REPORT

Wellington City Council

Sea Level Rise Options Analysis

Tonkin & Taylor

In association with:

Raukura Consultants

nzier
authoritative analysis

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ENVIRONMENTAL AND ENGINEERING CONSULTANTS

REPORT

Wellington City Council

Sea Level Rise Options Analysis

Report prepared for:

Wellington City Council

Report prepared by:

Tonkin & Taylor Ltd

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This study has been prepared by consulting firm Tonkin & Taylor Ltd with respect to the specific brief given to them and does not necessarily reflect the views of Wellington City Council. The study is an initial step in a long-term decision-making process. As such, the focus has been on developing a structure and approach that has a spatial basis, is repeatable and can be refined with time.

Foreword

Wellington City Council commissioned this report as an input into the Council's wider analysis and planning work. The Council's efforts to understand the impacts of climate change are driven by the need to protect and enhance the city's prosperity. Legislation requires the Council to consider risks and natural hazards. The challenge is to understand the timeframes, scale, when to act and how to plan for action.

Scientific research is driven by questions. While there are still 'uncertainties' about some aspects of climate change, the basic questions are well understood and we know the sea level is rising. Planning in the face of uncertainty is not new for Wellington. For example, our building standards provide a high level of earthquake strengthening, even though we do not know when the next big earthquake will happen.

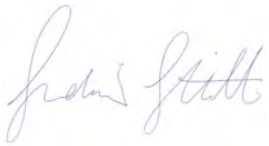
In this context, the report on sea-level rise by Tonkin & Taylor for Wellington City Council is a necessary input into understanding climate change and the implications for decision-making. It is consistent with approaches being developed in New Zealand and other countries.

The risk-based approach is important. We must consider how the risk compares to other hazards or risks we face and how they connect. From a risk management perspective, a range of scenarios needs to be looked at, including higher-end sea level scenarios. Higher scenarios for sea-level rise are important for understanding the possible implications for long-term economic resilience and growth.

This report provides us with good input for considering the impacts on coastal property and infrastructure in Wellington, and for talking with businesses and the community. It broadly covers cultural, economic, environmental and social values, looking at the potential impacts for different scenarios. The report also explores links between sea-level rise and other hazards, going beyond storm surge to include potential changes in groundwater levels, greater risk of liquefaction and more extensive floods.

With broad and widely dispersed impacts, community involvement at all levels is of utmost importance. Approaches to the issue of sea-level rise will be developed over time with residents and businesses taking into account local preferences. As a council, we're already working with the community through our city planning and through initiatives arising from the 2013 Climate Change Action Plan, such as the Water Sensitive Urban Design Guide, the Smart Energy Challenge, and working with the community to find a long-term solution for the storm damaged Island Bay seawall.

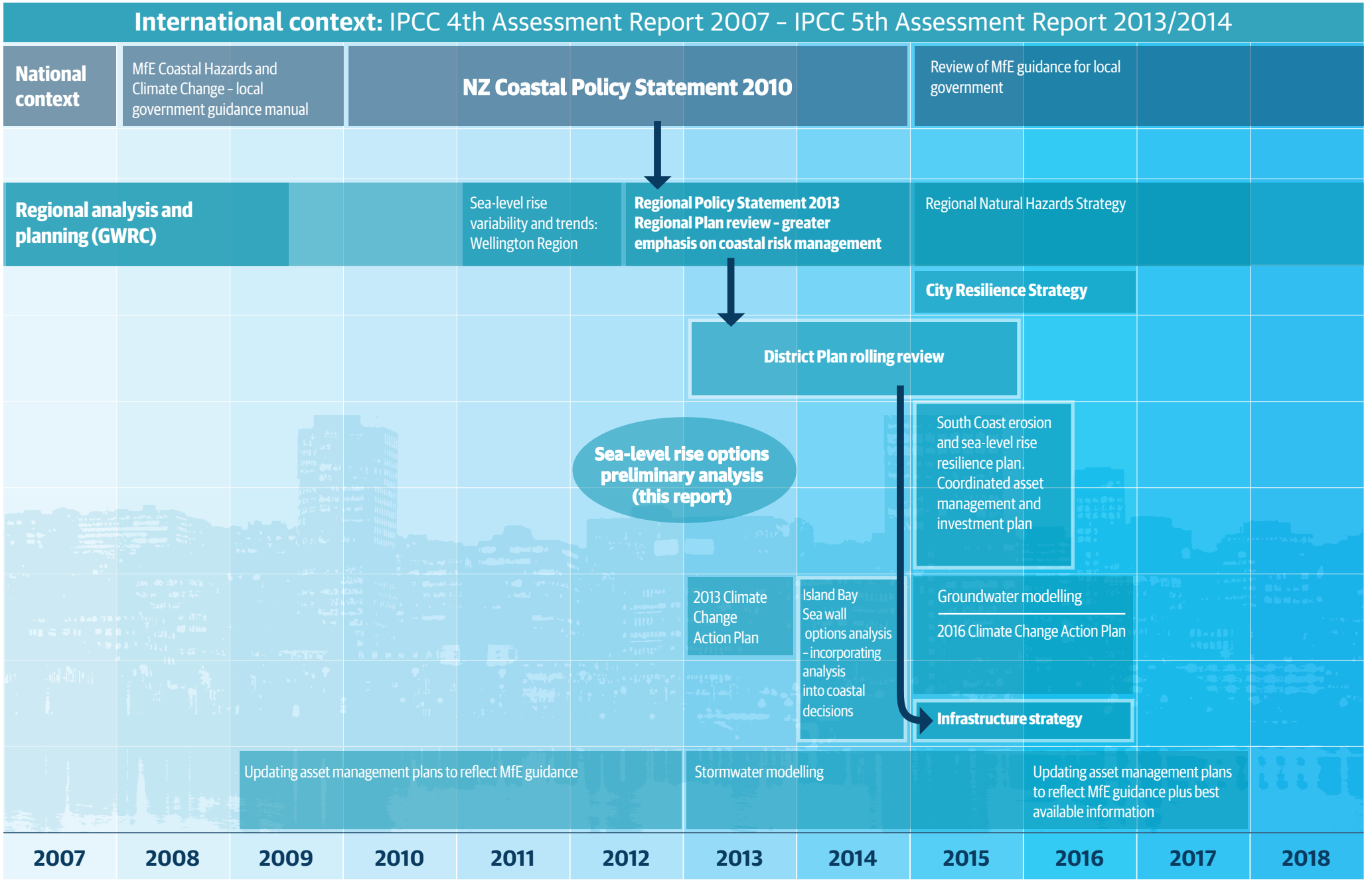
This report provides a starting point for Wellingtonians to consider what is important to our city, and what we need to think about to plan for the future.



Andrew Stitt
Manager Policy

Absolutely Positively
Wellington City Council
Me Heke Ki Pōneke

Preparing for sea-level rise – planning ahead so Wellingtonians can make good decisions



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Executive summary

Wellington City Council (WCC) recognises the significance of climate change and understands the vulnerability of the city to climate change induced sea level rise. It has undertaken to address this issue as a priority. The analysis presented in this report provides the first step in a process of understanding and adapting to sea level rise in the Wellington area.

An assessment of the impact of sea level rise has been carried out for each coastal suburb, considering the impact on each of the four 'well-beings' – social, cultural, environmental and economic. This analysis was carried out for five sea level rise scenarios ranging from 0.6 metres (m) to 3.0 m plus a storm event with a 1% chance of occurring each year, recognising that the consequences of the highest scenarios may be so significant that they should be considered in current planning processes.

Impacts of sea level rise

A sea level rise of 1 m over the next 100 years is considered likely. Table A gives an indication of the scale of impact of a 0.6 m and 1.5 m sea level rise, the two scenarios considered in detail for this study that bound the 1 m value.

Table **A** City-wide impacts of sea level rise for Scenarios **1** and **2**

	Scenario 1 (0.6 m sea level rise)	Scenario 2 (1.5 m sea level rise)
Assets affected	$0.4bn	$6.5bn
Residents potentially displaced	~150	~2,000
Area of environmental significance affected	~60 ha	~100 ha
Cultural sites affected	~30	~120

Damage incurred during storm events, as the result of rising groundwater levels, or due to increased vulnerability to other natural hazards would be in addition to the values tabulated above and damages discussed below.

The effects of a 0.6 m rise in sea level are typically limited to the vicinity of the coastal fringe. Areas that are temporarily affected by coastal storms at present may become more frequently inundated and some areas may become permanently inundated. With no responses to the issue of sea level rise impacts will be the most financially significant in the highly urbanised suburbs of the Central Business District (CBD), Oriental Bay, Hataitai and Pipitea due to the high level of infrastructure development along the coast at these locations. Large areas of the low-lying suburb of Makara Beach will be inundated in this scenario. This will also significantly impact the Makara Estuary, one of the largest and valued salt marshes in the Wellington area, as well as the ecologically unique Makara foreshore reserve. Whilst some plant communities and species may be able to migrate upstream to match the rise in sea level, others may not be able to adapt at a rate that keeps up with the changing levels and could be adversely affected.

A 1.5 m rise in sea level has a much more widespread impact. At this level large areas of the CBD would be inundated, along with much of the low lying area of Kilbirnie. Impacts will also be most financially significant in these suburbs, with damage to land, buildings and infrastructure of around $5bn in the CBD area alone.

Options for responding to sea level rise

Wellington can consider a range of options to respond to sea level rise. These can be broadly considered in the following categories:

- Non-intervention (do nothing, or 'unmanaged retreat');
- Managed retreat, including planning restrictions;
- Hold the line (defend);
- Accommodate; and
- Expand into the coastal zone.

A number of available options may not be appropriate for Wellington in the short term, such as raising sections of the city onto stilts. Others may only provide short term protection, such as a tidal barrier, which could only operate up to a sea level rise of around 0.6 m due to the small tidal range in the Wellington Harbour.

However, the available data and the level of option development appropriate for a suburb (high) level assessment was too limited to enable a true cost benefit assessment to be carried out for these various options. Consideration of a single option for the entire area (i.e. only hard or soft protection works and managed retreat for the entire suburb) is not meaningful. In many, if not all, cases a composite solution comprising a combination of hard and soft protection and managed realignment may prove to be a preferred option. However, this requires a greater consideration of specific, rather than generic, options and is beyond the scope of this study.

Other hazards

Rising sea levels may increase the likelihood or consequence of other natural hazards, including surface water and groundwater flooding, landslides and the consequences of earthquakes including liquefaction. When deciding how to respond to sea level rise WCC will need to consider if the proposed solution increases the vulnerability of communities to these other hazards and whether this is appropriate.

As sea level rises, groundwater levels, which in coastal areas may be controlled by the sea level, will also rise. This could result in a range of impacts, some of which include possible water infiltration to basement structures, requiring waterproofing and pumping, saline intrusion into the aquifer system and corrosion or other effects to underground assets. A rise in sea level and an associated rise in groundwater level can result in a reduced depth to the top of liquefiable soils. This reduced depth can result in greater surface damage in the event of liquefaction.

As sea levels rise, the frequency and severity of existing flooding is likely to increase and the areas at risk of flooding will increase. In a similar way the area at risk from tsunami inundation will increase. Inundation or erosion of the toe of existing slopes or landslides will also increase the likelihood of slope instability.

Roadmap

Wellington, like many parts of New Zealand, has a long coastline and finite resources to fund work required to protect vulnerable coastal areas. The process of managed retreat is therefore likely to be central in the approach to sea level rise adaptation, as it may not be affordable to provide protection to all areas that are vulnerable to sea level rise and have value to communities.

However, unless planning responses are implemented now to change land use practices within the more critical areas, hard protection options will be more likely to be the

preferred response at some time in the future rather than managed retreat and non-intervention options.

Managed retreat can be implemented in many ways, including creating zones where new development is not permitted, changing the zoning of existing areas to activities that result in a lower vulnerability to the impacts of sea level rise, such as recreational open space or requiring the construction of more resilient buildings in areas at risk, such as buildings on stilts, or removable buildings.

Whilst a range of implementation tools exist, choosing to retreat or change the use of parts of the city will not be an easy decision to make. Dialogue with stakeholders and the community will be an important and ongoing component of WCCs response to sea level rise.

Phasing interventions and monitoring their success will be central to ensuring sustainable adaptation in the long term. This will require data collection and more detailed studies to evaluate cost and benefits.

This study recommends that WCC develop a Sea Level Rise Adaptation Strategy (Strategy). This document would normally be produced in close consultation with stakeholders and the local community. Following the development of a Wellington wide strategy, WCC specific, local adaptation plans or community resilience plans may follow, setting out proposed responses for different locations within Wellington.

Key areas that WCC may wish to include in the Strategy are:

- Actions required now to provide protection from future risks, including policy statements, appropriate response options for vulnerable areas and recommendation for changes to building codes or design requirements;
- How future risks can be avoided or managed, including impacts on insurance and how the risk of sea level rise should be communicated to land owners or property purchasers;
- How emergency response can or should be strengthened to support proposed interventions;
- What communities resilient to sea level rise look like;
- How scarce WCC and ratepayer resources should be prioritised and allocated;
- What protection should be provided to the environment and how can the environment help to protect Wellington; and
- How the Strategy will be implemented, monitored and updated.

Interactive modelling tool

Alongside this report, a web based interactive modelling tool has been developed to enable WCC to consider in finer detail the impact of any future decisions. The interactive tool uses the outputs of sea level rise modelling and presents these at 0.1 m increments. The user is able to 'slide' the sea level up or down to view the effects of changing sea levels. For a selected inundation area the model outputs includes the length of assets, value of land and buildings, community sites, etc.

1 Introduction

1.1 Background

Wellington City Council (WCC) recognises the importance of climate change and the need for a comprehensive and cohesive response. WCC understands the vulnerability of Wellington to climate change induced sea level rise and has undertaken to address the issue of sea level rise as a priority.

In its 2010 Climate Change Action Plan, WCC decided to implement an 'Analysis of Options for Responding to Sea Level Rise'. Tonkin & Taylor Ltd (T&T), along with sub-consultants NZIER, Corydon and Raukura Consulting, have been engaged to undertake this study.

1.2 Purpose

The analysis presented in this report is the first step in a process of understanding and adapting to climate change induced sea level rise in the Wellington area. Adaptation is an important concept in climate change planning. WCC defines the process of adaptation as *'preparing for the impacts of climate change so we can safeguard the community, the environment and the economy from likely risks'.*

The purpose of the project is to establish:

- The full range of values, across the four well-beings, in areas affected by a range of sea level rise scenarios;
- The scale of cost of a range of possible response options for mitigating the risks from each sea level rise scenario; and
- Tools for use by WCC and the public to interact with sea level rise scenarios and explore response options.

The full range of values has been assessed across the cultural, social, environmental and economic well-beings, to enable WCC to understand the impact on communities and the environment in the widest sense.

This report is intended for distribution to WCC staff, politicians, stakeholders, central government and the public, recognising that the implications of sea level rise are of interest to many parties. It sets out a roadmap for WCC to enable it to determine how best to respond to the challenge of sea level rise.

Alongside this report, a web based interactive modelling tool has been developed to enable WCC to consider in finer detail the impact of any future decisions. The interactive tool uses the outputs of sea level rise modelling and presents these at 0.1 m increments. The user is able to 'slide' the sea level up or down to view the effects of changing sea levels. For a selected inundation area the model outputs includes the length of assets, value of land and buildings, community sites, etc.

1.3 Structure of this report

This report records the approach taken to considering the possible impact of sea level rise on Wellington. It provides the reader with an understanding of the process that has been followed for this project and where appropriate details of the science that has underpinned the analyses. It is not intended to be a detailed method statement, rather to provide sufficient information for the reader to understand how key conclusions have been drawn and hence to enable debate and discussion of the findings that arise.

The report is structured as follows:

- Section 2 of this report sets out how rising sea levels have been modelled for this study, the development of parameters defining a severe storm event in Wellington and how a number of sea level rise scenarios were selected to assess in more detail;
- Section 3 focuses on the values assessment. The overall approach for the values assessment for each well-being is set out;
- Section 4 presents a summary of the outcomes of the values assessment, providing an overview at a city level as well as for key themes arising from the impacts at a suburb level;
- Options for responding to sea level rise are set out in Section 5. A list of options was considered, each of which has its advantages and disadvantages;
- Section 6 provides an introduction to the web based interactive model that has been developed for WCC; and
- In Section 7 a recommended roadmap for the future is set out. This is designed to ensure that Wellington is able to respond flexibly to the challenge of sea level rise.

1.4 Limitations and assumptions

This study is the first step in a long-term decision-making process. As such, the focus has been on developing a structure and approach that has a spatial basis, is repeatable and can be refined with time.

The study has been undertaken for the whole of the WCC region. First order 'values' on a 0 to 5 scale have been assigned across the four well-beings to those areas possibly impacted by sea level rise. By necessity, the focus has been on significant or material impacts and costs. As such, detailed or site specific issues may not have been taken into account and the inputs and outputs from this work will need refinement at a more local level in consultation with the public and stakeholders.

The following limitations are noted in particular:

- The underlying digital elevation model provided by WCC is of varying detail and accuracy, which impacts the accuracy of sea level rise modelling and the values assessments;
- A 'bath tub' approach has been taken to sea level rise modelling, so no potential change from dynamic coastal processes has been accounted for;
- The effects of a storm event with an Annual Exceedance Probability (AEP) of 1% (a storm event that has a 1% chance of happening in any given year) have been considered. The derivation of this event has been based on empirical formulae and published work by NIWA. It is intended to provide a conservative upper bound to the area affected by a storm of this nature, including wave run up. More detail on this is provided in Section 2;
- The analyses have been primarily based on WCC datasets. The veracity of these datasets has not been challenged or improved for this study. However, for some analyses it was clear that there were data missing from the information provided;
- A GIS routine was used to identify sites that lie within areas affected by possible future sea level rise. This routine assumed that if a new sea level boundary intercepted a site or location then the full value of the site was included in the impact assessment. This precautionary approach generally tends to overestimate effects rather than under estimate them. When specifically applied to the economic assessment this comprises an assumption that the value of a property will be written off as soon as it is partially inundated. This is appropriate for the urban parts of Wellington but a manual adjustment has been made to

the economic values affected for Makara and Ohariu to reflect the larger properties in these suburbs;

- The values assessed do not allow for any future growth or change in land use etc.;
- The study is focussed on consequence, not risk;
- The social analysis has been underpinned by quantitative datasets with minimal qualitative analysis. This was considered appropriate for this high level review;
- For all values assessments the information provided by WCC was able to be supplemented to some extent by the project team's local knowledge. On balance it is considered that the relative values afforded to each suburb, based on the available information, are sufficiently accurate for the purposes of this study;
- The difference between storm event episodes and permanent inundation by the sea have not been modelled for this study, this is discussed further in Section 3.1.1;
- The cumulative effects of other natural hazards and the interrelationship with climate change have not been considered. The study has been cognisant of existing and future natural hazards and provides a platform from which the interrelationship of these hazards with sea level rise can be considered in further studies;
- There are a large number of utility and infrastructure organisations within the WCC area, including electricity and telecommunications utilities, KiwiRail, the New Zealand Transport Agency, Wellington Airport and CentrePort. Due to the short project time frame and commercial sensitivity of the asset value information of these organisations not all of them have been approached for information as part of this project; and
- Population estimates are from the 2006 Census mesh block data (published by Statistics New Zealand).

2 Sea level rise

2.1 Current projections

Sea level rise projections for the next 100 years are based on the outputs of global emissions models. These models assume a range of emissions scenarios. Current government advice for responding to sea level rise is for New Zealand Councils to use a risk management approach and consider a 0.5 m base value of sea level rise by 2090 relative to the 1980 – 1999 average sea levels, with 10 cm additionally per decade thereafter (Ministry for the Environment, 2008). Ministry for the Environment (MfE) recommends that the consequences of a sea level rise of 0.8 m should also be considered and recommends that scenarios above the 0.8 m are also considered for planning beyond 2100 as well as for low probability/high consequence considerations.

Current guidance is based on the work of the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC). The Fifth Assessment Report is due for publication in 2013/14 and it is likely that MfE guidance will be updated to reflect the latest science and international recommendations.

2.2 Range of scenarios

WCC recognises that sea level rise represents a long-term and dynamic risk, requiring new approaches to prepare and respond. WCC is following MfE guidance by focussing on sea level rise scenarios between 0.6 m to 1.1 m, understanding that a rise of around 1.0 m should be planned for over the coming 100 years. For this study no deduction in actual sea level rise from the 1980s to the present has been made.

For strategic city planning WCC has decided to take a scenario-based risk management approach, which allows for possible higher sea level rise over the long-term. As a result, WCC required that this study consider the potential implications of sea level rise from 0.6 m to 3 m, understanding that the consequences of these high scenarios may be so significant that WCC must consider the possible impacts.

The interactive model lets WCC consider the impacts of sea level rise scenarios at a 0.1 m increment. For the detailed assessment of values against the four well-beings, five scenarios were chosen. This section of the report sets out how these five scenarios were selected and the associated inundation modelling and mapping that was undertaken.

2.3 Scenario selection

A range of published sources were consulted to determine five reasonable scenarios for the more detailed values assessments. Four of the scenarios represent 'baseline' sea level rise scenarios, so represent a new high water springs mark. The fifth scenario that was considered includes the effects of storm surge and waves (combined wave set up and run up as explained in Section 2.3.1) along the coast, modelled in addition to Scenario 4 (a sea level rise of 3 m). Table 2-1 summarises the development of the scenarios used in this study, their source and their level relative to the Wellington Vertical Datum (WVD). WVD is based on the Mean Sea Level (MSL) recorded in 1953. Totals are rounded to one decimal place. The development of the storm effect is discussed further in Section 2.3.1.

Table 2-1 Sea level rise scenarios

Scenario	Source	Sea level rise (m)	MHWS (m above WVD)	Sea level variability (m)	Storm effects (m)	Total (m above WVD)
1	Ministry for the Environment (MfE) (2008)	0.6	0.83	0.25		1.7
2	Department of Climate Change Australia (2009)	1.5	0.83	0.25		2.6
3	Grinstead et al (2009)	2.2	0.83	0.25		3.3
4	WCC upper scenario	3	0.83	0.25		4.1
5	Scenario 4 with storm surge and wave effects	3	0.83	0.25	1.1 (Harbour) 3.4 (Open coast)	5.2 (Harbour) 7.5 (Open coast)

An upper bound value for sea level variation of 0.25 m (MfE, 2008) was included to account for seasonal and longer term climate cycle variances in water level (Auckland Regional Council, 2010). The sea level rise and sea level variation components were added to Mean High Water Spring (MHWS) relative to Wellington Vertical Datum 1953 (WVD) incorporating Mean Level of the Sea (MLOS) for 2012.

Whilst the storm tide effects are only specifically included in Scenario 5, the interactive model will enable the user to consider the effect of a storm event combined with any 0.1 m sea level rise increment.

2.3.1 Storm effects

Wave effects can vary significantly along the coast due to variations in offshore bathymetry and onshore topography. An assessment of actual wave effects along the shoreline has been concurrently undertaken by NIWA. The results of this recent NIWA analysis have not been considered in this study due to its parallel timescales. Available data were used (Gorman et al. 2006; Stephens et al. 2011) relating to the wave climate affecting the Wellington Harbour and open coast shorelines during a 1% Annual Exceedance Probability (AEP) event. This is a storm event that has a 1% chance of happening in any given year.

For this study, the delineation between the open coast and Wellington Harbour shorelines for wave modelling purposes was assumed to be the Seatoun cliffs north of Breaker Bay, the location of which is shown in Figure A-2 in Appendix A.

Three storm components are included in this analysis;

- *Storm surge* is the temporary increase in sea level above that expected by tidal variation caused by extreme meteorological conditions such as low pressure system and/or strong winds;
- *Wave setup* is the super-elevation in water level across the surf zone caused by energy expended by breaking waves. This occurs even in calm conditions, but is exacerbated during storm events; and
- *Wave run-up* is the ultimate height reached by waves after running up the beach and coastal barrier.

Figure 2-1 illustrates how these components interact. Highest astronomical tides were not specifically included but differ from the standard tidal variation by 0.07 m and as such are

considered to be represented within the accuracy of the modelling undertaken and addressed within the 0.25 m allowance.

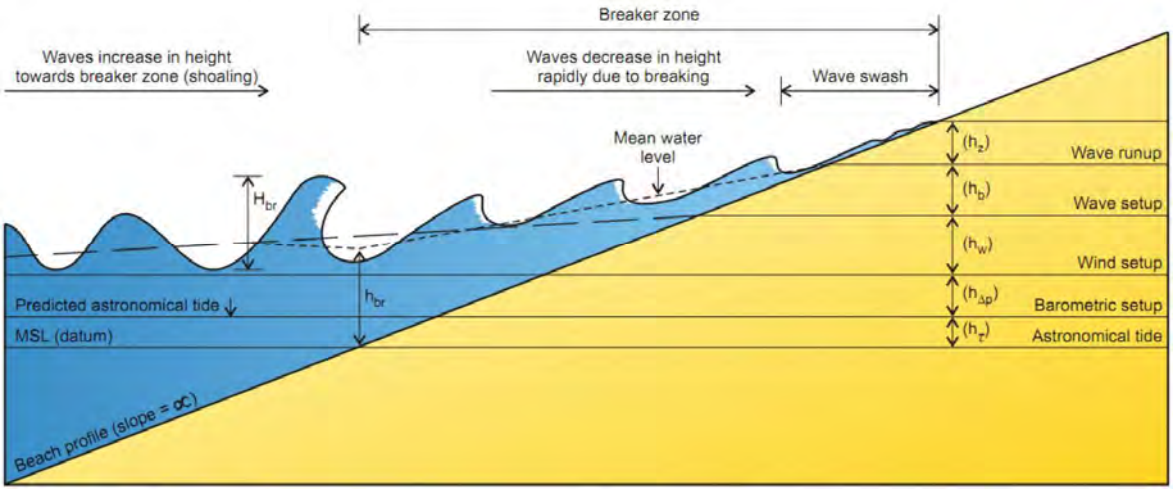

Figure 2-1 Storm components (Source: Shand et al. 2011)

For the harbour shoreline, wave set up and run up were derived from empirical methods with waves resulting from a 30 m/s wind over the maximum 10 km fetch across the harbour. Storm surge within the harbour was derived from Stephens et al. (2009). The total inundation level derived for the harbour using these methods compared very well with observed and predicted inundation levels contained within the 2009 report.

For the open coast, the joint probability of water level and wave heights for a site off Owhiro Bay (Site 5, Stephens et al. 2011 – refer Figure A-1 in Appendix A) was used to derive a total water level and wave inundation component for the entire open coast shoreline.

The derived 1% AEP storm effect elevations are considered to provide a conservative upper bound of water levels in addition to the Scenario 4 sea level rise component of 3 m. Further assessment of storm effects, especially wave effects, is recommended and is likely to be available later in 2013 from NIWA.

There are a number of factors that can influence future storm events that are not considered by this analysis. These include:

- Increased sea level resulting in greater water depths, possibly longer fetches and different shoaling patterns, leading to a different wave climates;
- Increased 'storminess' resulting in higher winds; and
- A change in the prevailing weather, resulting in changing wave climates.

The 'building block' additive approach used for this study is considered sufficiently conservative that these processes are likely to be encapsulated within the levels considered.

2.3.2 Inundation zones

Throughout this report the term inundation is used to define an area which will be submerged by the sea. Areas where groundwater levels may rise or which become prone to flooding are described as being 'flooded'. Inundation typically refers to an area permanently submerged, but is also sometimes used in relation to temporary inundation during storm events.

Inundation modelling was undertaken using GIS. A 'bathtub' concept was applied, where a uniform depth of water is applied to the existing land surface. This model is widely used in

studies of this type, for example in the work of the NOAA Coastal Services Centre in the United States, and is considered appropriate for the purposes of this study. Inundation extents for the five modelled scenarios are shown in Figure 2-2 and in larger scale in Appendix A, Figures A-3 and A-4.

There are limitations to this approach particularly that it does not consider any dynamic or changing coastal processes, which could change areas of inundation and its duration. However, it is suitable to provide high level extents of inundation hazard and is commonly applied as a first order assessment (AGDCC, 2009).

Inundation zones at 0.1 m intervals from 1.7 m to 5.2 m above WVD (Wellington Harbour) and 7.5 m (Open coast) have been created based on both WCC supplied 1 m (1 m x 1 m cell size) and 5 m (5 m x 5 m cell size) Digital Elevation Models (DEMs).

The 1 m DEM is derived from detailed LiDAR data and extends from the WCC boundary with Lower Hutt City Council to just east of Sinclair Head. The 5 m DEM is derived from photogrammetry and covers the WCC region. The 1 m DEM was used in preference to the 5 m where overlap occurred, apart from the Makara area, where the 5 m provided a more consistent coverage.

Figure 2-2 Inundation zones

2.4 Other hazards

Sea level rise may exacerbate other existing natural hazards in the Wellington region. A detailed assessment of these issues lies outside the scope of this study but the extent of possible impact is discussed here and these existing hazards will inform the development of options.

2.4.1 Groundwater

As sea level rises, groundwater levels, which in coastal areas may be controlled by the sea level, will also rise. A rise in groundwater level can result in wet and soft near surface soils. This is more of an issue for silt and clay type soils due to capillary action than it is for sand and gravel type soils. Fortunately sand type soils are more prevalent in Wellington's low lying areas, although rising groundwater could result in a range of impacts, including:

- Increased uplift on buildings with sealed basements, possibly requiring strengthening of these structures;
- Underground tanks and services could start to 'float'. This is particularly likely to impact large lightweight pipes (such as gas pipes) and fuel tanks;
- Possible water infiltration to basement structures, requiring waterproofing and pumping;
- Saline intrusion into the aquifer system;
- Increased risk of liquefaction, as detailed in Section 2.4.2;
- Near surface saline water could affect terrestrial vegetation on the coast and cause corrosion to underground assets; and
- A possible increase in landslide risk in some locations.

A literature review undertaken for this study found that there is little information collated on near surface groundwater in the WCC area. Recent studies including Brown (2010) and GNS (2010) have focussed on the feasibility of the underlying greywacke aquifer as an emergency water source for the Wellington region.

GNS (2010) reports that groundwater occurs within permeable lenses in the marine and fluvial deposits which overlie the greywacke in some locations. GNS further notes that flowing artesian groundwater conditions occur in some wells in the groundwater aquifer systems in the Central Business District (CBD, Te Aro and Wellington South areas), indicating confined aquifer conditions. Groundwater is reported as ranging from 0 m to 3 m above sea level near the coast, to about 17 m to 35 m above sea level inland where the greywacke outcrops at ground surface.

2.4.2 Liquefaction

Liquefaction is an existing hazard in the Wellington region that may be exacerbated in some areas by higher groundwater levels resulting from sea level rise. Hazard maps are available showing areas at risk of liquefaction in Wellington City, providing a useful overview of the current situation (refer Figure 2-3 and Figure A-5 in Appendix A). In the Central Wellington area (extending along the State Highway 2 corridor) the zones of higher risk comprise land that has been reclaimed. A rise in sea level can be expected to result in an increase in the potential for damage as a result of liquefaction over part of this reclaimed land.

A rise in sea level and an associated rise in groundwater level can result in a reduced depth to the top of liquefiable soils. This reduced depth can result in greater surface damage in the event of liquefaction. The general construction method for the city's reclamations was loose tipping of material below the sea level, followed by construction and in some instances compaction of the layers above water level. Where good compaction was provided above water level, a rise in water level will not reduce the thickness of the 'crust' of non-liquefiable soil. The compact materials

which go below water would not have a high liquefaction potential. Where the upper soils were not compacted, rise in water level would reduce crust thickness and increase potential for damage as a result of liquefaction.

The other major zone of liquefaction risk in the Wellington area spans from Kilbirnie to Miramar and south across Lyall Bay. These are predominately natural soils and are not as loose as the reclamation fills and thus the liquefaction potential is not as high. A rise in water level could reduce the 'crust' thickness and increase the potential for damage as a result of liquefaction.

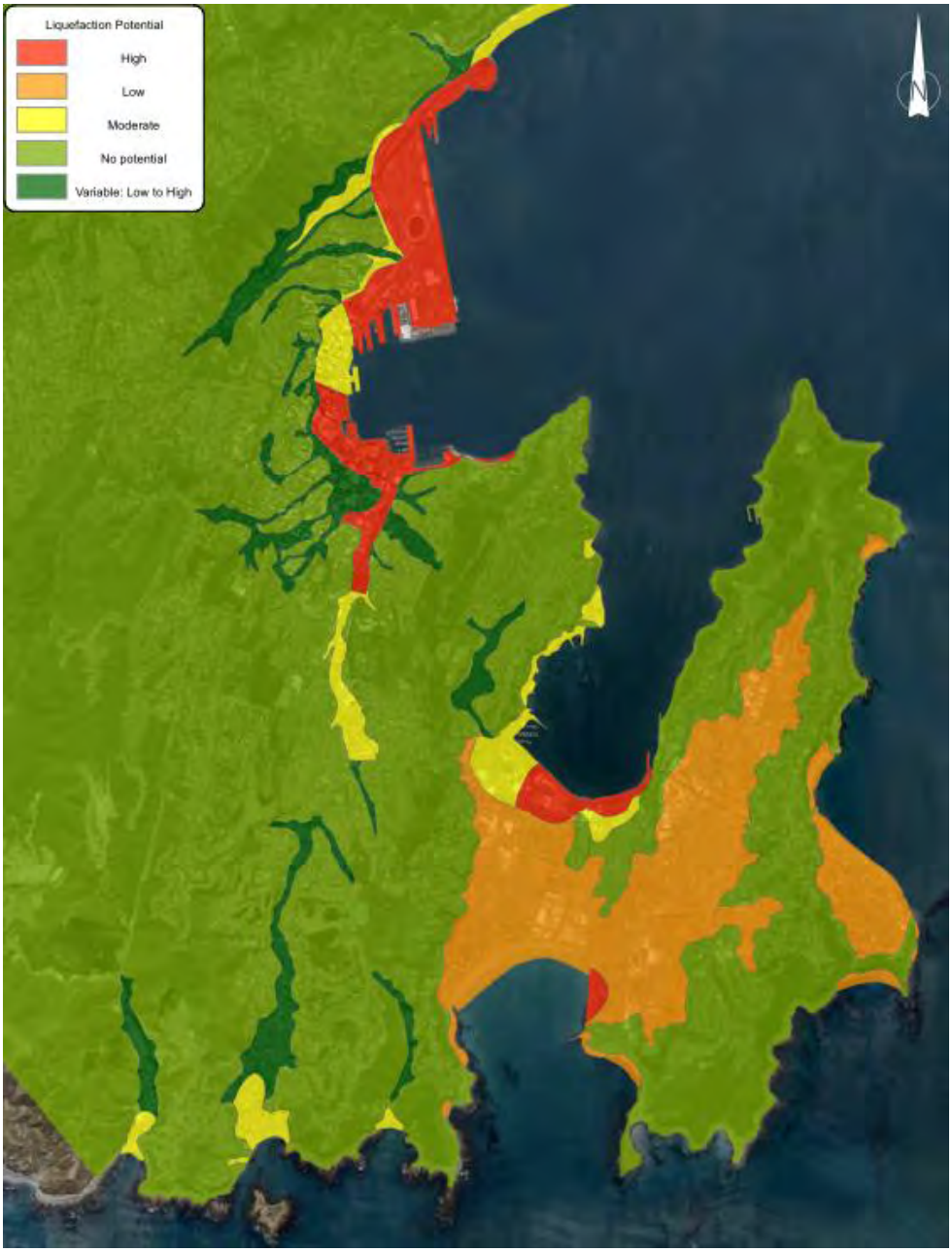

Figure 2-3 Current liquefaction potential (Source: WCC)

Overall, some areas currently subject to this hazard may become more vulnerable to liquefaction in the future. In areas where there is high liquefaction potential the scale of this potential may increase as a result of sea level rise.

2.4.3 Tsunami

The current mapped tsunami evacuation zones broadly match the highest sea level rise scenario developed for this study. As sea level rises areas currently above the potential tsunami inundation zones will be exposed to this hazard. These effects will have a limited impact in many parts of Wellington, where steep cliffs or hillsides sit behind reclaimed marginal land. However, in flatter areas such as Newtown and Miramar the effects could be widespread. Increased sea levels may also mean greater water depths closer to the shore that can increase near shore wave heights and may also modify tsunami impacts.

2.4.4 Flood risk

Some of the areas vulnerable to inundation from sea level rise are already within flood risk zones, in particular, Kilbirnie, areas within the CBD and Miramar. Figure 2-4 shows the current areas at risk of flooding across the Wellington City area (1 in 50 year flood event) and a larger scale figure is included as Figure A-6 in Appendix A). As sea levels increase the frequency and severity of flooding in these areas is likely to increase both due to inundation from the sea and the higher sea levels reducing the gradient of the land based flows. Flooding in adjacent low-lying areas will also be exacerbated. Behind the existing hills that provide natural sea defences around Miramar the increased flood risk will be realised prior to inundation from the sea. This may also be the case in other low lying areas such as Kilbirnie.

Figure 2-4 Areas currently at risk of flooding in a 1 in 50 year flood event (Source: WCC)

2.4.5 Landslide

Higher sea levels may reduce or remove the toe support of existing slopes along the coastal edge, increasing the likelihood of slope failure. Elevated groundwater levels may result in saturation of slope toe material, again increasing the likelihood of slope failure.

The majority of the urban Wellington coastline is protected by hard defences at present, including roads and seawalls. If these are removed then more rapid erosion of the cliffs behind them may result. This hazard has not been considered in detail for this study. Figure 2-5 and Figure A-7 in Appendix A shows the current landslide risk in Wellington City.

