Ministry for the Environment
Manatū Mō Te Taiao

Coastal Hazards and Climate Change

A Guidance Manual for Local Government in New Zealand

2nd Edition
July 2008

New Zealand Government

This Guidance Manual was commissioned by the Ministry of the Environment. The first edition was originally prepared by scientists, planners and engineers from NIWA, BECA Consultants Ltd, DTec Consultants Ltd, and Tonkin and Taylor Ltd in consultation with a wide range of people from local government organisations.

This present edition of the Guidance Manual has been rewritten by Doug Ramsay and Rob Bell of NIWA with assistance on a number of chapters from Robin Britton. Advice and assistance with the revision has also been provided by Ministry for the Environment, Northland Regional Council, Auckland Regional Council, Environment Waikato, Environment Bay of Plenty, Hawke's Bay Regional Council, Whakatane District Council, BECA Consultants Ltd, Jim Dahm (Eco Nomos Ltd). Comments we also considered from Peter Barrett and Martin Manning (Victoria University), Roger Crimp (Engineering Lifelines), John Hannah (Otago University), Charles Willmot (IPENZ); and from informal discussions with a wide range of other organisations and individuals. The resulting text does not necessarily represent the views of any of the above individuals or organisations.

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Executive Summary

Risks related to coastal hazards are not new to planners and resource and hazard managers of New Zealand local government. However, the foreseeable future provides some challenges for those tasked with the sustainable management of coastal margins.

A high proportion of New Zealand's urban development has occurred in coastal areas. Some of this development has been located in areas that are vulnerable to coastal hazards such as coastal erosion and inundation. In recent years, coastal development and associated infrastructure have intensified, and property values have increased enormously. As development and property values in coastal margins increase, the potential impacts and consequences of coastal hazards also increase. Managing this escalating risk over the coming decades now presents a significant challenge for planning authorities in New Zealand.

Climate change will exacerbate existing coastal hazards

Risk will be exacerbated in many places by the effects of climate change. Climate change will not introduce any new types of coastal hazards but it will affect existing coastal hazards by changing some of the hazard drivers. It will exacerbate coastal erosion and inundation on many parts of the New Zealand coast, further increasing the impacts of coastal hazards on coastal development.

Local government is required to take account of climate change

Climate change effects are gradual, but many land-use planning decisions have long-term implications because of the permanency of structures (eg, buildings, roads, network utilities). While it is a requirement under the planning framework of the Resource Management Act 1991, it is also wise and good business practice to consider climate change implications in coastal planning.

What this Guidance Manual does

This Guidance Manual has been written primarily to support local authorities (policy, planning, consents, building and engineering staff) in dealing with some of these challenges. It provides best practice information and guidance to strengthen the integration of coastal hazards and climate change considerations in land-use planning and during resource consent decision-making. More specifically, the Guidance Manual:

- provides information on the key effects of climate change on coastal hazards
- provides a risk assessment framework for incorporating coastal hazard and climate change considerations into the decision-making processes associated with policy development, planning and the awarding of resource consents
- promotes the development of long-term adaptive capacity for managing coastal hazard risk through the adoption of adaptive management and no-regrets response options.

What's new in this edition?

This is the second edition of this Guidance Manual, and it supersedes the first edition published in 2004. This edition's publication follows an updated assessment of the science of climate change by the Intergovernmental Panel on Climate Change (IPCC) in 2007.

The IPCC's Fourth Assessment, 2007 concluded that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. The Fourth Assessment also showed that it is likely that anthropogenic warming has had a discernable influence on many physical and biological systems. The IPCC concluded that continued emission of greenhouse gases at or above current rates would cause further warming; this could induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

This conclusion may have significant implications for some coastal infrastructure and development, especially those that will need to cope with climate conditions in 50–100 years' time or even after that time.

The main changes in this edition of the Guidance Manual are:

- it updates the climate change science and provides guidance and recommendations relevant to coastal margin issues in New Zealand
- there is a new chapter on local government response to climate change, emphasising how climate change adaptation fits within the key principles of local government actions (Chapter 4)
- there are minor revisions to the risk assessment process to enable local authorities to better characterise coastal hazard risk (Chapter 5)
- the chapter on managing coastal hazards and climate change risk has undergone major revision (Chapter 6)
- supporting material in the appendices has been revised and updated where necessary.

The structure and format of the Guidance Manual have also been significantly revised in response to stakeholder feedback, to make the document and the information in it more accessible to the user.

Sea-level rise

Relative mean sea levels have risen by 0.16 m on average over the last 100 years around New Zealand. This is comparable to global rates of mean sea-level rise over the same time period.

Sea-level rise projections for the next 100 years are based on different computer simulations of the atmosphere and ocean for a range of emission scenarios (ie, different greenhouse gas emission scenarios based on how the human race may live over the next 100 years). For New Zealand, there may be some variation in the rate of future sea-level rise compared to the global average, but these differences are not yet well defined.

In its Fourth Assessment Report, the IPCC has found that "Because understanding of some important effects driving sea-level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea-level rise." While there are uncertainties associated with the science around sea-level changes, national and local governments and individuals must continue to make decisions that either implicitly or explicitly make assumptions about what this rise will be over a planning timeframe.

This Guidance Manual advocates the use of a risk assessment process to assist incorporating sea-level rise and the associated uncertainties, within local government planning and decision-making. This requires a broader consideration of the potential impacts or consequences of sea-level rise on a specific decision or issue. Rather than define a specific climate change scenario or sea-level rise value to be accommodated, it is recommended in this Guidance Manual that the magnitude of sea-level rise accommodated is based on the acceptability of the potential risk.

To aid this risk assessment process, this Guidance Manual recommends that allowance for sea-level rise is based on the IPCC Fourth Assessment Report; and that consideration be given to the potential consequences from higher sea-levels due to factors not included in current global climate models.[1]

For planning and decision timeframes out to the 2090s (2090–2099):

a. *a **base** value sea-level rise of **0.5 m relative to the 1980–1999 average** should be used,* **along with**
b. ***an assessment of the potential consequences from a range of possible higher sea-level rises** (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise* **of at least 0.8 m** *relative to the 1980–1999 average. Guidance on potential sea-level rise uncertainties is provided within the Guidance Manual to aid this assessment.*

For planning and decision timeframes beyond 2100 where, as a result of the particular decision, future adaptation options will be limited, an allowance for sea-level rise of **10 mm per year beyond 2100** is recommended (in addition to the above recommendation).

[1] Such factors relate to uncertainties associated with increased contribution from the Greenland and Antarctica ice sheets; carbon cycle feedbacks; and possible differences in mean sea level when comparing the New Zealand region with the global average.

Other coastal hazard drivers

Climate change will also impact on other coastal hazard drivers, such as tides, storm surge, waves, swell and coastal sediment supply. The potential changes and their impacts are at present much less well understood, but this manual provides pragmatic guidance informed by expert judgement and the current state of scientific knowledge.

