor. Although it is noted that residents who benefit from tourism may live anywhere within (or outside of) the project area.
5. The gathering places within the project area are primarily located within or close to Kaiaua township. If Waharau (and potentially Whakatiwai) are cut-off by road following an event they will not be able to attend community gatherings, potentially resulting in increased isolation and decreased social connectedness, particularly if they are cut-off for an extended period of time. This may result in increased vulnerability for residents of Waharau and Whakatiwai for this factor.

# 9 Conclusions

This natural hazard risk assessment provides the information required to understand and evaluate the potential impacts of coastal erosion, coastal inundation and freshwater flooding; the most significant natural hazards for the Wharekawa Coast 2120 project area. As such, this report and the workshop resources developed from it will enable the determination of initial thresholds by the Panel and other key stakeholders, which can then be used to provide context when assessing adaptation options and pathways. It is recognised that more detailed risk assessment work will likely be required when assessing specific adaptation options; this will be carried out later in the process (as recommended by the MfE Guidance) and will allow the refinement of thresholds.

This assessment shows that in terms of potential impacts, coastal inundation is the most significant natural hazard to the Wharekawa Coast 2120 project area. Exposure to coastal inundation is greatest in sub-compartment 1a (Pūkorokoro Miranda) in the south, and reduces towards the north as the land becomes more elevated. Estimated damage costs are greatest in sub-compartment 2a (Kaiaua township), due to the high exposure and large number of buildings. Damage costs are also high in sub-compartment 1a, due to the high exposure and large areas of pasture land, as well as significant costs to buildings and roads. Estimated damage costs to sub-compartments 3a (Whakatiwai), 4a (Waihihi) and 5a (Waharau) from coastal inundation are less but still significant. The estimated resident displacement time ranges from two weeks to two months, with the greatest number of residents displaced in sub-compartment 2a.

Hauarahi Stream flooding is also a significant natural hazard, particularly for sub-compartment 2a, although estimated damage costs and resident displacement from Hauarahi Stream flooding are much lower than for coastal inundation (for both the project area and sub-compartment 2a).

At present day, any impacts from coastal erosion events are expected to be low; however, impacts will potentially be significant for all coastal sub-compartments in the future, with shoreline retreat likely to be primarily driven by coastal inundation and sea level rise.

For the five streams assessed qualitatively for freshwater flooding risk, impacts are expected to be very low to low where stopbanks are present and flood events do not exceed stopbank design. Even for events that overtop or breach stopbanks, impacts from Pūkorokoro, Miranda and Taramarie Streams are still expected to be low as rural land is the main element exposed. However, the potential impacts of a stopbank breach or overtopping at Whakatiwai Stream are high, as much of the village could be flooded (as was seen in the 1960s). Waharau Stream does not have stopbanks and flooding could cause moderate impacts.

There are many characteristics that influence vulnerability in the project area. Some characteristics such as limited road access and a relatively high socioeconomic deprivation rating can result in increased vulnerability, whereas others such as an ability to muck in and get things done (for example cleaning up following the January 2018 storm tide event), can result in increased resilience (and reduced vulnerability). Other characteristics vary spatially, such as the predominance of pasture land exposed to coastal inundation in sub-compartment 1a, and result in vulnerability varying across the project area. These vulnerability factors may affect when impacts from natural hazard events become intolerable, and as such should be considered when determining thresholds.

# References


Atkinson J, Salmond C, Crampton P 2019. NZDep2018 Index of Deprivation. Wellington, Department of Public Health, University of Otago.

Bryant R. 10 April 2017. Stuff News - Small coastal community of Waharau forced into isolation thanks to Ex-Cyclone Debbie. https://www.stuff.co.nz/waikato-times/news/91297827/small-coastal-community-of-waharau-forced-into-isolation-thanks-to-excyclone-debbie
[accessed 30 June 2020].

Craig H 2017. Regional flood summary: Rainfall event 7 to 12 March 2017. Waikato Regional Council Technical Report 2017/21. Hamilton, Waikato Regional Council.

Craig H, Koh, S, Williams J, Lovatt D, Stewart D 2017. Regional flood summary: Ex-Tropical Cyclone Debbie (4-6 April), Tasman Low (11-13 April), and Ex-Tropical Cyclone Cook (13-14 April). Waikato Regional Council Technical Report 2017/20. Hamilton, Waikato Regional Council.