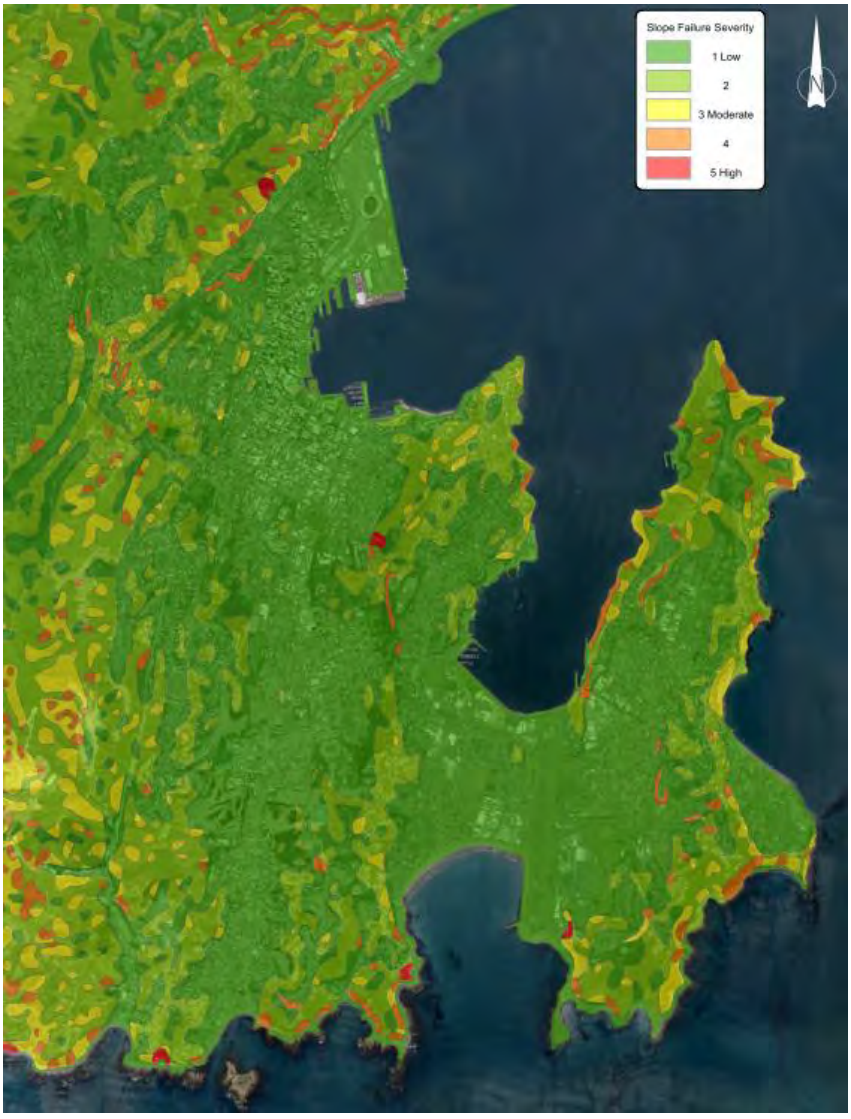

Figure 2-5 Slope failure severity (Source: Greater Wellington Regional Council)

2.4.6 Summary

Many of the areas around Wellington City that are vulnerable to the effects of rising sea levels are already subject to risk from natural hazards. Sea level rise will increase the extent, frequency and consequence of natural hazards including surface flooding, liquefaction and landslide risks.

3 Values assessments

3.1 Overview

This project is the first step in a process of understanding and adapting to climate change induced sea level rise. As such, the focus has been on developing a structure and approach to assessing values across the four well-beings that has a spatial basis, is defensible and can be refined with time.

Five scenarios were selected for the more detailed analysis of the impacts of sea level rise against the four well-beings. The process for selecting these scenarios is covered in Section 2.3.

It is important to note that the values assessment sets the scale of *consequence* of sea level rise for each suburb. A full risk based approach to considering the impact of sea level rise also requires the probability of any outcome to be determined. The method used for this work has been mindful that WCC may wish to develop a full risk based approach in the future.

The philosophy of the values assessment was to assign a numeric value, on a scale of 0 to 5, to the consequences of sea level rise for each suburb and scenario, for each of the four well-beings.

The 'Do Nothing' scenario was considered for the values assessments. This can be translated to mean that no action is taken to prevent the impact of sea level rise and therefore sets out the total scale of associated loss in today's terms or currency.

3.1.1 Storm effects

Detailed consideration was given to an appropriate means of treating the impacts of storm effects in the values assessment.

The storm event that was selected for modelling purposes currently has a 1% AEP. This storm has a 1 in 100 chance of happening in any given year at present. The storm therefore differs to the effects of sea level rise as the area affected is not always inundated. However, other effects can be anticipated such as:

- Increased difficulty in obtaining insurance in areas at risk of storm events;
- Increased social vulnerability as larger population areas are exposed to storm effects;
- Significant damage (for example inundation greater than around 2 m) would result in assets being fully written off; and
- A single large storm event can destroy cultural sites or severely compromise environmental values.

There are published approaches to determining the economics of storm damage. These typically require the derivation of annual average damages, using a range of storm events. This level of detail was considered inappropriate for the high level study being undertaken. A literature review did not identify any robust 'rule of thumb' type approaches that could be applied. No known strategic level approaches exist for quantitatively considering the differing effects of temporary and permanent effects on cultural, social and environmental well-being.

In addition, the frequency of storm effects will increase with increasing sea level rise. For example, NIWA (May 2012) have recently postulated that the 1 in 100 year storm event in Wellington today could become an annual event in the future should sea levels rise 0.5 m.

Given the uncertainty in the future frequency of significant storm events and the lack of a robust strategic approach to comparing temporary and permanent effects across the four well-beings, at this time the full value is attributed to areas affected by storm damage. The interactive model

that has been developed for WCC will let them consider the significance of this assumption and to investigate this further if required.

3.1.2 Data and general process

A literature review at the commencement of the project did not identify any readily transferrable methods for developing a strategic level impacts assessment across the four well-beings, particularly in the New Zealand context. Quantitative or semi-quantitative impacts assessments have typically been limited to specific infrastructure proposals, where the effects can be well described and understood. To apply these detailed methods on a city-wide level was not practical given the scope and scale of this study. The general approach taken to developing a 0 to 5 scale for each of the four well-beings is summarised in Figure 3-1.

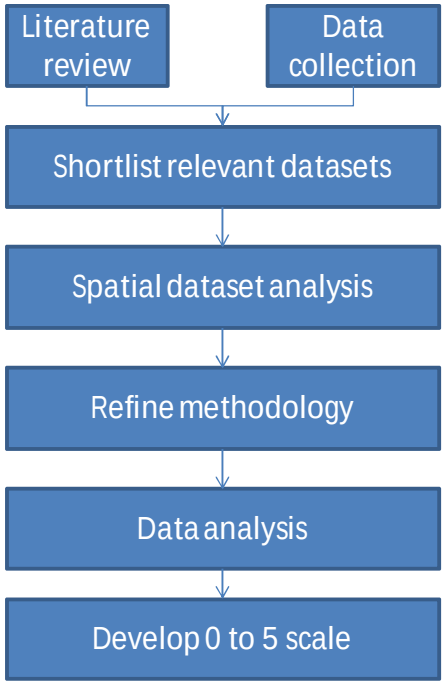

Figure 3-1 Process for developing 0 to 5 scale for the four well-beings

For each of the four well-beings a brief literature review was undertaken. These reviews aimed to identify how sea level rise could be expected to impact the 'components' or 'attributes' of the well-being. This assisted in identifying which datasets were the most relevant for the analysis. Given the high level nature of the study and the volume of data involved in the analysis it was important to identify those indicators that would be significantly affected by sea level rise and that are in themselves an important indicator of the well-being. For example, a literature review was carried out to assess how the economic value of parks and open spaces could be incorporated into the economic impact assessment. This highlighted that the scale of economic value of these sites is immaterial compared to the direct damage costs to land, buildings and infrastructure.

Underpinning the values assessment for each of the four well-beings were a large number of data sources, generally provided in spatial form by WCC. A full list of data sources provided is included in Appendix G.

Using GIS it was possible to analyse the available spatial data for each suburb and scenario and provide outputs to inform the values assessments.

Two simple examples are provided to illustrate this:

1. All properties within the Scenario 1 outline for Island Bay were identified. WCCs valuation database was incorporated into the GIS model to enable the calculation of the monetary value of all of the land and buildings in Island Bay that are affected by Scenario 1.
2. All listed heritage buildings in Central Wellington were identified. A count of these for the suburb was created, along with a summary of any of the other information held in the GIS dataset, for example a brief description of the site.

The suburbs used for this study were as defined by WCC's suburb GIS layer and are shown on Figures A-1 and A-2 in Appendix A.

Methodologies were developed that captured the key indicators for each well-being. In some cases these were refined following an initial review of the spatial data and following sensitivity analyses where appropriate. The method for each well-being is necessarily different. For each well-being the highest impacts were assigned a value of 5 and a threshold was set for a score of 0, representing a no or very low impact. This method results in a comparable scale across the four well-beings. A score of 5 is considered equivalent for each well-being.

It is important to note that this approach has meant that a value of 5 is always assigned to the greatest impact, often associated with Scenario 5. This inherently means that the lower scenarios are more likely to have a lower value. It has also meant that the scale is unique to Wellington and the impact of sea level on the City. However, it could be adapted and applied to other areas and to other hazards.

The detailed approach taken for each of the four well-beings is set out below. Section 3.6 provides an overview of the 0 to 5 scales across all four well-beings.

3.2 Cultural values

An initial cultural values assessment has been undertaken for this study by Raukura Consultants Limited. It is recognised that different sites will have different value for different interested parties. These will include the various iwi groups in Wellington, those with a specific interest in the heritage of the built environment and also the people of Wellington.

For clarity, sites of particular significance to Māori are considered as well as those of cultural importance to all New Zealanders, identified through the District Plan and Archaeological Association Sites.

3.2.1 Defining cultural value

Cultural values by their nature are intrinsic values and therefore difficult to quantify. This study has comprised a review of sites and structures that could be impacted by sea level rise. Impacts on communities of different cultures have not been considered, as all cultures are assumed to be equally vulnerable to the impacts of sea level rise and this component is assessed under the social values assessment.

The cultural sites around Wellington's coastline and likely to be adversely affected by sea level rise are made up of sites of cultural significance to Māori, archaeological sites of all types, historical structures and places of cultural importance to all New Zealanders. These sites form a part of our cultural heritage and provide valuable insights into the history of human occupation in Wellington. Many sites are part of a broader cultural landscape which showed the extent of communities living around Wellington's coastline.

The oldest sites date back to the arrival of Polynesian explorers to Aotearoa/New Zealand in the 13th Century, such as Kupe, embodied in the names of sites including rocks, reefs, and places. The

stories of these places are recorded through oral tradition and preserved in today's written record. Myths and legends tell of links with various natural events. For example, the significant tectonic changes including uplifts of the Miramar Peninsula, which was at some time an island as recorded in Māori oral tradition. Much of Wellington's coastline has been subject to multiple uplift events with the most recent major uplift in 1855.

Later Māori sites set out the first human settlements around Wellington's coastline. The Pā and kainga were located around most of the Wellington coastline. Many are known by name and some archaeological sites remain today. These remain important parts of the heritage of Wellington. Pā sites were generally elevated above sea level and so are unlikely to be inundated with sea level rise but may become affected by erosion processes over time. Sites such as Rangitatau and Te Ika a Maru that are located on rocky headlands which will remain stable with sea level rise are unlikely to be directly affected. However some Pā, and associated sites such as middens, can be near sea level any may be eroded or inundated.

Early European settlements around the coastlines often coincided with Māori settlements and often served to destroy the previous Māori sites. Similarly, military defence sites were located on top of the old Pā sites around the coastline and on the headlands. The European heritage sites in the Wellington area that could be impacted by sea level rise include early wharf structures and seawalls. Heritage buildings within the sea level rise scenarios range from Wellington Town Hall to early settler cottages. There are also areas such as the Patent Slip area at Evan Bay and the Clyde Quay Boat Harbour. The dominance of these buildings is within the Central Wellington, Te Aro and Oriental Bay suburbs with many on reclaimed land.

3.2.2 Data used in the analysis

Many Māori sites around the coastline have been registered on the District Plan and listed in the Heritage Section of the plan in two lists. These are registered as 'M' sites. The second list includes sites that are registered for information only. Where there are a number of sites clustered together forming a cultural landscape they are included in a Māori precinct. Other sites, which for one reason or another are not included in the District Plan Heritage List, would include sites which are either more modern and/or have both a cultural component and a commercial component. The Wharewaka on Taranaki Wharf is an example of this and in such cases local knowledge has augmented the formal data sources.

The District Plan lists of heritage buildings, heritage objects and heritage trees were used in this analysis. The dataset of New Zealand Archaeological Association sites in the Wellington region was provided by WCC and these data also form the basis of the cultural assessment.

3.2.3 **0** to **5** scale

The cultural values for this study were developed using the following process:

- Identify all sites of cultural significance impacted by each scenario;
- For Māori sites, rank each site from 0 to 5 in terms of its importance and whether sea level rise will have an impact as set out in Table 3-1. Consider also whether the site has local, regional or national significance and weight the ranking accordingly using a scale of 1 to 3. Sum the ranking scores for each suburb and scenario then adjust to a 1 to 5 scale at suburb level;
- A similar approach was trialled for other heritage sites. However, through discussions with WCC it was agreed that there is no accepted basis for differentiating between these heritage locations. Several methodologies and weighting criteria were considered, but the balance of sites are located in the Wellington CBD area and the analysis was found to be

insensitive to other weightings. As such a simple 'number of sites' approach was taken, adjusted to a 1 to 5 scale at suburb level using the scale shown in Table 3-2; and

- The highest of the two cultural values for each suburb has been used as the final value.

Māori cultural sites are often known to be associated with historical places or events. Some will include significant archaeology whereas others may not include any remaining archaeological evidence. Not all sites have been recently assessed and some may have records that are now quite old. Some sites will have other values associated with them such as ecology and geology. A few are part of the urban infrastructure such as the Te Aro Pā site in Taranaki Street, which is preserved in the ground floor of an apartment building. In these instances they become additional to the values of the infrastructure, the value of which is reflected in the economic assessment. These aspects have been incorporated into the analysis in the manner set out in Table 3-1.

Table 3-1 Scale used to value individual sites of significance to Māori

Ranking of site	Description	Example
0	These include sites known only by name where no physical manifestation remains and there would be no physical loss if the site were inundated. A residual cultural value remains associated with the historical connection with the site.	Ohau Pā, known to be in Ohau Bay near Oterongo.
1	Low significance or common sites that are known by name. Preservation is largely focussed on the 'mana' of the site. No mitigation measures would be required and no further investigation of the site would be required. These sites are generally small in size and may not have been specifically located. This may include a number of 'M' sites which are listed as 'information only' in Heritage List for Māori sites of significance in the District Plan.	Maraenui – the pre-1855 flat land at Seatoun.
2	Sites with known locations. The site is named but there is no known archaeology and it is unlikely that any would be discovered. However, the site may warrant further investigation to ensure a record remains. It is unlikely that there would need to be any mitigation measures at these sites. These sites are associated in some instances with the very first human presence in Wellington. Some of these would continue to have significance even when covered in water.	Significant rocks such as toka haere (offshore), Te Aroaro a Kupe etc. Sites known as tauranga ika or important fishing places, noting these may be unchanged by sea level rise.
3	Sites with a number of values such as sites used for waka ama bases and where waka taua and waka tete are launched (Tauranga waka) and may include wharewaka. Karaka groves are included here as they are an important marker for coastal settlements or even burials.	Ohariu Pā and environs at Makara Beach and a karaka grove near the end of the Long Gully Road on the South Coast.
4	Extensive sites that may constitute a full cultural landscape. Some of these sites may warrant some protection but if that is not possible then they should be	Examples include Te Ika a Maru and the other Pā and kāinga sites in the bay, Te Kani a Maru but also the landscape around Island Bay

Ranking of site	Description	Example
	intensively recorded with intrusive surveys to ensure the full archaeological record is kept.	including Tapu te Ranga and the kainga sites.
5	Known urupa and significant pā sites remaining in good condition. Also working marae and cultural centres. These sites would be regarded as regionally significant and in a few cases nationally significant, warranting detailed recording and possible protection.	Te Aro Pā and Pipitea Marae. The urupa at Oterongo Bay and Waiariki would also come into this category.

Table 3-2 **0** to **5** scale for heritage sites

Value	Number of heritage sites
0	0
1	1-5
2	6-15
3	16-40
4	41-60
5	> 60

3.3 Economic values

3.3.1 Defining economic value

For this study economic value is a monetary measure of those assets affected by sea level rise. It indicates the financial cost of replacing the affected assets at a given point in time or a present-value estimate of the income flows from an asset. It measures what an asset is 'worth' in a financial or monetary sense.

A wider economic analysis, incorporating impacts on the local, regional and national economy, has not been considered in this study. The effect of sea level rise on asset values alone is significant and is considered an appropriate indicator of economic impact to underpin the WCCs decision making processes.

The approach to assessing the economic values under the do-nothing scenario assumes that, even though the different sea level rise scenarios will occur at times in the future, the current valuations reflect the loss to society. In other words, this would be the loss incurred if the sea level rose immediately and the assets affected were to be written-off.

As detailed in Section 3.1 the focus of the analysis is on the consequence of the various sea level rise scenarios rather than examining both the consequence and likelihood (a risk management approach). The consequence of sea level risk in this part of the analysis assumes that inundated assets are written off.

3.3.2 Data used in the analysis

Given the large amount of assets in Wellington City, the focus has been on materiality to ensure that the key significant values are captured. The magnitude of values (particularly the capital value of land and buildings) mean that smaller assets (such as street lighting, urban parks and cell phone towers) make very little difference to the total damage value. The value of privately owned

utilities including power, gas and telecommunications has not been included in this study due to issues relating to confidentiality and the short time frames of the study. Non-rateable land has also not been accounted for. Assets have been assigned to the following categories for the analysis:

- Land and buildings;
- State highways;
- Local roads;
- Water infrastructure (including potable water supply, wastewater and stormwater networks); and
- Rail infrastructure.

Values have been taken from existing valuation databases, existing asset valuations or from consultation with asset owners. Many of the valuations are commercial in confidence; to avoid any breach of confidentiality the economic values are presented as a total score for each suburb and for each sea level rise scenario in Appendix C.

3.3.3 0 to 5 scale

In order to allow comparability between the well-beings, a 6-point scale (0 to 5) has been used for the economic damages. Given the large variability in the damage costs, the highest damage value (Wellington CBD, with a total asset damage value of $3.5bn) has been used as an upper 'anchor point'. The process for the derivation of each score is as follows:

- Take the logarithm ('log') of the damage value (in $millions) for each scenario and each suburb[1];
- Calculate the ratio of the log of suburb damage to the log of damage to the CBD;
- Multiply this result by 5 to place it on a scale up to a maximum score of 5;
- Remove any negative values (generated by a relatively low damage value); and
- The final score can then be plotted against total damage to provide the log-damage score curve.

The result is economic damages on a scale of 0 to 5 that can be compared qualitatively with the other damage dimensions. A score of zero means that there is either no damage in that suburb or the damage did not reach the relative threshold across the suburbs. An example of the output is provided in Figure 3-2.

[1] The logarithm of economic value rather than the raw values has been used because damages are distributed according to a power law rather than linearly. That is, they vary by several orders of magnitude across the suburbs. In such cases, if a linear scale is used, most economic damage would appear inconsequential. Logarithmic scales are used in other similar instances, such as the Richter scale or decibels.

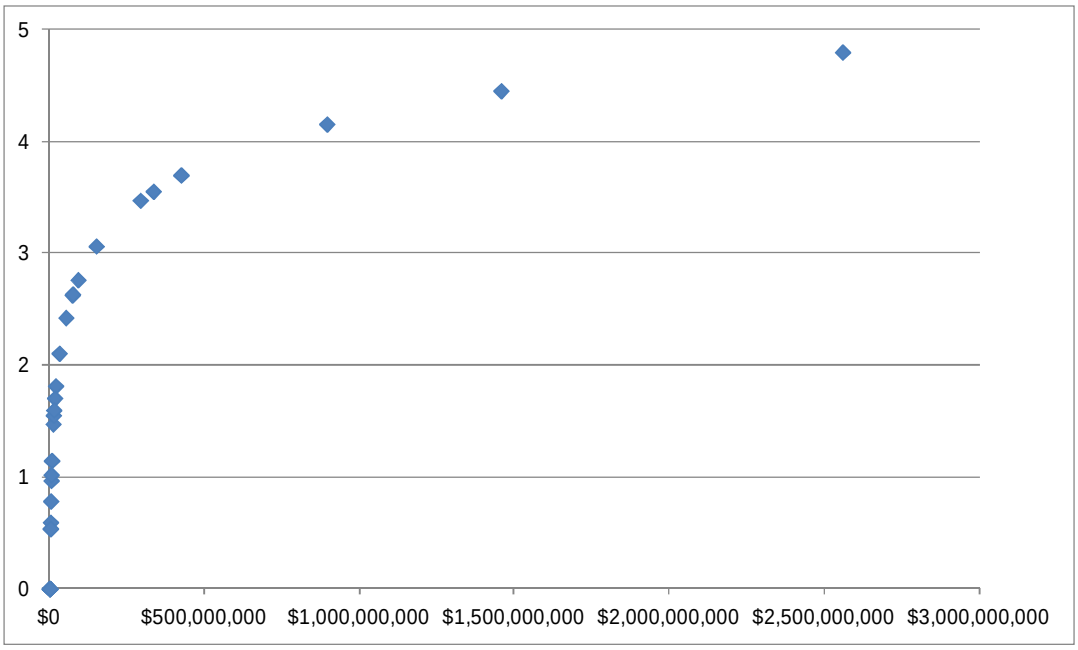

Figure 3-2 Range of economic values for Scenario 2

3.4 Environmental values

3.4.1 Defining environmental value

For the purpose of this high level study environmental value was linked to the ecological significance criteria outlined in Section 18.1.1 of the Wellington City District Plan. This includes 19 criteria under eight main headings including rarity, diversity, distinctiveness, continuity and linkage, national and regional importance, size, viability and other.

This approach enabled a consistent approach to assigning environmental value at a strategic level across Wellington City.

3.4.2 Data used in the analysis

The bulk of ecological sites within the WCC coastal area that may be affected by sea level rise were identified through review and analysis of ecological site GIS databases. Key data sets/layers were obtained from Greater Wellington Regional Council (GWRC), WCC and the Department of Conservation (DOC) and included:

- Greater Wellington Wetlands (GWRC)
- Parks Ecological Sites (WCC)
- Parks and Reserves (WCC)
- Bush Remnants (WCC)
- Parks Bush (WCC)
- Parks Revegetation (WCC)
- Prime Bush Remnants WCC)
- Public Conservation Sites (DOC)

Most sites include ecological description fields but with varying levels of detail.

A literature review was undertaken to identify any other important ecological sites around the WCC coastline that weren't captured by the available GIS datasets. The literature review was also used to supplement ecological description for GIS sites where less detail was available. A full bibliography is provided in Appendix G.

Key documents included:

- The Proposed Regional Policy Statement for the Wellington Region (GWRC, 2009) – Table 16 in Appendix 1 contains a list of rivers and lakes with significant indigenous ecosystems including criteria for inclusion. Criteria include a high percentage of indigenous vegetation in the catchment, habitat for threatened indigenous fish species, six or more indigenous fish species present in the catchment and the presence of inanga spawning habitat;
- The Wellington Regional Freshwater Plan (GWRC, 1999, updated 2012) – In particular Appendices 2 and 3 that list water bodies with a high degree of natural character and with threatened native fish and plants respectively;
- The Wellington Regional Coastal Plan (GWRC, 2000) – In particular Appendices 2 and 3 that detail the Areas of Significant and Important Conservation Value respectively; and
- MfE (2004) – Water Programme of Action: Potential Water Bodies of National Importance.

The sites listed in the documents above and relevant to the Wellington City coastline (and sea level rise) were considered to be of regional/national importance.

Other important information sources included The Conservation Management Strategy for the Wellington Conservancy (DOC, 1996), the National Freshwater Fish Database (administered by NIWA) and Chapter 18 of the Wellington City District Plan (WCC, 2000) that includes a list of Conservation Sites.

3.4.3 **0** to **5** scale

Each ecological site was allocated one (1) point for each of the 19 ecological significance criteria that were evident at the site based on the available information. A total score between 0 and 19 was then generated for each site. The assessment considered the available ecological descriptions and other GIS information including landownership (i.e. potential for access/protection and creation of buffer zones), vegetation cover and land use (existing buffers/pressures) and the proximity to other ecological or protected sites as viewed on the GIS maps.

All criteria were considered to have equal weighting although because of the desktop nature of the exercise and variability in available information between sites there is higher confidence in some criteria over others. For example, there is high confidence in the 'nationally or regionally significant' criteria and lower confidence in determining whether the site can be 'ecologically sustainable'.

The overall impact of sea level rise was developed for each scenario by multiplying the score per site by the area affected then summing the sites per suburb. Similarly to the economic analysis, a logarithmic scale was applied to develop the 0 to 5 scale. Table 3-3 summarises the 0 to 5 scale.

Table 3-3 **0** to **5** scale for determining environmental value

Environmental score	Value score multiplied by area	Description
0	0	No ecological sites present in the suburb and/or the impacted coastal area.
1	1 – 10,000	Low level of environmental impact. Includes indirect effects on coastal sites that are not directly inundated.
2	10,001 – 100,000	Moderate level of environmental impact.
3	100,001 – 1,000,000	Moderate to high level of environmental impact. Moderate total area affected.
4	1,000,001 – 10,000,000	High level of environmental impact, moderately large areas or a number of sites affected. May include sites that are regionally or nationally significant or support threatened species.
5	10,000,001+	High level of environmental impact, large areas and/or number of sites affected, including numerous sites (>3) that are regionally or nationally significant or support threatened species.

3.5 Social values

3.5.1 Defining social value

A literature review informed the range of social effects of sea level rise, which include effects on:

- Recreation, cultural, historic and amenity values;
- Community well-being;
- Economic well-being;
- Health;
- Private property and associated displacement;
- Social equity (refers to unequal distribution of impacts among different population groups); and
- Political and social tensions.

From the social effects identified in the literature, measureable aspects relevant to the Wellington context were used to inform the selection of indicators used in the analysis. The literature review is included in Appendix B.

3.5.2 Data used in the analysis

The focus areas for the analysis of social factors were population, community facilities, community connectivity and social equity. These focus areas were selected on the basis of providing the most value to the analysis within the time and resources available. Initially a larger range of aspects was selected, but through the analysis process it was determined that the value gained for the research effort required was unlikely to add sufficient value to the end-product.

Focus areas that were discarded through this process included amenity[2]/sense of place, heritage aspects, and the number of users and usage pattern of affected community facilities and services.

The data used for the four focus areas were:

- Population – Statistics New Zealand Census 2006 data on the size of the resident population affected, number of elderly (65 years and older) and number of children (under ten years of age). Other population factors could have been considered, but these three were selected on the basis of being relatively easy to retrieve from the population census, and being indicative of the vulnerability of the population especially in the event of an evacuation resulting from an extreme weather event;
- Community facilities – services and facilities provided from WCC databases and supplemented by the local knowledge of the assessors;
- Community connectivity – impact on transport networks (road, rail and air); and
- Social equity – Census 2006 data on the percentage of rental housing and the percentage of households on low income ($30,000 or less).

3.5.3 **0** to **5** scale

The range of values was determined by an analysis of the actual numbers falling within the four focus areas described in Section 3.1.2, and the range and patterns that emerged. The values do not therefore represent actual values, but rather values relative to other suburbs, which is consistent with the other values assessments.

An overall score for each suburb was developed to reflect the overall impact of sea level rise. A 0 to 5 scale was defined from the range of scores.

3.5.3.1 Facilities and services

Within Wellington City there are a plethora of facilities and services that could have been included in the analysis. In the interests of providing the most value in the time and resources available, a decision was made to focus on four key types of facilities and services which the literature review indicated as being particularly important in terms of damage, 'replaceability' and importance for community well-being. These were:

- Emergency services (defined as including civil defence centres, police stations, sea rescue facilities, fire-stations and hospitals);
- Schools (concentration of children in a particular area for extended periods of time that do not show up on the Population Census mesh block data);
- Services important for the social well-being at a suburban level (community libraries, community centres, community recreation areas); and
- Facilities and services important to the city/region as a whole (e.g. Central Library, Council Service Centre, large recreation centres and sports grounds, jetties and surf-clubs, recreational reserves).

The services and facilities included in the analysis were provided from WCC databases supplemented by the local knowledge of the assessors (it was noted that facilities and services

[2] A range of factors contribute to the amenity value of an area, including natural character, visual character, cultural and recreation value, and public access to these areas. For the purposes of this review, an assessment of amenity value is limited to the effects on cultural values in the cultural assessment, the effects on the recreational use of public areas (such as a loss of beaches, jetties etc.) in the social assessment, and on the effects on areas of environmental importance in the environmental assessment.

were missing from the databases). The relative values afforded to each suburb on the impacts on services are considered sufficiently accurate for the purposes of this study. For scenarios where no services or facilities were listed as being within the affected area, a value of 1 was allocated on the basis that any inundation of urban areas will affect some level of facility (e.g. footpaths, small-scale facilities) that is of value to communities at a suburb and city level.

3.5.3.2 Community connectivity

Many aspects contribute to community connectivity. For the purposes of this high level study the social analysis only focussed on impacts on transport networks – road, rail and airport.

The weighting assigned to this aspect was doubled to reflect the severity of this particular impact and the fact that connectivity works both ways – affecting two population groups – those wanting to get out and those wanting to get in.

3.5.3.3 Social equity

Experience in New Zealand and elsewhere shows that properties regularly subject to flooding become increasingly difficult to insure. For this reason the number of properties that would be in this situation under each scenario has been used as an impact measure.

Social research shows that those on low incomes and those in rented housing are likely to have less equity to enable them to relocate in the event of severe damage to their home as a result of for example, severe storm events or flooding from sea level rise. While home owners may be compensated for home damage or for being required to relocate as a result of a policy of managed retreat, those who rent the property are unlikely to be compensated in such events. The percentage of rental housing and the percentage of households on low incomes were therefore used as impact measures.

Home owners with high mortgages are also likely to be much more disadvantaged than those who have low or no mortgages, as they also will be left with little equity to start again. Data for this indicator was not obtained within the scope of this study but is an aspect that should be considered in more detailed analysis and in the development of mitigation strategies.

3.6 Summary of **0** to **5** scales

Each 0 to 5 scale represents a composite value of key components or attributes of the four well-beings. Because of the composite nature of each value a simple representation of each score would be an oversimplification of the analysis, but Table 3-4 below provides a summary intended as a guide to each scale. All scores are assigned to individual suburbs.

Table 3-4 Summary of **0** to **5** scales for the four well-beings

Value	Description	Cultural	Economic	Environmental	Social
0	None or very low	Suburb includes Maori sites only known by name or not impacted by a change in sea level *Or* No heritage sites affected.	<$2m damage to land, building and infrastructure assets in suburb.	No sites of environmental significance present or only very small area affected.	Outside of main urban areas.
1	Low	Up to 5 small sites of low local significance affected *Or* 1 to 10 general heritage sites affected.	$2m – $12m	<100 m^2 of significant sites impacted, no threatened species present, sites not identified as nationally or regionally important.	Up to 50 residents affected and/or impact limited to local roads.
2	Moderate	A small number of sites with some regional significance affected *Or* 11 to 20 general heritage sites affected.	$12m – $60m	Up to ~1000 m^2 of significant sites affected across suburb, rare or threatened ecosystem may be present.	50 – 500 residents affected and/or impact on local road network and/or impact on local community facilities and/or limited impact on vulnerable populations
3	High	One or a few sites of regional or national significance affected *Or* 21 to 30 general heritage sites affected.	$60m – 300m	~1,000-10,000m^2 of significant sites affected across suburb, rare or threatened species may be affected.	500 – 1,500 residents impacted and/or city-wide roads affected and/or a number of community facilities affected and/or a moderate impact on vulnerable populations.
4	Significant	A number (more than 5) sites of regional and national significance affected *Or* 31 to 40 heritage sites affected.	$300m – $1.5bn	~5,000 – 50,000 m^2 of significant sites affected across suburb, rare or threatened species affected, sites of regional or national significance affected.	250 – 2,500 residents affected and/or impact on nationwide road network and/or impact on many community facilities and/or high impact on vulnerable populations.

Value	Description	Cultural	Economic	Environmental	Social
5	Highly significant	Many (more than 20) sites of local, regional and national significance affected *Or* >40 heritage sites affected.	>$1.5bn	>~50,000 m^2 of significant sites affected across suburb, a range of threatened species affected and more than one site of regional or national significance affected.	1,200 – 6,000 residents affected and impacts on city-wide or national road network and an impact on many community facilities and/or high impact on vulnerable populations.

4 Summary of impacts

This section provides an overview of impacts across the Wellington City area, a discussion on the patterns of impact that are seen. This section includes a short commentary on significant impacts at a suburb level. Appendix D provides a detailed summary of impacts per suburb. The location of each of the suburbs described here is shown on Figures A-1 and A-2 in Appendix A.

4.1 Overview

Table 4-1 gives an indication of the scale of impact of a 0.6 m and 1.5 m sea level rise and Figure A-8 in Appendix A shows the extent of inundation for these two scenarios. Damage incurred during storm events, as the result of rising groundwater levels, or due to increased vulnerability to other natural hazards would be in addition to the values tabulated below.

Table 4-1 City-wide impacts of sea level rise for Scenarios **1** and **2**

Affected item	Scenario 1 (0.6 m sea level rise)	Scenario 2 (1.5 m sea level rise)
Assets	$0.4bn	$6.5bn
Residents potentially displaced	~150	~2,000
Area of environmental significance	~60 ha	~100 ha
Cultural sites	~30	~120

The extents of a 0.6 m and 1.5 m sea level rise within the Wellington City urban area are shown in Figure 4-1.

A 0.6 m rise in static sea level impacts the coastal fringe. Areas that are temporarily affected by coastal storms at present will become permanently inundated. Impacts will be the most financially significant in the highly urbanised suburbs of Oriental Bay, Hataitai and Pipitea, where there is a lot of infrastructure development along the coast.

A 1.5 m rise in sea level has a much more widespread impact. Large areas of the CBD would be inundated, along with much of the low lying area of Kilbirnie. Impacts will also be most financially significant in these suburbs.

Figure 4-2 shows the impact of a 0.6 m rise in sea level in each suburb against the four well-beings. The 0 to 5 scores for each well-being, the derivation of which is described in Section 3, have been summed to show the overall impact of the sea level rise scenario. The environmental impact of a 0.6 m rise in sea level is considerable and has a significant influence on the suburbs which have the highest impact score for this scenario. The timescale over which the projected rise in sea level is expected to occur is significantly more rapid than the geological time frames that the valued habitats require to adapt. For example, the wave cut platforms at the base of the cliffs along the southern Wellington coastline will not be recreated at a higher level in a 100 year period. Therefore this habitat and the associated high value ecosystems will be significantly impacted by a relatively small rise in sea level. The impacts on the low lying suburb of Makara Beach are discussed in more detail in Section 7.

The combined economic, social and cultural impacts of a 1.5 m rise in sea level are more significant. Figure 4-3 shows the scores across the four well-beings for each suburb impacted by this sea level rise scenario, which has the greatest impacts on the Wellington CBD suburbs, Kilbirnie and Makara Beach.

Figure 4-1 Extent of inundation in the Wellington urban area (0.6 m and 1.5 m rise in sea level)

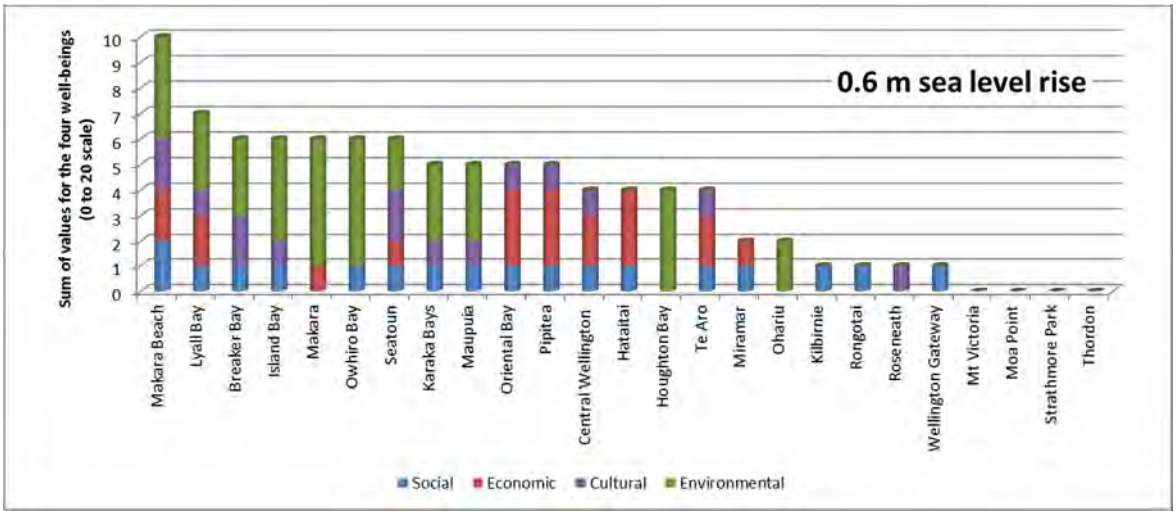

Figure 4-2 Impact of a 0.6 m rise in sea level across the four well-beings

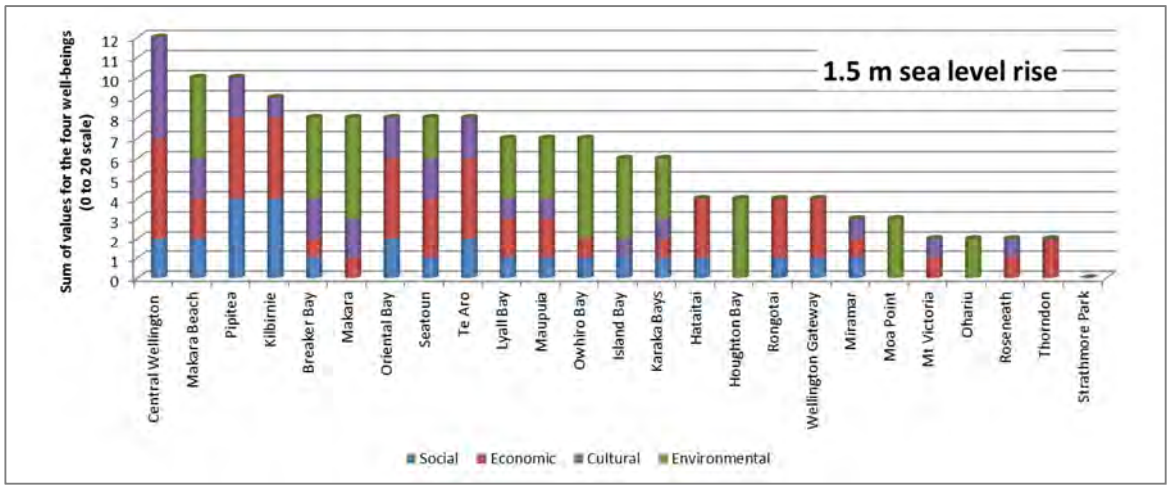

Figure 4-3 Impact of a 1.5 m rise in sea level across the four well-beings

It is interesting to compare Figure 4-1, which shows areas that would be inundated by a 1.5 m rise in sea level, with Figure 4-4, which shows Wellington's growth spine. The area currently earmarked for intensification within the CBD is likely to be inundated by the forecast future rise in sea level. Sections of the proposed growth spine area are vulnerable to the impacts of sea level rise.