Tide range and relative frequency of high tides

The present Mean High Water Spring level will be exceeded much more frequently by high tides in the future, particularly on sections of the coast where the tide range is relatively small (compared with those sections of the coast where the tide range is relatively large). Sea-level rise will have a greater influence on storm inundation and rates of coastal erosion on the central parts of the east coast and Cook Strait / Wellington areas than on coastal regions with larger tidal ranges (eg, west coast).

Storms

The IPCC Fourth Assessment, 2007 suggests in general a likely:

- decrease in the total number of extra-tropical cyclones
- slight poleward shift of the storm track and associated precipitation, especially in winter
- increased number of intense cyclones and associated strong wind, particularly in winter over the South Island.

Changes in storm conditions will affect coastal margins around New Zealand through possible changes in the frequency and magnitude of storm surges and storm tides, and in swell and wave conditions.

Storm surge and storm tides

This Guidance Manual recommends that planners assume that storm-tide (ie, extreme) levels will rise at the same rate as mean sea level until more certainty emerges on likely changes to wind and central pressures associated with storm systems.

Wave climate

Expected changes in wind and atmospheric patterns, storms and cyclones around New Zealand and the wider southwest Pacific and Southern Ocean regions also have the potential to change the wave climate experienced around New Zealand. In turn, this will influence patterns of coastal erosion and the movements of beach and nearshore sediments within coastal zones. Little definitive guidance can be provided on how wave climates around New Zealand will change and what this may mean for coastal erosion and inundation.

This Guidance Manual sets out recommended assumptions for carrying out 'what if' scenarios for wave modelling, depending on the location of the coastline in question and whether it is exposed to, or sheltered from, oceanic swell.

Sediment supply to the coast

The potential for change in sediment supply will vary from place to place, with changes in the west–east gradient in rainfall (wetter in the west and drier in the east) likely to be a significant factor, along with increased rainfall intensities during severe rainstorms. Where changes in sediment delivery to the coast are an important consideration, sediment delivery from river systems will need to be determined based on detailed specific investigations and an assessment of how sediment volumes may change under future rainfall projections carried out.

Risk assessment process

The magnitude of the impacts of climate change on coastal margins will differ between regions and even between localities within regions. Such impacts will depend on the complex interaction between the localised impacts of climate change on the physical drivers that shape the coast, the natural characteristics of the coast and the influence that humans have had or are having on the coast. This Guidance Manual provides a risk assessment process to assist local authority staff in ensuring that coastal hazards, and the effects that climate change may have on these coastal hazards, are appropriately taken into account in policy, planning and resource consent decision-making. The assessment process permits a structured approach to thinking about, and working through, coastal hazard and climate change issues.

The risk assessment process and use of up-to-date knowledge of climate change can assist local government in helping communities adapt, especially through their regional and district plans. The risk assessment process fits comfortably into plan preparation and review, and the resource consent process.

Principles in managing coastal hazard risk

This Guidance Manual recommends that local authorities incorporate the following principles into all aspects of their decision-making about coastal margins:

- **Precautionary approach:** A precautionary approach is adopted when making planning decisions relating to new development, and to changes to existing development within coastal margins. Decision-making takes account of the level of risk, utilises existing scientific knowledge and accounts for scientific uncertainties.
- **Progressive risk reduction:** New development is not exposed to, and does not increase the levels of, coastal hazard risks over their intended serviceable lifetime. Progressively, the levels of risk to existing development are reduced over time.
- **Coastal margin importance:** The dual role of natural coastal margins as *the* fundamental form of coastal defence and as an environmental, social and cultural resource is recognised in the decision-making processes and, consequently, natural coastal margins are secured and promoted.
- **Integrated, sustainable approach:** An integrated and sustainable approach to the management of development and coastal hazard risk is adopted, which contributes to the cultural, social and economic wellbeing of people and communities.

To achieve these principles, local government will need to:

- identify and effectively account for coastal hazards, vulnerabilities and potential consequences within coastal margins
- communicate effectively to build community awareness, and public and political support for activities associated with coastal hazard risk planning
- engage the community in consultation and participation in achieving effective community planning outcomes.

1 Introduction to the Guidance Manual

1.1 Increasing coastal hazards and risk

A high proportion of New Zealand's urban development has occurred in coastal areas.[1] Some of this development has been located in areas that are vulnerable to coastal hazards such as coastal erosion and inundation (see Box 1.1).

In recent years, coastal development and associated infrastructure have intensified, and property values in some areas have dramatically increased (Figure 1.1). As development and property values in coastal margins increase, the potential impacts and consequences of coastal hazards also increase. Managing this escalating risk over the coming decades now presents a significant challenge for planning authorities in New Zealand.

Climate change will not introduce any new types of coastal hazards, but it will affect existing coastal hazards by changing some of the hazard drivers. It will exacerbate coastal erosion and inundation in many parts of the New Zealand coast, further increasing the impacts of coastal hazards on coastal development from now on.

Climate change effects are gradual. However, as many land-use planning decisions have long-term implications because of the permanency of structures (eg, buildings, roads, network utilities), incorporation of climate change is now a necessary consideration for the majority of coastal planning.

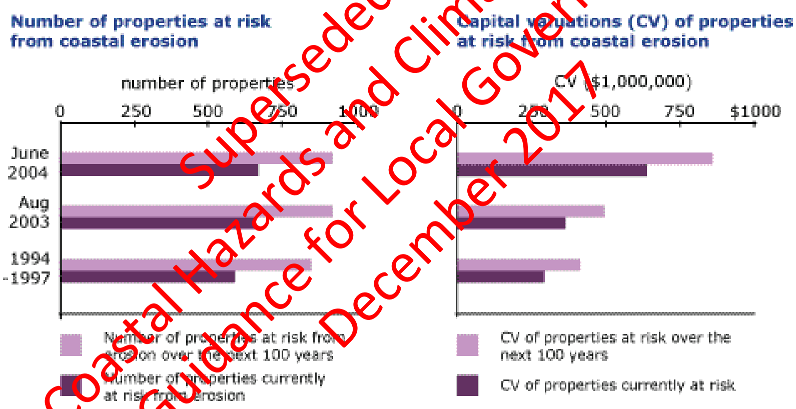

Figure 1.1: Existing coastal development at risk from coastal erosion in the Coromandel Peninsula, Waikato Region. Source: Environment Waikato 2008.

[1] In this Guidance Manual, 'coastal' refers to all areas defined to be part of the Coastal Marine Area plus the adjacent land referred to as the 'coastal environment'. So, 'coastal' includes open coasts, estuaries, harbours, inlets, river mouths and adjacent land.

Box 1.1: Ohiwa Spit. What goes around ...

The patterns of coastal change on Ohiwa Spit in the Bay of Plenty, and the effect this has on coastal development, exemplify the problems in land planning and coastal hazard management that are occurring around the New Zealand coast. Similar issues are being faced at Mokau on the western coast of the Waikato region and in most other regions around the country.