Craig H, O'Shaughnessy D 2018. Regional event summary: Storm surge event, 4-6 January 2018. Waikato Regional Council Internal Series 2018/25. Hamilton, Waikato Regional Council.

EnviroStrat 2020. Wharekawa Coast 2120: Natural hazards social impact assessment for Wharekawa: Social impact and implications of sea-level rise on communities along the Wharekawa Coast, Auckland: EnviroStrat.

FEMA 2019. Hazus flood model. https://www.fema.gov/hazus-mh-flood-model
[accessed 8 May 2020].

Grant D, Marsh S, Munro A, Rick L 2020. Rapid flood hazard assessment of Hauarahi Stream, Kaiaua. Hamilton, Waikato Regional Council. Doc. No. 16080983.

Green C, Viavattene C, Thompson P 2011. Guidance for assessing flood losses CONHAZ Report. London, Flood Hazard Research Centre – Middlesex University .

Hume T 2020. Wharekawa Coast 2120: Coastal processes and hazards. Hamilton, Waikato Regional Council. Doc. No. 20221185.

Hunt S, Townsend M 2020. Wharekawa Coast 2120: Ecological values impact assessment. Hamilton, Waikato Regional Council. Doc. No. 18162391.

Mason M, Phillips E, Okada T, O'Brien J 2012. Analysis of damage to buildings following the 2010-11 Eastern Australia floods. Brisbane, National Climate Change Adaptation Research Facility, Australia.

Ministry for Primary Industries 2015. June 2015 Taranaki and Horizons Regions storm: Primary sector impact assessment. Wellington, Ministry for Primary Industries.

Ministry for the Environment 2017. Coastal hazards and climate change: Guidance for local government. Wellington, Ministry for the Environment.

Murphy N 2020a. Wharekawa Coast 2120: Community overview. Paeroa, NZ, Hauraki District Council.

Murphy N 2020b. Wharekawa Coast 2120: Economic profile. Paeroa, NZ, Hauraki District Council.

Ngawhika D 2018. Project feasibility report - East Coast Road RP3.2km. Auckland, Auckland Transport.

Opus 2015. Kaiaua Coast: High level coastal erosion study - Coastal erosion assessment and cost benefit anlyses. Paeroa, NZ, Hauraki District Council.

Prahl B, Boettle M, Costa L, Kropp, JP, Rybski D 2018. Damage and protection cost curves for coastal floods within the 600 largest European cities. Scientific Data, 5(180034).

Quality Planning 2017. Risk-based approach to planning. *h*ttps://www.qualityplanning.org.nz/node/809 [accessed 17 June 2020].

Quotable Value n.d. Rating valuation*.* https://qvgroup.qv.co.nz/rating-values [accessed 26 May 2020].

Reese S, Ramsay D 2010. RiskScape: Flood fragility methodology*.* Wellington, NIWA.

Rovins J, Wilson tM, Hayes, JW, Jensen, SJ, Dohaney J, Mitchell J, Johnston DM, Davies A 2015. Risk assessment handbook. Wellington, GNS Science.

Stats NZ 2013. 2013 Census QuickStats about a place: Kaiaua*.* http://archive.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-a-place.aspx?request_value=13646&parent_id=13645&tabname=&p=y&printall=true#gsc.tab=0 [accessed 15 July 2020].

Stats NZ 2018. *2018* Census place summaries - Miranda-Pūkorokoro. https://www.stats.govt.nz/tools/2018-census-place-summaries/miranda-pukorokoro#population-and-dwellings [accessed 28 July 2020].

Stephens S, Robinson B, Bell R 2015. Analysis of Whitianga, Tararu and Kawhia sea-level records to 2014. NIWA Client report no. HAM2015-046. Prepared for Waikato Regional Council. Doc.No. 3460508.

Taylor M, Kruger N 2018. Report on the effects of salt water flooding of agricultural land and subsequent recovery - Kaiaua, 5 January 2018. Waikato Regional Council Internal Series 2018/21. Hamilton, Waikato Regional Council.