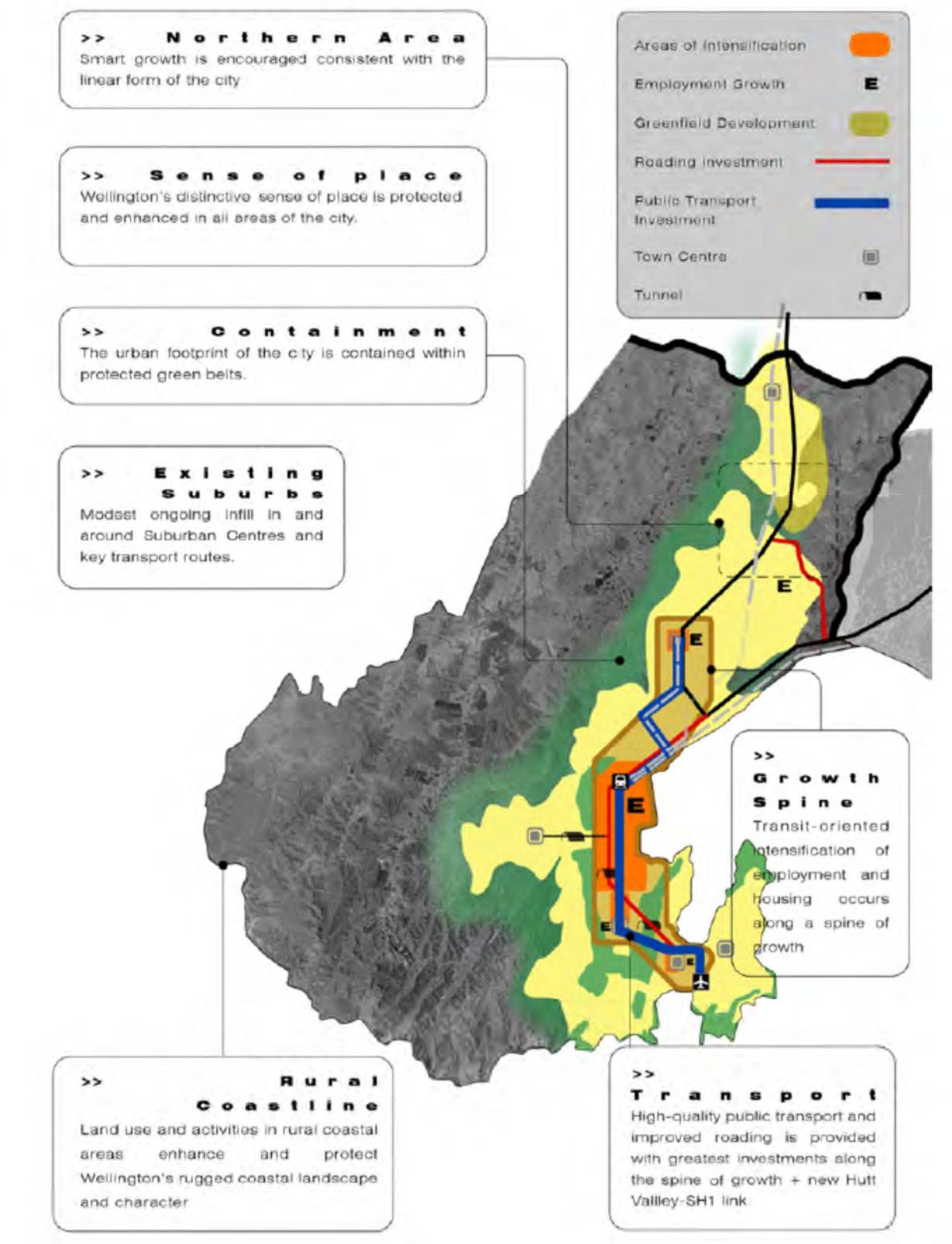

Figure 4-4 Wellington Growth Spine (Source: WCC website)

The sum of impacts across the four well-beings for the five scenarios considered in detail for this study (0.6 m, 1.5 m, 2.2 m and 3.0 m static sea level rises and a 3.0 m sea level rise plus large storm event) is presented in Figure 4-5.

Close inspection of the figure shows that there are a number of suburbs where there is a step change in impact between scenarios. For example, a 1.5 m rise has a much greater effect on Kilbirnie than a 0.6 m rise. Miramar is largely unaffected until Scenario 4, when the sea would overtop Miramar Avenue. These threshold levels or tipping points will be significant when selecting appropriate responses and time frames.

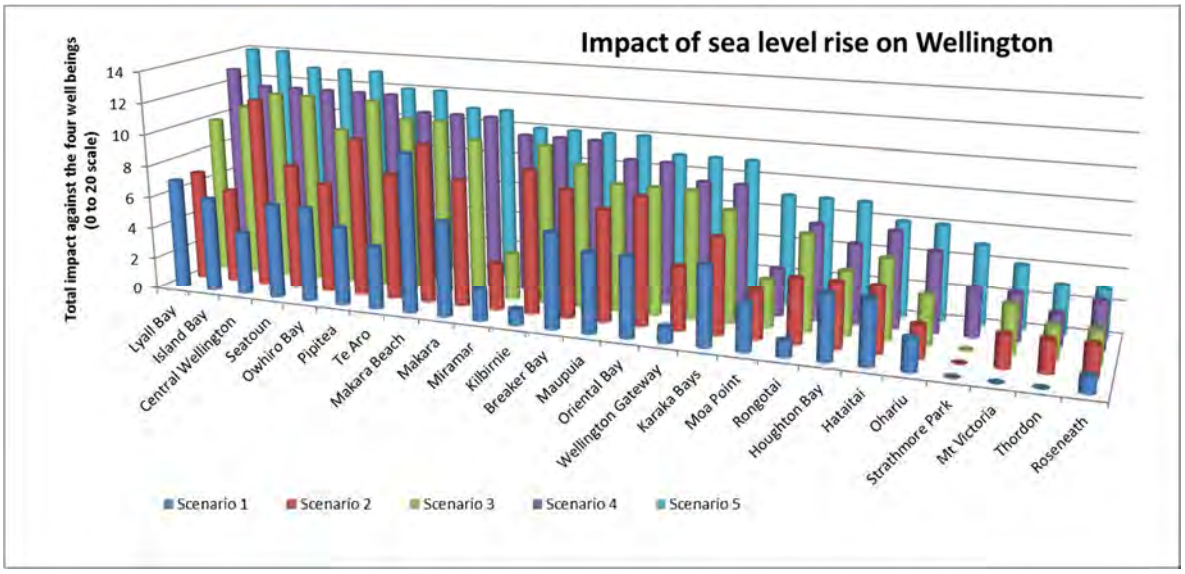

Figure 4-5 Impact of sea level rise scenarios from 0.6 m rise to 3.0 m rise plus storm event against the four well-beings

It may appear surprising that Lyall Bay and Island Bay show the highest impacts in Scenario 5. The reason for this, as shown in Figure 4-6, is that these suburbs have moderate to highly significant impact scores across all four well-beings. Central Wellington, Pipitea and Te Aro have higher economic and cultural impact scores but no environmental score, which results in slightly lower overall impact scores.

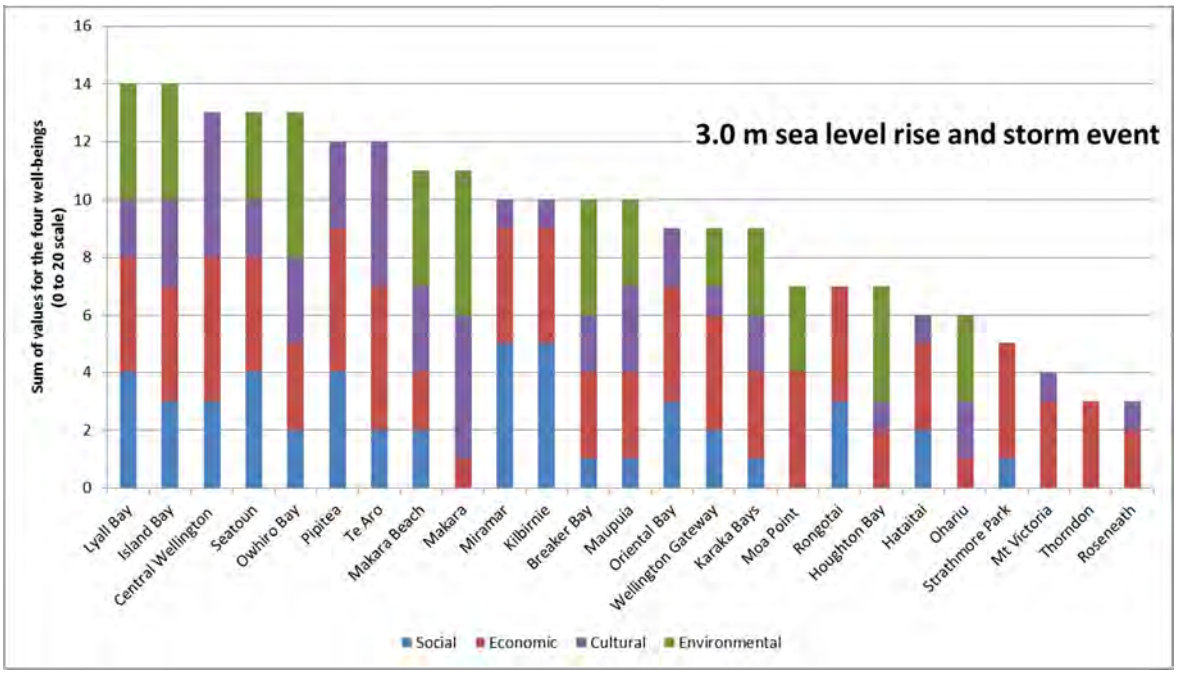

Figure 4-6 Impact of a 3.0 m rise in sea level, combined with a storm event, across the four well-beings

4.2 Suburb level impacts

The impact of sea level rise on Wellington is spatially variable as would be expected. There are no locations where the impact is consistently high across the four well-beings, although there are some suburbs such as Roseneath and Mt Victoria where it is consistently low.

The overview presented here provides commentary in relation to specific areas of interest. The scoring system uses '0' for a very low impact and '5' for a highly significant impact as described in Section 3.

A 'spider diagram' for each suburb was developed to provide a visual summary of the balance of impacts across the four well-beings (the four axes) and for each scenario (the coloured lines). Some scenarios overlie each other, so differing line types were selected for each image to provide the clearest information for each suburb. As a result the line types between suburbs may not be consistent. Where the coloured lines on the spider diagram lie towards the outside of the axes, there is a large impact. Where they are close to the centre point there is a small impact. This is illustrated in Figure 4-7.

A pattern has emerged whereby suburbs with high cultural and environmental values generally have lower social and economic scores, and vice versa. This is shown in Figure 4-8 which provides a summary of the values assessments for Makara and Kilbirnie. The long Makara coast has significant cultural and environmental value, which will be impacted by any increase in sea level rise. For Kilbirnie there is a significant economic impact from a 1.5 m sea level rise arising from the inundation of the road to the airport.

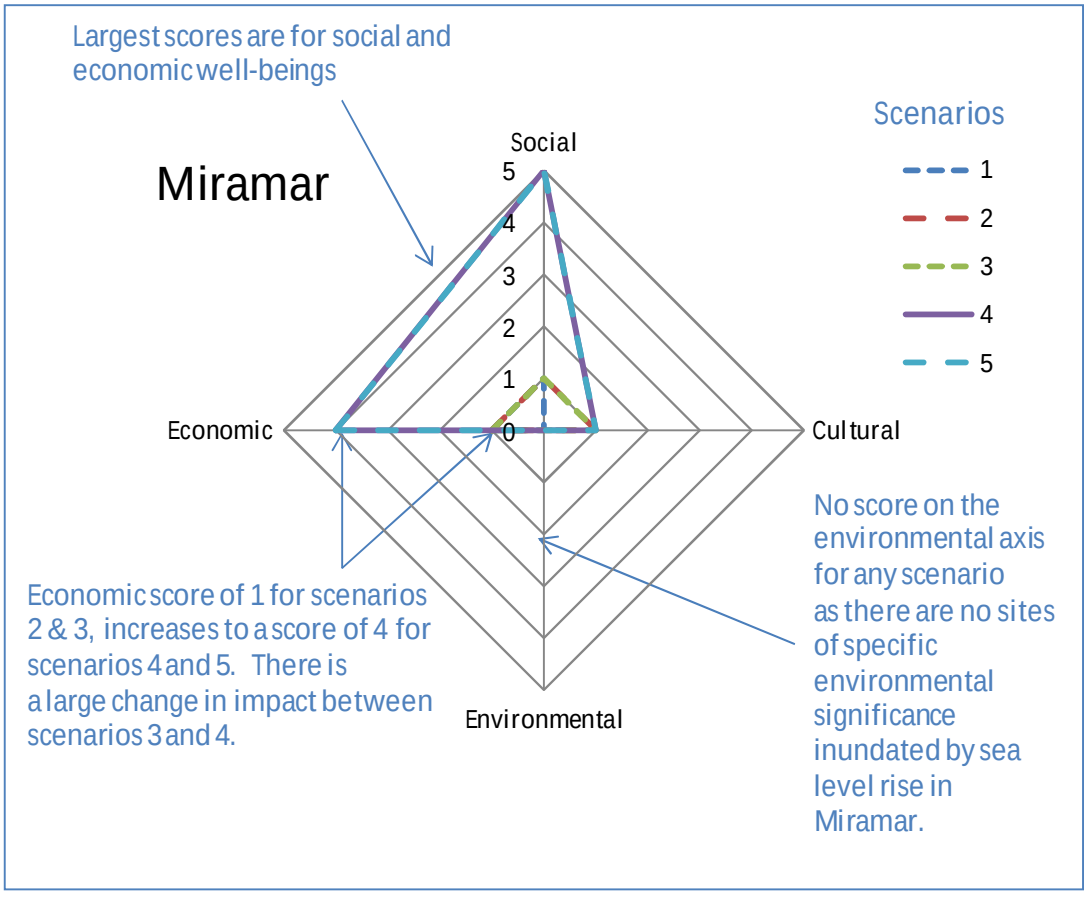

Figure 4-7 Guidance on how to read a spider diagram

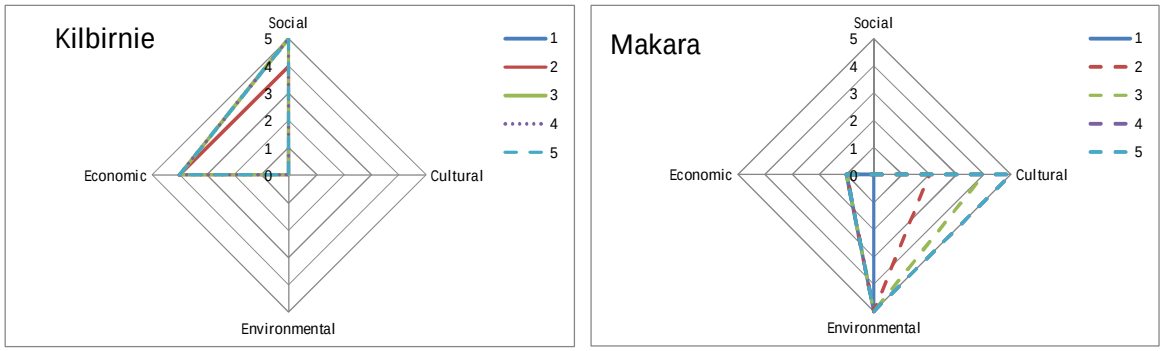

Figure 4-8 Kilbirnie and Makara values assessments

Oriental Bay and Te Aro (Figure 4-9) all demonstrate similar patterns, with significant impacts on economic and cultural well-beings and a moderate social impact compared to primary residential suburbs such as Kilbirnie and Miramar. Broader social and economic impacts, such as employment, are not included in this initial high level assessment so do not influence this score. As there are no sites of environmental significance within this highly modified area there is no assigned environmental score.

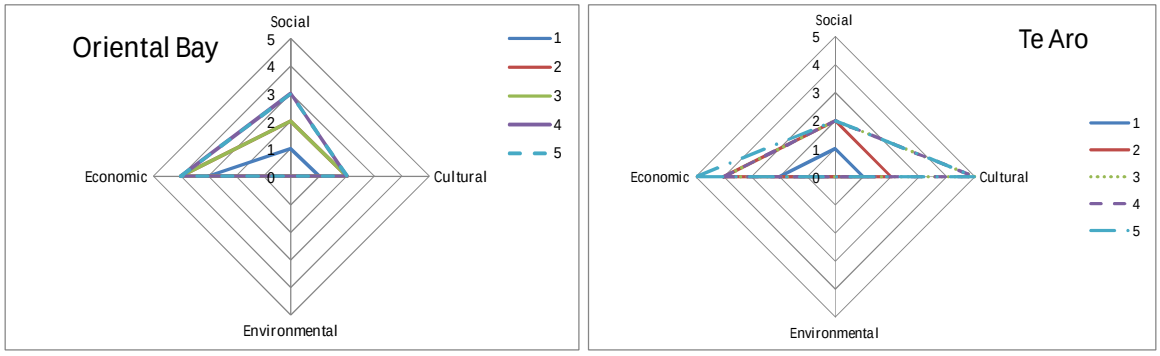

Figure 4-9 Oriental Bay and Te Aro values assessments

As mentioned earlier, Miramar is not impacted by sea level inundation until an elevation of 4.0 m is reached, when the sea would overtop Miramar Avenue and the hinterland area would be flooded. Storm events may impact Miramar from the south before permanent inundation occurs.

Miramar will become vulnerable to other hazards before it is impacted by sea level inundation. Rising sea levels may exacerbate existing surface water drainage and flooding issues. A rise in the groundwater table could occur prior to inundation, which may require pumping or similar intervention at an earlier stage.

The largest impacts on Miramar relate to social and economic well-beings as shown in Figure 4-7, with the suburb being extensively affected by inundation. A high proportion of households are on a low income and/or live in rented properties. Notably, in the worst case scenario considered, this suburb has the highest population affected. There are no sites of environmental significance within this urban area and few heritage sites.

A sea level rise of 2.9 m would also inundate the northern extents of Strathmore Park, affecting greenspace and exacerbating existing flooding issues. Storm effects would be more severe and may impact Strathmore Park from the south before permanent inundation occurs.

As shown in Figure 4-5 and the plots in Appendix D, there is a step change to the impacts on Lyall Bay and Island Bay in Scenario 5, a storm event combined with a 3 m sea level rise. As with other suburbs the impacts associated with lower sea level rise scenarios combined with storm events

have not been explicitly considered, but would be expected to be significant particularly on this exposed southern coast. Rising sea water levels will affect underground infrastructure, particularly stormwater drainage systems, before there is widespread inundation of land areas. The impact on the environment and cultural sites in the Island Bay area, particularly related to Tapu te Ranga Island, will be significant even at lower sea level rise scenarios.

5 Response options

The purpose of this section is to provide a range of interventions to assist in managing the response to and effects of sea level rise.

Response options are typically derived from an assessment approach that considers wider issues in a more comprehensive risk framework (such as the Australian and New Zealand Standard for Risk Management ISO/SA/NZS 31000). A general approach to managing coastal hazard and related climate change risks are also set out in the MfE guideline (2008) and the general legislative requirements are set out in the New Zealand Coastal Policy Statement (2010) and the Resource Management Act (1991).

Decisions should take into account the wider context of the hazard and include consideration of tolerable risk, which is the level of risk individuals, or the community are prepared to 'tolerate' under certain circumstances in return for a specific benefit. For this to happen there needs to be focussed discussion with the communities and stakeholders affected. There also needs to be an understanding of both the likelihood and consequence of the hazard to inform this discussion.

It is anticipated that the risk assessment process will naturally progress from this present study. However, in general terms New Zealand legislation supports a precautionary approach that looks to progressively avoid, remedy or mitigate against risks arising from natural hazards.

The preferred approach in the legislative context is therefore to avoid development and redevelopment in hazard prone areas. Avoidance can manage the effects of future climate change for new and existing communities, for example minimising infrastructure assets situated in areas that could be impacted. Managed retreat is a form of planned avoidance.

In the sea level rise context, remedying effects is linked to a reduction of our impact on the environment by reducing greenhouse gas emissions. WCC (2010) has a strategy to reduce the city's emissions. However, reducing carbon emissions is a global issue and therefore outside the direct control of the Wellington community. In climate change language the reduction of carbon emissions is termed mitigation. Despite increasing global efforts to reduce carbon emissions, many commentators believe that some amount of sea level rise is inevitable due to historical emissions.

In Wellington, as is common in many instances, sea level rise will impact existing developed areas and avoiding all effects within areas at risk of may not be possible. Options to mitigate the effects of sea level could range from managed retreat through to 'conventional' protection options like seawalls/flood walls and property raising or flood proofing. Confined areas may also enable more creative interventions including floating suburbs and new or retrofitted stilt cities or canals. Property raising and flood proofing tend to be solutions that apply to individual dwellings (NIWA, 2012) and can be managed through policy and rules in the District Plan. The other options are more suited to application across a community.

In the context of options for responding to sea level rise, the following broad categories can be considered:

- Non-intervention (do nothing, or 'unmanaged retreat');
- Managed retreat;
- Hold the line;
- Accommodate; and
- Expand into the coastal zone.

It is generally considered (Defra, 2002) that the most realistic options are non-intervention, managed retreat and hold the line. However, it is likely that a combination of options may be needed over time and in different locations. Options relating to accommodating sea level rise are discussed within this document but not considered as specific intervention options at this time. Three options for expanding into the coastal environment are presented. Of these, WCC has indicated that reclamation, which has an existing precedent in the Wellington area, should be considered as a specific option in the case studies presented. As the other options are more likely to occur sometime into the future more specific consideration has not been made for this study.

The different response options will result in different levels of service. This is both in terms of the impact of sea level rise and the impact of any given storm event. Table 5-1 summarises an approximate level of service for the response options considered in cost terms for this study.

Table 5-1 Level of service for intervention options

Response option	Protection level (coastal storm)
Non intervention	Reducing to 0
Managed retreat	Variable (could reduce to 0)
Soft coastal defences	Design for 1% AEP event
Hard coastal defences	Design for 1% AEP event

There is a broad range of highly innovative responses available, including proposing for self-sufficient floating islands to house climate refugees or 'water scrapers' where development occurs below the water. Such futuristic options have not been included within this options assessment as WCC has elected to focus on options more likely to proceed over the foreseeable planning horizon.

Figure 5-1 provides an overview of the options considered for this study. For each option the technical, economic, environmental, social and cultural advantages and disadvantages were considered in a generic manner, which is appropriate for this level of options consideration. Summaries are provided in this section for the more likely interventions and a more detailed description of each option is presented in Appendix E. As discussed, many options are likely to be used in combination.

Non-intervention	Managed retreat or realignment	
 Image: Bob Jones (2008)	 Image: Wellington City Council (2012)	
Hold the line		
Soft coastal protection (sand, shingle or cobble beaches, beach and dune nourishment)  Image: Steve Partridge (2007)	Hard coastal protection (seawalls and embankments)  Image: Nigel Chadwick http://www.channelcoast.org/	Barrier  Image: Peter Trimming (2009)
Accommodate		
Canal city  Image: Jessica Curtin (2011)	Ferry service  Image: Roger Kidd (2011)	
Expand		
Reclamation  Image: Albert Bridge (1999)	Floating suburbs  Image: Sue Elias (2005)	Stilt City  Image: Ian Cunliffe (2010)

Figure 5-1 Response options considered

5.1 Non-intervention

Non-intervention is presented here as the 'Do Nothing' scenario, where the status quo continues. Normal maintenance would be ongoing as part of business as usual but this 'Do Nothing' option

does not include the gradual enhancement of existing assets to respond to sea level rise. This gradual response would be one means of delivering the 'hold the line' options.

Under the non-intervention scenario a large storm event or series of storm events, combined with a small rise in sea level, could trigger abandonment of areas of Wellington, resulting in significant economic and social loss. An awareness of this risk is important when making decisions on the manner and speed of response.

Whilst most climate change adaptation plans assume that the increase in sea level rise will be slow and progressive, some commentators have hypothesised that change could be rapid at times. If this is the case, then those communities that are poorly prepared as a result of no intervention may have no choice but to abandon the areas they currently inhabit.

Appendix E includes the assessment of impacts of non-intervention against the four well-beings and a summary is also included in Table 5-2.

Table 5-2 Summary of non-intervention impact on the four well-beings

Well-being	Impact
Cultural	Loss of sites and buildings
Economic	Loss of all assets
Environment	Loss of terrestrial habitat and no protection of marine or intertidal habitats
Social	Complex social issues for residents and communities forced to move, including the loss of community networks and identity, employment, ability to purchase a house of comparable value (in economic and sentimental terms), and marginalisation.

5.2 Managed retreat

Managed retreat or realignment is defined as any *strategic* decision to withdraw, relocate or abandon private or public assets that are at risk of being impacted by coastal hazards (MfE, 2008). The process of managed retreat is central in the approach to sea level rise adaptation as it is unlikely to be affordable to provide protection to all areas vulnerable to sea level rise and of value.

There are a large suite of tools that sit within the managed retreat option. Planning tools form a significant lever to implement managed retreat and to minimise the overall impact of sea level rise. Typical planning interventions in areas at risk from sea level rise that are being considered by authorities around the world include:

- Creating zones where new development is not permitted;
- Changing the zoning of existing areas to prohibit any modifications or upgrades to existing housing or building stock. With time this is likely to lead to a natural withdrawal from the area;
- Changing the zoning of existing areas to activities that result in a lower vulnerability to the impacts of sea level rise, such as recreational open space. This is another intervention which becomes more effective with time;
- Requiring the construction of more resilient buildings in areas at risk, such as buildings on stilts, or removable buildings, designs that withstand storm events, the provision of access routes above expected future sea level rise, etc.; and
- When carrying out major infrastructure upgrades or renewals, making decisions to locate assets in areas of lower risk or to adapt designs to accommodate changes due to sea level

rise. This could comprise non-corrodible pipe types, additional storage or pumping in stormwater systems, etc.

Each of these interventions can result in a society that is more resilient to the impacts of sea level rise.

Managed retreat can be at a range of spatial scales, from individual properties to whole communities and infrastructure. It can also be implemented over a range of temporal scales. Provision of alternative road alignments, either elevated or following different routes, or even tunnels, are all managed retreat options.

In the environmental context, managed retreat could have a number of manifestations. A pro-active approach could be taken with regard to providing refuges for significant or representative ecosystems/species that include sufficient buffer zones to allow natural migration inland as sea rises. This could include protecting and enhancing the existing values through control of pest plant and animal species and other pressures that may otherwise prevent or reduce the rate at which communities can respond naturally.

Artificial enhancement such as re-vegetation could be undertaken to speed up the process. Habitat creation for key and threatened species could also be undertaken where the habitats lost are only replaced naturally over geological time scales (e.g. rocky shelves and seal haul out areas). Important species that may be lost from other areas where protection is not possible could be translocated.

Managed retreat differs to non-intervention in a number of aspects:

- There is generally a planned and programmed change rather than allowing change to take place in an unmanaged manner;
- There might be construction of a new defence further inland;
- In urban areas it is likely that existing structures will be demolished or relocated, which could enhance habitat opportunities; and
- There may be detailed studies such as modelling of the effects of the realignment to assist in plan development.

From a social perspective managed retreat may appear undesirable particularly for those communities affected. Possible effects that have been identified include:

- Complex social issues for residents and communities that relocate, including the loss of community networks and identity, employment, the ability to purchase a house of comparable value (in economic and sentimental terms), and marginalisation;
- Social issues for communities where displaced residents relocate to, such as overcrowding of community facilities and services, greater competition for employment and increased house prices;
- Psychological impacts as people come to terms with loss of valued aspects of city and fear of change; and
- Health issues related to the sense of loss of control/safety and uncertainty.

Appendix E includes the assessment of impacts of managed retreat against the four well-beings and a summary is also included in Table 5-3.

Table 5-3 Summary of managed retreat impact on the four well-beings

Well-being	Impact
Cultural	Planned approach means value of sites can be documented and some may be relocated.
Economic	Can be developed/planned for incrementally, resulting in phased cost. Direct costs include demolition costs.
Environment	Makes space for new marine/intertidal habitat. Management of habitat may assist ecosystems in responding naturally to sea level rise over time.
Social	Complex social issues for residents and communities deciding to move, including the loss of community networks and identity, employment, ability to purchase a house of comparable value (in economic and sentimental terms), and marginalisation. However, a planned approach is more empowering than the do-nothing option.

5.3 Hold the line

Any of the options that result in a raised coastal edge without an accompanying increase in elevation of the land being protected will present significant challenges in dealing with flooding from surface water flooding and from rising groundwater. For Wellington there are additional risks associated with a seismically active environment. Any defence option, particularly hard defences, will need to be designed to meet a certain earthquake standard. Any exceedance of this standard, or unexpected response, could have catastrophic effects, with a breach in the defences potentially resulting in widespread inundation. In addition, elevated groundwater levels could also increase the likelihood of liquefaction and the low lying areas will be more vulnerable to impacts of a tsunami.

The effects of Hurricane Katrina on New Orleans give some insight into the type and scale of risk that would be created to low lying land areas.

5.3.1 Hard protection

Coastal protection works such as seawalls, flood barriers and revetments are typically required to 'hold the line' maintaining the shoreline position at a certain position. They are generally designed to have a specified asset life and to withstand a certain design event.

Many of the historic erosion and inundation works provide discrete protection for a relatively short term, but in Europe it has been found that their longer-term effectiveness has mostly been unsatisfactory (AGS, 2000) and has often resulted in a 'domino effect', of progressive hard protection works. 'Hold the line' type works tend to be (MfE, 2008):

- Reactive;
- Rarely the most effective or sustainable long term option;
- Lead to a false sense of future security and can often result in increased risk, with intensification of development on the landward area (i.e. increased consequences);
- Lead to other environmental damage and impacts on other coastal values; and
- Lead to an expectation that defence will be maintained in perpetuity.

However, hard defence options can also appear the most attractive to communities. The perception is that they will provide a long term solution to sea level rise. For small changes in sea level, the overall impact of hard defences may not be significant. However, when a long term position is considered, hard defences could substantially change the 'look and feel' of the Wellington cityscape. The current design of the Wellington waterfront maximises a sense of

connectivity with the harbour environment. Building defences, for example up to 2 m higher than existing, with associated drainage systems could significantly alter this connectivity.

Appendix E includes the assessment of impacts against the four well-beings of hard coastal defences and a summary is also included in Table 5-4.

Table 5-4 Summary of hard coastal defences' impact on the four well-beings

Well-being	Impact
Cultural	Can be used to protect areas of cultural significance but construction may affect areas of cultural significance.
Economic	Can be cost effective where large areas are protected by relatively short lengths of wall. Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.
Environment	Difficult to maintain natural environment on seaward side. Loss of natural intertidal hard-shore habitat in areas without existing hard defences. Provides protection for terrestrial ecological sites.
Social	Increased vulnerability to other natural hazards behind defences, including flooding, liquefaction and tsunami. Altered cityscape and amenity. Reduced need to relocate existing communities and infrastructure.

5.3.2 Soft protection

Soft protection such as dune and beach nourishment and the restoration of wetlands as energy dissipaters can provide an alternative 'hold the line' type of approach to managing the effects of erosion and inundation. These options require a good understanding of the coastal cell and the processes operating within in it and may not be successful or cost effective at all locations, particularly areas such as the CBD where there are existing hard defences, or in areas with deep water close to the shoreline.

Properly designed they can assist in reducing natural hazards while protecting conservation values, public access and recreational use. They may also be combined with hard defences to provide areas of amenity along a raised shoreline.

Appendix E includes the assessment of impacts against the four well-beings of soft coastal defences and a summary is also included in Table 5-5.

Table 5-5 Summary of soft coastal defences' impact on the four well-beings

Well-being	Impact
Cultural	Can be used to protect areas of cultural significance but construction may affect areas of cultural significance.
Economic	Ongoing nourishment required. Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.
Environment	Mimics natural systems so may provide habitat. However, locations where this is technically feasible do not protect any significant environmental sites.
Social	Increased vulnerability to other natural hazards behind defences, including flooding, liquefaction and tsunami. Provides amenity area but can take up a lot of space. Reduced need to relocate existing communities and infrastructure.

5.4 Accommodate

These options comprise the same use of space to achieve a desired outcome, in a different way.

For suburbs the main alternative option is to consider a canal form of development, with habitable space above the maximum expected storm level. This option does not lend itself to a progressive rise in sea level, as the habitable level would need to be above the maximum expected sea and storm level and access from existing levels could thus be challenging.

A change of use could be more appropriate for some coastal roads, which could be replaced by ferry services.

Appendix E includes the assessment of impacts against the four well-beings of accommodating sea level rise.

5.5 Expand

Expanding into areas currently occupied by the sea could be a means of providing alternative habitable land to replace abandoned areas.

Expansion options include reclamation, which could also be a form of defence. Reclaimed land would also need to be set above the level of predicted future sea level rise and storm events, or include sea defence systems around the perimeter.

Floating homes or even suburbs are an alternative option. Some homes in the Netherlands are already constructed using floating foundations to enable them to survive flood events. House boats are an accepted form of living in many parts of the world, although management of these in large numbers could be challenging. Floating cities or suburbs, essentially large permanent cruise liners, are also proposed by some proponents.

Buildings on stilts are another means of expanding into the existing sea area. Their use internationally at present is largely in areas that are prone to coastal storms or fluvial flooding. In this form they may provide a useful interim response to sea level rise. Note that both floating homes and development on stilts could also be classified as accommodating sea level rise.

Appendix E includes the assessment of impacts against the four well-beings of expanding into the coastal environment as a response to sea level rise.

5.6 Assessment process

When considering the options available to respond to sea level rise in each part of Wellington, the following aspects were considered:

- The nature of the area at risk;
- Whether the option is technically feasible for the location;
- Whether the option broadly addresses the values at risk; and
- Costs were developed for selected relevant options at each location and for each scenario.

In developing a final approach, WCC will need to be cognisant of many issues, including affordability and where the burden of cost lies. A short discussion of these issues is also included below.

5.6.1 Areas at risk

The areas at risk can be considered as either ‘links’ or ‘nodes’. In the Wellington context key links affected by sea level rise include the State Highway 2 corridor and rail link (referred to within this

report as the Wellington Gateway) and many of the low-lying coastal roads. Suburbs, or groups of suburbs, affected by sea level rise, can be termed nodes.

The possible intervention options for links are shown in Figure 5-2 and nodes in Figure 5.3. For each category the same generic response options are available, although the detail and practicality of them may differ. Managed retreat options for links include abandoning a length of road where alternative routes are available, realigning the road at a higher elevation, perhaps on a flyover, or tunnelling. Managed retreat options for the nodes could include accepting the effects of sea level rise in low density areas, or retreating from some areas that are at high.

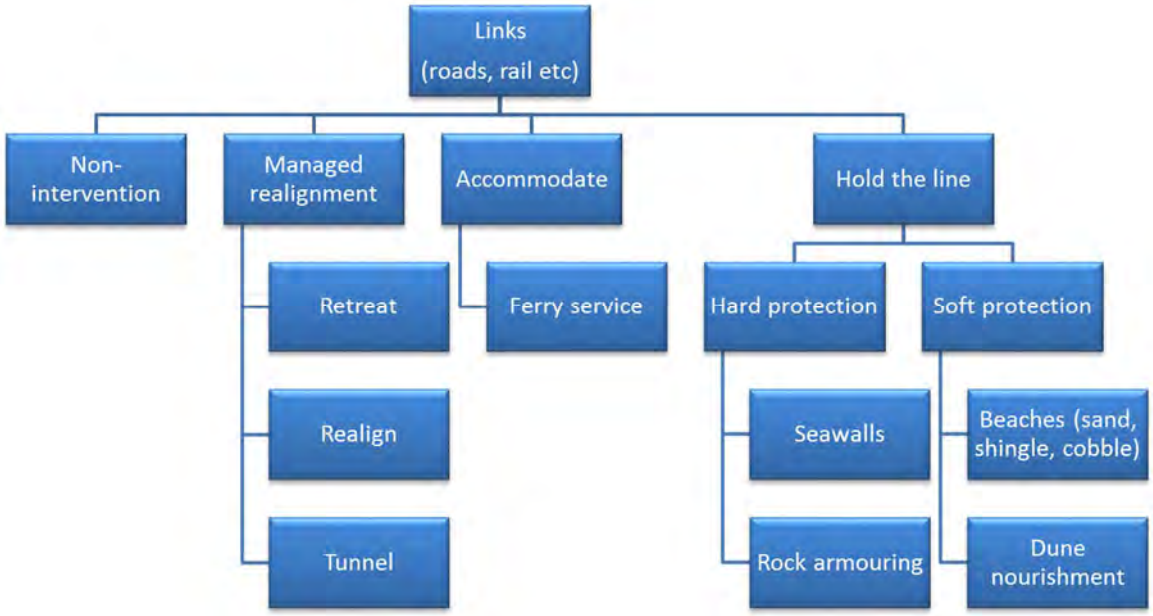

Figure 5-2 Intervention options for links

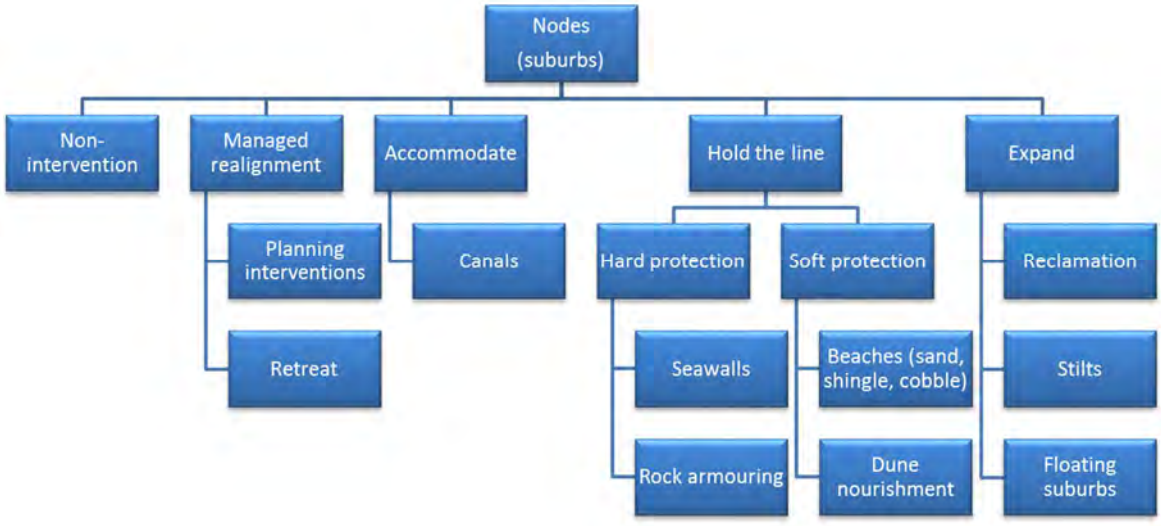

Figure 5-3 Intervention options for nodes

Consideration of the existing type of coast also informs the appropriate technical intervention. For example, locations which currently comprise a 'hard' coastal environment, whether this is natural cliffs or man-made seawalls, are unlikely to lend themselves to soft protection interventions.