Ohiwa Spit has a long history of fluctuations in the position of the coastline. Between 1867 and 1911, the coastline of the Spit tended to build seawards, or accrete. This period was followed by an erosive phase over the next few decades to around 1949. In the decade that followed, the spit once again started to build seaward until around 1959, when an erosive phase once again began.

Photograph courtesy of R.K. Smith

This phase culminated in a series of storms in the mid- to late 1970s, which resulted in a number of properties falling into the sea. However, this was not the first time that property had been lost owing to the natural cyclic changes that occurred on the Spit.

In the late 1800s, a hotel was built on the Spit and, in the early 1920s, the area subdivided. Within a few years, subsequent erosion was so rapid that the Ferry Hotel was lost and the township was abandoned, with a tidal channel ending up where the main street had been.

In the following years, the Spit appeared to stabilise and a generation or so later, in 1949, a new subdivision further down the spit was created and developed on during the early 1950s. However, by 1965, erosion was again affecting property and several dwellings were lost to the sea over the subsequent decade despite various attempts to protect the coast with ad hoc seawall and railway-iron protection. The buildings that did not fall into the sea during the storms in 1976 were removed from the coastline. In the aftermath, some landowners received compensation whereas others retained their titles to the land.

Since these storms, the Spit has been again going through a phase of accretion, with the beach building in width and dunes that had been lost during the storms re-established. In early 2006, a number of the remaining section titles were put up for sale and some have sold. The issue of whether the new owners should be permitted to build new dwellings on these ephemeral sections is currently (April 2008) under appeal to the Environment Court.

Sources: from Richmond, B.M., Nelson, C.M., Healy, T.R., 1984, Sedimentology and evolution of Ohiwa Harbour, a barrier impounded estuarine lagoon in the Bay of Plenty, New Zealand, Journal of Marine and Freshwater Research, 18; EDS 2006; Environment Bay of Plenty unpublished.

1.2 Changing paradigms for coastal hazard management

Coastal erosion and inundation are natural processes that help shape the character of the coastline around New Zealand. Most coastal hazard problems have been caused by coastal development and subdivision being located too close to the existing shoreline to accommodate natural changes and trends in shoreline movements. Subsequent management of the hazard has been dominated by reactive and engineering-based approaches that, over time, often lead to the level of risk increasing (not diminishing) and the wider consequences becoming more complex to manage (Box 1.2).

Box 1.2: The development–defend cycle (adapted from Carter et al 1999)

Our traditional approach to managing coastal hazards is predominantly reactive, characterised by 'holding the line' using engineering structures, such as rock revetments to protect coastal development. Such 'solutions' often adversely impact on other environmental values, conflict with wider public values and typically tend to ignore the human dimension of the problem. They often lead to ongoing intensification of development in hazard areas, resulting in the problems becoming more complex over time. It is now realised that continuing to defy natural coastal processes, and defend the coastline as a means to decrease the risk to coastal development, is an unsound management approach in most instances (Dahm 2007, unpublished).

The functions of local government are set by the Local Government Act 2002 (LGA) and other specific statutes, particularly the Resource Management Act 1991 (RMA). Key requirements of the Local Government Act[2] are *democratic local decision-making* and sustainable development: *the social, economic, environmental and cultural well-being of communities, in the present and for the future*. The needs and expectations of future generations in the decision-making process need to be considered.

The purpose of the RMA is to promote the sustainable management of the natural and physical resources (specifically: environmental, social, economic and cultural aspects of them). This includes management of coastal environments, particularly preserving natural character from inappropriate development and maintaining or enhancing public access.[3] Policies intended to achieve the purpose of the RMA in relation to the coastal environment[4] are contained in the mandatory New Zealand Coastal Policy Statement.[5] 'Avoidance and mitigation of natural hazards' is also included as a function of local government with respect to the RMA.[6]

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2 Local Government New Zealand 2003.

3 LGA section 6.

4 RMA sections 56–58.

5 Under review – out for public consultation: March 2008.

6 RMA sections 30 and 31.

The RMA (Energy and Climate Change) Amendment Act 2004 introduced the requirement for anyone exercising powers or functions under the RMA to have particular regard to *the effects of climate change*.[7] This amendment has relevance to:

- local government decision-making
- the increasing need to plan for the effects of climate change that can exacerbate coastal hazards
- the increasing need to plan for the effects of adaptation measures put in place to protect natural and physical coastal resources to alleviate the risks from climate change.

Achieving sustainable coastal development that meets the reasonably foreseeable needs of future generations requires a fundamental shift in the way we approach coastal hazard management. Some of the paradigm drivers and shifts are summarised in Figure 1.2.

Historical or prevailing paradigm	Changing paradigm
Hazards such as coastal erosion viewed as 'abnormal' coastal behaviour.	Living with coastal erosion as a natural cyclic process that helps shape the natural characteristics of the coastal margin.
Predominantly re-active approach to managing coastal hazards after an event occurs.	A proactive and strategic long-term approach to managing coastal hazards.
Managing coastal processes.	Influencing people.
Focus on a single management objective based on physical impacts, such as protection of front-row property owners.	Balanced consideration of a wide range of environmental and social objectives, including protection, but also issues such as natural character, public access, cultural values, kaitiakitanga, kaimoana and customary uses.
Uncertainty about the occurrence of climate change and a tendency to wait for more certain information.	Certainty about the occurrence of climate change and the need to respond.
Consideration and management of different coastal hazards separately (eg, erosion, storm inundation, tsunamis).	Integrated approach to managing multiple hazards, including dealing with residual risk, eg, emergency management.
Decision-making based on short-term timeframes.	Support for long-term planning appropriate to the intended timeframe of the decisions being made and ongoing climate change impacts.
Little control over existing use rights with respect to hazard management.	Increased control over existing use rights with respect to hazard management.

Figure 1.2: The paradigm changes required to enable successful and sustainable management of the impacts of coastal hazards (adapted from Dahm 2007, unpublished).

However, coastal hazard risk is increasing. This is a result of the legacy of past development decisions, increasing development and property values, and increasingly the effects of climate change. These increased risks place considerable pressure on local authorities to achieve long-term sustainable management of the coastal environment, as well as sustainable development of coastal communities.

[7] RMA section 7(i).

Challenges include:

- the need to provide for the natural character, ecological, landscape, amenity, public access, cultural and spiritual values of the coast
- the increasing social and economic pressures to intensify the use and development of coastal areas, particularly with respect to redevelopment, subdivision and associated infrastructure
- the public's and property owners' perceptions of existing use rights, permanence of property and local government responsibilities for protection from impacts of coastal hazards
- the perceived need to protect people, property and infrastructure from the impacts of natural hazards
- the complex and uncertain nature of assessing risks associated with multiple coastal hazards and climate change
- potential liability on local authorities for present and future impacts on consented and permitted coastal properties
- the need to integrate risk governance and risk transfer by coordinating land-use planning and the management of residual risk through emergency management arrangements, insurance cover etc
- the need to raise people's awareness and understanding of the risks they face
- the need to plan for tomorrow's coastline, including minimising the costs of inter-generational adaptation and sharing the costs more equitably.