Tonkin & Taylor 2010a. Kaiaua/Wharekawa coastal compartment management plan/volume 1. S.l., Franklin District Council/Environment Waikato/Auckland Regional Council. Doc. No. 2061088.

Tonkin & Taylor 2010b. Kaiaua coastal compartment management plan/volume 2 - Coastal processes. S.l., Franklin District Council/Environment Waikato/Auckland Regional Council. Doc. No. 2061091.

Tonkin & Taylor 2016. Hawke's Bay coastal strategy: Coastal risk assessment. Hawke's Bay, Hawke's Bay Regional Council.

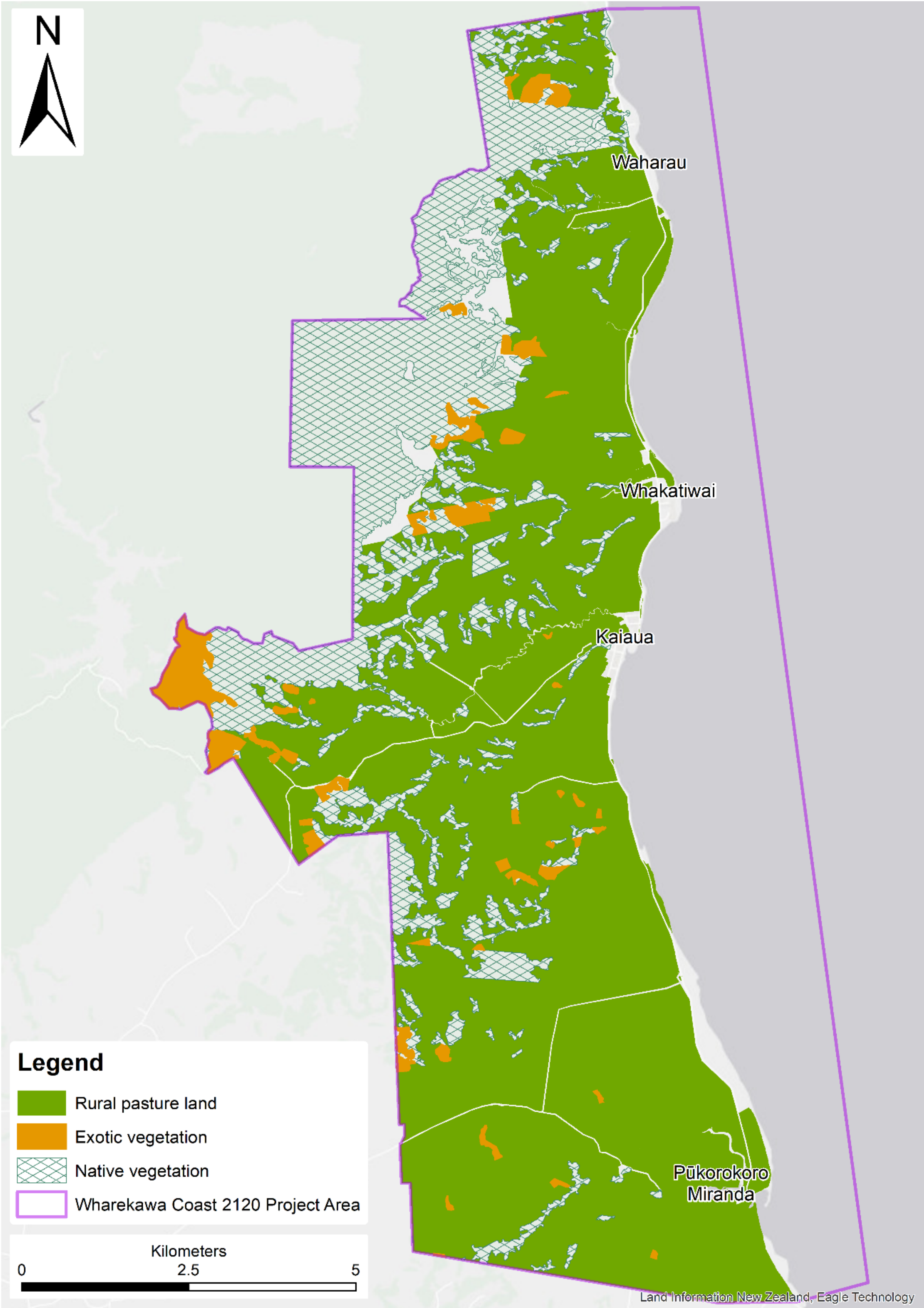
Waikato Regional Council 2019. Coastal inundation tool guidance. https://www.waikatoregion.govt.nz/assets/WRC/Services/regional-services/hazards-and-emergency-management/coastal/Coastal-Inundation-Tool-V2-User-Guide.pdf [accessed 18 June 2020].