5.6.2 Technical feasibility

Not all intervention options are readily technically feasible for each node or suburb. Some intervention options that have been considered are not technically feasible for all scenarios or would require considerable further investigation to prove their effectiveness.

For example, soft protection options require effective management of surface water runoff to avoid erosion of the defences. For smaller watercourses this is normally achieved by diverting runoff into pipe systems which discharge beyond the coastal defences. For larger watercourses, such as at Makara Beach, diverting the surface water flow would be challenging.

Another example is a Tidal Barrier across Wellington Harbour, similar to the Thames Barrier protecting London, which initially appears an attractive option. A single line of protection could protect a large area, including the CBD and Lower Hutt. However, this solution will not be technically viable for Wellington in the long term. To maintain the quality of water behind the Barrier and to enable freshwater entering the harbour to reach the sea, the passage of water needs to be maintained. Wellington has a small tidal range, of around 0.8 m at neaps. If the sea rises by more than this amount the Barrier would have to be closed at all times. The Harbour would become a freshwater area and all of the freshwater entering this area, including the full flow of the Hutt River, would need to be pumped over the Barrier. This is not technically feasible.

5.6.3 Addressing the values at risk

Some solutions would not address the values at risk, particularly environmental values. An example where hard protection would not protect the environmental values at risk is the Pariwhero/Red Rocks reserve. The reserve includes hard and soft-shore intertidal habitat, coastal cliffs with threatened plant species, stream mouth and stream systems that support threatened fish species. A seawall or similar structure would destroy the delicate intertidal habitat and interrupt the connectivity of the stream.

Whilst a direct intervention may not be possible, progressive purchase of land surrounding or buffering this significant ecological site could be an alternative management approach. Early purchase, retirement and protection would create space for marine and/or terrestrial communities to adapt naturally by progressively retreating inland as conditions change. Active management of retired land may be required up front to prevent weed species from becoming dominant.

5.6.4 Timing of adoption

Most authorities responsible for implementing adaptation strategies are seeking 'no regrets' or 'low regrets' interventions, so the flexibility of each option is an important part of its likely future success. This concept also generally aligns with the decreasingly preferential hierarchy set out in the Resource Management Act to avoid, remedy or mitigate effects.

A 'low regrets' option is one where preparing now costs little, so proceeding with the intervention is justifiable, despite any uncertainties about future sea level rise. Examples include (Titus and Newmann, 2009):

- Setting new development back from the sea or above expected future sea levels;

- Requiring higher floor levels for development within areas that may be vulnerable to higher sea levels;
- Designing larger pipes for new or refurbished drainage systems in areas that could become prone to flooding as sea levels rise; or
- Rebuilding roads to a higher elevation during routine reconstruction.

At the opposite end of the scale are options that would cost a lot now and may not provide long term protection from sea level rise. Constructing a Tidal Barrier, as discussed in Section 5.6.2, is an example of this. Costs would be very high and protection would be only practically provided for sea level rise up to around 0.6 m. The investment in this high cost asset could become redundant before it reaches the end of its design life.

Most other options lie along a continuum between low and high regrets options.

Short term decisions will influence longer term policies. Electing to protect areas now is likely to result in increased development behind coastal defences, concentrating economic value and social vulnerability, resulting in a higher demand for protection in the long term. These options may not be sustainable in the long term either in terms of cost or technical feasibility.

Over time sea level rise may result in major behavioural change or technical innovation. Some innovators have mooted self-sustaining islands that float upon the oceans. Whilst this may be an extreme example, experience around the world provides examples where communities have elected to change the way they live to accommodate flooding or coastal inundation. New homes built on stilts are one example of this.

5.6.5 Scale of cost development

A high level approach was adopted to develop the scale of cost on a 0 to 5 scale based on literature reviews, generic costs, relative comparisons and experience. This approach is appropriate for a very high level analysis but includes many implicit assumptions, limitations and uncertainties.

Costs for the following options have been developed at a high level for this study:

- Soft protection;
- Hard protection comprising either:
    a A seawall with a raised road behind it, for links; or
    b A seawall and an allowance for stormwater management, for nodes; and
- Managed retreat.

Table 5-6 summarises the interventions considered by suburb for costs purposes.

Table 5-6 Interventions considered by suburb for cost purposes

Suburb	Road raising and seawall	Seawall and stormwater management	Soft protection	Managed retreat
Breaker Bay	✓			✓
Central Wellington		✓		✓
Hataitai	✓			✓
Houghton Bay	✓			✓
Island Bay	✓		✓	✓
Karaka Bays	✓			✓
Kilbirnie		✓	✓	✓
Lyall Bay		✓	✓	✓
Makara				✓
Makara Beach		✓		✓
Maupuia	✓			✓
Miramar		✓		✓
Moa Point	✓			✓
Mt Victoria	Protected by Oriental Bay defences			✓
Ohariu				✓
Oriental Bay	✓		✓	✓
Owhiro Bay	✓		✓	✓
Pipitea		✓		✓
Rongotai		✓	✓	✓
Roseneath	✓			✓
Seatoun		✓	✓	✓
Strathmore Park	Protected by Miramar and Rongotai defences			✓
Te Aro		✓		✓
Thorndon	Protected by Pipitea and Central Wellington defences			✓
Wellington Gateway[3]	✓			✓

The scale of cost figures is included in Appendix C. As this study has been carried out at a suburb level, costs have also been developed at a suburb level using a simplifying assumption for hard and soft intervention options that the coastal edge of each suburb would be defended. Implicit in this assumption is that adjacent suburbs would also be protected using some form of intervention. For example, if Central Wellington is protected then Pipitea and Te Aro would also be protected.

The tables show that:

- Costs are generally lowest for the managed retreat option;
- Soft protection is more costly than hard protection due to the larger volumes of material required; and
- The most costly option is a Tidal Barrier.

[3] Khandallah, Kaiwharawhara, Horokiwi, Newlands, Ngauranga

As discussed in Section 5.6.2 a Tidal Barrier would only be effective for sea level rise up to around 0.6 m due to the small tidal range in the Wellington Harbour, so a scale of cost is presented only for Scenario 1.

A comparison of the scale of cost for three interventions, managed retreat, soft and hard interventions (seawall and water management or road raising and seawall construction, as indicated in Table 5-6) are compared for the suburbs where soft protection options have been considered. The results for Scenarios 1 and 2 are included in Table 5-7 and Table 5-8. These tables show that costs are typically lowest for managed retreat, then hard protection options and most expensive for soft protection. A notable exception is for Scenario 2 in Kilbirnie where hard protection is a lower cost intervention than managed retreat. The cost of retreating from this area could be significant requiring the demolition or relocation of major roads and other infrastructure.

Table 5-7 Comparison of scale of cost of managed retreat, soft and hard interventions for Scenario **1**

Scenario 1 (0.6 m sea level rise)			
	Managed retreat	Hard protection	Soft protection
Kilbirnie	0	1	2
Rongotai	0	1	1
Island Bay	0	1	2
Lyall Bay	0	2	2
Oriental Bay	0	1	2
Owhiro Bay	0	1	2
Seatoun	0	1	2

Table 5-8 Comparison of scale of cost of managed retreat, soft and hard interventions for Scenario **2**

Scenario 2 (1.5 m sea level rise)			
	Managed retreat	Hard protection	Soft protection
Kilbirnie	2	1	2
Rongotai	1	1	2
Island Bay	0	2	3
Lyall Bay	0	2	3
Oriental Bay	1	2	3
Owhiro Bay	0	2	3
Seatoun	1	2	3

5.6.6 Affordability

Wellington, like many parts of New Zealand, has a long coastline and finite resources to fund work required to protect vulnerable coastal areas.

For example, there are significant lengths of coastal road which are already damaged from significant storm events. Even small rises in sea level, less than the 1 m considered likely within the next 100 years, will increase the cost of maintaining these roads. To prioritise the use of finite resources difficult decisions will have to be made. Where alternative routes or modes exist, or are feasible, then the people of Wellington may decide to abandon sections of road. In the short term, these roads could continue to provide amenity value, making space for cycling and walking. They may also be used to provide opportunities for vegetation areas and habitat enhancement if the physical structures were removed. In the longer term, as the assets deteriorate or the sea rises, this value too may be lost. This type of decision making process will need to be applied across all land use types and each part of the Wellington area.

The issue of affordability of coastal defences and water management can perhaps be best exemplified by the Netherlands. The present cost of water management, including coastal protection, in the Netherlands is about 1000 million euro per year or 0.2% of Dutch Gross Domestic Product. The estimated *additional* cost for a 1 m sea level rise in 100 years is another 1000 million euro per year (Vellinga, 2009).

5.6.7 Burden of cost

For any of the available response options there will be the difficult question to answer, 'Where should the burden of cost lie?'

This is a complex and emotive topic that will need to be worked through with the Wellington City community. Is it fair for those living and working in the elevated suburbs to contribute towards protection of low lying areas? Should people who are forced to abandon their homes, perhaps after a storm event coupled with sea level rise, be compensated for this loss? Where planning tools are used to encourage migration away from low lying areas, should owners be compensated if there has been a loss in land value?

These questions and many that are similar are not new and are played out on a large and a small scale in many New Zealand locations that are affected by natural hazards. A long term response will require a long term approach that is equitable and affordable. The answer may differ in each location – for example, it may not be appropriate to respond in the same way to the risk to the State Highway 2 corridor into Wellington and the coastal road from Rongotai to Seatoun.

The sea level rise debate is also complex as it involves issues of intergenerational equity. How funds should be raised and how costs should be borne now and in the future are other questions that WCC will need to address.

All of these issues will need to be debated and agreed by the community to enable an effective long term response strategy to be designed and implemented.

5.7 Case studies

Five case studies are presented to provide an insight into different types of sea level rise impact and possible intervention options. A variety of links and nodes have been selected, each with a different character and each of which is impacted in the 0.6 m and 1.5 m sea level rise scenarios. The five case study areas are:

1. The CBD area, comprising the suburbs of Te Aro, Wellington Central and Pipitea;
2. The Wellington Gateway (road, rail and utility corridor into Wellington);
3. Kilbirnie;
4. The coastal road from Rongotai to Seatoun; and
5. Makara Beach.

Each suburb has different existing characteristics and will be impacted in different ways. Therefore the focus of the discussion provided here differs between suburbs.

5.7.1 Central Business District

5.7.1.1 Impacts

For the purposes of this assessment the Wellington CBD comprises the suburbs of Pipitea, Central Wellington and Te Aro as shown on Figure A2 in Appendix A. The impacts of Scenarios 1 and 2 are discussed here, providing focus on the impacts more likely over the next 100 years.

A 0.6 m rise in sea level (Scenario 1) could have an impact on land, property and infrastructure assets with a combined value of over $100m. This rapidly increases to nearly $5bn of assets if sea level rises by 1.5 m (Scenario 2), representing 75% of the land, property and infrastructure losses associated with a 1.5 m sea level rise across the WCC area. The number of residents impacted by sea level rise also increases rapidly from around 50 in Scenario 1 to around 1000[4] in Scenario 2.

Figure A-9 in Appendix A shows the extent of inundation on the CBD in a 1.5 m rise in sea level while Figure 5-4 shows the relative impact of a 1.5 m rise in sea level on the CBD suburbs compared with the other WCC suburbs. Due to the very developed nature of this location, environmental factors are not significantly affected (zero value scores for these areas) so the impacts are assessed across three of the four well-beings; economic, social and cultural.

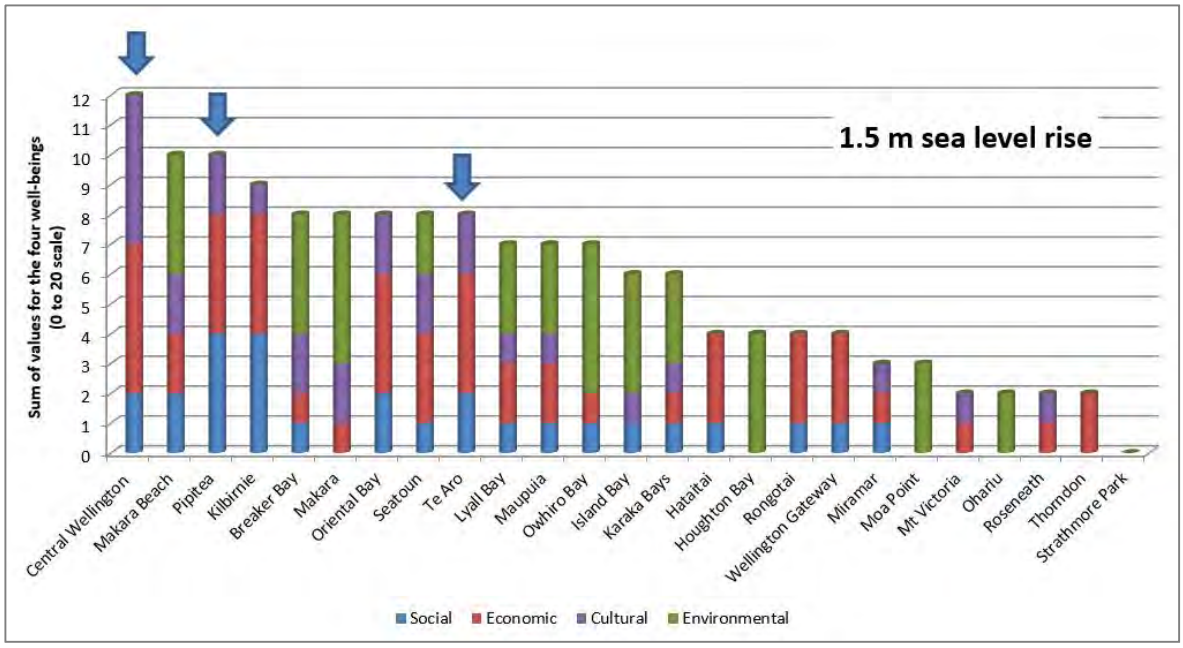

Figure 5-4 Impact of a 1.5 m rise in sea level with arrows showing the Wellington CBD suburbs

Notable sites and buildings affected by a 1.5 m sea level rise include:

- The Central Railway Station;
- Old Government House;
- Wellington Central Library;
- Wellington Town Hall; and

[4] Based on the 2006 New Zealand Census

- The operational port area.

The railway and State Highway 2 would be inundated, severing the primary transport links between Wellington City and the north. Buried infrastructure, including water supply pipelines and electricity and telecommunications infrastructure, would also be at risk. These impacts are discussed further in relation to the Wellington Gateway case study in Section 5.7.2.

The Wellington CBD area is also currently vulnerable to other hazards, particularly liquefaction and flooding, as Figure 5-5 illustrates. The effects of these hazards could be exacerbated by sea level rise, as discussed in section 2.4, with significant impacts including:

- More frequent flooding;
- Flooding over a wider area; and
- Increased vulnerability to liquefaction as the crust thickness reduces as sea level rises.

Rising groundwater levels linked to rising sea levels could also impact the Wellington CBD, with effects on underground pipe networks, building foundations and other underground infrastructure such as storage tanks.

Figure 5-5 Liquefaction and flooding risks in the Wellington CBD (Source: WCC)

5.7.1.2 Intervention options

Three main intervention options have been considered for the Wellington CBD area:

1. Managed retreat;
2. A seawall, with associated water management as shown on Figure A-10 in Appendix A; and
3. A raised reclamation, combined with seawall as required and associated water management, as shown on Figure A-11 in Appendix A.

Soft protection options have not been considered for the CBD area, due to the current engineered sea front. However, options may exist to create an engineering option that has amenity and other values. This can be seen at Oriental Bay, where the beach nourishment has provided increased amenity and also provides a protection function to the existing seawall. Other examples are shown in Figure 5-6 and Figure 5-7.

Figure 5-6 Softening a hard coastal edge (Source: Stephenson and Turner, 2012)

Figure 5-7 Coastal defence at Cleveleys, United Kingdom[5]

Figure 5-7 also demonstrates the advantages that can be gained from a retreat from the coast, with space created for recreation and coastal defences.

The seawall alignment in Figure A-10 (Appendix A) has been nominally aligned with Waterloo Quay and Cable Street, as the construction of a structure along the full extent of the current coastline would be complex and challenging. The nominal alignment does not provide protection to all current coastal assets – a wider range of options need to be considered in future phases of this project, including combinations of options.

The scale of cost for each option has been combined for three suburbs but maintained on the same overall 0 to 5 scale as the suburb level analysis shown in Section 1 to give an indication of the relative order of cost of the three options. The results of this are shown in Figure 5-8. Reclamation costs are significantly higher than the other costs, although new land is created, which has different benefits, lying outside the strategic analysis completed for this study.

[5] (Source: http://webarchive.nationalarchives.gov.uk/20110107183648/http:/www.betterpublicbuilding.org.uk/finalists/2008/cleveleys/)

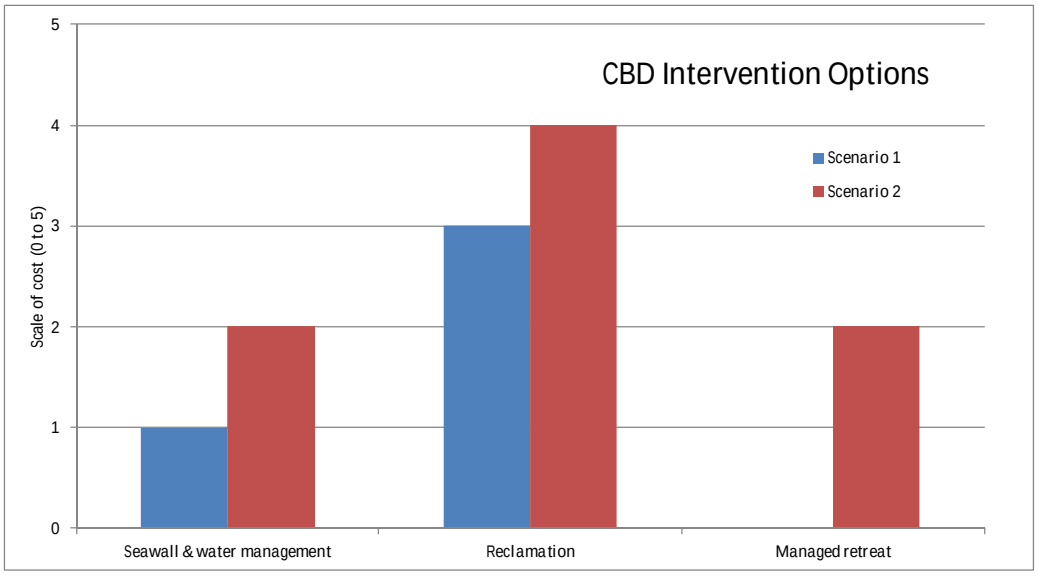

Figure 5-8 Scale of cost – CBD intervention options

Hard intervention options to prevent inundation from sea level rise in the Wellington CBD area will have a number of inherent risks, notably:

- The existing and projected future population will be highly vulnerable in the event of the failure of the engineered structures – earthquake, liquefaction and overtopping design standards may need to exceed current normal design standards;
- The existing and projected future population will also be more vulnerable to other natural hazards, including the effects of liquefaction, surface flooding and tsunami; and
- Once protection works are in place there may be ongoing community pressure to restore amenity and access that has been lost by the installation of the physical works.

5.7.2 Wellington Gateway

5.7.2.1 Impacts

The Wellington Gateway or State Highway 2 corridor is one of Wellington's 'lifelines', providing road and rail access to the city from the north and also providing a corridor for utilities such as water supply. For this study the Wellington Gateway comprises the suburbs of Khandallah, Kaiwharawhara, Horokiwi, Newlands and Ngauranga, shown in Figure A-1 in Appendix A. The impacts of Scenarios 1 and 2 are discussed here, providing focus on the impacts more likely over the coming 100 years. Scenario 4, a 3.0 m rise in sea level, is also discussed as there is a step change in inundation at this elevation. Figure 5-9 shows the extent of inundation along this corridor for the five scenarios.

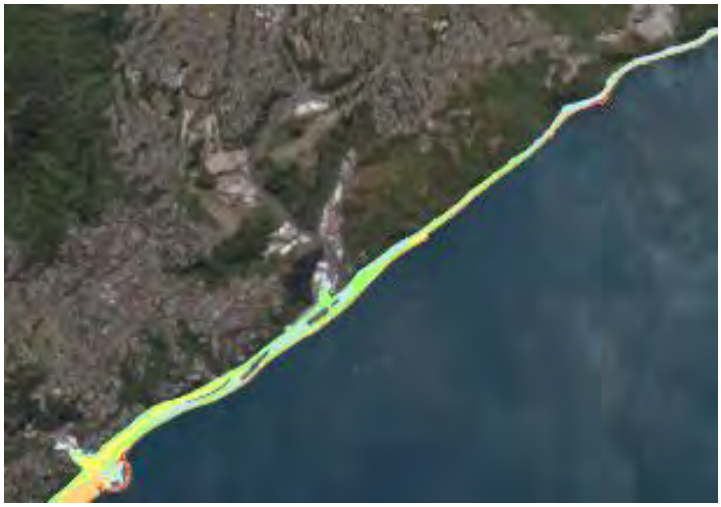

Figure 5-9 Wellington Gateway inundation extent

Static sea level rise of 0.6 m would not result in any significant inundation and damage to assets would be small. However, a 1.5 m rise in static sea level could result in inundation of the transport corridor around Kaiwharawhara. Storm effects would result in considerable interruption and damage to this corridor before the impacts of inundation are realised. Complete inundation of the full length of the corridor would not occur until sea levels rise by at least 3 m.

The impact of sea level rise on the four well-beings for the Gateway suburb are shown in Figure 5-10.

The relatively low social score for the Gateway suburbs is a function of the approach taken to this study. This regionally significant transport link is recognised in the score. However, there is a comparatively small impact on residents and communities which is reflected in a maximum score of 2 out of 5.

The cultural score reflects the damage done by existing infrastructure to cultural sites, including the Kaiwharawhara Pā and Nga-uranga Pā.

Environmental sites affected by sea level rise include both the Kaiwharawhara Stream and remnants of coastal forest along this corridor.

The economic assessment is based on average unit costs for the underground water, sewer and stormwater infrastructure and also for the state highway. This approach is reasonable for a city-wide analysis, but may understate the value of the assets along this corridor where there may be a greater concentration of underground infrastructure.

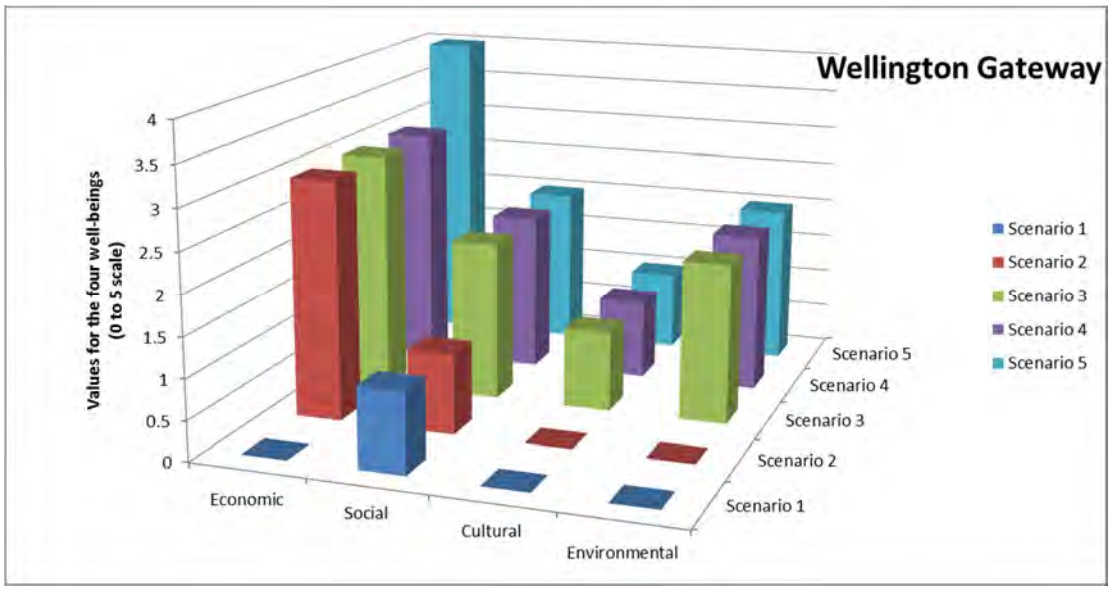

Figure 5-10 Impact of sea level rise on the Wellington Gateway across the four well-beings

5.7.2.2 Intervention options

Three intervention options have been considered for the Wellington Gateway:

1. Managed retreat;
2. A seawall, with associated water management; and
3. Road raising with an associated seawall.

The scale of costs for each option is shown in Figure 5-11. The two hard protection options are similar in cost. Managed retreat appears the least cost option, but no allowance is made in this estimate for the replacement of infrastructure elsewhere.

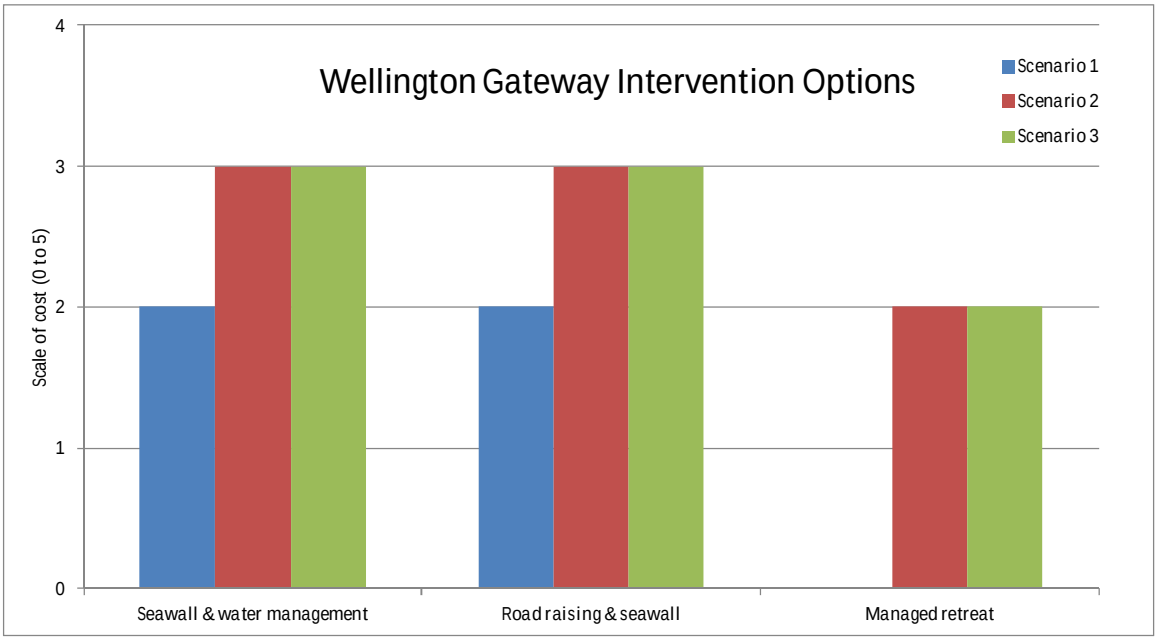

Figure 5-11 Scale of cost – Wellington Gateway intervention options

More detailed analyses are required to, as a minimum:

- Provide more specific estimates of asset values, rather than relying on average unit costs;
- Incorporate the wider economic benefits provided by this lifeline corridor, which have not been considered in this study;
- Consider costs for realignment or tunnelling of this access route; and
- Consider the impact of storm events.

Balancing the social impact to this lifeline corridor with the social impact on communities and homes may be an area of discussion with the wider Wellington community.

5.7.3 Kilbirnie

5.7.3.1 Impacts

The impacts of Scenario 2 are discussed here, providing focus on the impacts more likely over the coming 100 years. Scenario 4 is also discussed to place the impacts and possible interventions into a longer term context. Figures A-12 and A-13 in Appendix A show the extent of inundation of Kilbirnie in a 1.5 m and 3.0 m rise in sea level respectively.

A 1.5 m rise in sea level could have an impact on land, property and infrastructure assets with a combined value of over $400m. This increases to around $500m of assets if sea level rises by 3.0 m.

The number of residents impacted by sea level rise increases rapidly from less than 50 in Scenario 1 (a 0.6 m rise) to around 1000[6] in Scenario 2 (a 1.5 m rise) and to over 1500 in a 3 m sea level rise scenario. The population is considered vulnerable to the effects of sea level rise, comprising a higher than average proportion of elderly residents, low income and/or rental properties.

Figure 5-12 shows the impacts of a 1.5 m and 3.0 m rise in sea level rise on each of the four well-beings in Kilbirnie.

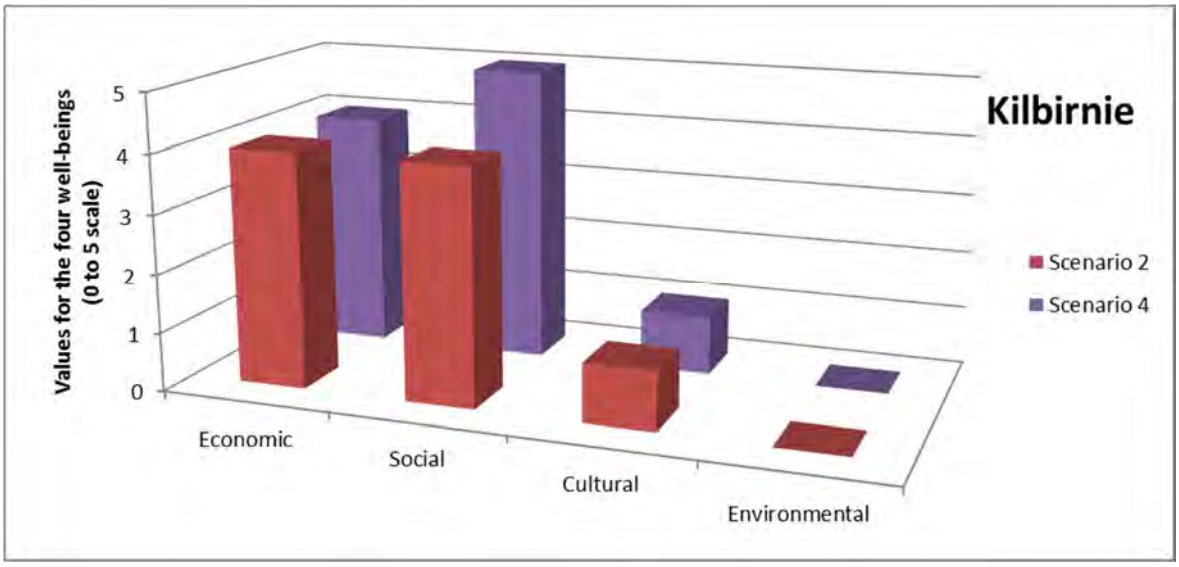

Figure 5-12 Impact of a 1.5 m and 3.0 m rise in sea level on Kilbirnie

[6] Based on the 2006 New Zealand Census

A 1.5 m sea level rise effects:

- The Wellington Regional Aquatic Centre;
- Kilbirnie and Evans Bay Parks;
- The main route to the airport;
- St Patricks College; and
- The ASB Sports Centre.

Kilbirnie is also currently vulnerable to other hazards, particularly liquefaction and flooding as Figure 5-13 illustrates (legend as per Figure 5-5). The effects of these hazards could be exacerbated by sea level rise, as discussed in Section 2.4 of the main report, with significant impacts including:

- More frequent flooding;
- Flooding over a wider area; and
- Increased vulnerability to liquefaction as the crust thickness reduces as sea level rises.

Figure 5-13 Liquefaction and flooding risks in Kilbirnie

Rising groundwater levels linked to rising sea levels could also impact Kilbirnie, with effects on underground pipe networks, building foundations and other underground infrastructure such as storage tanks. Kilbirnie is also currently at risk of inundation by tsunami events.

5.7.3.2 Intervention options

Three main intervention options have been considered for the Kilbirnie area:

1. Managed retreat;
2. A seawall, with associated water management as shown on Figures A-14 and A-15 in Appendix A; and
3. A soft protection option.

The scale of cost for each option is shown in Figure 5-14. The cost scale is zero for managed retreat for Scenario 1.

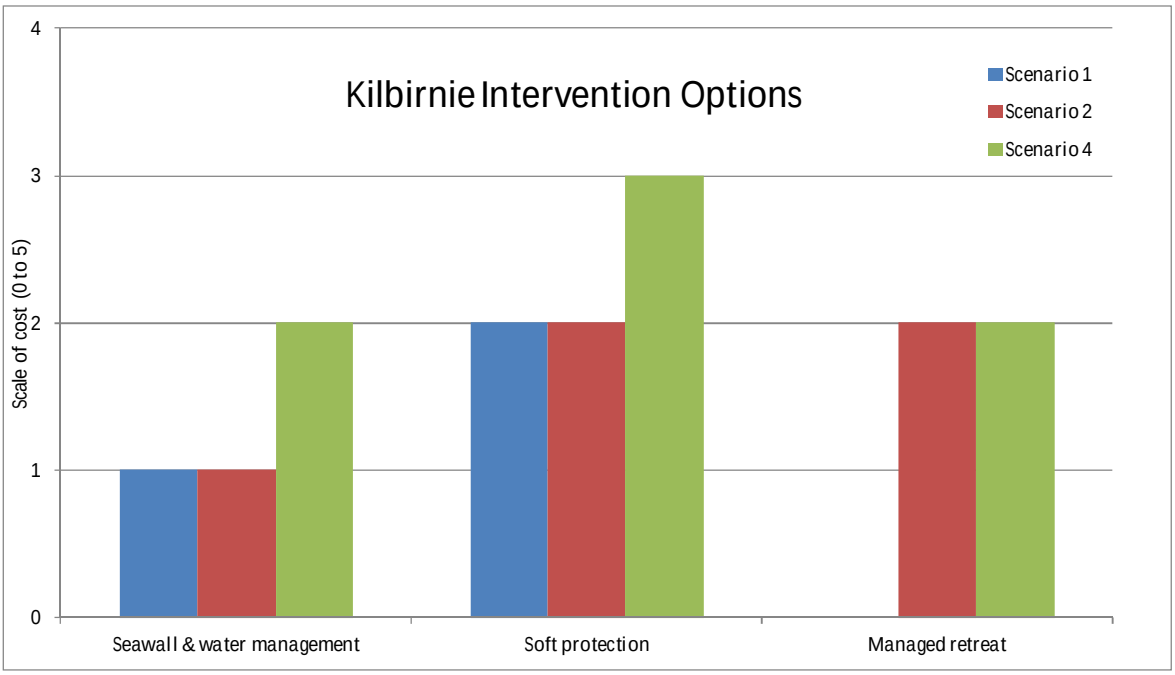

Figure 5-14 Scale of cost – Kilbirnie intervention options

Both hard and soft intervention options to prevent inundation from sea level rise in the Kilbirnie area will have a number of inherent risks, notably:

- The existing and projected future population will be highly vulnerable in the event of the failure of the engineered structures – earthquake, liquefaction and overtopping design standards may need to exceed current normal design standards;
- The existing and projected future population will also be more vulnerable to other natural hazards, including the effects of liquefaction, surface flooding and tsunami; and
- Once protection works are in place there may be ongoing community pressure to restore amenity and access that has been lost by the installation of the physical works.

A single solution is unlikely to be the preferred outcome for an entire suburb and a range of solutions are likely to be more appropriate with a combination of hard and soft engineering as well as managed realignment or retreat. For example, an alternative response, comprising a hard intervention and managed retreat combined option is presented in Figures A-16 and A-17 of Appendix A, which is a causeway following the alignment of Cobham Drive. This option retains access to the airport and other outer suburbs but does not protect the existing properties from inundation. Habitat creation in the area behind the causeway may be possible. A detailed assessment of this combined option or similar combined solutions, along with a more tailored range of response options for Kilbirnie, should be considered in future investigations.

5.7.4 Shelley Bay Road to Karaka Bays Road

5.7.4.1 Impacts

The suburbs of Maupuia and Karaka Bays, as shown on Figure A-2 in Appendix A, are included in the consideration of Shelley Bay Road to Karaka Bays Road. The coastal road from Miramar, north around Point Halswell to Seatoun may be inundated in localised areas even with the lowest sea level rise scenario of a 0.6 m rise (Scenario 1). Scenario 3 (a 2.2 m rise in sea level) would result in inundation of this entire roadway. The impacts of Scenarios 1 to 3 are discussed here, providing

focus on the impacts to that point when the coastal road is fully inundated. Figure 5-15 shows the extent of inundation around this coast road in all five scenarios.

The impacts of sea level rise against the four well-beings are shown on the spider diagrams in Figure 5-16. These show that the greatest effects are on the environmental well-being, followed by the cultural and economic well-beings.

There are a number of sites of cultural and environmental significance in Maupuia and Karaka Bays that would be affected by sea level rise, such as:

- Kau Point (which may support threatened species), Point Gordon and scattered patches of coastal vegetation around the coastline;
- The Mataki-kai-poinga precinct which stretches from Scorching Bay to Shelley Bay; and
- Mahinga-kai sites.