1.3 Purpose of this Guidance Manual

This Guidance Manual has been written primarily to support local authority staff (policy, planning, consents, building and engineering staff) dealing with some of these challenges to effectively manage and minimise coastal hazard risks. It focuses on the three main types of coastal hazards:

- coastal erosion caused by storms and long-term processes
- coastal inundation caused by storms or gradual inundation from high tides due to sea-level rise
- coastal inundation caused by tsunamis.

The Guidance Manual aims to provide best practice information and guidance to strengthen the integration of coastal hazards and climate change considerations within the land-use planning and resource consenting process. More specifically, the Guidance Manual:

- provides information on the key effects of climate change on coastal hazards
- provides a risk assessment framework for incorporating coastal hazard and climate change considerations into the decision-making processes associated with policy development, planning and awarding resource consents
- promotes the development of long-term adaptive capacity for managing (ie, reducing) coastal hazard risk through adoption of adaptive management and no-regrets response options.

1.4 What's new in this edition?

This is the second edition of the Guidance Manual; it supersedes the first edition published in 2004. It follows an updated assessment of the science of climate change produced by the Intergovernmental Panel of Climate Change (IPCC) in 2007.

The main changes in this Guidance Manual are:

- it updates the climate change science and provides guidance and recommendations relevant to coastal margin issues in the New Zealand
- there is a new chapter on local government response to climate change, emphasising how climate change adaptation fits within the key principles of local government actions (Chapter 4)
- there are minor revisions to the risk assessment process to enable local authorities to better characterise coastal hazard risk (Chapter 5)
- the chapter on managing coastal hazards and climate change risk has been extensively revised (Chapter 6)
- supporting material in the appendices has been revised and updated as necessary.

The structure and format of the Guidance Manual has also been significantly revised with the aim of making the document and the information contained within it more accessible to the user.

1.5 A roadmap through the Guidance Manual

1.5.1 Structure of the Guidance Manual

This document is in two main sections, supported by a range of resources and further information in appendices (Figure 1.3). The climate change guidance section is generally applicable to all involved with local government activities in coastal margins, whereas the decision-making guidance and supporting resources are aimed at those wanting to assess the coastal hazard risks arising from climate change.

Figure 1.3: Structure of the Guidance Manual.

FS 1

Throughout the Guidance Manual, links are provided to the coastal hazard factsheets contained in Appendix 3, where further information on the characteristics of coastal hazards can be obtained. These links are shown by the boxed 'FS' with a number that refers to the factsheet number. Reading the fact sheets first may be a useful strategy, particularly for those new to the area of coastal hazards and climate change.

1.5.2 Supporting guidance

In addition to this Guidance Manual, a range of complementary guidance is available or in preparation on climate change, hazard management and coastal development aspects from the Ministry for the Environment. These include:

- *Climate Change Effects and Impacts Assessment: A Guidance Manual for Local Government in New Zealand*.[8]
- Ministry for the Environment Quality Planning website: *Coastal development Guidance Note*.[9]
- Ministry for the Environment Quality Planning website: *Natural Hazard Guidance Note*.[10]

Further sources of information and guidance are provided in Chapter 7 at the end of this Guidance Manual.

8 MfE 2008a.

9 MfE 2008b.

10 MfE 2008c.

2 The Changing Climate

2.1 Introduction

2.1.1 The certainty of climate change

The Intergovernmental Panel for Climate Change (IPCC) released its Fourth Assessment Report in April 2007. It found that *Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level*.

It concludes that *most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.*

The IPCC was formed in 1988 to provide reliable scientific advice on climate change. Approximately every six years, it has produced a full assessment of the current state of scientific knowledge on climate change and what it means for us. Its reports provide syntheses of evidence and analyses that have been published either in peer-reviewed scientific journals or in other credible sources. The Fourth Assessment Report involved over 1200 scientific authors and 2500 expert reviewers from more than 130 countries.[11]

Progress has also been made in understanding the spatial and temporal changes in climate, and we now have a better understanding of the uncertainties. A broader and more robust assessment of the relationship between warming and observed changes to natural systems has been possible.

Headline-making global changes that have been observed are summarised in the IPCC 'Summary for Policymakers' from *The Physical Science Basis. Contribution of Working Group I.*[12] They include:

- concentrations of carbon dioxide have increased from a pre-industrial value of about 280 ppm[13] to 379 ppm in 2005, with a concentration growth rate for the period 1996 to 2005 of 1.9 ppm per year. The average rate over the entire period since direct measurements began in 1960 has been 1.4 ppm per year
- concentrations of other greenhouse gases have likewise continued to increase. Methane concentrations have increased from a pre-industrial value of 715 ppb to 1732 ppb in the early 1990s to 1774 ppb in 2005. Both methane and carbon dioxide concentrations far exceed the natural range over the last 65,000 years. Nitrous oxide concentrations have increased from a pre-industrial value of 270 ppb to 319 ppb in 2005
- globally, 11 of the 12 years from 1995 to 2006 rank among the 12 warmest years in the record of global surface temperatures (based on instrument measurements). The 100-year (1906–2005) linear rise was 0.74ºC (0.56–0.92ºC). Over the last 50 years, the rise per decade has been nearly twice that of the last 100 years. Since 1950, there has been a 0.3–0.7ºC warming across the Australia–New Zealand region as a whole
- observations since 1961 show that the average temperature of the global ocean has increased to depths of 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system
- global mean sea levels have risen by an average of 1.8 mm per year (1.3–2.3 mm per year) over the period 1961 to 2003, and by 1.7 mm per year (1.2–2.2 mm per year) over the entire 20th century.

11 Adapted from NIWA & the Royal Society of New Zealand 2008.

12 IPCC 2007a.

13 ppm = parts per million; ppb = parts per billion.

A more detailed summary of global changes that are known to have occurred can be found on the IPCC website, in the above-cited 'Summary for Policymakers', in the full Working Group I report;[14] and in the Fourth Assessment *Synthesis Report*.[15]

2.1.2 Future climate change projections

Projections of future climate change are made using computer models of the Earth's climate. These Global Climate Models[16] (GCMs) simulate the effect on the atmosphere and oceans of different possible future scenarios of greenhouse gas emissions. A range of future scenarios are used as we do not know exactly how human-induced greenhouse gas emissions will vary over the coming century, and therefore cannot define exactly how the emissions will translate into climate changes and sea-level rise. Mainly because of this uncertainty projections of changes in temperature, sea-level rise etc, are presented as ranges, rather than a single value.