Woodley K 2018. The day the Firth came forth. Pukorokoro Miranda News, February, Issue 107, pp. 2-5.

WSP 2020. Hauraki District Council valuation of roading assets as at 01 July 2019. Paeroa, NZ, Hauraki District Council.

# Appendices

## Appendix 1: Rural pasture land map



# Appendix 2: Content of Google Form questionnaire that was sent to the Panel

**Questions for the community about the impacts of January 2018 storm tide event and river flooding events:**

*Following the January 2018 storm tide event, Waikato Regional Council and Hauraki District Council collected some information about the impacts that occurred (such as number of damaged dwellings, approximate area affected by pasture burn, direct welfare costs for septic tank cleaning, rubbish removal, etc.). However, we do not have the full picture, and those best placed to provide more information are the community members who experienced the event.*
*In addition, some information about the impacts of the 2017 flooding in Hauarahi Stream was collected, generally to do with home and property damage, but again this was far from complete. We are also aware of concerns with flooding in Whakatiwai.*

*We are requesting information from the community on the impacts of these events, as per the questions below, and any other relevant information. This will inform the natural hazard risk assessment that is being carried out as part of Wharekawa Coast 2120.*

**Impacts to Agriculture (Jan 2018 event)**

*There was an internal report completed following the event which investigated the effects of salt water flooding on the land, however this primarily focused on measuring salt concentrations in the soil and how they decreased over time. More information is requested on the direct impacts to the farms.*

1. What are the main types of farming within the project area, e.g. sheep and beef, dairy, etc. (this relates to impacts)
2. How long after the Jan 2018 event was it before the pasture quality returned to pre-event levels?
3. Was re-seeding, cultivation, fertiliser application, etc. required? If so, what were the approximate costs of this?
4. Were there any follow on impacts, e.g. needing to reduce stock numbers?
5. Any photos to illustrate agricultural impacts would be appreciated (limit 5)

**Community Impacts (Jan 2018 event)**

*Information on the implications of assets, etc. being inundated will help to further inform the risk assessment.*

1. Were there any impacts to drinking water supply? What were they, and how long did they last?
2. What impacts resulted from flooding of septic tanks? How long did they last?
3. How were recreation areas impacted – were boat ramps, DOC reserves, playgrounds, etc. closed? For how long? Any longer lasting loss of amenity?
4. Was the school or school grounds damaged? Might it have been closed if the event occurred during term time, and how would this affect families?
5. Were there any other significant impacts that occurred?
6. Any photos to illustrate community impacts would be appreciated (limit 5)

7. Other: Is there a typical or most common building construction type (e.g. timber, concrete, masonry) or age for the area? What about typical floor levels (to a datum or height above ground)? This will inform the risk assessment.

**River flooding**

*We are also seeking more information on the impacts of the 2017 river flooding, or any other significant river flood events. The information that Waikato Regional Council (WRC) holds for the 2017 event is fairly limited - see summary below:*
*The event caused a significant amount of disruption to infrastructure such as roading, power networks and water supplies. Kaiaua was isolated due to flooding on roads from the early hours*

*of the morning until just before midday on 8 March. WRC staff were sent to investigate the situation in Kaiaua, where several houses were inundated and farmland damaged. Hauraki District Council assisted residents with sandbagging to protect properties from flood water.*

1. Can you provide any information of the impacts of the 2017 flooding in Hauarahi Stream?
2. Photos of impacts from 2017 flooding in Hauarahi Stream (limit 5)
3. Can you provide any information on the impacts of river flooding north of Kaiaua, such as in Whakatiwai?
4. Photos of river flooding at Whakatiwai or other communities (limit 5)
5. Any other information or comments on the impact of natural hazards on your community?