Figure 5-15 Coastal road around Point Halswell

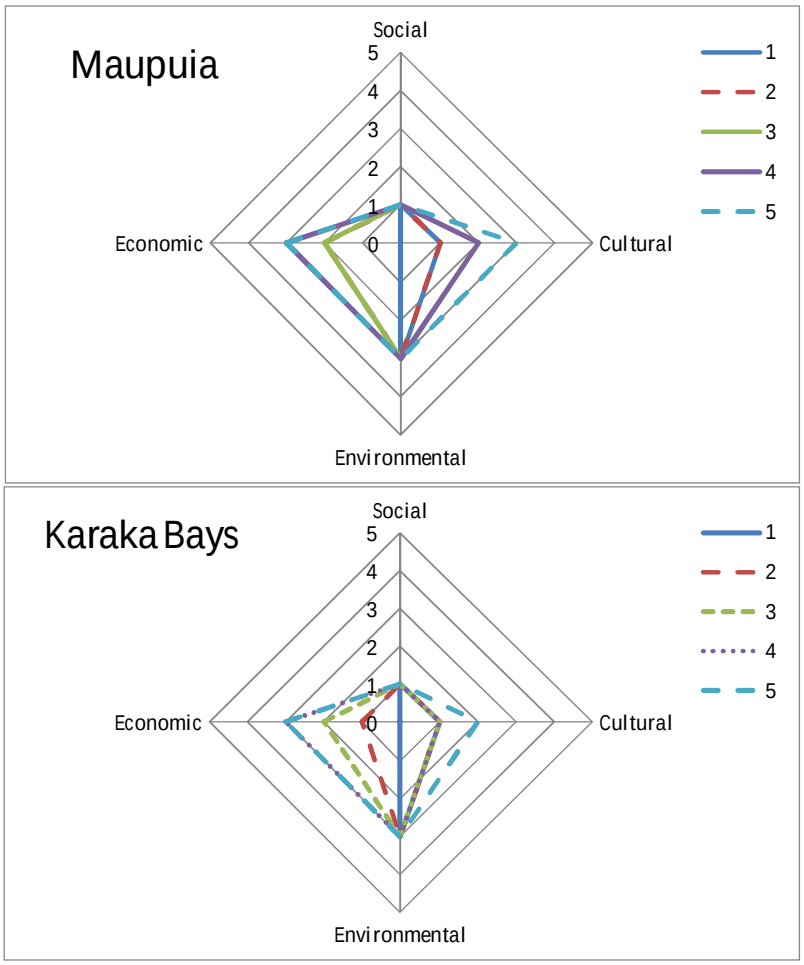

Figure 5-16 Impact of sea level rise on the four-well beings for Maupuia and Karaka Bays

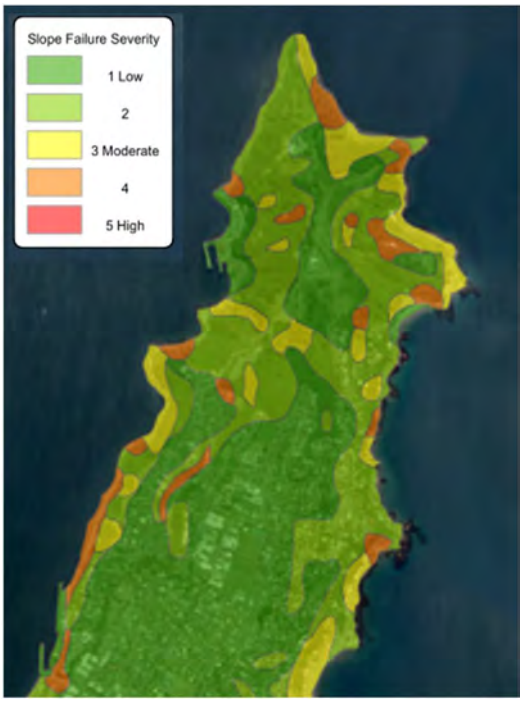

Figure 5-17 Slope failure severity around Maupuia and Karaka Bays

The majority of the economic impact relates to land and property values. Whilst only a small area may be directly inundated, as Figure 5-17 illustrates, there is moderate to high slope instability around this section of coast. Rising sea levels, combined with storm effects, may further increase the risk of slope failure, resulting in coastal cliff line retreat.

5.7.4.2 Intervention options

Two main intervention options have been considered for the Maupuia and Karaka Bays areas:

1. Managed retreat; and
2. Road raising with an accompanying seawall.

Soft protection options have not been considered for this area, due to the hard natural coastline and current engineered sea front. However, a more detailed assessment with a mix of combinations may deliver a range of options for this long shoreline that may be appropriate.

The scale of costs for each intervention option for each suburb for Scenarios 1 to 3 is provided in Table 5-9. In this situation managed retreat involved the abandonment of the coast road as the topography does not enable retreat of this infrastructure. As a result, for both suburbs the cost of managed retreat or realignment is lower than a hard protection option, reflecting the length of coastline requiring protection compared to the relatively small landward area that benefits and the managed retreat option involving the abandonment of the coastal road.

Table 5-9 Scale of cost for response options in Maupuia and Karaka Bays

	Scenario 1	Scenario 2	Scenario 3
Sea level rise	0.6 m	1.5 m	2.2 m
Maupuia			
Road raising and seawall	2	3	3
Managed retreat	0	0	0
Karaka Bays			
Road raising and seawall	1	2	2
Managed retreat	0	0	1

Managed retreat from this section of coast may provide an opportunity to create recreation and/or habitat space in the period until inundation occurs, for example by creating new habitat or by changing the designation of the road, using the existing roadways for walking and cycling.

5.7.5 Makara Beach

5.7.5.1 Impacts

The impacts of Scenario 1 are discussed here, providing focus on the impacts most likely over the coming 100 years. Figure A-18 in Appendix A shows the extent of inundation of Makara Beach in a 0.6 m rise in sea level.

A 0.6 m rise in sea level would have an impact on land, property and infrastructure assets with a combined value of over $20m and around 150 residents would be impacted.

There will be significant impacts on the Makara Estuary, one of the largest and most significant salt marshes in the Wellington City area, and the ecologically unique Makara foreshore reserve. Whilst some plant communities and species may be able to migrate upstream with a changing

saline interface, others will not be able to adapt at a rate that keeps up with change arising from sea level rise.

Land use and land ownership may also be barriers to the gradual movement of people and ecological communities further inland.

Figure 5-18 compares the impacts of a 0.6 m rise in sea level rise on each of the four well-beings in Makara Beach compared with the other Wellington City suburbs. It illustrates that the impacts are across the four well-beings and also that Makara Beach is significantly affected in this scenario.

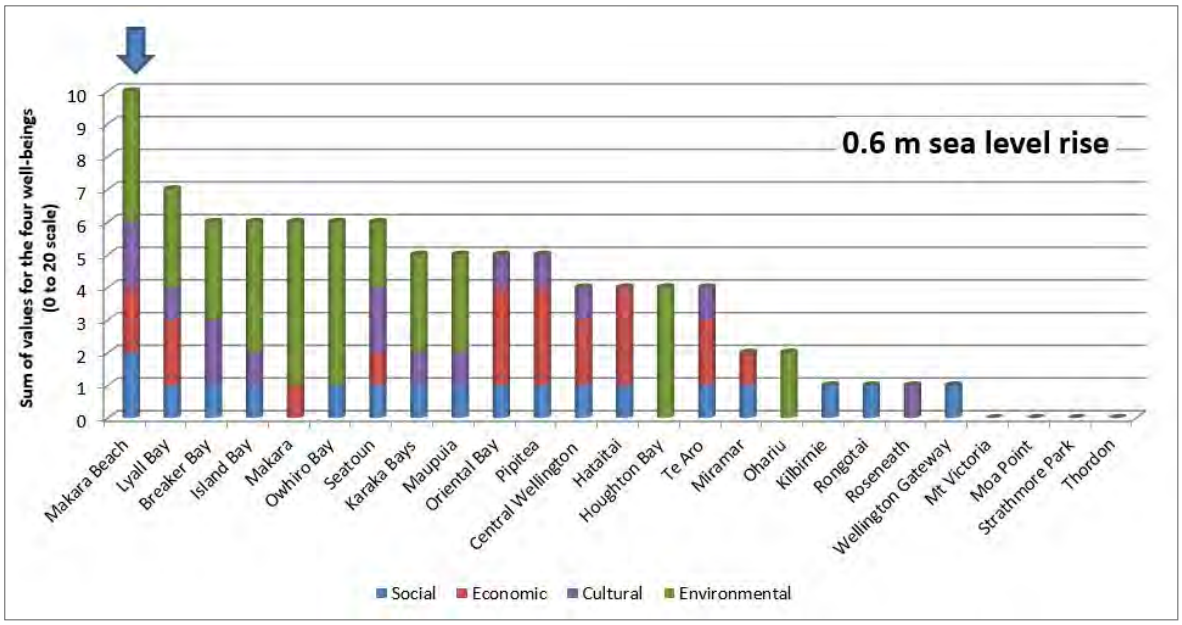

Figure 5-18 Impact of a 0.6 m rise in sea level on Makara Beach

Impacts that have not been directly modelled for this study include the increased area of land subject to flooding from the Makara River and the impact of rising groundwater levels on buried infrastructure and the environment. The low lying areas next to the Makara River will be impacted by both of these effects.

5.7.5.2 Intervention options

Two main intervention options have been considered for Makara Beach:

1. Managed retreat; and
2. A seawall, with accompanying water management.

Figure A-19 in Appendix A shows the seawall intervention option for Scenario 1. Soft protection options have not been considered for this suburb, as it would be necessary to also construct a pumping station or outfall structure to enable the Makara Stream to discharge to the sea. This type of combination option could be considered in future more detailed studies and could provide a more effective approach to manage the effects of climate change at this location.

The scale of cost of the two intervention options for Makara Beach is the same for Scenario 1, with a cost score of 1. Detailed optioneering is required to confirm whether to protect the homes in Makara Beach over the long term and the benefits of this compared to protecting other parts of Wellington City.

6 Interactive model

6.1 Model capabilities

Alongside the values assessment and options consideration presented in this report, T&T has also developed an interactive sea level rise model for WCC using 'Project Orbit', an interface originally developed by T&T to assist the Canterbury Earthquake Recovery Authority (CERA) and insurance companies to manage the response to the Canterbury earthquakes.

The WCC model uses the outputs of the 'bathtub' modelling undertaken for the scenario analyses and presents these at 0.1 m increments. The user is able to 'slide' the sea level up or down to view the effects of changing sea levels. An example of the model visual output is shown in Figure 6-1.

It is also possible to model the cumulative effect of an extreme storm event on top of the sea level rise elevation.

For any selected sea level elevation the model reports the following:

- Value of land and buildings affected;
- Length of road, rail, water, wastewater and stormwater assets affected; and
- Values across the four well-beings, as reported in Section 3 of this report.

The model holds a number of background layers, including:

- Other natural hazard areas (tsunami, flooding etc.);
- Conservation areas;
- Locations of cultural significance; and
- Community facilities such as hospitals, schools and civil defence locations.

The user can model the impact of a prescribed rise in sea level on a selected suburb or suburbs, assign a weighting to the values of each well-being and view the output in tabular or chart form. An example of the model output is provided in Figure 6-1. One of the key strengths of the model is that it enables the user to understand the 'tipping point' in sea level rise terms for different areas within Wellington City. For example, sea water inundation of Miramar does not occur until a sea level increase of 2.9 m (RL 4.0 m), although the impacts of rising groundwater levels and exacerbated difficulties with stormwater drainage will occur before this time.

Figure 6-1 Orbit model output

6.2 Future development of the model

In addition to data updates, the model can be incrementally developed in a range of areas. These include:

- Modelling of a range of return period storm effects;
- Including the impact of rising groundwater and increased fluvial flooding in the model;
- Consideration of other natural hazards;
- Refinement of values assessments;
- Consideration of implementation options;
- An increased range of output parameters, for example consideration of assets owned by other organisations, such as telecommunications or power companies, if this is desired; and
- Modelling the net present value of affects over a period of time.

These are briefly discussed below.

6.2.1 Storm and flooding effects

One of the earliest impacts of sea level rise will be increased storm damage. Communicating this to stakeholders in a visual manner is possible using the Orbit model output interface. NIWA has recently published work that should enable the return period of different coastal storm levels to be confirmed. Once these are available, the model could be readily updated to enable the user to select a storm return period to show on top of any given sea level rise scenario.

Modelling of the impact of sea level rise on groundwater and fluvial flooding is more complex. However, the output of any technical modelling could be reflected in the Orbit model, to enable

this to be considered in both the impacts assessment and to present the information in a visual manner.

6.2.2 Natural hazards

It is possible to view any type of spatially represented hazard on the Orbit interface. The model already includes static information regarding areas at risk of fluvial flooding, liquefaction or tsunami. These layers can be linked to the underlying datasets, for example land and building value, to enable reporting of the effect of damage arising from these different hazards.

The impacts against the four well-beings could be considered for each type of hazard and also reported from the Orbit model.

6.2.3 Refinement of values assessments

The Orbit model was developed in parallel with the values assessments undertaken for this study. The values assessments relied upon output from the intersection of key sea level rise scenarios with underlying GIS datasets at a suburb level. Orbit replicates this and could be enabled to either consider values across different areas (not restricted to suburb boundaries) or to refine values assessments by incorporating additional or alternative datasets. This would need to be done alongside cultural, social, economic and environmental technical experts.

6.2.4 Consideration of implementation options

WCC would like to be able to model the impact of selecting an implementation option, for example a seawall. This more complex functionality is possible with the Orbit interface but is not included in this report. There are probably a range of 'technically sensible' intervention options that could be built into the model, enabling modelling of both the effect of protecting an area and the visual representation of this.

6.2.5 Output parameters

The model has been set up to report on a range of agreed output parameters. Should WCC or others be interested in considering the effect of sea level rise on a range of other assets or values, then these can be incorporated in the Orbit model and reported upon.

6.2.6 Changing values with time

The model can be enabled to consider the impact of a fast or slow rise in sea level on the values affected over a period of time using a net present value approach. Similarly, the phasing of options, once developed and enabled, could be considered over time, including the overall required expenditure.

7 Roadmap

This study is the first step in Wellington's response to the climate change induced hazard of sea level rise. WCC acknowledges that there will be more work needed to better understand the risks resulting from sea level rise and to work with the community to decide how to respond to these risks.

The work completed in this study enables WCC to:

- Visualise, across the WCC area, the extent of sea level rise;
- Use the Orbit model to consider the impact of sea level rise, at 0.1 m increments, from 0.6 m to 3.0 m across the Wellington area, along with the additional impact of a significant storm event;
- Identify those areas where the impact of sea level rise will have the highest consequence across each of the four well-beings and use this to assist in prioritising future work/assessments;
- Use the Orbit model to understand 'thresholds' or trigger points regarding how sea level rise will impact the WCC area;
- Consider a range of options available and viable for managing sea level rise over the foreseeable planning horizon (up to approximately 100 years) and the relative order of costs and range of benefits associated with each of these; and
- Understand some key data gaps and areas where further studies/investigations and consultation with the wider Wellington community are required.

This section builds on this work, providing a 'roadmap' for WCC that will assist it to determine how best to respond to the challenges related to sea level rise. It identifies issues that WCC needs to consider when responding to sea level rise in Wellington, outlining key areas/issues where further work is needed and assigning a possible priority.

Importantly, the recommendations set out here are not intended to form a binding pathway for WCC to follow, rather to guide areas for consideration and key questions that need resolution. Ultimately the Wellington community and its elected representatives will define the response that is most appropriate for their circumstances.

The 'roadmap' has been developed with reference to MfE Coastal Hazards and Climate Change Guidance Manual (2008), NIWA's Urban Impacts Toolbox and international frameworks, particularly the Victorian Coastal Hazard Guide (Department of Sustainability and Environment, 2011). These documents present means of responding to coastal or climate change risks in a number of different ways, but share some key attributes that have been used to develop this roadmap. Notably, these include:

- Consultation with the community and stakeholders as an essential activity;
- Adopting a risk based approach, including consideration of risk management activities; and
- Recognising a staged response is required, both for the analysis of options and their implementation.

7.1 Roadmap overview

Drawing on the available frameworks and experiences of this project, the areas WCC should consider for incremental development following this study are illustrated in Figure 7-1. The process can be viewed as a continuum, with information and progress in each area resulting in an improved understanding of the appropriate WCC response to sea level rise.

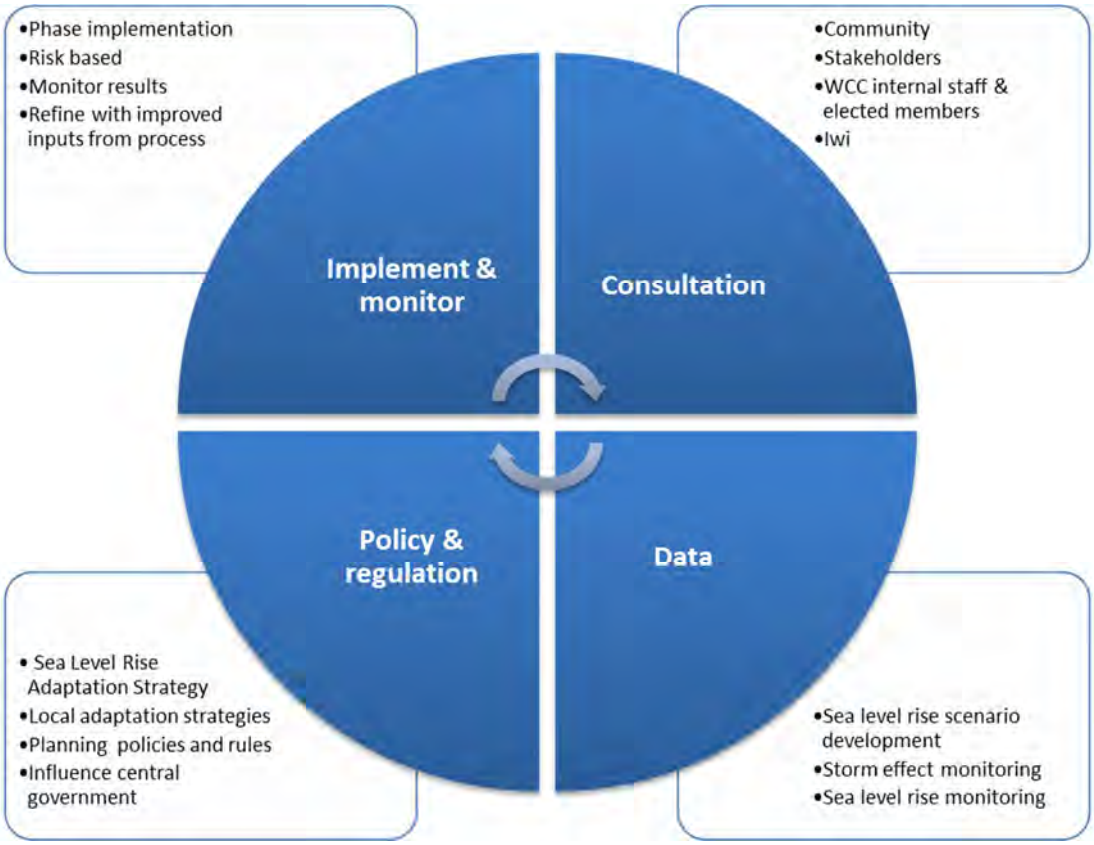

Figure 7-1 Sea level rise adaptation process

These areas and the key questions WCC should explore within these areas are set out below.

A key recommendation of this study is that WCC should develop a Sea Level Rise Adaptation Strategy and options for this document are also discussed in more detail in Section 7.6.

7.2 Consultation and communication

New Zealander's views on climate change, its impacts and the urgency of responding to them, are varied. Around 40%[7] of New Zealanders consider climate change to be a serious issue. If this is assumed to be representative of the Wellington community then over half of the WCC population may consider that sea level rise is not a serious issue. WCC should consider whether an improved understanding of the views and beliefs of the local community is required to establish a baseline for consultation activities. A survey within WCC could act as a pilot in this regard and would also provide meaningful insights into any barriers to adoption of a Sea Level Rise Adaptation Strategy. An awareness raising campaign, perhaps modelled on the successful tsunami preparedness campaign, could follow – both within WCC and across the wider Wellington community.

During the development of the values assessments for this study it was clear that consultation with a wider range of stakeholders is required to confirm what is important to the Wellington community. Particular areas for consultation include:

- How to prioritise between very different heritage sites in the cultural values assessment?
- How impacts on communities and connectivity should be balanced in the social values assessment?

[7] http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10743959

- Whether wider economic consequences should be incorporated into the economic values assessments?

These are important questions to confirm the initial values assessments undertaken for this study, which form the baseline presented within this report.

Even more significant is the likely need to consult and communicate with communities about the possible local responses to sea level rise and the consequences, including affordability and who should bear the costs. WCC should consider whether dialogue is required to build awareness and acceptance of the risk and to understand the level of 'tolerable risk' to the community. This could be followed by a more detailed review of possible options, augmented by a conventional cost-benefit study. This consultation would need to be carried out both locally and across the WCC area as there may not be sufficient financial resources to protect all parts of the city from sea level rise. A combination of options may be required over time and across the city area.

Other asset owners in the WCC area may be interested in the outcomes of this study and should be consulted with as part of the development of future responses. The adaptation of city lifeline services will be critical to ensuring a community that is resilient in the face of sea level rise.

7.3 Data collection and assessment

The results of the present study identify key areas and values that could be affected by sea level rise and possible means of responding to this hazard. There are limitations associated with the high level assessment approach applied that will be refined with additional data and assessments. Gaps in the data underpinning the analyses were filled by local knowledge and the overall assessments are considered reasonable for the purposes of this study. However, WCC may wish to consult on the values at a detailed level or automate the calculation of values in the Orbit model, which would require improved spatial data.

Ongoing monitoring of tidal gauges will enable long term trends in sea level rise to be monitored and this information will continue to be supplemented by and compared with data from other New Zealand and international tidal gauges. This, combined with the outcome of international and national studies and policies (refer Section 7.4), will enable refinement of sea level rise scenarios with time.

WCC may wish to also improve its collection of data related to the effects of coastal storm events. Data could be collected that enables an understanding of the impact of storm events across the four well-beings, enabling a refinement of this component of the values assessment. These data could also help identify trends in coastal storm frequency and severity, which could enable the development of an estimate of annual average damages arising from the combined sea level rise and storm damage probabilities.

The two activities described above would enable the work carried out for the current study to be developed from a consequence based analysis to a risk based approach.

Also related is the inter-relationship of sea level with other natural hazards. The cumulative risks arising from multiple hazards could be modelled to provide a more flexible and comprehensive response across the WCC area. An appreciation of the overall risk resulting from a range of natural hazards for Wellington could inform the appropriate response to sea level rise.

In particular, staff involved in this study was concerned about the impact of rising groundwater levels on the four well-beings. Data on groundwater levels are available within individual consent files held by WCC and could be collated to inform an improved model and assessment of how groundwater levels could change with sea level rise.

Included within this component is the ongoing refinement of technical analysis. This study has by its nature been carried out at a high level. It provides a means for WCC to prioritise which areas of the city it should focus on first when considering responses to sea level rise and provides an overview of the relative costs associated with a range of options. However, within each high level option there are many multiples of detailed response options, from the use of different planning tools to the form and extent of any coastal defence structure. More detailed technical work will be required to inform city-wide and local strategies and responses.

7.4 Policy and regulation

7.4.1 Policy

Climate change science is continually evolving. WCC has used this study to consider a wide range of sea level rise scenarios. There is a general consensus that New Zealand is likely to experience a rise in sea levels of up to 1.0 m over the next 100 years. The next IPCC report with updated scenarios and projections is due for publication in 2014 and a review of local modelling and policy is likely to follow. Any required updates should be incorporated into WCCs strategy, policy and regulations.

The New Zealand Coastal Policy Statement (NZCPS) is a national policy statement which must be given effect in policy statements, regional plans and district plans as soon as practicable and consent authorities must also have regard to the NZCPS when considering consent applications. Of particular applicability for this study are policies 24 (Identification of coastal hazards), 25 (Subdivision, use and development in areas of coastal hazard risk), 26 (Natural defences against coastal hazards) and 27 (Strategies for protecting significant existing development from coastal hazard risk). Policy 24 requires consideration of sea level rise and climate change and Policy 25 requires consideration over at least the next 100 years. WCC will need to be cognisant of these policies in developing its response to sea level rise.

WCC may also seek to influence Central and Regional Government policy as it relates to sea level rise. Information from WCC studies, consultation and policy development can provide useful leading edge case studies to inform and influence Central Government decision making. This could include, for example, changes to the Building Act design standards for properties in areas vulnerable to the impacts of sea level rise. Needs arising from this work can also be communicated to GWRC, to inform dialogue around regional policy and regulatory tools required to implement selected sea level rise response strategies.

7.4.2 Regulation

It may be possible for WCC to agree internally on an appropriate scenario for future planning, perhaps drawing on the Central Government recommended 1.0 m rise over the next 100 years. If this is the case, then engineering standards and planning regulations could be developed now to manage the risk to WCC-owned infrastructure over its lifetime. Examples include:

- Critical infrastructure within the at risk area could be relocated when it is renewed;
- Engineering design standards for coastal defences could require an inclusion of an allowance for expected sea level rise over the asset lifetime; and
- Buried infrastructure could be designed to be corrosion resistant.

Specific response options also require the implementation of regulatory mechanisms. These could include a requirement for the design of resilient buildings or developments within areas vulnerable to future sea level rise. This could include elevated or demountable buildings, elevated access ways or restrictions on the type of development occurring in each area.

The Sea Level Rise Adaptation Strategy is likely to require changes to the regulatory framework for successful implementation. This could include, but not be limited to:

- Planning for 'set back' areas or land use changes in vulnerable locations; or
- Changes to engineering standards.

7.5 Implementation, monitoring and evaluation

An adaptive management strategy aims to enhance the capacity of a community to adapt to the impacts of climate change, by minimising, accepting or maximising the benefits of the consequences (Department of Sustainability and Environment, 2011). Central to any adaptive management strategy is a phased and flexible response.

The benefits of phased implementation are illustrated in Figure 7-2. A decision not to adapt or respond to the pressures of climate change can result in society being exposed to unacceptable levels of risk. An adaptive response results in decisions or interventions at key points in time that reduce risk to tolerable levels. An adaptive response is most often more cost effective than a precautionary response, where significant upfront investment is usually required to create long-term benefits. There is also a risk that a less flexible or precautionary response will result in stranded assets or inappropriate investment – a tidal barrier for Wellington would be an example of this. Adaptive approaches, where implementation is followed by monitoring, informing future interventions, more often result in low or no-regrets decision making. Nevertheless, a precautionary response may be appropriate when decisions are being made relating to long life infrastructure or long term planning horizons.

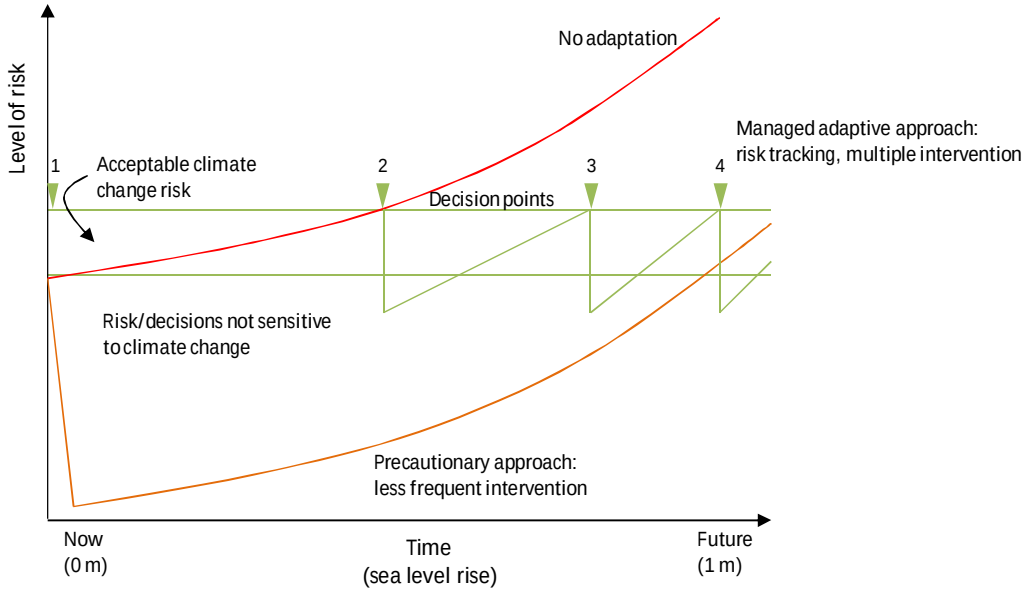

Figure 7-2 Approaches to adaptation and their effect on the level of risk over time (Source: Department of Sustainability and Environment, 2011)

Determining a level of 'acceptable' or tolerable risk is an important area for community dialogue, as mentioned in Section 7.2. It all underpins the further development of the consequence focussed analysis presented in this study to a fuller risk based approach.

Monitoring of the effectiveness of each response or intervention will enable future decisions to be made on a more informed basis. Monitoring could cover aspects such as:

- The ability of businesses and homeowners to obtain insurance;

- Actual costs for the implementation of response options;
- Compliance with planning and/or regulatory changes; or
- A record of the protection provided by response options, including protection from storm events.

Monitoring should be designed to enable refinement of the decision making process and the Sea Level Rise Adaptation Strategy. The Strategy should be reviewed every three years to assess the effects on policy development, resource consents and other decision making with a summary report and recommendations.

7.6 Sea Level Rise Adaptation Strategy

This study recommends that WCC develop a Sea Level Rise Adaptation Strategy (Strategy).

This document would normally be produced in close consultation with stakeholders and the local community. Following the development of a Wellington wide strategy, WCC specific, local adaptation plans or community resilience plans may follow, setting out proposed responses for different locations within Wellington.

WCC may seek to model its Strategy on templates or examples developed elsewhere. The content and focus of existing strategies depends on the jurisdiction of the agency preparing the strategy. An example which may be useful is the Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change (Maryland Commission on Climate Change Adaptation and Response and Scientific and Technical Working Groups, 2008). The document has two main parts, a first phase considering response to sea level rise and coastal storms, the second covering climate change more broadly and focussed on increasing the resilience of the Maryland community to climate change.

Key areas that WCC may wish to include in the Strategy are:

- Actions required now to provide protection from future risks, including policy statements, appropriate response options for vulnerable areas and changes to building codes or design requirements;
- How future risks can be avoided or managed, including impacts on insurance and how the risk of sea level rise should be communicated to land owners or property purchasers;
- How emergency response can or should be strengthened to support proposed interventions;
- What communities resilient to sea level rise look like;
- How scarce WCC and ratepayer resources should be prioritised and allocated;
- What protection should be provided to the environment and how can the environment help to protect Wellington; and
- How the Strategy will be implemented, monitored and updated.

7.7 Where to start?

This study provides some guidance on where WCC may wish to focus more refined future analyses, by screening the impact by suburb of sea level rise. Figure 7-3 shows the outcome of this assessment for a 1.5 m static sea level rise.

The areas that have the highest impacts across the four well-beings are the Wellington CBD, Makara Beach, Kilbirnie and Breaker Bay areas. Environmental impacts are highest in Owhiro Bay, Makara and Breaker Bay. Oriental Bay and Seatoun area are also significantly affected by a 1.5 m sea level rise. This information can help to guide dialogue with stakeholders around priorities and

areas for action. The Wellington Gateway has a low score in this study, as it has been assessed using an approach that is consistent across all suburbs. Its criticality means that it should be an area of specific focus.

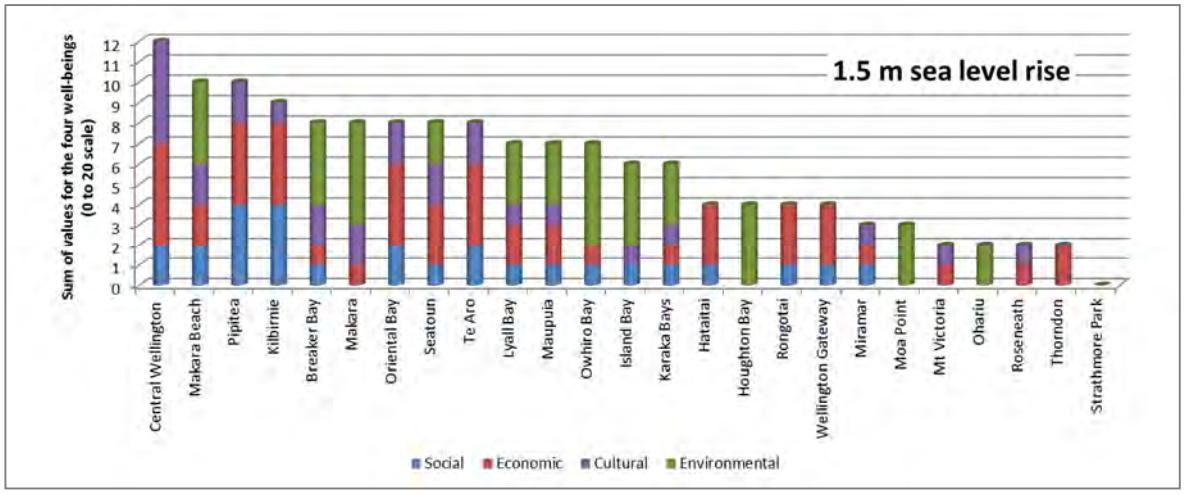

Figure 7-3 Impact of a 1.5 m sea level rise on the four well-beings

WCC may wish to use the outcomes of both the impact assessment and comparison of response options and benefits to open dialogue with internal and external stakeholders. These outcomes could also be used to prioritise areas for more detailed analyses and optioneering. However, it is reiterated that community buy-in to the assessment of impacts and education on the realities of sea level rise are an important next step in the process of responding to the hazard of sea level rise in the WCC area.

8 Applicability

This report has been prepared for the benefit of Wellington City Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
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10 Glossary

Term/Acronym	Meaning
AGDCC	Australian Government Department of Climate Change
AEP	Annual Exceedance Probability
CBD	Central Business District
CMA	Coastal Marine Area
DEM	Digital Elevation Model
DOC	Department of Conservation
Flooding	Rising groundwater levels or areas prone to surface water flooding
GIS	Geographical Information Systems
GWRC	Greater Wellington Regional Council
Inundation	An area which will be submerged by the sea. Inundation typically refers to an area permanently submerged, but is also sometimes used in relation to temporary inundation during storm events
IPPC	Intergovernmental Panel on Climate Change
MfE	Ministry for the Environment
MHWS	Mean High Water Springs
MLOS	Mean Level of the Sea
MSL	Mean Sea Level
NIWA	National Institute of Water and Atmospheric Research
NZCPS	New Zealand Coastal Policy Statement
Storm surge	The temporary increase in sea level above that expected by tidal variation caused by extreme meteorological conditions such as low pressure system and/or strong winds
T&T	Tonkin & Taylor Ltd
Wave run up	The ultimate height reached by waves after running up the beach and coastal barrier
Wave set up	The super-elevation in water level across the surf zone caused by energy expended by breaking waves. This occurs even in calm conditions, but is exacerbated during storm events
WCC	Wellington City Council
Wellington Gateway	Wellington key links, including State Highway 2 corridor and rail link
WVD	Wellington Vertical Datum

Appendix A: A3 Figures

- Figure A-1 Suburb Location Plan
- Figure A-2 Suburb Location Plan – Detail
- Figure A-3 Inundation Scenarios
- Figure A-4 Inundation Scenarios – Detail
- Figure A-5 Liquefaction Potential
- Figure A-6 Flooding Potential (50 year Return Period)
- Figure A-7 Slope Failure Severity
- Figure A-8 Inundation Scenarios
- Figure A-9 CBD – No mitigation
- Figure A-10 CBD – Sea wall
- Figure A-11 CBD – Harbour reclamation
- Figure A-12 Kilbirnie – No mitigation (1.5 **m** SLR)
- Figure A-13 Kilbirnie – No mitigation (3.0 **m** SLR)
- Figure A-14 Kilbirnie – Sea wall (1.5 **m** SLR)
- Figure A-15 Kilbirnie – Sea wall (3.0 **m** SLR)
- Figure A-16 Kilbirnie – Causeway (1.5 **m** SLR)
- Figure A-17 Kilbirnie – Causeway (3.0 **m** SLR)
- Figure A-18 Makara Beach – No mitigation
- Figure A-19 Makara Beach – Sea wall

Path: P:\61579\61579.0020\WorkingMaterial\GIS\MXD\61579_A1.mxd Date: 17/06/2013 Time: 12:09:19 p.m.

Notes: Aerial photograph source: WCC
Suburb information source: http://koordinates.com/

A3 SCALE 1:70,000

0 1 2 3 4 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Suburb Location Plan

FIGURE No. Figure A-1.

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Notes: Aerial photograph source: WCC
Suburb information source: http://koordinates.com/

A3 SCALE 1:30,000

0 0.5 1 1.5 2 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Suburb Location Plan - Detail

FIGURE No. Figure A2.