Key future projections from the Fourth Assessment Report are also summarised in the IPCC 'Summary for Policymakers'. They include:

- a rise in global average temperature of 0.6ºC (0.3–0.9ºC) by 2090–2099 relative to the average for 1980–1999 *if emissions did not exceed 2000 levels*. Over the next two decades, temperature will rise at a rate of about 0.1ºC per decade owing to the slow response of the oceans. This rate will increase to about 0.2ºC per decade if emission rates continue to increase within the range of the future scenarios
- a best estimate of global average temperature rise of between 1.8 and 4.0ºC (the full range of emission scenarios, including all uncertainties, suggest 1.1–6.4ºC) by 2090–2099 relative to the average global temperature for 1980–1999. For a mid-range emissions scenario (A1B), the best estimate is a 2.4ºC (1.7–4.4ºC) rise in temperature by 2090–2099 relative the average for 1980–1999.

A more detailed summary of global projections of future climate change can again be found in the IPCC 'Summary for Policymakers' and in the full Working Group I report.[17] Details of the potential changes in climate within the New Zealand region are summarised in Box 2.1 and provided in a companion Guidance Manual.[18]

[14] IPCC 2007a, 2007c.

[15] IPCC 2007e.

[16] Also known as 'Global Circulation Models' or 'Atmosphere–Ocean Global Circulation Models' (AOGCMs).

[17] IPCC 2007a, 2007c.

[18] MfE 2008a.

Box 2.1: Summary of expected climate change in New Zealand

		Confidence level
Temperature	• Increase in mean temperature, of more than observed in the 20th century warming.	Very confident
	• Increase in mean temperature by 0.9ºC by 2040 and 2.1ºC by 2090.	Moderate confidence
	• Least warming in the spring.	Low confidence
	• Fewer cold temperatures and frosts and more high temperature episodes.	Very confident
Precipitation	• Increase in annual mean rainfall is expected for Tasman, West Coast, Otago, Southland and Chatham Islands regions.	Moderate confidence
	• Decrease in annual mean rainfall in Northland, Auckland, Gisborne and Hawke's Bay regions.	Moderate confidence
	• Heavier and/or more frequent extreme rainfalls where mean rainfall increases are predicted.	Confident
	• Heavier and/or more frequent extreme rainfalls.	Moderate confidence
Snow	• Shortened duration of seasonal snow lying.	Confident
	• Rise in snowline.	Moderate confidence
	• Decrease in snowfall events.	Low confidence
Glaciers	• Continued long-term reduction in ice volume and glacier length.	Confident
Wind	• Increase in annual mean westerly component of windflow across New Zealand.	Moderate confidence
	• About a 10% increase in annual mean westerly component of flow by 2040 and beyond.	Low confidence
	• By 2090, increased mean westerly in winter (> 50%) and spring (> 20%), and decreased westerly in summer and autumn (20%).	Low confidence
	• Increase in severe wind risk possible.	Moderate confidence
	• Up to a 10% increase in strong winds (eg, > 10m/s or top 1st percentile) by 2090.	Low confidence
Storms	• More storminess possible, but little information for New Zealand	Low confidence

2.2 Impacts of climate change on sea level

2.2.1 Causes of changes in sea level

Long-term changes or trends in relative sea level in a particular region are typically due to a combination of three main components:[19]

- global average eustatic or absolute sea-level rise. This is due to a combination of:
  - an increase in ocean volume due to lower seawater density, arising from a warmer ocean temperature and lower salinity
  - an increase in ocean mass due to a re-distribution of fresh water from land-based storage (eg, glaciers, ice sheets, dams, lakes, rivers and groundwater) to the oceans.
- departures (positive or negative) from the global average in different sub-regions of the world's oceans (New Zealand being part of the Southwest Pacific sub-region). Examples are differences due to non-uniform patterns of temperature and salinity change, variations in mean surface atmospheric pressure and wind stress, and varying response of ocean currents to climate change. As yet, these geographical variations are poorly understood but could be significant.

[19] Nicholls and Lowe 2004.

- local vertical land movements. The landmass can be stable, subsiding or rising. The latter two can be either incremental tectonic shifts (eg, as the result of an earthquake), or gradual (eg, due to crustal loading of sediments or rebound of the crust following the last Ice Age).

It is important to note that the IPCC provides projections for the first bullet point above (global mean) and some general guidance on the regional changes only.

2.2.2 Recent sea-level change

Measurements of sea-level changes over the last two centuries have come primarily from long-term data from tide gauges mounted on land. The longest records suggest that the rate of rise of global sea levels began to increase from around the early to mid-1800s after relatively stable sea level in the preceding century. Tide gauges provide measurements of *relative* sea-level rise. Defining *absolute* sea-level change from such data is difficult owing to their limited spatial distribution (they are located around continental margins and dominantly in the northern hemisphere), and because of vertical land movements (which are often not accurately quantified).

Tide gauge data have been supplemented since 1993 with satellite altimeter data from the TOPEX/Poseidon and Jason-1 satellites. These satellites provide a recurring measurement of sea levels along a ground track every 10 days between the latitudes 66ºS to 66ºN.

The *Fourth Assessment Report* reconfirmed the best estimate rates of 20th-century sea-level rise summarised previously in the *Third Assessment Report*. Table 2.1 reproduces these estimates from the Fourth Assessment Report. The key advance since the Third Assessment is the ability to now balance the global sea-level 'budget', accounting for the various processes that contribute to sea-level rise. At the time of the Third Assessment, there was still a substantial unexplained gap between what was known to be contributing to the linear sea-level rise up to end of last century and the actual measured rise (which was higher).

Table 2.1: Estimated rates of global mean sea-level rise for different periods over the 20th century summarised within the Fourth Assessment Report[20]

Period	Mean rate of sea-level rise	Notes
20th century	1.7 (1.2 to 2.2) mm/yr	
1961–2003	1.8 (1.3 to 2.3) mm/yr	
1993–2003	3.1 (2.4 to 3.8) mm/yr	Whether this faster rate reflects decadal variability or an increase in the longer-term trend (or both) is unclear.

There is less certainty yet whether an acceleration in global mean sea-level rise has begun. Using reconstructed global mean sea levels from 1870 to 2004, a small acceleration of sea-level rise of 0.013 ± 0.006 mm per year over the 20th century has been observed.[21] If this rate of acceleration remained constant, this factor alone would result in a mean increase in sea level of between 0.28 m and 0.34 m for 1990–2100 (compared with a rise of 0.12–0.22 m if the observed linear rate over the 20th century continued without the acceleration). However, this rate of acceleration is expected to increase (see next section).

In New Zealand, tide gauge records from our four main ports average out to a linear rise in relative mean sea level (with respect to the land surface) of 1.6 mm per year (or 0.16 m per century) over the 20th century[22] (Figures 2.1 and 2.2). Up until 1999 (when the last analysis was done), there was no statistically significant long-term acceleration.