# Appendix 3: Coastal erosion qualitative risk assessment – further information

**Background and considerations for the coastal erosion qualitative risk assessment approach:**

Mean sea level which sits at 1.8 m (MVD-53) today is expected to rise 0.5 m to 2.3 m (MVD-53) by 2070 (RC8.5) and by 1.1 m to 2.9 m (MVD-53) by 2120 (RCP8.5) (Ministry for the Environment, 2017). A sea level rise of 1 m will inundate existing land, effectively moving the shoreline landward, some 200 m at Wharekawa, 300 m at Whakatiwai, 400 m at Kaiaua and almost 2,000 m at Miranda (Figure 60). Storm tide events will push water levels much higher to 3.1 to 4.2 m (MVD-53) elevation (lower and upper storm tide estimates) increasing the inundation even further during events. Some key questions with respect to coastal erosion are:

1. Will the shoreline simply erode landwards, and the gravel ridge roll back to the same extent, as the land is inundated by sea level rise (i.e., erosion effectively keeping pace with sea level rise)?
2. Will the land simply flood forming marsh and lagoon areas (effectively moving the shoreline seawards)?
3. Will coastal inundation due to sea level rise by offset to some degree by sediment input allowing the beach ridge system and the coastal plain behind to build up and stay dry (and only flood in storm events)?