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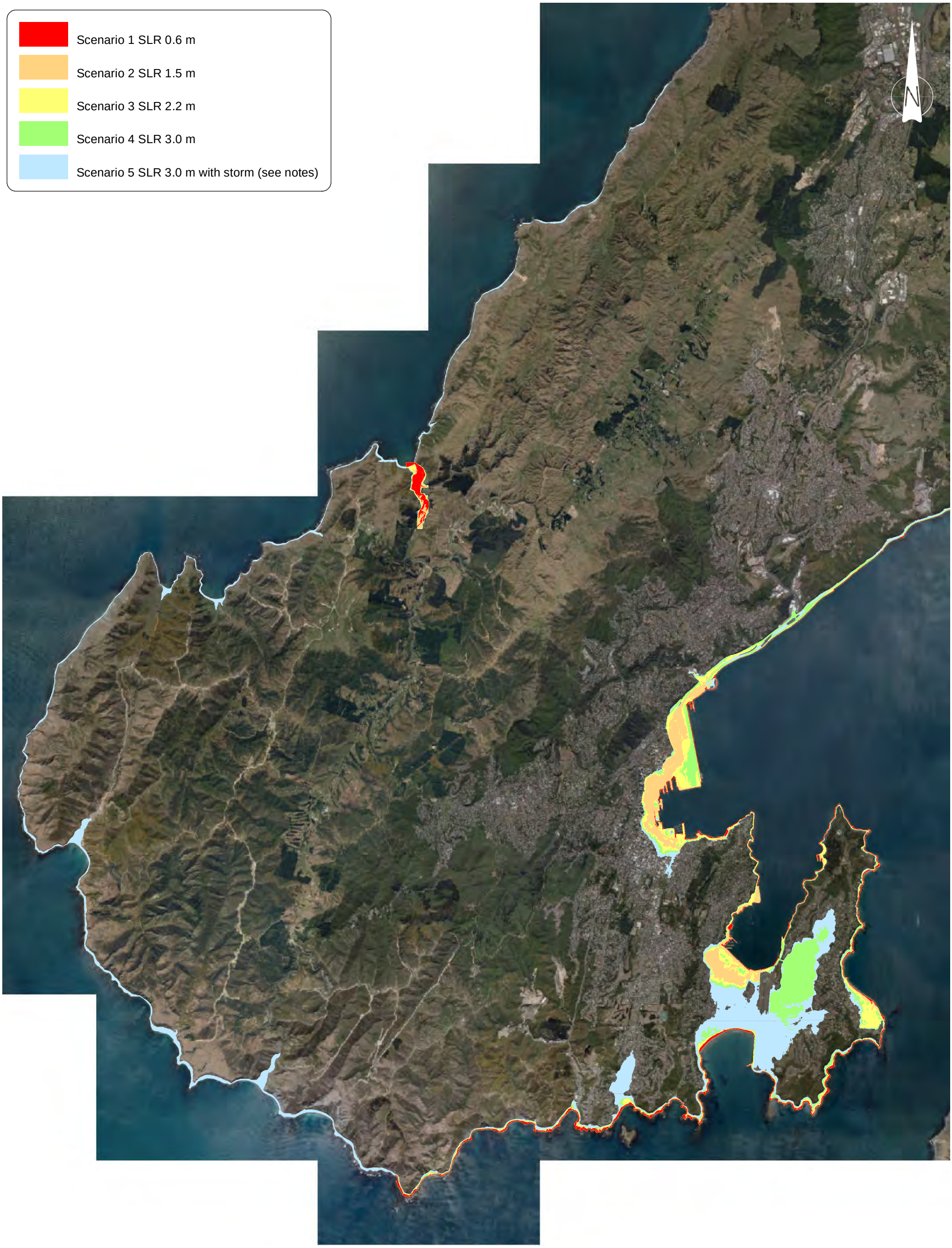

Notes: Aerial photograph source: WCC
Scenario 5 includes Storm effects (storm surge, wave set up and run up) along the opencoast (7.5 m WVD) and Harbour (5.2 m WVD)

A3 SCALE 1:75,000

0 1 2 3 4 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Inundation Scenarios

FIGURE No. Figure A-3.

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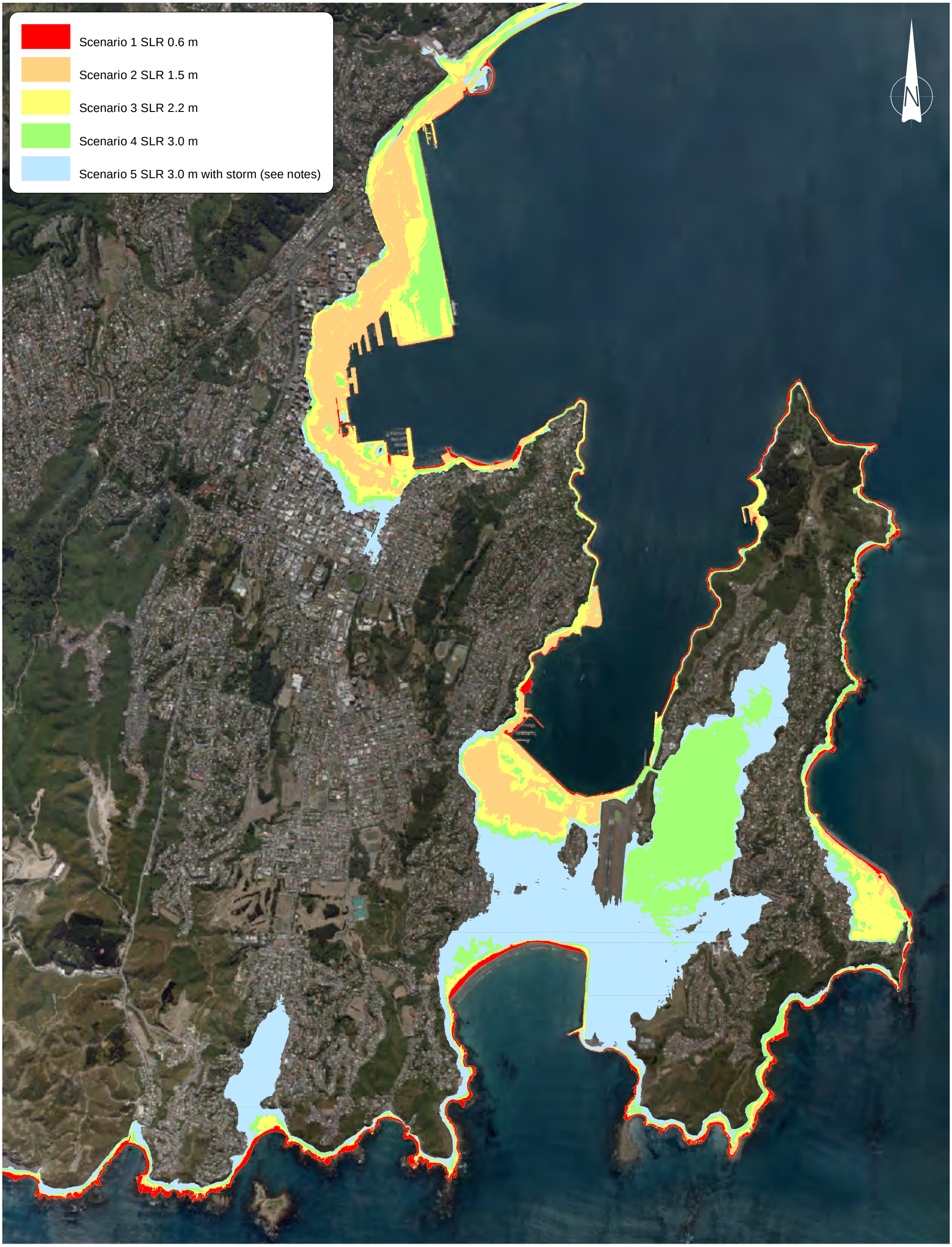

Notes: Aerial photograph source: WCC
Scenario 5 includes Storm effects (storm surge, wave set up and run up) along the opencoast (7.5 m WVD) and Harbour (5.2 m WVD)

A3 SCALE 1:30,000

0 0.5 1 1.5 2 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Inundation Scenarios

FIGURE No. Figure A-4.

Rev. 0

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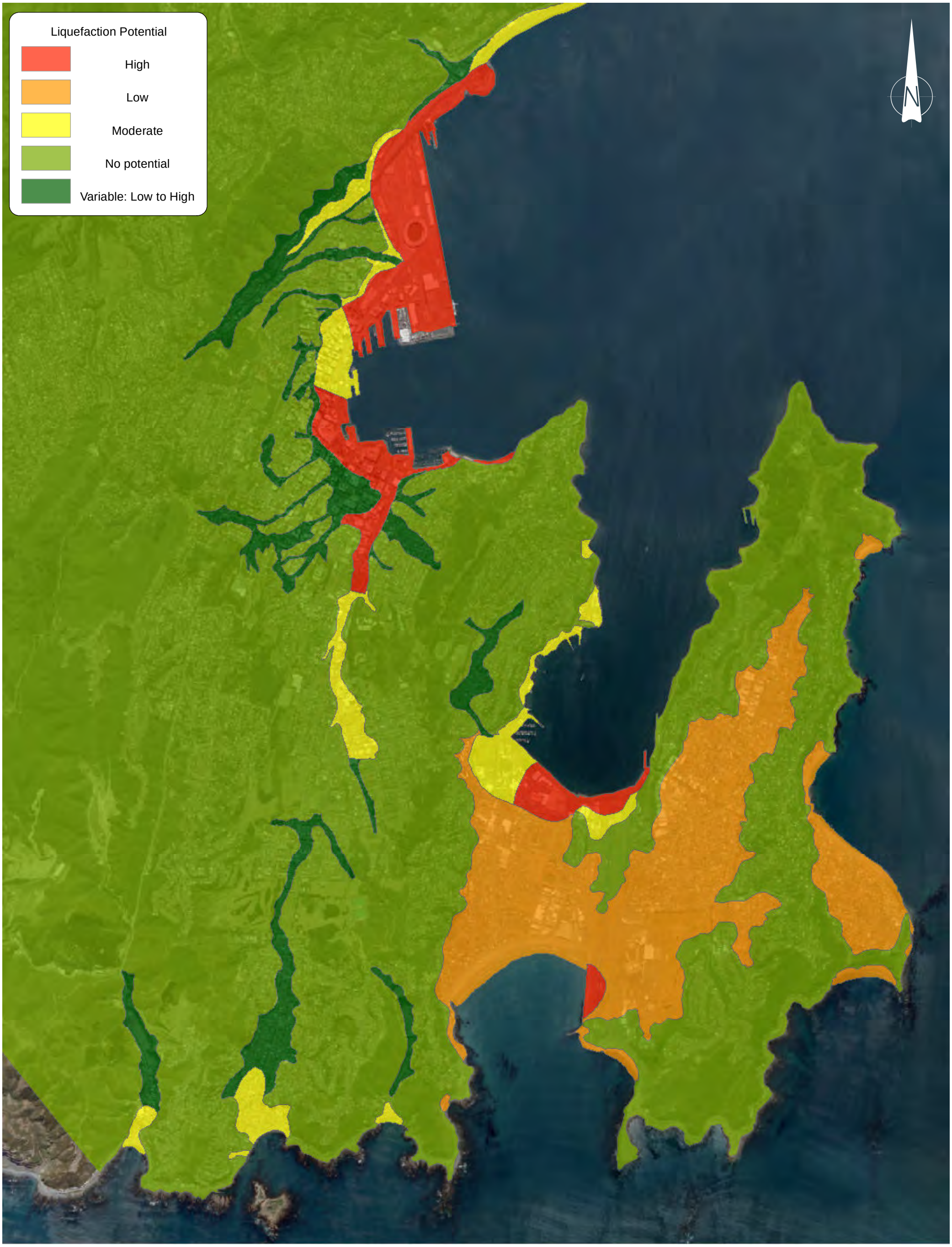

Notes: Aerial photograph source: WCC

A3 SCALE 1:30,000

0 0.5 1 1.5 2 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Liquefaction Potential

FIGURE No. Figure A-5.

Rev. 0

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Notes: Aerial photograph source: WCC
Flooding data source: WCC

A3 SCALE 1:30,000

0 0.5 1 1.5 2 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Flooding Potential (50 year Return Period)

FIGURE No. Figure A-6.

Rev. 0

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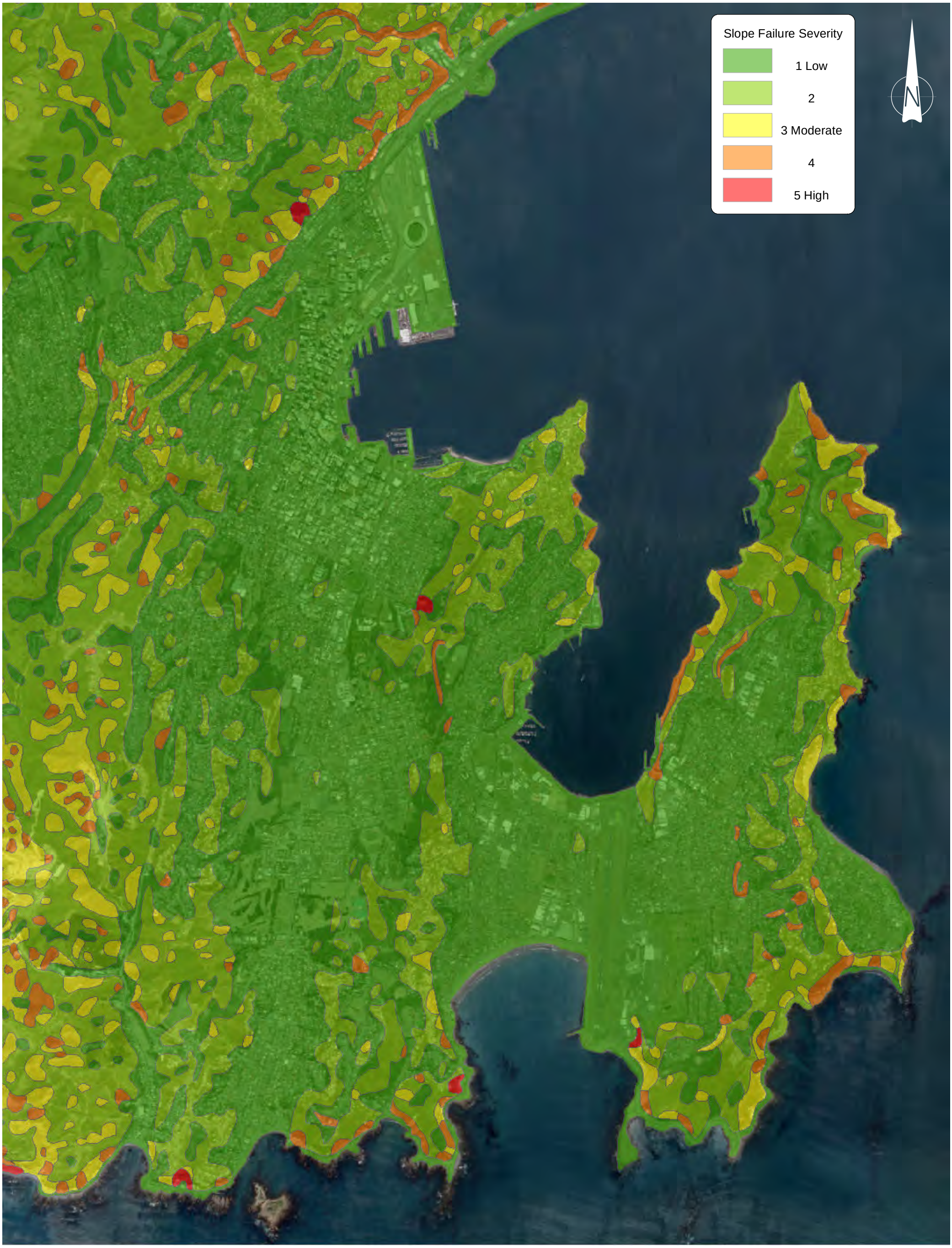

Notes: Aerial photograph source: WCC
Slope Failure data owned by GWRC

A3 SCALE 1:30,000

0 0.5 1 1.5 2 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Slope Failure Severity

FIGURE No. Figure A-7. Rev. 0

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Notes: Aerial photograph source: WCC

A3 SCALE 1:25,000

0 0.4 0.8 1.2 1.6 (km)

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE OPTIONS
Inundation Scenarios

FIGURE No. Figure A-8. Rev. 0

Modelled inundation - scenario 2 (1.5 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.

A3 SCALE 1:15,000

0 290 580 870 1,160 1,450 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
CBD - No mitigation

FIGURE No. Figure A-9. Rev. 0

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CBD seawalls

Modelled inundation - scenario 2 (1.5 m sea level rise)

Modelled inundation without seawall (1.5 msea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Sea wall location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:15,000

0 300 600 900 1,200 1,500 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
CBD - Sea wall

FIGURE No. Figure A-10. Rev. 0

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CBD raised seawall

Harbour reclamation

Modelled inundation - scenario 2 (1.5 m sea level rise)

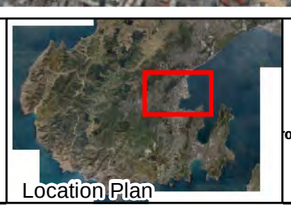
Modelled inundation without mitigation (1.5 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Sea wall location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:15,000

0 300 600 900 1,200 1,500 Meters



Location Plan

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SEA LEVEL RISE MITIGATION OPTIONS
CBD - Harbour reclamation

FIGURE No. Figure A-11.

Rev. 0

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Modelled inundation - scenario 2 (1.5 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.

A3 SCALE 1:5,000

0 100 200 300 400 500 Meters

Location Plan

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SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - No mitigation

FIGURE No. Figure A-12.

Rev. 0

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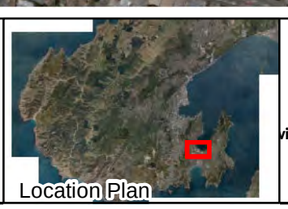
Modelled inundation - scenario 4 (3.0 m sea level rise)

N

Notes: Background aerial taken in 2009 sourced from WCC.

A3 SCALE 1:5,000

0 90 180 270 360 450 Meters



Location Plan

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SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - No mitigation

FIGURE No. Figure A-13. Rev. 0

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Cobham Drive raised seawall

Modelled inundation - scenario 2 (1.5 m sea level rise)

Modelled inundation without seawall (1.5 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Sea wall location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:5,000

0 100 200 300 400 500 Meters

Location Plan

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - Sea wall

FIGURE No. Figure A-14. Rev. 0

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Cobham Drive raised sea wall

Modelled inundation - scenario 4 (3.0 m sea level rise)

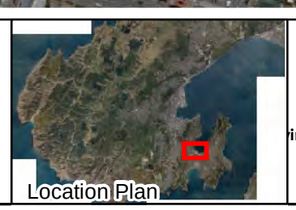
Modelled inundation without sea wall (3.0m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Sea wall location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:5,000

0 100 200 300 400 500 Meters



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SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - Sea wall

FIGURE No. Figure A-15. Rev. 0

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Cobham Drive raised causeway

Modelled inundaton - scenario 2 (1.5 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Causeway location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:5,000

0 90 180 270 360 450 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - Causeway

FIGURE No. Figure A-16. Rev. 0

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Cobham Drive causeway

Modelled inundation - scenario 4 (3.0 m sea level rise)

N

Notes: Background aerial taken in 2010 sourced from WCC.
Causeway location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:5,000

0 90 180 270 360 450 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
Kilbirnie - Causeway

FIGURE No. Figure A-17. Rev. 0

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Notes: Background aerial taken in 2010 sourced from WCC.

A3 SCALE 1:5,000

0 100 200 300 400 500 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
Makara Beach - No mitigation

FIGURE No. Figure A-18. Rev. 0

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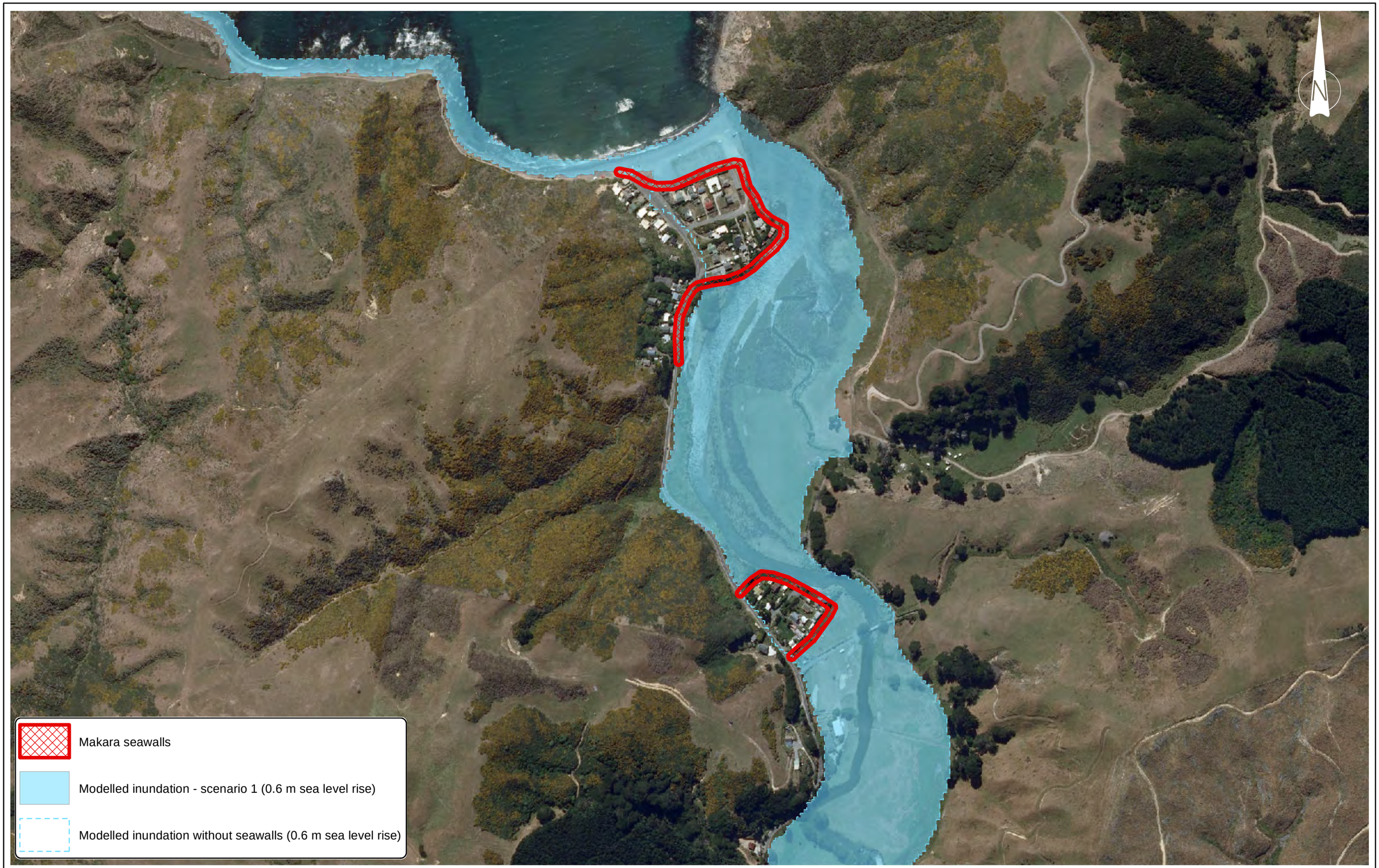

Notes: Background aerial taken in 2010 sourced from WCC.
Sea wall location & dimensions are indicative and for illustrative purposes only.

A3 SCALE 1:5,000

0 90 180 270 360 450 Meters

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WELLINGTON CITY COUNCIL
SEA LEVEL RISE MITIGATION OPTIONS
Makara Beach - Sea wall

FIGURE No. Figure A-19. Rev. 0

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Appendix B: Social impact literature review

Literature Review – Social Impacts from Sea Level Rise

Predicting the potential social effects of sea level rise is complex. Firstly, the social effects of sea level rise will result from the actual rise in sea level, as well as from the mitigation/adaptive measures that are implemented. The severity of the social effects of sea level rise will largely depend on the quality of these mitigation processes.

Secondly, sea level rise will be a relatively slow process that will provide communities with time to adapt. However, climate change research predicts that sea level rise will be accompanied by increased extreme events, such as storm surges, which will create coastal flooding and associated social, economic and environmental effects.

Mitigation of sea level rise effects can take a variety of forms from hard structures (such as seawalls and stopbanks to policy decisions such as changes to land-use zoning and managed retreat. Mitigation measures will also generate social effects of varying degrees of severity.

Full references are provided in the Bibliography in Appendix G.

Recreation values

Coastal and low lying areas are often valued for the recreation activities that they provide. Recreation opportunities include swimming, walking, fishing and picnicking at beaches, and water-based activities such as recreational boating, kayaking, fishing and diving.

Recreational values may be affected if existing beaches are reduced in width or disappear altogether. There may also be a knock-on effect for the visitor experience at the remaining beaches if they suffer from increased congestion (Bin et al, p44).

Recreational fishing may be affected as a result of a loss of coastal wetlands and associated habitats, changing fish patterns, and a loss of marinas and beaches (USGCRP, 2003; Bin et al, p54).

Cultural and historic values

Many areas of historic and cultural significance to New Zealanders are located along coastal and low lying areas, which will create a social effect if they are compromised by sea level rise. For example, the loss of inter-tidal food gathering areas and sacred places such as urupa and marae close to the coast will impact on the cultural values of Maori. The high spiritual value on some coastal land may also restrict conventional adaptation options for sea level rise. This could compound the effects of sea level rise on Maori values (NZCCC, p108).

Much of the conservation estate is located along the coast. Any loss to the flora and fauna in these areas, or recreation activities that they provide, would affect many New Zealanders.

Amenity values

Mitigation measures such as hard structures (e.g. seawalls, groynes and dykes) can affect factors that contribute to amenity values, such as visual effects, natural character, and public access to the coastal area (MfE 2009, p29).

Research has shown that allowing shores to retreat can lead to coastal blight when homes and other buildings are left to deteriorate (USCCSP 2009, p100).

Income (loss of employment, productivity of land, livelihood, property loss)

Sea level rise may adversely affect peoples' incomes by reducing employment opportunities, the profitability of businesses and the value of properties. A loss of income will have a social effect for those individuals and for the local economy as a whole by decreasing the standard of living, and affecting the economic base of a community.

Income can be affected as a result of changes to coastal-based employment opportunities. For example, sea level rise has the potential to affect commercial fisheries and the aquaculture industry by damaging coastal wetlands and changing the water quality of estuarine areas (USGCRP, 2003; Oliver, p33). Communities that are dependent on coastal tourism could experience a decrease in tourist expenditure (Bin et al, p90).

Sea level rise can affect agriculture through salt water intrusion, which reduces the productivity of crops that are not suited to salty soils (Awuour et al, p233). Agricultural land located adjacent to the coastal marine area may also be directly lost by an increase in sea level.

The reduced productivity of businesses that rely on infrastructure which is affected by sea level rise (such as the transportation network), or which incur costs in mitigating sea level rise, will have a knock-on effect on the local economy.

Health

When sea level rise is combined with extreme surge events (floods), there is an increased risk of death (Chapman, p143). However, the most common cause of health effects are:

- *Contamination of drinking water* - rising sea levels create salt water intrusions that infiltrate ground water supplies such as aquifers and wells (USGCRP 2003; Awuour et al, p233). This is currently being experienced in Kiribati and Tuvalu.
- *Malnutrition* - sea level rise in Kiribati has highlighted the potential for malnutrition as a result of a decline in subsistence agriculture and fisheries. On the island of Abaiang milkfish which traditionally fed the whole village disappeared as the coast line encroached inland, and plant life, such as taro, has declined with increasing soil salinity (www.climate.gov.ki).
- *Infectious diseases* - population movement combined with overcrowding increases the transmission of infectious diseases (such as tuberculosis). This has already been experienced when Pacific Islanders from low-lying islands with high levels of tuberculosis have been accommodated in overcrowded housing in New Zealand (NZCSS, p114).
- *Living with stress and uncertainty* - mental health issues including anxiety, depression and suicide can arise from the loss of property, historic and cultural sites of value, community networks (as people are forced to relocate, income, displacement from homes, and the uncertainty of risk. Mental health issues can also result from environmental disasters such as flooding. (NZCCC, p116)

Community infrastructure

A rise in sea level may compromise the performance of surface and stormwater drainage systems, sewerage systems, drinking water supplies, and communication lines in low-lying coastal settlements. Sea level rise could also damage transport infrastructure (roads, rail and ports) by flooding and/or eroding roads, rail and port facilities. Changes in sedimentation around the coastline could affect navigation routes. (MfE 2009, p10-17; MfE 2008, pp28-29)

This infrastructure has been paid for by residents through rates and tax. Therefore, the reallocation of public funds to flood hazard protection, infrastructure repair and upgrade, and disaster relief is a cost to the community, particularly when it is at the expense of funds for other community requirements such as health and education. (NZCCC, p127; Chapman, p143-176)

Loss of property and displacement

The social impacts of displacement from sea level rise may be felt both in terms of New Zealanders being displaced by a rise in sea level, and by accommodating migrants from low-lying coastal islands in the Pacific.

The loss of property may arise from coastal waters encroaching onto or eroding private property, if coastal protection works are not undertaken, or are not successful (Chapman et al, p143).

In addition to the loss of property and homelessness, displacement can result in a complex range of social issues such as unemployment, a breakdown in family and other social networks, a loss of community/cultural identity, adaptive stresses, personal debt and marginalisation within the new neighbourhood, city or country (Oliver, pp34 -41). Displacement can also contribute to problems of overcrowding on the remaining land, depending on how much suitable land remains, and how well the resettlement is managed. Overcrowding has a knock-on effect on health as described above.

Social inequality

Long term adaptation to sea level rise will depend on two main factors: technology and the empowerment of local social organisations (Oliver, p33). These two factors may not be readily available to many of the communities facing sea level rise.

Coastal protection usually costs more than the market value of undeveloped rural land, but less than the value of developed land and structures (USCCSP 2009, p87). Coastal protection works are therefore more likely to be prioritised in areas with higher land value. This may lead to inequality in areas with lower land values (typically areas with lower socio-economic characteristics, rural areas and conservation areas), where residents will be at greater risk of the social effects of displacement/migration. Research also indicates that residents who are likely to migrate/relocate first when a risk is perceived are the highest skilled and productive residents, thus exacerbating economic hardship for the remaining population (Hallegatte, p5).

Political and social tensions

Political and social tensions may arise as a result of the mitigation measures undertaken to address sea level rise. For example, the large investment required in coastal areas may not be considered an appropriate economic response by people living elsewhere. Conversely, coastal people may feel that the public sector is not committing enough investment in affected areas and will feel unprotected. In addition, communities that accommodate sea level rise migrants may feel that their jobs, community identity, food sources etc. are threatened by the 'outsiders' (Awuour et al, p237; Hallegatte, p3; ACECRC, p15).

Community well-being

Many of the social effects noted above can impact on the well-being of the community as a whole. Migration in particular can create a loss of social networks, culture, traditions and sense of place (Hallegatte, p5). However, a positive impact on community well-being from sea level rise and coastal inundation issues can be an increase in community empowerment. For example, dune restoration initiatives such as Coastcare have been

successful in enhancing the buffer provided by the natural dune system, and an effective way of empowering a community and raising their awareness of coastal hazards (MfE 2009, p27).

Appendix C: Tables of values assessment outputs and scale of costs

- Table C1 - Table of impacts against the four well-beings by suburb – Scenario **1**
- Table C2 - Table of impacts against the four well-beings by suburb – Scenario **2**
- Table C3 - Table of impacts against the four well-beings by suburb – Scenario **3**
- Table C4 - Table of impacts against the four well-beings by suburb – Scenario **4**
- Table C5 - Table of impacts against the four well-beings by suburb – Scenario **5**
- Table C6 - Scale of cost of Tidal Barrier by scenario
- Table C7 - Scale of cost of road raising and seawall intervention by suburb and scenario
- Table C8 - Scale of cost of seawall and stormwater management intervention by suburb and scenario
- Table C9 - Scale of cost of soft coastal protection intervention by suburb and scenario
- Table C10 - Scale of cost of managed retreat intervention by suburb scenario

Table C1- Table of impacts against the four well-beings by suburb – Scenario **1**

Scenario 1	Social	Economic	Cultural	Environmental	Total
Makara Beach	2	2	2	4	10
Lyall Bay	1	2	1	3	7
Breaker Bay	1	0	2	3	6
Island Bay	1	0	1	4	6
Makara	0	1	0	5	6
Owhiro Bay	1	0	0	5	6
Seatoun	1	1	2	2	6
Karaka Bays	1	0	1	3	5
Maupuia	1	0	1	3	5
Oriental Bay	1	3	1	0	5
Pipitea	1	3	1	0	5
Central Wellington	1	2	1	0	4
Hataitai	1	3	0	0	4
Houghton Bay	0	0	0	4	4
Te Aro	1	2	1	0	4
Moa Point	0	0	0	3	3
Miramar	1	1	0	0	2
Ohariu	0	0	0	2	2
Kilbirnie	1	0	0	0	1
Rongotai	1	0	0	0	1
Roseneath	0	0	1	0	1
Wellington Gateway	1	0	0	0	1
Mt Victoria	0	0	0	0	0
Strathmore Park	0	0	0	0	0
Thorndon	0	0	0	0	0

Note: tables sorted by total impact.

Table C 2- Table of impacts against the four well-beings by suburb – Scenario 2

Scenario 2	Social	Economic	Cultural	Environmental	Total
Central Wellington	2	5	5	0	12
Makara Beach	2	2	2	4	10
Pipitea	4	4	2	0	10
Kilbirnie	4	4	1	0	9
Breaker Bay	1	1	2	4	8
Makara	0	1	2	5	8
Oriental Bay	2	4	2	0	8
Seatoun	1	3	2	2	8
Te Aro	2	4	2	0	8
Lyall Bay	1	2	1	3	7
Maupuia	1	2	1	3	7
Owhiro Bay	1	1	0	5	7
Island Bay	1	0	1	4	6
Karaka Bays	1	1	1	3	6
Hataitai	1	3	0	0	4
Houghton Bay	0	0	0	4	4
Rongotai	1	3	0	0	4
Wellington Gateway	1	3	0	0	4
Miramar	1	1	1	0	3
Moa Point	0	0	0	3	3
Mt Victoria	0	1	1	0	2
Ohariu	0	0	0	2	2
Roseneath	0	1	1	0	2
Thorndon	0	2	0	0	2
Strathmore Park	0	0	0	0	0

Table C 3- Table of impacts against the four well-beings by suburb – Scenario 3

Scenario 3	Social	Economic	Cultural	Environmental	Total
Central Wellington	2	5	5	0	12
Pipitea	4	5	3	0	12
Seatoun	3	4	2	3	12
Island Bay	2	2	3	4	11
Makara Beach	2	2	3	4	11
Te Aro	2	4	5	0	11
Kilbirnie	5	4	1	0	10
Lyall Bay	2	2	2	4	10
Makara	0	1	4	5	10
Owhiro Bay	1	1	3	5	10
Breaker Bay	1	2	2	4	9
Maupuia	1	2	2	3	8
Oriental Bay	2	4	2	0	8
Wellington Gateway	2	3	1	2	8
Karaka Bays	1	2	1	3	7
Rongotai	2	4	0	0	6
Hataitai	1	3	1	0	5
Houghton Bay	0	0	0	4	4
Miramar	1	1	1	0	3
Mt Victoria	0	2	1	0	3
Ohariu	0	0	1	2	3
Moa Point	0	0	0	3	3
Roseneath	0	1	1	0	2
Thorndon	0	2	0	0	2
Strathmore Park	0	0	0	0	0

Table C 4- Table of impacts against the four well-beings by suburb – Scenario 4

Scenario 4	Social	Economic	Cultural	Environmental	Total
Lyall Bay	3	4	2	4	13
Central Wellington	2	5	5	0	12
Island Bay	2	3	3	4	12
Owhiro Bay	2	2	3	5	12
Pipitea	4	5	3	0	12
Seatoun	3	4	2	3	12
Makara	0	1	5	5	11
Makara Beach	2	2	3	4	11
Te Aro	2	4	5	0	11
Breaker Bay	1	3	2	4	10
Kilbirnie	5	4	1	0	10
Miramar	5	4	1	0	10
Maupuia	1	3	2	3	9
Oriental Bay	3	4	2	0	9
Karaka Bays	1	3	1	3	8
Wellington Gateway	2	3	1	2	8
Hataitai	2	3	1	0	6
Rongotai	2	4	0	0	6
Houghton Bay	0	1	0	4	5
Ohariu	0	1	1	3	5
Mt Victoria	0	2	1	0	3
Roseneath	0	2	1	0	3
Moa Point	0	0	0	3	3
Strathmore Park	1	2	0	0	3
Thorndon	0	2	0	0	2

Table C 5- Table of impacts against the four well-beings by suburb – Scenario 5

Scenario 5	Social	Economic	Cultural	Environmental	Total
Island Bay	3	4	3	4	14
Lyall Bay	4	4	2	4	14
Central Wellington	3	5	5	0	13
Owhiro Bay	2	3	3	5	13
Seatoun	4	4	2	3	13
Pipitea	4	5	3	0	12
Te Aro	2	5	5	0	12
Makara	0	1	5	5	11
Makara Beach	2	2	3	4	11
Breaker Bay	1	3	2	4	10
Kilbirnie	5	4	1	0	10
Maupuia	1	3	3	3	10
Miramar	5	4	1	0	10
Karaka Bays	1	3	2	3	9
Oriental Bay	3	4	2	0	9
Wellington Gateway	2	4	1	2	9
Houghton Bay	0	2	1	4	7
Rongotai	3	4	0	0	7
Hataitai	2	3	1	0	6
Ohariu	0	1	2	3	6
Mt Victoria	0	3	1	0	4
Roseneath	0	2	1	0	3
Moa Point	0	4	0	3	7
Strathmore Park	1	4	0	0	5
Thorndon	0	3	0	0	3

Table C 6 Scale of cost of Tidal Barrier by scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Tidal Barrier scale of cost	5	N/A	N/A	N/A	N/A

Table C 7- Scale of cost of road raising and seawall intervention by suburb and scenario

Suburb	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Breaker Bay	2	2	2	3	3
Hataitai	1	2	2	2	3
Houghton Bay	1	2	2	2	3
Island Bay	1	2	2	2	3
Karaka Bays	1	2	2	2	3
Maupuia	2	3	3	3	3
Moa Point	1	2	2	2	3
Oriental Bay	1	2	2	2	3
Owhiro Bay	1	2	2	2	3
Roseneath	1	2	2	2	3
Wellington Gateway	2	3	3	3	4

Table C 8- Scale of cost of seawall and stormwater management intervention by suburb and scenario

Suburb	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Central Wellington	1	1	2	2	2
Kilbirnie	1	1	1	2	2
Lyall Bay	2	2	2	2	3
Makara Beach	1	1	2	2	2
Miramar	1	1	1	1	2
Pipitea	1	2	2	2	3
Rongotai	1	1	1	1	2
Seatoun	1	2	2	2	3
Te Aro	1	1	1	1	2