20 IPCC 2007c: Chapter 5.

21 Church and White 2006.

22 Hannah 2004.

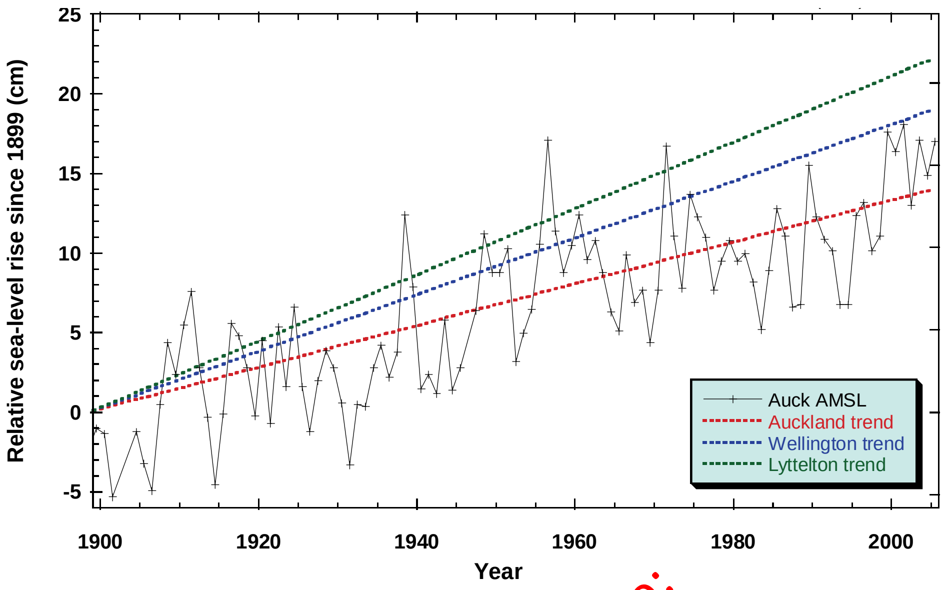

Figure 2.1: Annual mean sea-level data from the Port of Auckland (Waitemata Harbour) up to 2005, which represents the longest, most consistent record in New Zealand. Trend lines in *relative* sea-level rise since 1899 were calculated from data measured at Auckland (1899–1999), Wellington (1899–2001 with gaps), Lyttelton (1901–2001 with gaps). Sources: Hannah 2004; Ports of Auckland Ltd unpublished; NIWA unpublished.

Sea level is also measured at about 35 other gauges around New Zealand by various agencies such as port companies, NIWA, regional councils and territorial authorities. Unfortunately, most of these have digital records of less than 10 years' duration – too short to allow any valid statement to be made on local variations in sea-level trends. However, a medium-length record of 33 years at Mt Maunganui (Moturiki) shows that sea level in the Bay of Plenty is responding in a similar way to that recorded at the Auckland gauge.[23]

These New Zealand rates of rise are relative to the landmass on which the tide gauges are mounted. To extract the absolute sea-level rise for the New Zealand region, information is required on the vertical land rise or subsidence over the term of the record. Quantifying vertical land motion is difficult because:

- differential movement of the gauge facility must be determined from regular accurate surveying back to a 'stable' benchmark representative of the landmass
- incremental or sudden changes due to tectonic movements need to be isolated from continuous 'creep' of the landmass
- measuring changes in vertical movements at each location requires either regular, but expensive, high-order survey traverses of primary benchmarks in a region, or continuous Global Positioning System (GPS) monitoring with a GPS receiver at the gauge site. The latter is being undertaken by GeoNet,[24] but will require around 10 years of data before long-term (decadal) trends can be evaluated.

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23 Bell et al 2006.

24 www.geonet.org.nz/resources/gps (23 April 2008).

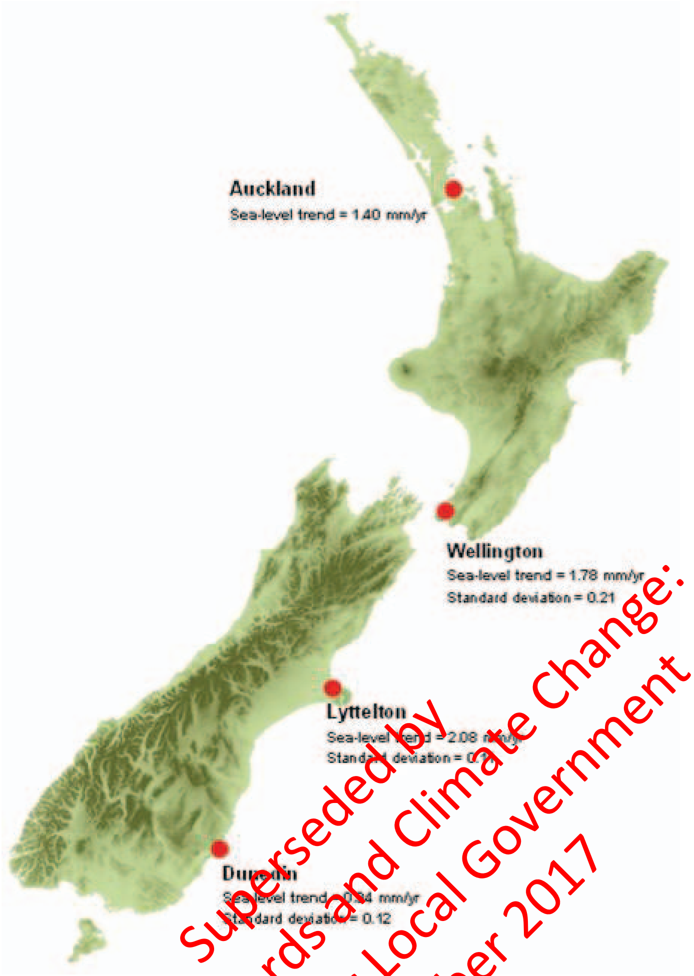

Figure 2.2: Linear trends in relative sea-level derived from New Zealand's four long-term port records for data up to 1998 (Dunedin), 2006 (Auckland) and 2001 (Wellington and Lyttelton). Corrections to mean annual sea level have been made for datum shifts, nodal tides (8.8- and 18.6-year tides) and annual pressure and temperature differences. The lower rate of rise for Dunedin is due to the low quality of the data and poor wharf stability, so less weight is given to this value in deriving the New Zealand average rate of rise. Sources: Hannah 2004; NIWA (for the update to 2006 for Auckland).

In the interim, crustal model estimates of regional vertical movements of the land due to isostatic adjustment for New Zealand suggest an average rise of around 0.5 mm per year.[25] Adding this to the average relative sea-level rise for New Zealand of 1.6 mm per year suggests the eustatic (or absolute) sea-level rise is around 2.1 mm per year. This is close to the observed global average sea-level rise of 1.7 ± 0.5 mm per year (Table 2.1) over the 20th century.

Within a few more years, there should be sufficient data from the monitoring of ground motion, from a combination of local levelling and a national network of stations tracking the GPS satellites. This will provide a more definitive separation of vertical land motion from absolute sea-level rise. However, the consistency of the trends in relative sea level between the sites (excluding Dunedin, where wharf and reclamation stability is a factor) suggests the differential ground motion between sites, if it exists, will be relatively small.