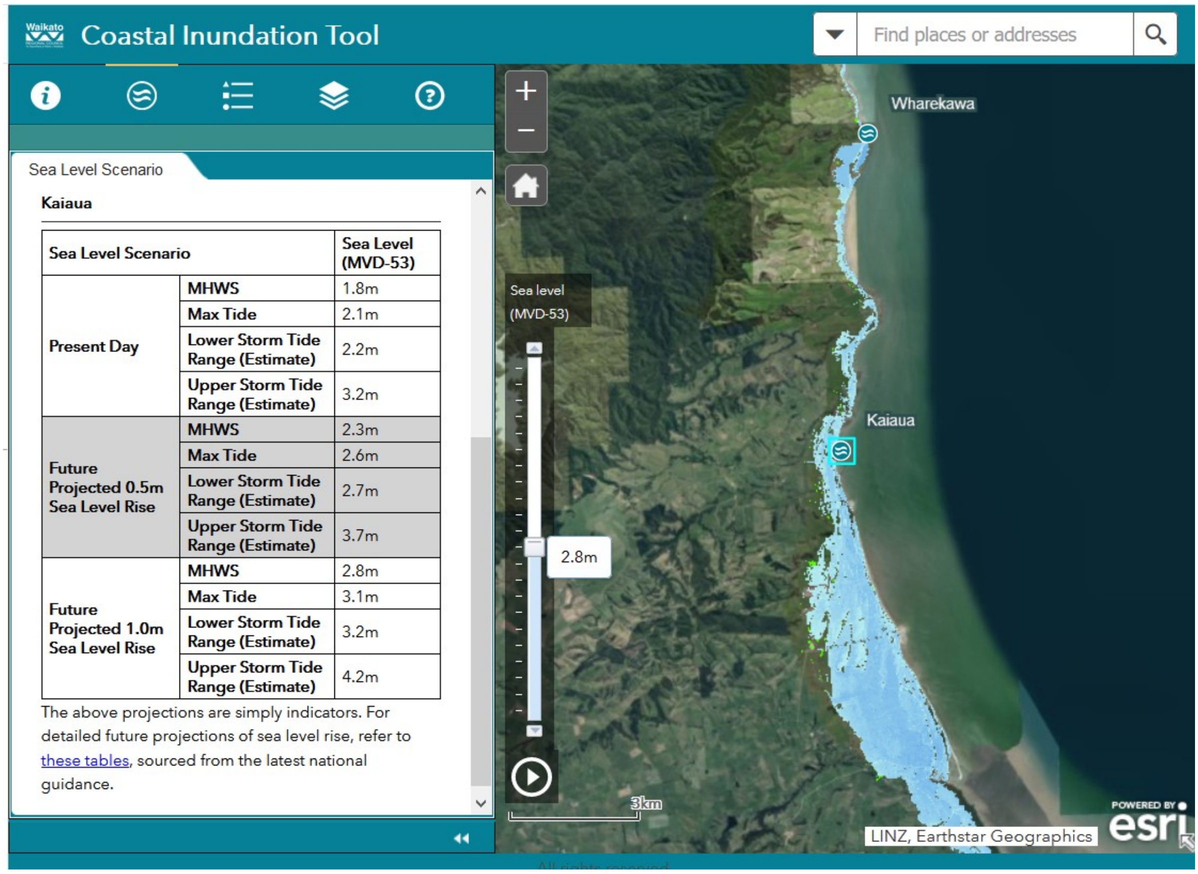



**Figure 60** **The Wharekawa coast showing the degree of coastal inundation in 2120 when mean sea level is predicted to reach 2.8 m (MVD-53) (actually 2.9 m (RCP8.5), but the Coastal Inundation Tool is in 0.2 m increments)**

We know with some certainty that the scale of the effect will vary from north to south along the shore, at least in the short term. This is because the coastal plain is narrower and higher in elevation in the north than the south. Furthermore, terrigenous sediment is being fed from steams in the north and the south receives little new terrigenous sediment. The south is supplied with shell from shell banks offshore. Because sediment input to the coast is small, it is unlikely that coastal erosion due to sea level rise will be offset by sediment supply. It is likely that shoreline erosion will move at a slower pace than coastal inundation.

Because of the uncertainties, the risk assessment for coastal erosion should consider the extreme case where in the long term shoreline retreat effectively matches retreat due to coastal inundation. Also, the risk assessment should focus on the consequences (rather than the likelihood) of the event occurring (in terms of % of assets exposed and costs for a few asset types) and provide only a best estimate for the worst case scenario at 2120.

**Kaiaua Coast: High Level Coastal Erosion Study – Coastal erosion assessment and cost benefit analyses** (Opus, 2015)**:**

A high-level coastal erosion risk assessment was undertaken for the Wharekawa coast by Opus (2015). Estimates of shoreline position (projected erosion) for the medium (30 years) and long term (100 years) were made for risk sites based on historical rates of coastal erosion reported in Tonkin & Taylor (2010b) (that did not consider the effects of climate change and sea level rise on future erosion rates). In developing their erosion rates Opus incorporated the effects of climate change in an unspecified (but reportedly conservative manner). Opus calculated the financial damage that would be suffered as a result of coastal erosion derived from the value of property and infrastructure at risk within the erosion lines for each of 16 'value at risk zones'. A multi criteria analysis was used to show, for each of the risk zones, the coastal erosion risk category over the 30 year and the 100 year horizons, the Present Value financial damages (for the 100 year horizon), the 'main' options for coastal erosion risk mitigation and potential 'secondary' mitigations options. A weakness of the Opus methodology is its predictions of coastal erosion over long times scales do not consider the fact that coastal inundation will probably completely dominate over coastal erosion at long time scales.

# Appendix 4: Outcomes from stakeholder workshops on thresholds

Thresholds for most impact categories and elements will be determined by the Panel. However, there are several stakeholders with level of service responsibilities in the Wharekawa Coast 2120 project area. These stakeholders will inform thresholds for elements and services that they are responsible for servicing or providing. To achieve this, two workshops were held:

1. Main workshop at Hauraki District Council, 2 September 2020
    a. Attendees were from NZTA, Waikato Group CDEM and HDC (emergency management, planning (and emergency recovery), roading, three waters and recreation).
    b. Apologies were received from DOC and Rural Fire.
2. Session at Waikato Lifeline Utilities Forum, 4 September 2020
    a. Attendees included staff from Chorus, Transpower and other utility companies.
    b. Counties Power (main provider within the project area) was not in attendance.