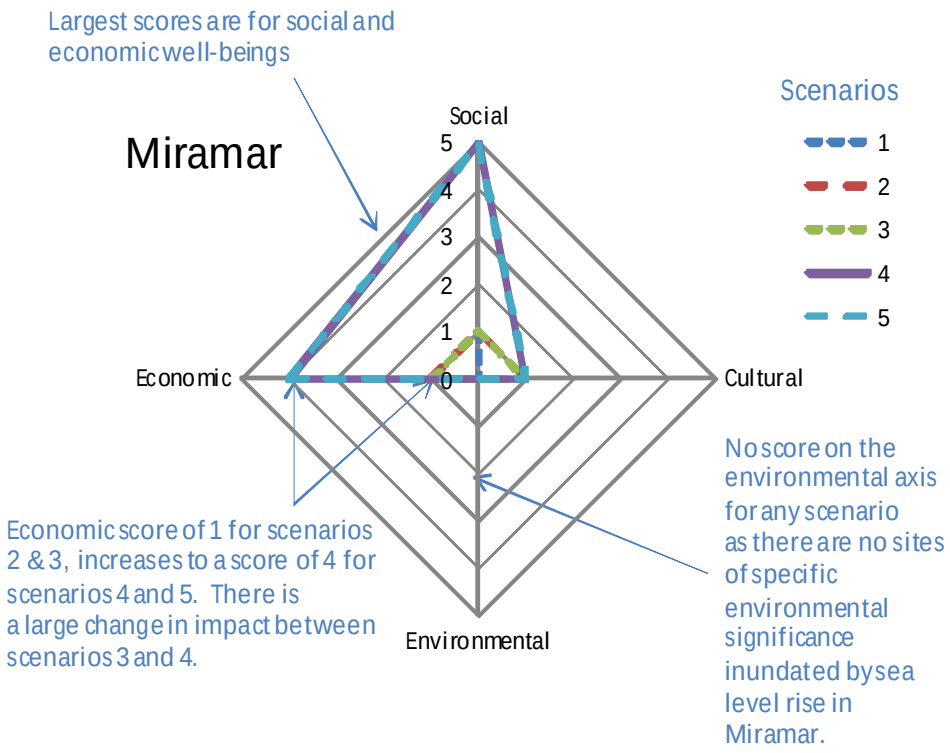
Table C 9- Scale of cost of soft coastal protection intervention by suburb and scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Kilbirnie	2	2	3	3	3
Lyall Bay	2	3	3	4	4
Oriental Bay	2	3	3	3	4
Owhiro Bay	2	3	3	3	4
Rongotai	1	2	2	3	3
Seatoun	2	3	3	3	4

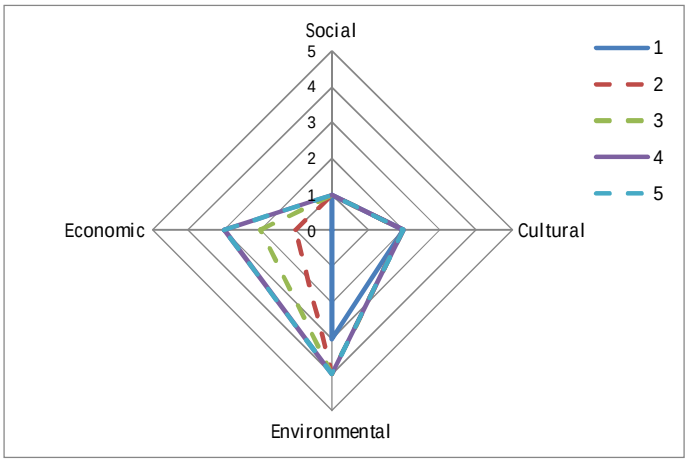
Table C 10- Scale of cost of managed retreat intervention by suburb and scenario

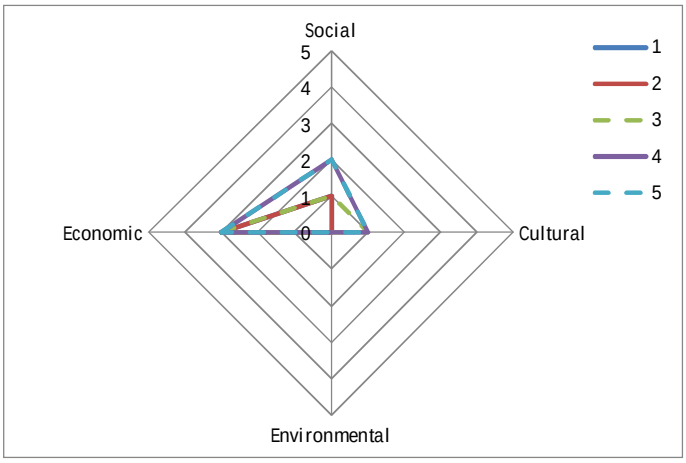
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Breaker Bay	0	0	1	1	1
Central Wellington	0	2	2	2	2
Hataitai	0	1	1	1	1
Houghton Bay	0	0	0	0	1
Island Bay	0	0	1	1	2
Karaka Bays	0	0	1	1	1
Kilbirnie	0	2	2	2	2
Lyall Bay	0	0	1	2	2
Makara	0	0	0	0	0
Makara Beach	1	1	1	1	1
Maupuia	0	0	0	1	2
Miramar	0	0	0	3	3
Mt Victoria	0	0	1	1	1
Ohariu	0	0	0	0	0
Oriental Bay	0	1	1	1	1
Owhiro Bay	0	0	0	1	1
Pipitea	0	3	3	3	3
Rongotai	0	1	1	2	2
Roseneath	0	0	0	1	1
Seatoun	0	1	2	2	2
Strathmore Park	0	0	0	1	2
Te Aro	0	1	2	2	2
Thorndon	0	0	0	1	1
Wellington Gateway	0	2	2	2	2

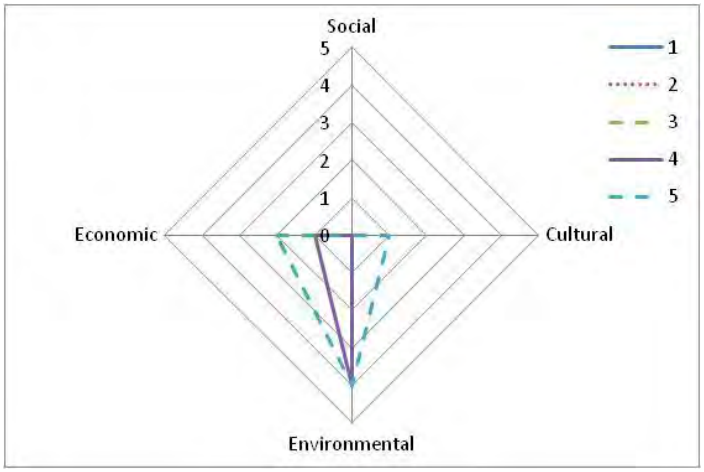
Appendix D: Suburb impact summary

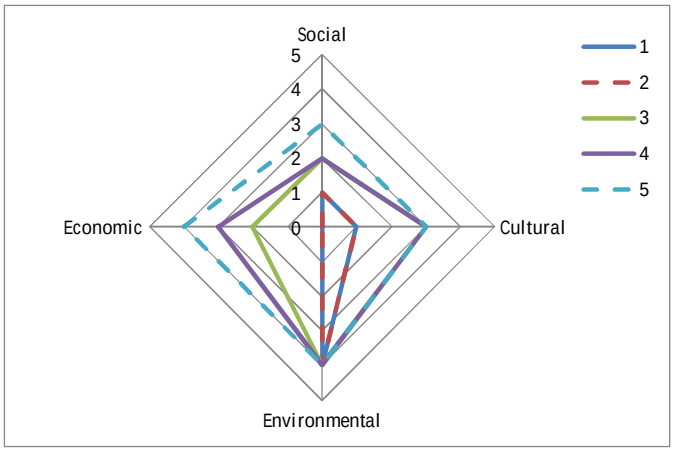


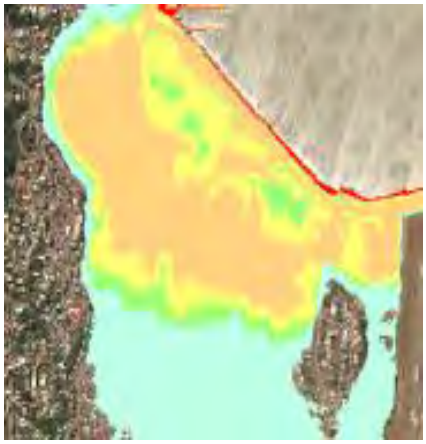
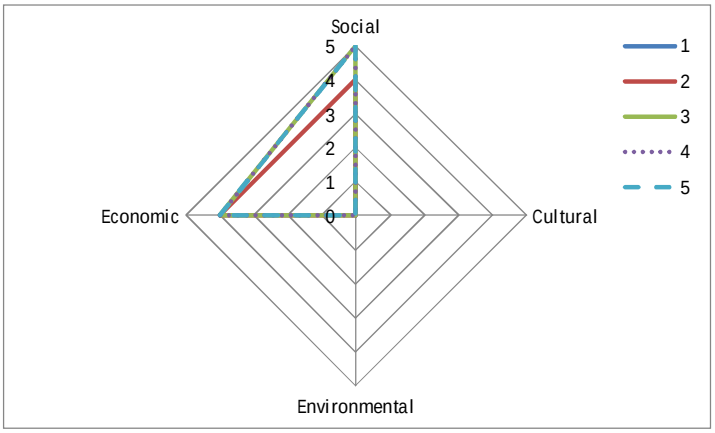
Guidance on how to read a spider diagram

BREAKER BAY	
	
CULTURAL	
The most significant impacts would be on the coastline below the old Pā high on the headland and the reduction in access around the coastline at sea level. Largely the impacts are minimal for these elevated sites. There are remnants of the WWII military sites which could be destroyed in Scenarios 4 – 5.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score increases from 0 (Scenario 1) to 3 (Scenarios 4 and 5). Damages peak at around $95m for Scenario 5.	
ENVIRONMENTAL	
Impacted ecological sites include Tarakena Bay and Point Dorset, both of which are listed as Conservation Sites in the Wellington City District Plan. Significance as Conservation Sites relate to the presence of rare and representative vegetation, dune habitat and habitat for little blue penguins at Point Dorset and typical, but under represented, vegetation at Tarakena Bay. A management plan exists for Point Dorset (WCC, 2011). Environmental scores reflect the moderately large areas of the identified sites that would be impacted and the moderately high significance score for the Point Dorset site. The main habitats impacted would be intertidal rocky hard shore, intertidal soft shore and dune habitat. These habitats would likely begin to be compromised under Scenario 1 and more severely compromised, or lost completely under Scenarios 2 to 5.	
SOCIAL	
All scenarios have a minimal overall social impact, affecting very few residents or homes. The coast road will be affected.	

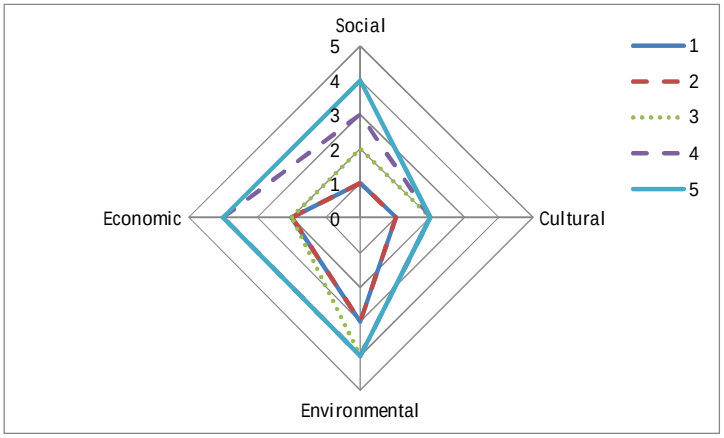
HATAITAI	
	
CULTURAL	
There are few cultural sites in this suburb, which are assigned little significance.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. The damage score is 3 across all scenarios. Damages peak at around $220m for Scenario 5.	
ENVIRONMENTAL	
There are no significant environmental sites within this suburb. The coastal fringe is highly modified.	
SOCIAL	
Scenario 1 has a low overall social impact, affecting three community facilities including the Sea Rescue Jetty, the main boat ramp and the yacht club jetty, but few residents. Scenarios 2 and 3 have a slightly higher overall social impact, but still only have a score of 2, although an additional community facility and emergency service is affected in this case and approximately 30 households. Scenario 4 affects more residents, up to around 150, with a relatively high proportion of children affected and with 50 households subject to flood risk. Scenario 5 has a moderate impact, affecting 240 residents and 90 households. The score for Scenarios 4 and 5 is 2.	

HOUGHTON BAY	
	
CULTURAL	
No significant impact.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. The damage score is zero for the first three scenarios and then increases to 1 (Scenario 4) and finally to 2 (Scenario 5). Damages peak at around $21m for Scenario 5.	
ENVIRONMENTAL	
Identified ecological sites and/or reserves extend along the entire coastline of Houghton Bay and the bay itself is part of the Tapu te Ranga Marine Reserve. Houghton Bay is also listed as a Conservation Site in the Wellington City District Plan with its significance recorded as being due to the presence of a rare sedge and the presence of several typical Wellington south coast ecological features in a small area. Habitats impacted by sea level rise will include wave exposed rocky reef, wave sheltered rocky reef, rock stacks, cobble beach, sandy shore and dunes. The impact of sea level rise on these sites will commence from Scenario 1, with the value of the compromised and/or lost habitat attributed a 4 for all scenarios.	
SOCIAL	
Impacts are limited to the coastal road.	

ISLAND BAY	
	
CULTURAL	
The most significant impacts would be on the island Tapu te Ranga, which is of high significance to the tangata whenua. Most of the Island Bay cultural sites are located on the island which would be affected by all scenarios to some extent.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. The damage score is zero for the first two scenarios and then increases to 2 (Scenario 3) and finally to 3 (Scenarios 4 and 5). Damages peak at around $640m for Scenario 5.	
ENVIRONMENTAL	
The Tapu te Ranga Island and Marine Reserve includes significant and under-represented habitats including bare ground/rock, flax communities, salt marsh and shrubland. The Marine Reserve protects wave exposed rocky reef, wave sheltered rocky reef, cobble beach and sandy shore habitats. The rocky shore at Sirens Rock and Elsdon Point also have environmental value. The impact of sea level rise on these sites will commence from Scenario 1, with the value of the lost rocky shore habitat attributed a 4 for all scenarios.	
SOCIAL	
Scenarios 1 and 2 have a low overall social impact, despite interrupting transport links along the coast and affecting the beach and the Island Bay surf club. Scenarios 3 and 4 impact a population of between 100 and 200 residents, with a relatively high proportion of children (under 10 years of age) and elderly persons affected. The storm event represented by Scenario 5 has a considerably higher impact, affecting around 1600 residents and 580 households. Approximately 200 of these households rent their homes and approximately 100 are on low incomes, both of which will limit the ability of residents to relocate to comparable areas/homes. Scenario 5 also affects five community facilities, including the Community Resource Centre and Library.	

KILBIRNIE	
	
CULTURAL	
No significant damage.	
ECONOMIC	
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. Although a small proportion of total damage in the suburb, the damage to water and roads is significant when compared to other suburbs. The damage score increases from 0 (Scenario 1) through to 4 (Scenarios 2 – 5). Damages peak at around $735m for Scenario 5.	
ENVIRONMENTAL	
No significant environmental values or damage.	
SOCIAL	
Kilbirnie is the most highly impacted suburb in terms of social effects. Scenario 1 has a minimal overall social impact, with a possible impact on the walk and cycle path along the foreshore. Scenarios 2 and 3 have significant impact, affecting around 900 to 1300 residents, with a high proportion of these elderly and children. 400 – 540 houses affected around half of which are rental properties and/or households on low income. Eight community facilities are affected, including Kilbirnie Park and the Wellington Regional Aquatic Centre, as well as State Highway 1 which provides access to the airport. An overall score of 4 is assigned. Scenarios 4 and 5 have major impacts, affecting around 1600 and 2700 residents respectively, with a high proportion of these (30%) being elderly and children. Nine community facilities and the airport road are affected, with 690 – 1100 households subject to flood risk, nearly half of these on low income and/or rental properties.	

LYALL BAY



CULTURAL

The impact on Lyall Bay is minimal for Scenarios 1 – 4 and because there are few sites at the periphery of the bay.

ECONOMIC

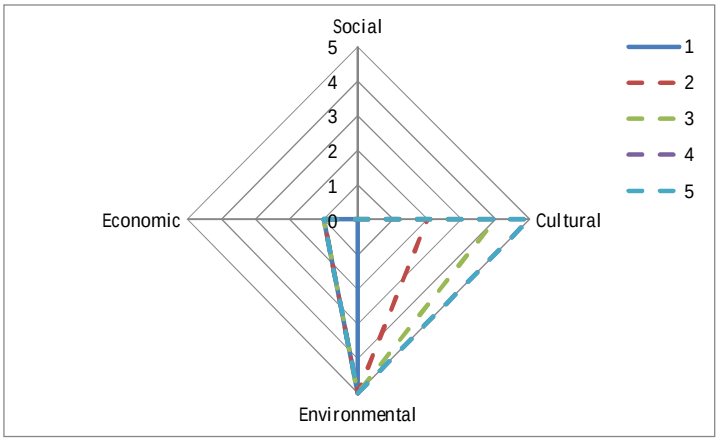
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score increases steadily from 2 (Scenarios 1 and 2) through to 3 (Scenarios 3 and 4) and finally 4 (Scenario 5). Damages peak at around $760m for Scenario 5.

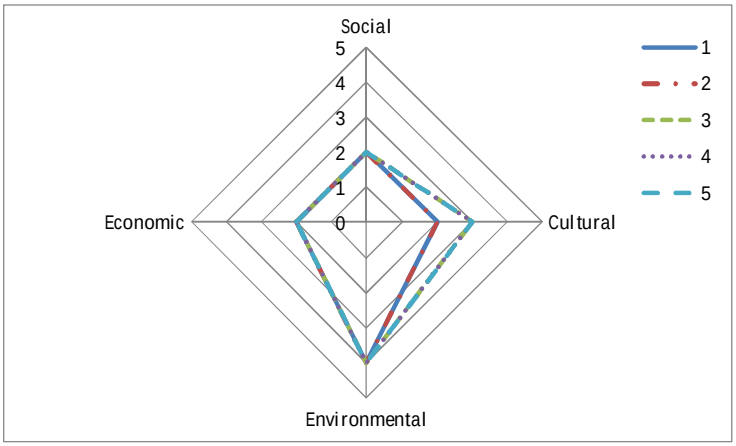
ENVIRONMENTAL

Environmental values are focused in the south western coastal area and comprise Te Raekaihau Point, Dorrie Leslie Park and Waitaha Cove. Habitats include sand and gravel beach, dunes, shore platforms and reef systems. The landward edge of all three sites have undergone a reasonable degree of modification, however, they score moderately in terms of significance criteria due to the fact that they are linked by continuous reserve areas, are close to other reserve areas inland and have good access. The environmental score of 3 for Scenarios 1 and 2 reflect effects changes to amount of intertidal hard shore habitat available, with an environmental score of 4 assigned to Scenarios 3 to 5 reflecting a higher degree of impact and complete loss of all intertidal habitats.

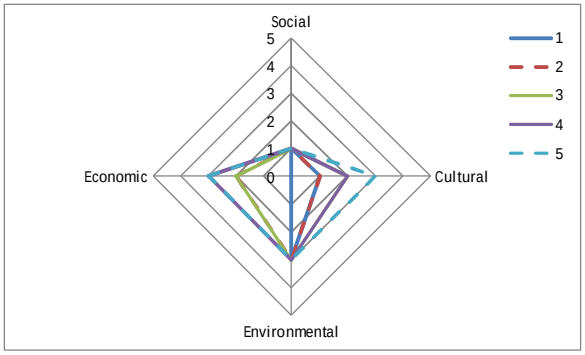
SOCIAL

Scenarios 1 and 2 have minimal overall social impact, affecting few residents, and only one or two community facilities. Scenario 3 has a moderate social impact, affecting around 100 residents with a high proportion of these elderly. Around 50 households would be subject to flood risk. Scenario 4 affects around 800 residents, and around 350 households. Scenario 5 would have a major social impact, affecting over 2000 residents, with many elderly and children impacted. Three community facilities would be affected, 900 households would be subject to flood risk, of which around 30% are living in rental properties and/or are on a low income.

MAKARA	
	
CULTURAL	
This suburb probably has the highest number of cultural sites on Wellington's coastline, however it has a very small population today. The Pā sites are probably the best preserved and are all close to the coast. Not all are affected by sea level rise.	
ECONOMIC	
Economic damage to this suburb is driven by damage to land with lesser damage incurred to water infrastructure and local roads. The damage score is steady at 1. Damages peak below $12m for Scenario 5.	
ENVIRONMENTAL	
Makara is the largest suburb in the Wellington City area, it has the largest proportion of coastline and is the most remote. As such Makara supports the highest number of ecological sites and some of the most valuable ecological sites in the city, including numerous sites of national or regional importance and sites that support threatened species. A wide range of intertidal marine and coastal habitats and large areas of identified ecological sites would be impacted by sea level rise. Therefore, the environmental impacts of sea level rise are considered to be high for Makara relative to other suburbs. A score of 5 has been assigned to all scenarios, notwithstanding the increasing impact that would occur with increasing sea level at any particular site.	
SOCIAL	
There is no significant impact on this sparsely populated suburb.	

MAKARA BEACH	
	
CULTURAL	
Generally there is little impact on cultural values with Scenarios 1 – 3, with some exceptions as most of the sites have been destroyed by more recent development. There are some archaeological sites, such as midden sites, that would be adversely affected by Scenarios 4 – 5. The recorded Pā site (Owhariu) on the beach is now not visible, but some archaeology may remain. Most significant impacts relate to loss of access to both cultural sites and places to gather kaimoana via coastal tracks both north and south (Scenarios 3 – 5).	
ECONOMIC	
Economic damage to this suburb is driven by damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score is steady at 2 for all scenarios. Damages peak at around $40m for Scenario 5.	
ENVIRONMENTAL	
Environmental values for Makara Beach are focused around the Makara Estuary and the foreshore, including the marginal strip administered by the Department of Conservation. The Makara Estuary supports the best and biggest area of salt marsh habitat in the city, is of regional significance and supports threatened species. A local care group has prepared a restoration plan for the estuary. An environmental score of 4 has been assigned to Makara Beach for all sea level rise scenarios, reflecting the large areas impacted and high significance scores. This is not withstanding that increasingly large areas of the estuary would be impacted from sea level rise Scenarios 1 to 5.	
SOCIAL	
All scenarios have a similar and moderate social impact, with around 150 residents affected. One community facility (the boat ramp bordering the stream) and the local access road are affected. Beach use in this area will also be compromised.	

MAUPUIA



CULTURAL

Maupuia has some of the oldest sites around Wellington which extend from the foreshore to the ridge tops. Much has been destroyed, however there is further archaeology that will be recorded in future investigations. The Shelly Bay site includes old wharves and a slipway. Some of these are likely to be removed. There are some cultural sites around Shelly Bay but most are elevated and not affected by sea level rise.

ECONOMIC

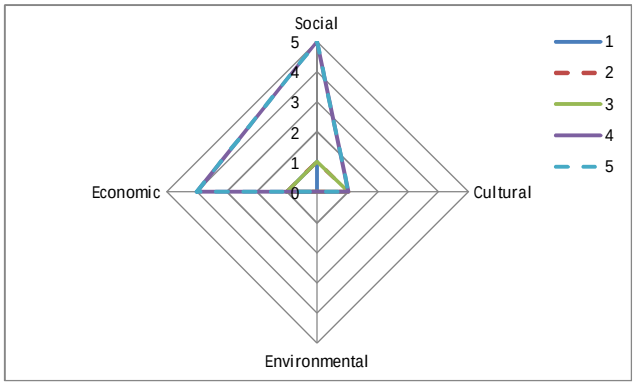
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score increases steadily from 0 (Scenario 1) to 3 (Scenarios 4 and 5). Damages peak at around $94m for Scenario 5.

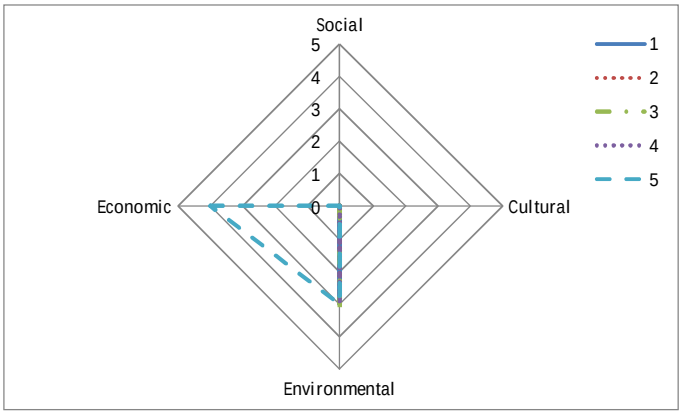
ENVIRONMENTAL

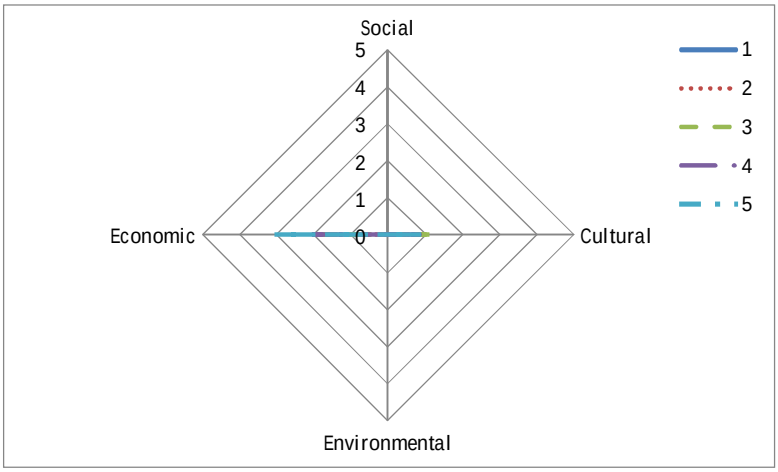
Ecological sites in Maupuia include Kau Point, Point Gordon and scattered patches of coastal vegetation around the coastline. While modified, Kau Point is indicated to support threatened plant species. An environmental score of 3 has been assigned to all sea level rise scenarios reflecting the impacts on moderate value ecological sites and intertidal hard shore and soft shore habitats around the coast.

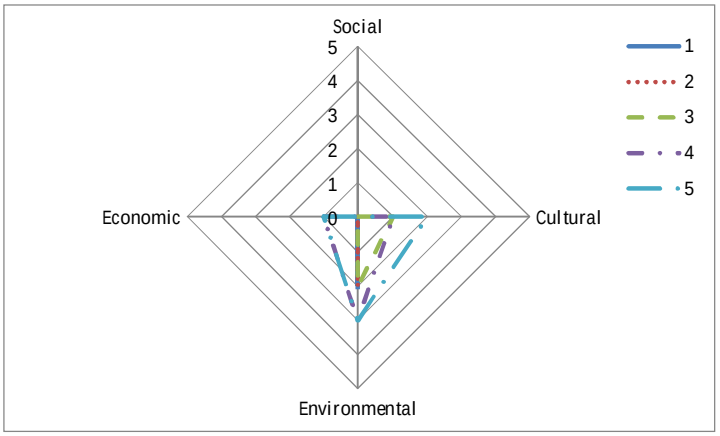
SOCIAL

All scenarios have a minimal overall social impact, with very few residents affected. One facility (the boat ramp) is affected and there will be impacts on the coastal road.

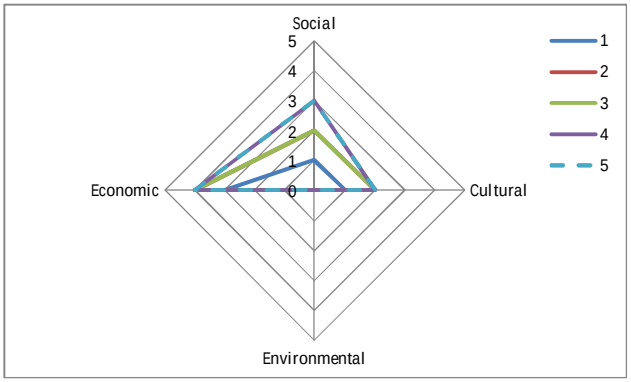
MIRAMAR	
	
CULTURAL	
The old Maupuia Pā site was probably destroyed by the cutting. There are no other sites along this shoreline. Miramar was partly under water in Māori times.	
ECONOMIC	
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to water infrastructure and local roads. Although a small proportion of total damage in the suburb, the damage to water and roads is significant when compared to other suburbs. The damage score increases from 1 (Scenarios 1 to 3) to finally 4 (Scenarios 4 and 5). Damages peak at around $1,520m for Scenario 5.	
ENVIRONMENTAL	
No significant damage.	
SOCIAL	
Scenarios 1, 2 and 3 have a low overall social impact. Scenarios 4 and 5 have a major social effect, with an overall score of 5. Scenario 4 affects over 400 residents, of which a high proportion are elderly and children. Approximately nine community facilities including three schools, the library and the polo ground, as well as the entire local transport network are also significantly impacted. Around 1800 households would be affected, with many rental properties and low income households. Scenario 5 affects around 6000 residents, many elderly and children. Approximately 2200 households would be affected, around a third of which are rental properties or low income homes.	

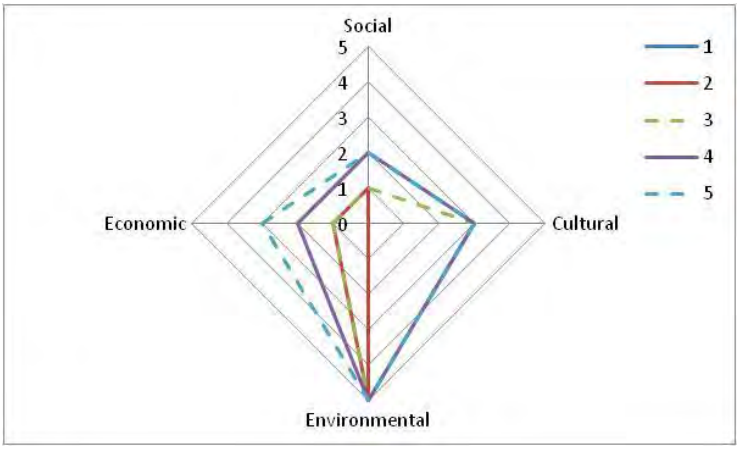
MOA POINT	
	
CULTURAL	
No significant effect. Impacts on Rangitatau Pā are included in Breaker Bay.	
ECONOMIC	
Economic damage to this suburb is driven by damage to land and buildings (primarily the airport) and lesser damage to water infrastructure and local roads. There is very little damage until Scenario 5. The first four scenarios score 0, while Scenario 5 scores a 3. Damages peak at around $310m for Scenario 5.	
ENVIRONMENTAL	
Identified ecological sites include Moa Point and Tarakena Bay, both of which are classified as Conservation Sites in the Wellington City District Plan. These two identified ecological sites are linked by a more or less continuous reserve area along the coast and inland from the coastal road. Moa Point supports threatened species. An environmental score of 3 has been assigned to all sea level scenarios reflecting medium level significance criteria scores for identified sites and the moderate amount of ecological sites and intertidal hard shore habitat impacted.	
SOCIAL	
Impact limited to the coastal road.	

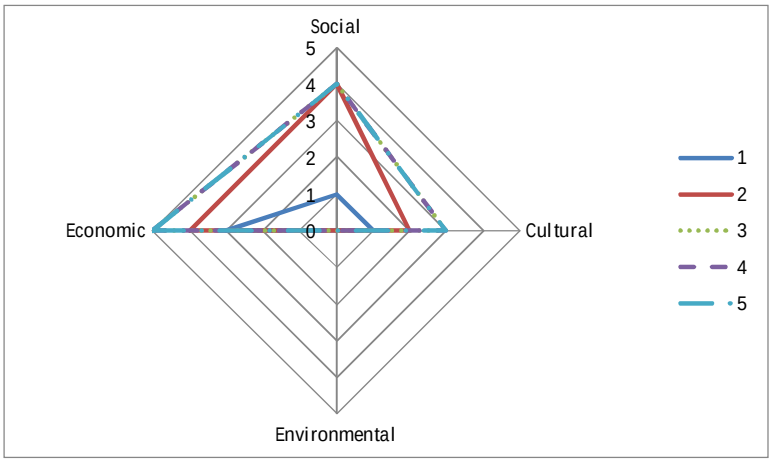
MT VICTORIA	
	
CULTURAL	
Minimal impact on cultural values across all scenarios. There are some Wellington heritage buildings, such as the Embassy Theatre, as well as Queen Victoria Memorial which would be adversely affected by Scenarios 4 – 5. No Maori cultural sites were identified.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure, local roads and state highways. The damage score increases steadily from 1 (Scenario 2) through to 2 (Scenarios 3 and 4) and finally 3 (Scenario 5). Damages peak at around $180m for Scenario 5.	
ENVIRONMENTAL	
There are no sites of significance in this suburb.	
SOCIAL	
Social impacts have been accounted for in neighbouring suburbs (Te Aro and Oriental Bay) due to the location of mesh block boundaries.	

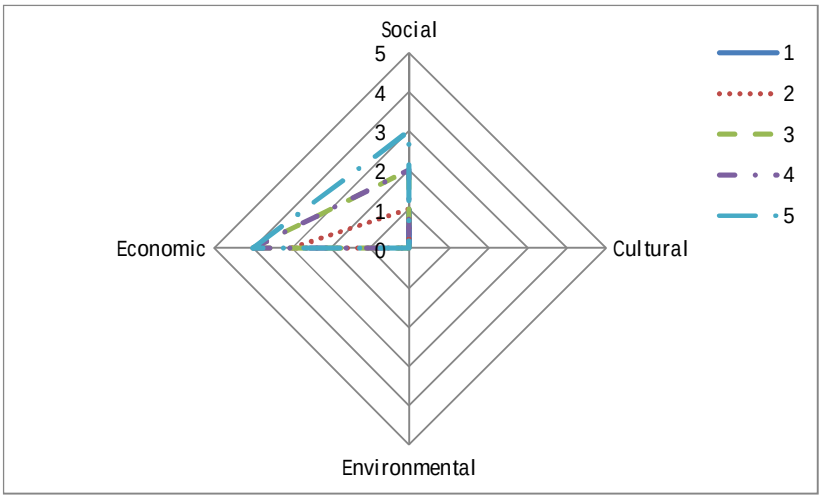
OHARIU	
	

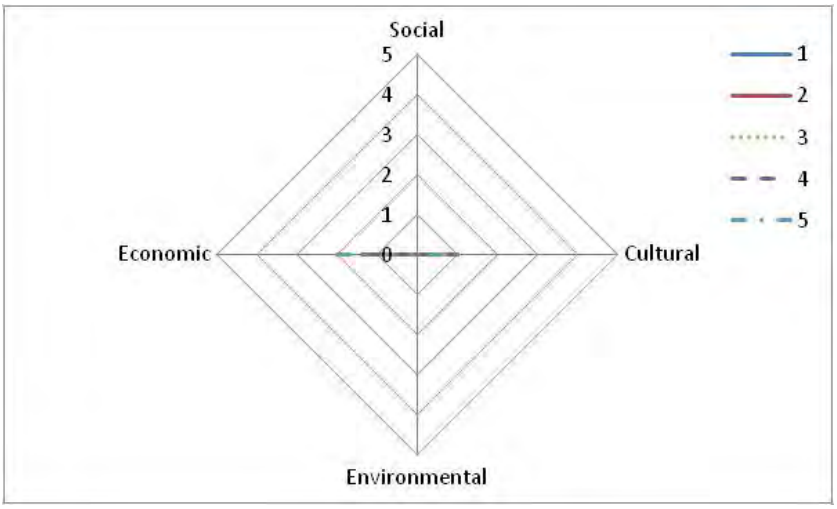
CULTURAL
Little impact on cultural values with Scenarios 1 – 3 as most sites are elevated. There are some archaeological sites, such as midden sites, that would be adversely affected by Scenarios 4 – 5. The recorded Pā site (Ngutu Kaka) was highly elevated. Most significant impacts relate to loss of access to both cultural sites and places to gather kaimoana via coastal tracks both north and south (3 – 5).
ECONOMIC
Economic damage to this suburb is driven solely by increasing damage to land and buildings. The damage score increases from 1 (Scenario 1) and then stays steady at 2 (Scenarios 2 to 5). Damages peak at around $10m for Scenario 5.
ENVIRONMENTAL
Ecological sites on the Ohariu coast include Boom Rock, which is considered to be the best example of coastal cliffs in Wellington, and the North Makara Esplanade Reserve. An environmental score of 2 has been assigned to sea level rise Scenarios 1 and 2 reflecting the low number of sites impacted with environmental scores increasing to 3 for Scenarios 3, 4 and 5 where larger areas of those sites would be directly inundated.
SOCIAL
No significant impact.

ORIENTAL BAY	
	
CULTURAL	
The impact on cultural values is low for Scenario 1 and limited to Wellington heritage buildings and trees. For Scenarios 3 – 5 the character of the Lambton Harbour area, a Wellington heritage seawall (constructed in 1920s – 1930s), and further heritage buildings are adversely affected. The Maori cultural sites at, or near, sea level which are likely to be submerged, however the mana of the sites remain.	
ECONOMIC	
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score increases from 3 (Scenario 1) to 4 (Scenarios 2 to 5). Damages peak at around $680m for Scenario 5.	
ENVIRONMENTAL	
There are no sites of significance within this suburb.	
SOCIAL	
Scenario 1 has a minimal overall social impact, affecting few residents although affecting facilities such as the marina and beach. Scenario 2 has a moderate overall social impact, affecting around 150 residents including a high proportion of elderly people, as well as four community facilities including the Freyberg Pool and Fitness Centre, the Band Rotunda and the NZ Fire Service City base as well as city-wide transport services that use Oriental Parade. Seventy households would be affected. Scenario 3 would affect over 200 residents with a high proportion of elderly, subjecting around 100 households to flood risk. Scenario 4 would affect 400 residents, with nearly 30% elderly, while subjecting nearly 200 households to flood risk. Scenario 5 would affect around 500 residents, with nearly 30% elderly, and subject over 200 households to flood risk. There are few households in the affected area on a low income, although around 70 affected households live in rental properties.	