2.2.3 Global sea-level change to the end of this century

Sea levels will continue to rise over the 21st century and beyond, primarily because of thermal expansion within the oceans and the loss of ice sheets and glaciers on land.[26]

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25 Hannah 2004.

26 IPCC 2007c: Chapter 10.

The basic range of projected sea-level rise that was estimated in the Fourth Assessment Report is for a rise of 0.18–0.59 m by the decade 2090–2099 (mid-2090s) relative to the average sea level over 1980–1999 (Figure 2.3). This range is based on projections from 17 different global climate models for six different future emission scenarios.

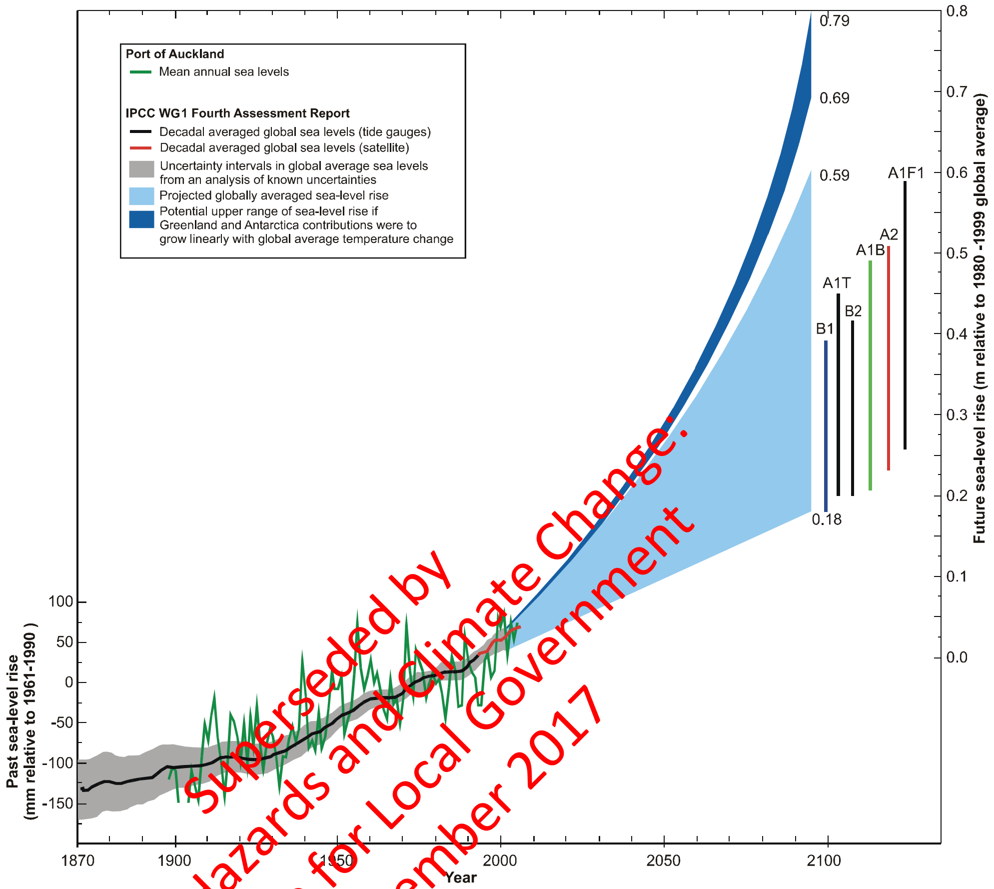

Figure 2.3: Projections of global mean sea-level rise to the mid-2090s. The black line and grey shading on the left-hand side show the decadal averaged global sea levels and associated uncertainty, respectively, as measured by tide gauges throughout the world. The red line is the decadal averaged sea levels as measured by satellites since 1993. The green line is the mean annual relative sea level as measured at the Port of Auckland since 1899. The light blue shading shows the range in projected mean sea level out to the 2090s. The dark blue line shows the potential additional contribution from Greenland and Antarctica Ice Sheets if contributions to sea-level rise were to grow linearly with global average temperature change. The vertical coloured lines on the right-hand side show the range in projections from the various GCMs for six emission scenarios.

The IPCC developed 40 different future emissions pathways or scenarios (referred to as the 'SRES scenarios'), which fall into four families (A1, A2, B1, B2). Each family envisages a different future, with different levels of technological development and global economic integration. There are six SRES 'illustrative' scenarios, each broadly representative of their 'family' and spanning a reasonable range of plausible futures. A more detailed description of these scenarios is contained in Appendix 1 of MfE (2008a).

The ranges for each emission scenario are 5% to 95% intervals characterising the spread of GCM results (bars on the right-hand side of Figure 2.3). However, these projections exclude uncertainties in carbon cycle feedbacks and the possibility of faster-than-expected ice melt from the Greenland and Antarctica Ice Sheets.

The basic set of projections (light blue shading in Figure 2.3) includes sea-level contributions due to ice flow from Greenland and Antarctica remaining at the rates observed for 1993–2003. But it is expected that these rates will increase in the future, particularly if greenhouse gas emissions are not reduced. Consequently, an additional 0.1–0.2 m rise in the upper ranges of the emission scenario projections (dark blue shading) would be expected if these ice sheet contributions were to grow linearly with global temperature change. An even larger contribution from these ice sheets, especially from Greenland, over this century cannot be ruled out.

It is important to note that the range of uncertainty in projections of future sea-level rise is largely related to different future scenarios of greenhouse gas emissions (based on scenarios of different future socio-economic profiles, energy use, transport) and the differences in projections from the various climate models used for each emission scenario. In terms of sea-level rise, all emission scenarios suggest a rise of at least 0.26 m to 0.38 m by the 2090s relative to the average for 1980–1999. However, constraining sea-level rise to within this range will require substantial reductions in greenhouse gas emissions very soon.

2.2.4 Comparison with the Third Assessment Report

Although expressed differently, the global sea-level rise projections in the Fourth Assessment Report are not all that different from those contained in the Third Assessment Report of 2001. The Third Assessment Report suggested a mean sea-level rise of between 0.09 m and 0.88 m by 2100, relative to 1990 for the full range of emission scenarios and GCM uncertainty (Figure 2.4). Subsequent improvements in the information available on global sea-level changes and land-ice storage gathered by satellites, along with improvements in the computer models used, have resulted in a reduced uncertainty range for the latest projections.

The major differences are in:

- the way the timeframes for the projections have been presented (2100 relative to 1990 in the Third Assessment Report, compared with 2090s relative to the average for 1980–1999 in the Fourth Assessment Report)
- the caveat in the Fourth Assessment Report of an additional 0.1–0.2 m in the upper ranges of the emission scenario projections if melting of the Greenland and West Antarctic Ice Sheet were to increase linearly with global average temperature change over this century
- that the Fourth Assessment Report does not assess the likelihood, nor provide a best estimate or upper bound for sea-level rise.