## Main workshop at Hauraki District Council, 2 September 2020

An overview of the Wharekawa Coast 2120 project and risk assessment was presented, then attendees were divided into groups (roading and bridges, stormwater and stopbanks, recreation and community facilities, Civil Defence/HDC emergency response) and provided the risk assessment results (for the project area as a whole) for their area of expertise. Each stakeholder group/individual was provided guidance by a member of the Wharekawa Coast 2120 Technical Advisory Group (TAG) to review the results and determine initial thresholds. Key outcomes are as follows:

### Roading and bridges

Thresholds for coastal inundation (ARP is annual return period; yr is year; m is month):

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | x | (but really 25) | | | | | |
| Moderate event | | | | | x | (but really 15) | | | | |

Thresholds for Hauarahi Stream flooding:
*Unable to determine*

1. Need to consider design life when determining thresholds.
2. Bridges are strong and unlikely to fail in themselves; scour and erosion of abutments is the major potential issue.
3. The roading damage cost results for Hauarahi Stream flooding do not provide an accurate representation of potential damage costs, as any damage is likely to be to the bridge (abutments), rather than the road, and bridge damage costs have not been estimated. The cost to repair Waharau Bridge in 2017 ($47,617) is an indication of potential damage costs, but it is unknown whether damage to County Bridge (over Hauarahi Stream) would occur in any given event scenario. Further, damage could occur to any bridge within the project area, not just to County Bridge. Thus, determining thresholds for Hauarahi Stream flooding is not possible at this stage.

### Stormwater and stopbanks (flood mitigation infrastructure)

Thresholds for coastal inundation:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | | | | | | x | |
| Moderate event | | | | | | | | | x | |

Thresholds for Hauarahi Stream flooding:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | | | | | | | x |
| Moderate event | | | | | | | | | | x |

1. Coastal inundation and flooding generally do not cause damage to the stormwater system, but blockages and other debris need to be cleared. If damage occurs, water velocity, rather than depth, is the determining factor.
2. The stormwater system is designed to the 10 year ARP event (10% AEP) (does not take into account the projected effects of climate change on rainfall intensity), but can still function if the 10 year ARP occurs every year. There will be a financial impact if debris from flood events is required to be cleaned out more than twice a year.
3. Beach outfalls are an issue as sediment can build up (though it can also be cleared naturally by coastal processes). HDC monitors beach outfalls and clears them as necessary.
4. There are currently no plans to increase the capacity of the stormwater system.
5. The stopbanks in the project area were not damaged in the January 2018 storm tide event.

### Recreation and community facilities

Thresholds for coastal inundation:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | | | x | | | | |
| Moderate event | | | | | | | x | | | |

Thresholds for Hauarahi Stream flooding:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | | | x | | | | |
| Moderate event | | | | | | | | x | | |

1. There are not many recreation and community facilities in the area.
2. Native species can be resilient to flooding.
3. The new rail trail terminus facility toilet has been designed to be moveable in event of coastal inundation and river flooding; the septic tank can be capped to prevent infiltration.
4. The community can still enjoy areas with no/damaged facilities. Equally they can still be impacted if they are unable to access an area which does not have facilities. Much of the recreation within the project area is purely related to enjoyment of the environment, and does not necessarily require infrastructure (that is generally provided and maintained by HDC).

### Civil Defence/HDC emergency response

Thresholds for coastal inundation:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | x | | | | | | |
| Moderate event | | | | | | x | | | | |

Thresholds for Hauarahi Stream flooding:

| ARP | 200yr | 100yr | 50yr | 20yr | 10yr | 5yr | 2yr | 1yr | 6m | 2.4m |
|---|---|---|---|---|---|---|---|---|---|---|
| Major event | | | | | | x | | | | |
| Moderate event | | | | | | | | | x | |

1. Not all flooding requires an emergency response from CDEM, e.g. flooding in paddocks (others such as Rural Support Trust may still respond) versus flooding in buildings.

2. The capability of CDEM and HDC to respond in any given area will depend on whether other events are occurring at the same time and how widespread the impacts are. This reinforces the message that households and communities should be prepared to look after themselves for at least the first three days.

## Session at Waikato Lifeline Utilities Forum, 4 September 2020

The purpose of this session was to provide an overview of the Wharekawa Coast 2120 project and risk assessment, and to source information from the utility companies (power and communications) on the following questions:

1. Is any critical infrastructure located within the project area?
2. Do the power and communications networks follow East Coast road (underground or aerial), and how resilient is the network?
3. Are there any thresholds beyond which existing levels of service will not be continued if damage starts to occur more frequently?
4. Are there requirements to restore services within a certain timeframe within the project area?