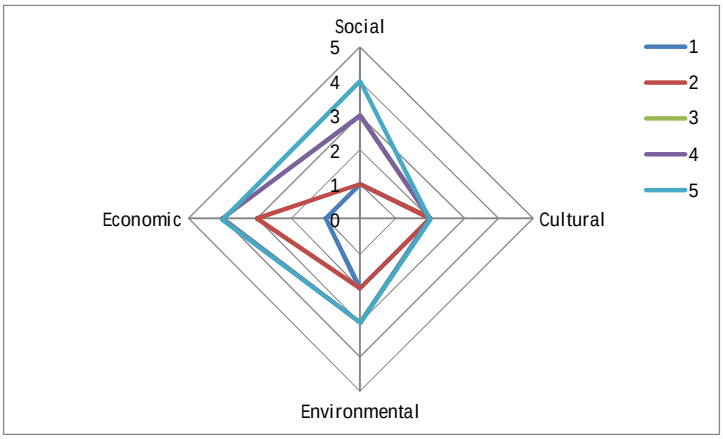
OWHIRO BAY	
	
CULTURAL	
There are few sites that would be affected in this suburb. Owhiro Bay gives road access to many sites on the Wellington south coast including Red Rocks, Sinclair Head and around to Waiariki which includes a number of sites, however most of these would not be effected except in Scenarios 4 – 5.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score begins at 0 (Scenario 1) then increases steadily from 1 (Scenarios 2 and 3), through to 2 (Scenario 4) and finally 3 (Scenario 5). Damages peak at around $70m for Scenario 5.	
ENVIRONMENTAL	
The Owhiro Bay coastline is fairly rich in sites of ecological value, including sites of regional significance such as Tapu te Ranga Marine Reserve, Red Rocks and the associated scientific reserve, the Sinclair Head Scientific Reserve, Owhiro Bay stream and Owhiro Bay itself is classified as a conservation site in the Wellington City District Plan. A wide range of intertidal and coastal marine habitats are represented along this part of the coast and several of the identified sites support threatened species. A score of 5 has been assigned to all scenarios notwithstanding the increasing impact that would occur with increasing sea level at any particular site.	
SOCIAL	
Scenarios 1, 2 and 3 have low social impacts, only affecting few residents and the coastal road, including access to amenity areas and the Owhiro Bay boat ramp. Scenarios 4 and 5 have moderate social impacts, affecting up to 350 residents in Owhiro Bay, with a high proportion of children.	

PIPITEA	
	
CULTURAL	
There are many historical sites in Pipitea which will be adversely affected. For Scenario 1, the cultural impacts will be limited to Lambton Harbour area and the operational port area. This will extend to include Wellington heritage buildings, trees and objects (e.g. Fraser Statue) for Scenario 2. Further heritage buildings, such as the Old Government House and the Railway Station, a functional Marae located along Thorndon Quay, and an important house/garden identified by the New Zealand Archaeological Association will be susceptible for Scenarios 3 – 5.	
ECONOMIC	
Economic damage to this suburb is spread across all asset types with significant damage to land and buildings including the port and the rail network, with lesser damage to the state highways and motorways, water infrastructure and local roads. The damage score increases from 3 (Scenario 1) to 4 (Scenarios 2) and 5 for Scenarios 3 to 5. Damages peak at around $1.9bn for Scenario 5.	
ENVIRONMENTAL	
There are no sites of significance in this suburb.	
SOCIAL	
Scenario 1 has a minimal overall social impact, with few residents affected, and no community facilities or transport networks affected. Scenarios 2, 3, 4 and 5 have a major impact. Scenarios 2 and 3 affect over 200 residents, the railway station and railway corridor as well as Waterloo Quay and Thorndon Quay. Scenarios 4 and 5 affect around 300 residents in addition to the significant disruption to road and rail services.	

RONGOTAI	
	
CULTURAL	
No significant damage.	
ECONOMIC	
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. Although a small proportion of total damage in the suburb, the damage to water and roads is significant when compared to other suburbs. The damage score increases from 0 (Scenario 1), through to 3 (Scenario 2) and finally 4 (Scenarios 3, 4 and 5). Damages peak at around $670m for Scenario 5.	
ENVIRONMENTAL	
There are no sites of environmental significance in this suburb.	
SOCIAL	
Scenarios 1 and 2 have a minimal social impact, with few residents affected. Scenarios 3 and 4 have a more significant social impact, with between 90 and 160 residents affected, including a high proportion of elderly and children. The road to the airport would also be disrupted in these scenarios. Scenario 5 would have a major impact, with over 1000 residents affected, affecting a school, and creating a flood risk for over 400 households.	

ROSENEATH	
	
CULTURAL	
There are few sites in this highly developed suburb.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score begins at 0 (Scenario 1) increases then steadily from 1 (Scenarios 2 and 3), through to 2 (Scenarios 4 and 5). Damages peak at around $30m for Scenario 5.	
ENVIRONMENTAL	
There are no sites of environmental significance in this suburb.	
SOCIAL	
The impact is limited to the disruption to the coastal road.	

SEATOUN



CULTURAL

The cultural sites for Seatoun are both on and off shore. Some of the rocks such as Te Aroaro a Kupe, while being culturally important, will start to disappear as the sea level rises but will still remain visible. Other sites are elevated well above sea level.

ECONOMIC

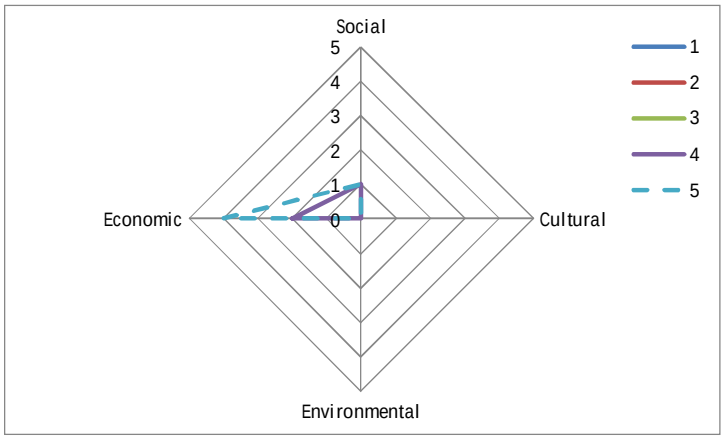
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to water infrastructure and local roads. Although a small proportion of total damage in the suburb, the damage to water and roads is significant when compared to other suburbs. The damage score increases from 1 (Scenario 1), through to 3 (Scenario 2) and finally 4 (Scenarios 3, 4 and 5). Damages peak at around $550m for Scenario 5.

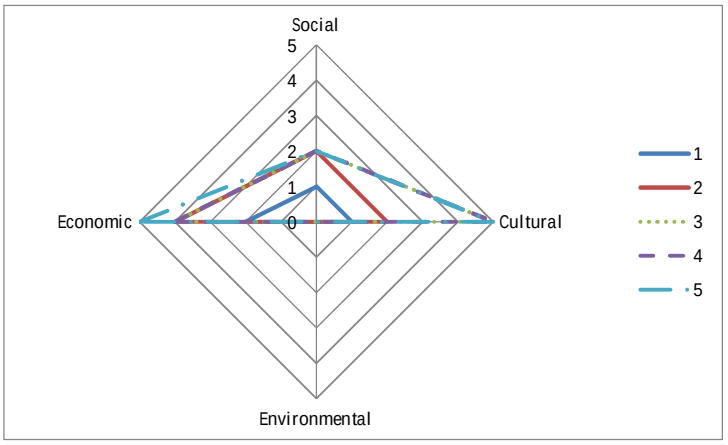
ENVIRONMENTAL

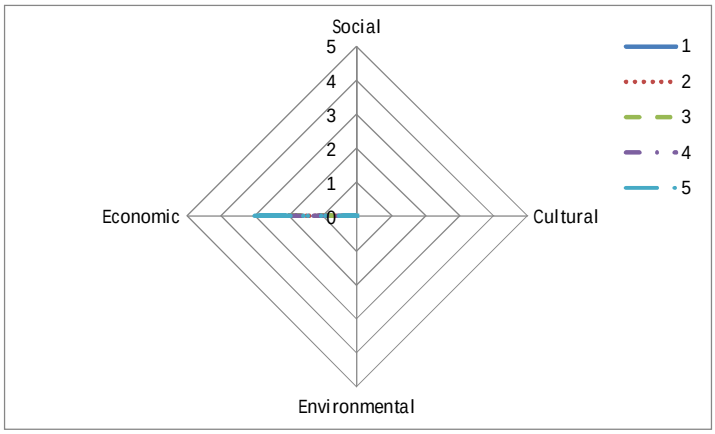
Ecological sites in Seatoun comprise Worser Bay and several patches of common coastal shrubs, all of which are highly modified and have low significance scores. The environmental score of 2 reflects the moderate sized areas of identified ecological sites impacted increasing to a score of 3 for Scenarios 3, 4 and 5.

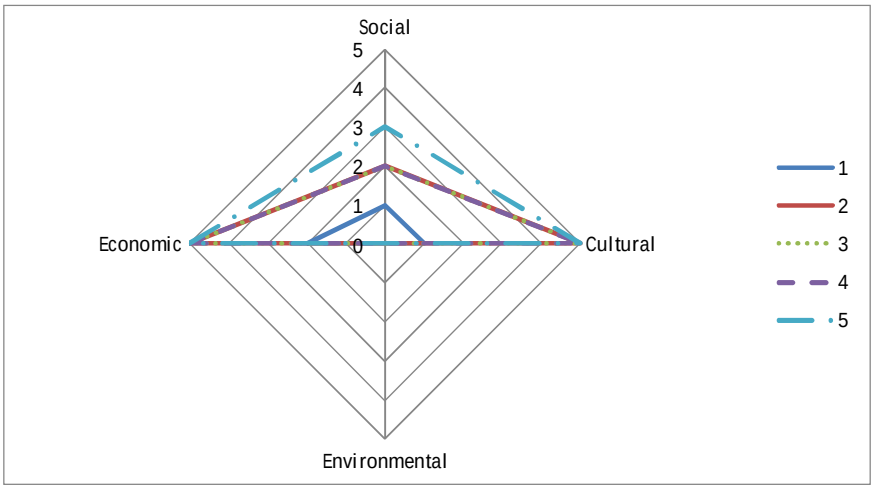
SOCIAL

Scenarios 1 and 2 have a minimal impact, affecting few residents and not disrupting transport networks. Scenario 3 has a moderate social impact, affecting over 200 residents, with a high proportion of children. Community facilities, including two schools, Churchill and Seatoun Parks and the civil defence base, as well as the coastal road, are also affected. Around 300 households are at risk of flooding, with 10% of these on a low income. Scenario 4 and 5 affect considerably more residents, between 1300 and 1400, with a high proportion of both elderly and children. Several community facilities are also affected. Over 450 households are subject to flood risk.

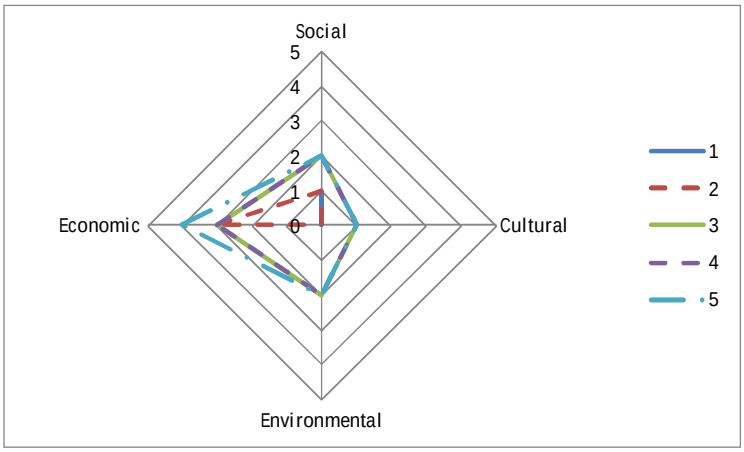
STRATHMORE PARK	
	
CULTURAL	
No significant damage.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to water infrastructure and local roads. The damage score begins at 0 (Scenarios 1, 2 and 3), increases to 2 (Scenario 4) and finally 4 for Scenario 5. Damages peak at around $400m for Scenario 5.	
ENVIRONMENTAL	
No significant damage.	
SOCIAL	
Scenarios 1 to 3 have minimal social impacts. Under Scenario 5, the Strathmore Community School would be affected.	

TE ARO	
	
CULTURAL	
The Maori cultural sites in this suburb are likely to be affected by Scenarios 4 – 5. An example is the Wharewaka building on Taranaki Wharf with a basement floor near sea level. Another is the archaeological remnants of Te Aro Pā preserved in situ near the pre-1855 foreshore. That site is vulnerable to Scenarios 4 – 5. The site is nationally unique as there are no other known examples of the punga whare preserved from the mid-19th century. The cultural impact on New Zealand – European sites will be moderate for Scenario 2. Affected areas will include Lambton Harbour, Civic Centre and the Courtenay character area, as well as Wellington heritage buildings. Many more heritage buildings will be affected for Scenarios 3 – 5 and the cultural impact will be high.	
ECONOMIC	
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. The damage score increases from 2 (Scenario 1), through to 4 (Scenarios 2, 3 and 4) and finally 5 (Scenario 5). Damages peak at around $1.8bn for Scenario 5.	
ENVIRONMENTAL	
There are no significant sites in this suburb.	
SOCIAL	
Scenario 1 had a minimal social impact because few or no residents of community facilities are affected. Scenario 2 had a moderate impact, with around 250 residents affected and the coastal road and important local road network disrupted. Scenario 3 affects Waitangi Park and Herd Street, as well as impacting around 700 residents. Scenario 4 affects around 1000 residents and Scenario 5 affects Te Papa, the national museum, as well as over 1200 residents, many of which live in rental properties.	

THORNDON	
	
CULTURAL	
No significant damage.	
ECONOMIC	
Economic damage to this suburb is driven by increasing damage to land and buildings with lesser damage incurred to state highways, water infrastructure and local roads. The damage score increases from 2 (Scenarios 2, 3 and 4) to finally 3 (Scenario 5). Damages peak at around $62m for Scenario 5.	
ENVIRONMENTAL	
No significant damage.	
SOCIAL	
No significant damage.	

WELLINGTON CENTRAL	
	

CULTURAL
Significant cultural impact will occur for Scenarios 2 – 5. Many Wellington heritage buildings and objects will be adversely affected, as well as character areas, such as the Civic Centre and the Lambton Harbour area. Several historical sites identified by the New Zealand Archaeological Association including an early hotel site and wharf will be susceptible during Scenarios 2 – 5. A building on Jervois Quay containing a traditional waka, several Pā remnants and surrounding areas of important Maori cultural significance will be adversely affected by Scenarios 3 – 5.
ECONOMIC
Economic damage to this suburb is driven by increasing and significant damage to land and buildings with lesser damage incurred to water infrastructure and local roads. Although a small proportion of total damage in the suburb, the damage to water and roads is significant when compared to other suburbs. The damage score increases from 2 (Scenario 1) to 5 (Scenarios 2 - 5). Damages peak at around $3.5bn for Scenario 5.
ENVIRONMENTAL
There are no significant sites in this suburb.
SOCIAL
Scenario 1 has a minimal social impact although lower lying areas around the waterfront will be affected. Scenarios 2, 3, 4 and 5 have a more considerable impact, affecting between 350 and 450 residents and around 150 households. Approximately nine community facilities of city-wide importance will be affected including Wellington Library, Town Hall, and the whole of the waterfront, Wellington Central Police Station, and the Civic Centre. These scenarios also have a significant effect on the cross city transport network.

WELLINGTON GATEWAY	
	
CULTURAL	
Low overall impact. Cultural sites in Kaiwharawhara and Ngauranga were previously destroyed by land reclamation and motorway development. These included the old Pā site and Tauranga waka or canoe landing sites. The most important aspect remaining is the name, history and word of mouth stream associated with these cultural sites.	
ECONOMIC	
Economic damage is spread across all asset types. Significant damage is associated with land, buildings and the rail network with lesser damage to the state highways and motorways, water infrastructure and local roads. There is limited economic damage to the Newlands area. For the combined Wellington Gateway region, the damage score increases from 0 (Scenario 1), through to 2 (Scenario 2) and finally to 3 (Scenarios 3, 4 and 5). The total damage for Scenario 5 is $310m.	
ENVIRONMENTAL	
Identified ecological sites for these suburbs comprise the Kaiwharawhara Stream and scattered patches of vegetation on the landward side of the highway. Environmental scores of up to 2 reflect minor impacts on the lower reach of the Kaiwharawhara Stream and minor and/or indirect effects on identified patches of vegetation near the coast.	
SOCIAL	
The social impacts on these suburbs primarily relate to the damage to the Wellington motorway and railway which results in the maximum score for impact on community connectivity of 8 for all scenarios. There are also a small number of residents affected in Kaiwharawhara.	

Appendix E: Options summaries

NON-INTERVENTION			
Option	Description	Possible locations	Technical pros and cons
 Image: Bob Jones (2008)	Reactively abandon areas subject to sea level rise, at risk of storm events or no longer insurable.	All suburbs.	- Health and safety hazard related to buildings and other structures left standing in coastal areas. - Pollutant risk from buildings and other structures left in coastal areas.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
- May result in complex social issues for residents and communities forced to move, including the loss of community networks and identity, employment, ability to purchase a house of comparable value (in economic and sentimental terms), and marginalisation. - May result in social issues for communities where displaced residents relocate to, such as overcrowding of community facilities and services, greater competition for employment , and increased house prices. - Psychological impacts as people come to terms with loss of valued aspects of city and fear of change. - Abandoned landscape is unsightly and offers no alternative use (water sports or similar). - As reactive, health issues related to the sense of loss of control / safety and uncertainty.	+/- Makes space for new marine habitat. - Will result in some existing terrestrial habitat loss where land ownership/use prevents natural ecosystem retreat.	- Loss of heritage buildings and sites.	- Full loss of all assets assumed.

MANAGED RETREAT OR REALIGNMENT			
Option	Description	Possible locations	Technical pros and cons
 Image: Wellington City Council (2012)	Allows an area that was not previously exposed to flooding by the sea to become flooded by removing coastal protection and establishing a new shoreline further landward. Demolish existing structures. A planned intervention. May also include habitat relocation or relocation of heritage sites. Tunnels and road realignments.	All suburbs.	+ Relocatable housing facilitates moving. - Some underground infrastructure may need to be relocated.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Creates opportunity to enhance access and use of the coastal edge. + Provides longer term certainty for the community. - May result in complex social issues associated with the need to relocate communities if not appropriately managed. - Social issues include the loss of community networks and identity, employment, ability to purchase a house of comparable value, and marginalisation. - May result in social issues for communities where residents are relocated to, such as overcrowding of community facilities and services, greater competition for employment, and increased house prices. - Psychological impacts as people come to terms with loss of valued aspects of city and fear of change.	+ Makes space for new marine/ intertidal habitat. + Allows ecosystems to respond naturally to sea level rise over time. - May result in some existing terrestrial habitat loss where land ownership/use prevents natural ecosystem retreat.	- Loss of heritage buildings and sites in all or part. + Planned approach means value of sites can be documented and some may be relocated.	+ Can be developed / planned for incrementally, resulting in phased cost. - Need to find replacement land. - Cost of moving or replacing facilities and services.

HOLD THE LINE			
Option	Description	Possible locations	Technical pros and cons
Soft coastal protection (sand, shingle or cobble beaches, beach and dune nourishment)  Image: Steve Partridge (2007)	Construct 'soft' sea defences by importing sand, shingle or cobbles. Most appropriate beach type likely to be controlled by wave environment. Ongoing nourishment will be required.	Lyall Bay Kilbirnie (Evans Bay) Owhiro Bay (part) Island Bay.	+ Known design and build techniques. +/- Adaptable intervention, with increased nourishment required to provide increased protection. - Vulnerable to failure from liquefaction.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Aesthetically pleasing, retains/increases recreational areas. + Maintains natural connection to the sea. - Can take up a lot of space, especially sand beach and dune systems, so relocation of housing, facilities and services may be required in some areas. - Loss of views and similar amenity value if land behind defences is not raised. - Increased vulnerability to other natural hazards, such as flooding, tsunami.	+ Mimics natural systems so could provide habitat. - May alter existing habitats. - Potential locations would not protect any existing ecological sites of significance.	+ Can be used to protect areas of cultural significance. -May affect areas of cultural significance.	- Ongoing nourishment will be required to match rising water level. - Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.

HOLD THE LINE (Continued)			
Option	Description	Possible locations	Technical pros and cons
Hard coastal protection (seawalls and embankments)  Image: Nigel Chadwick www.channelcoast.org	Construct 'hard' sea defences along the alignment of the existing coast to protect all existing land. Sea defences can comprise walls (vertical seaward face) or embankments (sloping seaward face). Visually variable, with rock armour, precast concrete blocks and masonry finishes, all viable options in different environments, with differing costs.	All suburbs except Makara and Ohariu.	+ Protects a large area. + Known design and build techniques. +/- Medium life structure means replacement likely over a 50 -100 year period. Adds cost but also adaptability. - Vulnerable to failure from liquefaction.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Maintains existing land availability. + Need to relocate communities may be reduced and in some cases removed. + Can provide a recreational area if a wide 'promenade' is included in the design. - Loss of views for harbour and coastal resident if land behind defences is not also raised. - Loss of existing recreational and amenity value where natural/soft coastal edges are replaced by hard coastal protection. - Increased vulnerability to other natural hazards. - Significant impact on the visual amenity of the city scape, particularly the city's harbour suburbs.	- Difficult to maintain natural environment on seaward side. - Major modification to coastal fringe habitats. - Loss of natural intertidal hard-shore habitat. + Possible to replicate some intertidal hard-shore ecological features (e.g. seal haul outs). + Protection for terrestrial ecological sites.	+ Can be used to protect areas of cultural significance. - May affect areas of cultural significance.	+ Can be cost effective where large areas are protected by relatively short lengths of wall. - Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.

HOLD THE LINE (Continued)			
Option	Description	Possible locations	Technical pros and cons
Combination of hard and soft intervention options  Image: http://www.mountainrunning.org.nz	Combination of hard and soft options. For example, groynes/outfall extensions supporting sand or shingle beaches or reducing size scale of seawall storm defence. Currently seen at Oriental Bay.	Lyall Bay Kilbirnie Oriental Bay Owhiro Bay (part) Island Bay.	+ Known design and build techniques. +/- Adaptable intervention, with increased nourishment and incremental hard structure construction required to provide increased protection.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Can be aesthetically pleasing, retains/enhances recreational areas. + Retains current city landscapes, for example at Oriental Bay and Lyall Bay. - Can take up a lot of space, especially sand beach and dune systems, so relocation of housing, facilities and services will be required in some areas. - Loss of views and similar amenity value if land behind defences is not raised. - Increased vulnerability to other natural hazards. + Need to relocate communities may be reduced and in some cases removed. - Impact on the visual amenity of the city scape – particularly the city's harbour suburbs.	+ Mimics natural systems in part so could provide habitat if incorporated into design. - Potential locations would not protect any existing ecological sites of significance.	+ Can be used to protect areas of cultural significance. - May affect areas of cultural significance.	- Ongoing nourishment will be required to address ongoing sea level rise. - Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.

HOLD THE LINE (Continued)			
Option	Description	Possible locations	Technical pros and cons
Barrier  Image: Peter Trimming (2009)	Designed to protect land from high water levels, barriers have typically been used for storm protection. London and Venice are two well-known examples. Water needs to be able to pass into and out of the sea or estuary behind the barrier to ensure flushing.	Wellington Harbour Mouth Evans Bay (Hataitai to Miramar) Port / CBD entranceway (Pipitea to Oriental Parade).	+ Protects a large area. +/- Long life structure provides long term certainty but little adaptability. - Only feasible for sea level rise up to around 0.5 m due to limited tidal range in Wellington (0.75 m range neaps). - Could increase risk of flooding from rivers and surface water behind barrier. - Technically challenging to design and build. - Significant consequences of failure.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
- May be considered visually undesirable. - Potential to affect accessibility. + Maintains existing land availability. + May become a local landmark/identity (e.g. as per the Thames Flood Barrier). - Potential to affect recreational water sports. - Increased vulnerability to other natural hazards.	- Impacts on coastal processes. - Could impact on sediment accumulation in Wellington Harbour. - Water quality: may be difficult to ensure adequate flushing for water quality. - May not allow free movement of marine life or freshwater migratory species. - Potential locations would not protect any existing ecological sites of significance.	- Large scale alteration of natural environment unlikely to be acceptable to Maori.	- Will increase travel time into and out of the Port of Wellington for Harbour mouth barrier option. - Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.

ACCOMMODATE			
Option	Description	Possible locations	Technical pros and cons
Canal City  Image: Jessica Curtin (2011)	Either excavate existing roadways to form canals and/or abandon ground floor of existing buildings and let water inundate streets. Travel between buildings by boat, suspended walkways, cable ways etc.	Central Wellington Te Aro Kilbirnie Seatoun.	+ Small tidal range favours this option. +/- More suited to areas with multi-storey buildings. + Suits small scale/discrete areas due to large storm effects. - Some underground infrastructure may need to be relocated. - Technical challenges not well understood. - May be vulnerable to storm effects unless additional protection constructed. - Ongoing adaptation required for changes in sea level rise, may be difficult.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Need to relocate communities may be reduced. - Single storey buildings will need to be abandoned. - Loss of living/commercial space unless additional stories are added. - Unfamiliar way of life. - Community connectivity may be affected. It will be difficult to transition between travel in canal city and travel in rest of Wellington. - Loss of recreational spaces. - Visual and amenity changes to the suburbs may be considered undesirable.	+/- Creates new marine habitat in canal areas although may be of low value. - Water quality issues and pollution effects may be significant. - Would not protect any existing ecological sites of significance.	- Loss of heritage buildings in all or part. - Some heritage sites and precincts may be drowned.	+ May be able to be developed incrementally, resulting in phased cost. +/- Need to replace existing transport services with new services (water taxis, ferries). - Need to replace some infrastructure.

ACCOMMODATE (Continued)			
Option	Description	Possible Location	Technical pros and cons
Ferry services  Image: Roger Kidd (2011)	Where a decision is made to allow retreat from existing road networks, ferry services may provide an alternative form of transport.	Access to Seatoun, around Oriental parade and waterfront to Kilbirnie.	+ Well known and understood infrastructure requirements. - Access during large storm events may not be possible.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Established mode of transport in Wellington. - Significant impact on property owners who use this service and may no longer have vehicular access to their homes.	+ No significant impact.		+ Infrastructure already in place although some adaptation will be required over time.

EXPAND			
Option	Description	Possible locations	Technical pros and cons
Reclamation  Image: Albert Bridge (1999)	Create new land for use above likely future sea levels by reclaiming areas of the current sea bed.	- Central Wellington (Pipitea to Oriental Parade). - Evans Bay (Hataitai to Miramar). - Coastal strip from Horokiwi to Pipitea.	+ Known design and build techniques. - Liquefaction risk may make this inappropriate or very costly for Wellington. +/- Long life structure provide long term certainty but little adaptability.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+/- Creates new 'city' space with all expected amenities and can protect existing land. + Opportunities to relocate entire existing communities. + Ability to provide enhanced sea access around edge. - May be considered visually undesirable without additional coastal edge design. - Loss of views and similar amenity value if land behind reclamation is not raised. - Potential loss of recreational water sports area.	+ Existing marine environment in possible locations already modified. - Possible locations currently support no sites of ecological significance. - Natural environment beneath reclamation lost. - Impacts on physical processes. - Difficult to maintain a natural environment on seaward side.	- Occupation of Coastal Marine Area (CMA) and connection to existing coastal edge may affect cultural values. + Can be used to protect areas of cultural significance. - May affect areas of cultural significance.	+ New land area within existing city. - Potential loss of operational port area. - Management of surface water runoff behind defences can be difficult/costly if land behind is not also raised.

EXPAND (Continued)			
Option	Description	Possible locations	Technical pros and cons
Floating suburbs  Image: Sue Elias (2005)	Construction of floating islands within the Wellington Harbour. Link to the mainland by tunnels, suspended highways and/or ferry services. Extension of this concept is a city that also extends below the water.	Wellington Harbour.	+ Floating structures enable constant adaptation to changing sea level. - Unproven technology for permanent residence. Technical challenges uncertain for long term use. - Vulnerable to tsunami risk.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Opportunity to relocate existing communities. - Potential loss of recreational water sports area. - Unfamiliar way of life. - May be considered visually undesirable.	+ May result in some habitat creation along edge of islands. - Could result in habitat loss depending on site. - Increased risk of accidental spills/pollution. - Would not protect any mainland ecological sites.	- Potential impact on cultural issues due to occupation part of CMA.	+/- Site needs to consider operational port requirements. - Significant upfront capital expenditure. - Significant ongoing maintenance expenditure.

EXPAND (Continued)			
Option	Description	Possible locations	Technical pros and cons
Stilt City  Image: Ian Cunliffe (2010)	Jack existing buildings onto stilts above sea level. Travel between buildings by boat, suspended walkways, cable ways etc.	Kilbirnie Seatoun Hataitai Miramar Lyall Bay Island Bay Owhiro Bay.	+ Small tidal range favours this option. + Suits small scale/discrete areas. - Some underground infrastructure may need to be relocated. - Technical challenges not well understood. - May be vulnerable to storm effects unless additional protection constructed.
Social pros and cons	Environmental pros and cons	Cultural pros and cons	Economic pros and cons
+ Need to relocate communities may be reduced. - Visual and amenity changes to the suburbs may be considered undesirable. - Some buildings that cannot be raised will need to be abandoned or replaced. - Unfamiliar way of life. - Community connectivity may be affected, particularly for people with restricted mobility. Also difficult to transition between travel in stilt city and travel in rest of Wellington. - Loss of recreational spaces. - Loss of views and similar amenity value if land behind buildings on stilts is not raised.	+/- Creates new marine habitat in residential areas. - Water quality issues and pollution effects may be significant. - Would not protect any existing ecological sites of significance.	- Could occupy areas of significance or value to iwi.	+ Can be developed incrementally, resulting in phased cost. +/- Need to replace existing transport services with new services (water taxis, ferries).

Appendix F: Key data sources

Note: This Appendix comprises a direct extract of WCCs GIS asset database register.

Layer	Description	Source	Filename
Suburbs	Polygons representing Wellington Suburbs. The official list of suburbs was defined in 2003 after public consultation. Small modifications to suburbs are made when new subdivisions cross suburb boundaries.	Koordinates	wellington-city-suburbs
Parks, Reserves, Cemeteries	Polygons representing Parks, Reserves and Cemeteries administered by Wellington City Council	Koordinates	wellington-city-parks-res
Swimming Pools	Points representing swimming pools administered by Wellington City Council. The Council owns and operates seven swimming pools - five indoor and two outdoor.	Koordinates	wellington-city-swimming
Service Centres	Point representing the Service Centre for the Wellington City Council.	Koordinates	wellington-city-service-c
Civil Defence Centres	Points representing the location of Wellington City Civil Defence Centres	Koordinates	wellington-city-civil-def
Libraries	Points representing Wellington City Libraries. Wellington City Council owns and manages 12 branch libraries.	Koordinates	wellington-city-libraries
Play areas	Points representing the location of public playground areas in the Wellington City administered by Wellington City Council. Includes accessible public conveniences.	Koordinates	wellington-city-play-area
Community Centres	Points representing Wellington City Community Centres.	Koordinates	wellington-city-community
Community Halls	Points representing Wellington City Community Halls.	Koordinates	wellington-city-community-2
Recreation Centres	Points representing Wellington City Council Recreation Centres	Koordinates	wellington-city-recreatio
Parks and Garden Tracks and Walkways	Wellington City Council maintained tracks and walkways	Koordinates	wellington-city-parks-and
Sports grounds	This dataset contains all Sports fields' built/maintained/owned/used by Wellington City Council.	Koordinates	wellington-city-sportsgro
Tsunami Evacuation zones	The evacuation zones are designed to encompass the range of inundation patterns for many individual possible tsunami. The use of tsunami evacuation areas/zones has the advantage of simplicity for emergency planning, public awareness and understanding.	Koordinates	wellington-city-tsunami-e

Layer	Description	Source	Filename
Sewer Network Pipes	Wellington City Council Sewer Network Pipes.	Koordinates	wellington-city-sewer-net
Stormwater Pipes	Wellington City Council Stormwater Pipes	Koordinates	wellington-city-stormwat
Water Service Pipes	Wellington City Council Water Service Pipes	Koordinates	wellington-city-water-ser
Water Network Pipes	Wellington City Council Network Pipes	Koordinates	wellington-city-water-net
Private Stormwater Pipes	Wellington City Council Private Stormwater Pipes	Koordinates	wellington-city-private-s
Private Stormwater Pipes	Wellington City Council Private Stormwater Pipes.	Koordinates	wellington-city-private-s-2
Private Water Pipes	Wellington City Council Private Water Pipes.	Koordinates	wellington-city-private-w
DP Designations	The feature class shows boundaries of designations. A designation is a provision made in the District Plan to allow land to be secured for public works or other projects and facilitate the establishment of what are often necessary or essential services	WCC	Wellington_DP_designations
DP Heritage Area Lines	The feature class shows areas with particular emotional, historical, design or technological significance(ie sites where some innovation of science or technology was associated),	WCC	Wellington_heritage_area_lines
DP Heritage Buildings	The feature class includes buildings with particular emotional, historical, design or technological significance(ie sites where some innovation of science or technology was associated),	WCC	Wellington_heritage_buildings
DP Heritage Objects	The feature class includes objects with particular emotional, historical, design or technological significance(ie sites where some innovation of science or technology was associated),	WCC	Wellington_heritage_objects
DP Heritage Trees	The feature class identifies individual and groups of trees within the City which have ecological, amenity or heritage value. Information concerning each listed item is contained in an Inventory of Heritage and Notable Trees (not part of District Plan).	WCC	Wellington_heritage_trees

Layer	Description	Source	Filename
DP Maori Sites	Sites of significance to tangata whenua for a variety of reasons. These may have particular historical significance, act as a marker on the landscape or be an example of a particular type of site	WCC	Wellington_Maori_sites
DP Maori Tracks	The feature class shows Maori tracks of significance to tangata whenua	WCC	Wellington_Maori_tracks
City Hospitals (complete)	This dataset contains point locations of Hospitals in the Wellington TLA area.	WCC	city_hospitals_complete
DP Boundary Character Area (complete)	Areas with distinct qualities that distinguish it from its wider surrounds. These may include the presence of old buildings, distinctive streetscapes, significant natural features, important public views, diversity of uses, and more.	WCC	dp_boundary_character_area_complete
DP Maori Precinct Boundary (complete)	The feature class shows boundaries of areas of significance to tangata whenua for a variety of reasons. These may have particular historical significance, act as a marker on the landscape or be an example of a particular type of site.	WCC	dp_maori_precinct_boundary_complete
Ecological Districts	This dataset contains ecological regions and ecological districts for the whole of the Wellington District. Ecological Regions and Districts for the whole region as captured from NZMS Ecological Region and Ecological District maps. Ecological regions and districts are subdivisions of New Zealand into contiguous and discrete areas that have relatively homogenous physical (climate, soil, topography, geology) and biological characteristics (including cultural pattern, i.e. land use). Ecological Regions are generally an aggregate of adjacent ecological districts with very closely related characteristics.	WCC	ecological_districts_complete
GW Wetlands (complete)	All known wetlands of the Wellington Region based on Orthophotography, Fuller (1993) DoC ecolsite database, and staff knowledge.	WCC	gw_wetlands_complete
Lakes (complete)	Lake polygons from the 2007 LINZ digital topographic data V14. Any standing body of fresh inland water.	WCC	lakes_wellington_region
NZ Archaeological Association Sites (complete)	This dataset contains all Archaeological Sites as defined within the boundaries of the Wellington City Council by the New Zealand Archaeological Association (NZAA).	WCC	nz_archeaological_association_ sites_wellington_region

Layer	Description	Source	Filename
TTR Road Carriageway	This dataset contains all Road carriageways built/maintained/owned/used by Wellington City Council. The development of this dataset was undertaken to allow Road carriageways to be spatially represented, and for use in WCC projects.	WCC	ttr_road_carriageway
Prime Bushremnants	Identified Original Remnant are located within the boundaries of Prime Forest Sites.	WCC	prime_bushremnants
Site Bushremnants	Primary Forest Sites within Wellington City identified through a survey carried out in 1999 by Geoff Park Landscape Ecology & History for the Wellington City Council.	WCC	site_bushremnanats
QE2 Covenants	The digital layer of QEII covenant boundaries has been compiled from various sources around the country, including regional and district councils, DOC conservancies and surveyors.	WCC	qe2_covenants
Ecological Sites	This dataset is a combination of bush remnants and areas of high ecological value.	WCC	parks_ecological_sites
Parks Bush	This dataset contains all Bush areas built/maintained/owned/used by Wellington City Council. The development of this dataset was undertaken to allow Bush areas to be spatially represented, and for use in WCC projects.	WCC	parks_bush
Parks Revegetation	WCC revegetation sites. Status of work: Ongoing	WCC	parks_revegetation
Reserves	This layer is a selection of WCC sites that are maintained by the Parks & Gardens business unit, primarily parks, sports fields and reserves.	WCC	parks_reserves
CRS Rail	CRS(Core Record System) data is data from LINZ's Landonline. It is supplied to Wellington City Council (WCC) by Terralink International Ltd (TIL).	WCC	crs_rail
CRS Road	CRS(Core Record System) data is data from LINZ's Landonline. It is supplied to Wellington City Council (WCC) by Terralink International Ltd (TIL).	WCC	crs_road
DP Lambton Harbour Char Area	not available	WCC	dp_lampton_harbour_char_area
DP Lighthouse	Listed as a heritage item in the District plan	WCC	dp_lighthouse
Lenz lvl 4	Land Environments of New Zealand (LENZ) is a classification of fifteen climate, landform, and soil variables chosen for their relevance to biological distributions. Classification groups were	WCC	lenz_lvl_4

Layer	Description	Source	Filename
	derived by automatic classification using a multivariate procedure. Four levels of classification detail have been produced from this analysis, containing 20, 100, 200, and 500 groups respectively. Detailed descriptions of the input data layers, the methods, and the resulting classification groups are contained in two publications: Leathwick et al. 2003. Land Environments of New Zealand. David Bateman Ltd, Auckland; and Leathwick et al. 2003. LENZ Technical Guide, Ministry for the Environment. This is the fourth and final layer with 500 different environments.		
DP Boundary Railway Lines	Shows the location of the railway tracks.	WCC	dp_boundary_railway_lines
Ecodomains	This dataset contains all Ecological domains used by Wellington City Council. The development of this dataset was undertaken to allow Ecological domains to be spatially represented, and for use in WCC projects.	WCC	ecodomains
Community Group Areas	Community group working areas on WCC land. Each polygon represents an area where a specific community group has an influence, such as revegetation planting. These areas are therefore flagged as community maintained areas which aids WCC operations.	WCC	parks_community_groups_areas
Public Conservation Areas	Department of Conservation - Public Conservation Areas. Spatial representation of DOC's management units (conservation units) defined by various acts of parliament and legislation.	Koordinates	doc-public-conservation-a
NZ Meshblocks 2006	The meshblock is the smallest geographic area used by Statistics New Zealand in the collection and/or processing of data. It is the building block for aggregation into larger areas such as area units and urban areas.	Koordinates	nz-meshblocks-2006-census

Appendix G: Bibliography

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