The information that was provided during the session in answer to these questions is as follows:

1. There does not appear to be any critical infrastructure that is exposed to coastal inundation or Hauarahi Stream flooding in the project area. There is a telephone exchange at Kaiaua and a cell tower above Kaiaua School (not classified as "critical infrastructure").
2. The power and communications network generally follow East Coast Road and is buried, except over bridges where it is aerial. The network is quite resilient to flooding events, except that maintenance requirements are increased when the lines get wet from flooding.
3. Chorus will continue to repair the communications network if it gets damaged, and may undertake work to increase the resilience of the network if required. The power network would also continue to be repaired, but if damage is frequent, providers may discuss alternative options with residents, such as moving to distributed generation sources (e.g. solar panels, batteries) that are owned by the residents.
4. There are industry-wide service level requirements based on annual averages but there are not requirements for repairing individual outages. Following the January 2018 storm tide event, Counties Power prioritised restoring the main feeds, followed by individual customers; 80% of power was restored within 24 to 36 hours, with 100% restored within five days.

Following the session, attempts were made to contact staff from Chorus and Counties Power to source more detailed information, but no responses were received.

# Appendix 5: Summary of Ecological Values Impact Assessment

The project area covers approximately 20 km of coastline and nine $km^2$ of intertidal flats. Pūkorokoro Miranda in particular has high ecological value and meets eight of the 11 criteria used to determine significant indigenous biodiversity in the Waikato Regional Policy Statement (WRPS) (Hunt & Townsend, 2020). It is also part of an area recognised as having significant conservation value under the Waikato Coastal Plan. Hunt & Townsend (2020) provide a summary of several significant ecological features of the project area, which are:

1. Supporting birdlife – Dowding (2019) classified the area as a 'Priority 1' site, meaning that it "regularly holds 1% of the global population of one or more species or subspecies that are classified as threatened or at risk…".
2. Chenier ridges - The Miranda chenier is regarded as "the best example globally of a Holocene coastal strand plain" (Hayward 2013) and is the most extensive chenier system in New Zealand.
3. Wetland habitat - Saltmarshes and mangroves are recognised as wetland habitats that support indigenous flora and fauna and have significant ecological value. Mangroves can also dissipate energy, reducing coastal erosion and inundation.
4. Intertidal habitats - Key components of most ecological features mentioned above are the constituent intertidal habitats. Although outwardly unremarkable, soft-sediment habitats can contain an abundance of life and webs of ecological interactions.

The above features contribute to the intertidal area south of Kaiaua (to the Waihou River mouth) being recognised as a Ramsar site (a wetland of international importance) and thus 'protected' by the Ramsar Convention.

Hunt & Townsend (2020) define three morphological units that are based on the ecological values described above, and describe these units in terms of the present functioning and likely future changes. The units are:

1. Intertidal flats
2. Chenier ridges
3. Intertidal vegetation

For each of these morphological units the broad changes that may occur as a result of sea level rise are similar. With sea level rise, under an idealised scenario the unit will theoretically migrate inland, but if this migration is constrained by either a structure (coastal protection, road, etc.) or rising topography then a portion of the unit will be lost (referred to as coastal squeeze) (Hunt & Townsend, 2020). Also, see the uncertainty outlined in Hunt & Townsend (2020).

For the intertidal flats and intertidal vegetation, if there is a sufficient supply of sediment then these units can theoretically rise vertically, despite being constrained, thus partly mitigating the effects of coastal squeeze. However, for the Wharekawa Coast, although the current sediment supply is sufficient there is no guarantee this will continue in the future. Further, if the chenier ridges are unable to migrate landward they are likely to eventually erode, removing the shelter they provide to intertidal vegetation in the lee of the cheniers, and the raised topography they provide for bird roosting. This highlights the importance of not creating (and potentially removing) barriers to landward migration if these ecological values are to have the best chance of being preserved – an important consideration when assessing adaptation options.

It is important to note that current stressors such as predation, invasive species and sedimentation affect the ecological values described above. The current management response (or lack of) to these stressors will have a significant impact on these values and their state in the future (Hunt & Townsend, 2020). Some of these stressors are being addressed through new restoration initiatives (including through the Living Water partnership) and catchment planning (EnviroStrat, 2020).