The Fourth Assessment Report is not suggesting that the projections for sea-level rise have reduced since publication of the Third Assessment Report.

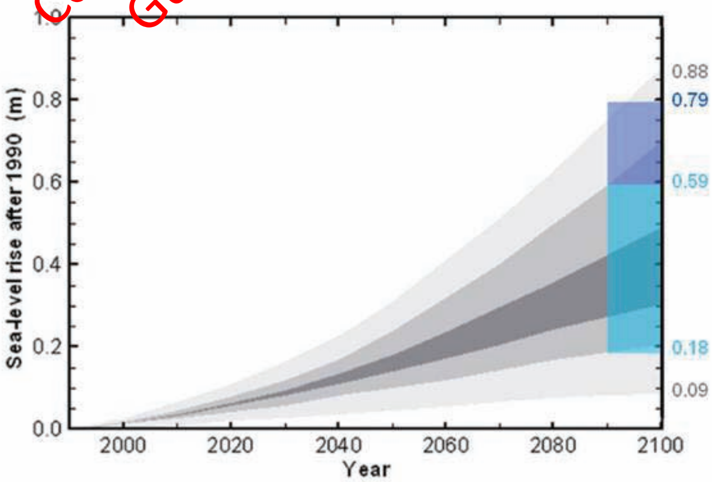

Figure 2.4: Comparison between sea-level rise projections from the Third Assessment Report (grey shading) and the Fourth Assessment Report (light blue shading shows the projection for the 2090s, dark blue shading shows the potential additional contribution from Greenland and Antarctica Ice Sheets if contributions to sea-level rise were to grow linearly with global average temperature change over this century).

2.2.5 Ocean sub-region departures from global averages

Ocean sub-region departures will occur from the global mean sea level owing to regional variations in thermal expansion rates and changes in oceanic circulation within and across the world's oceans.

Substantial spatial variation in sea-level rise can be seen in all the global climate models but the geographical patterns between different models are not generally similar in detail. However, more of the GCMs show an increase above the global mean in the New Zealand region, than a decrease.[27]

Figure 2.5 shows an ensemble mean from 16 GCMs forced with the A1B emission scenario[28] which suggests sea-level could be around 0.05 m higher relative to the global mean. However, further work is required to more accurately define the potential magnitude of any regional change around New Zealand relative to the global mean.

2.2.6 Local variability in New Zealand

Variations in vertical land movements around New Zealand will also influence relative sea-level rise around New Zealand. At a national scale, the sea-level records over the last century suggest that this influence may be relatively small. A system for the continuous measurement of vertical land movements has been in place since around 2002, but its period of operation is too short to allow any firm conclusions to be drawn on long-term regional movements. Approximately five more years of data collection is required. Abrupt tectonic movements that may occur after a major earthquake are not able to be forecast and, therefore, are not considered in planning for sea-level rise.

While vertical landmass movements are not yet definitive, in the end it is relative sea-level rise (as measured directly by stably-mounted sea-level gauges) for a particular region or locality that is of prime importance when considering the coastal impacts of climate change.

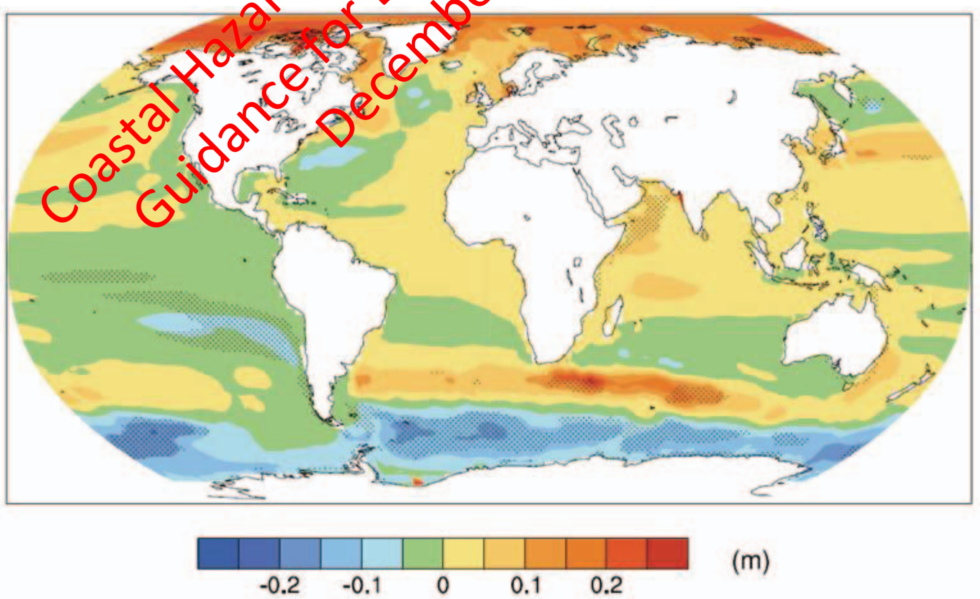

Figure 2.5: Local sea level change (m) due to ocean density and circulation change relative to the global average during the 21st century. Positive values indicate greater local sea level change than the global change. Values have been calculated as the difference between averages for 2080–2099 and 1980–1999, as an ensemble mean over 16 GCMs forced with the 'SRES A1B scenario'. Stippling denotes regions where the magnitude of the multi-model ensemble mean divided by the multi-model standard deviation exceeds 1.0. Source: Figure 10.32 in IPCC 2007c.

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27 Gregory et al 2001.

28 IPCC 2007c: Chapter 10.

2.2.7 Future sea-level change beyond the end of this century

Sea level will not stop rising at 2100, but will continue to rise for many centuries into the future. Given the permanence of infrastructure and development of entire subdivisions, consideration will need to be given for timeframes beyond 2100 to address sustainability and inter-generational resource management issues.

Future sea-level rise will consist of both a continued response to past emissions (due to the long lag times in the deep ocean's heating response to climate warming) and to future emissions (Figure 2.6). This lag response, known as the 'present future *commitment* to sea-level rise', will result in sea levels continuing to rise for many centuries even if emissions were stabilised today. Indeed, sea levels to about 2050 are relatively insensitive to changes in emissions over this timeframe (due to the inherited commitment), but future changes and trends in emissions become increasingly important in determining the magnitude of sea-level rise beyond 2050.[29] Figure 2.7 provides some indication of the total amount of sea-level rise that could be expected from thermal expansion (again excluding ice melting) for different levels of future carbon dioxide concentrations at stabilisation.

Stabilisation of future emissions will also play an important role in determining the potential contribution of the two major uncertainties associated with longer-term sea-level rise, that of the Greenland and West Antarctic Ice Sheets. Catastrophic contributions to sea-level rise from collapse of the West Antarctic Ice Sheet or the rapid loss of the Greenland Ice Sheet are not considered likely to occur in the 21st century, based on currently understanding (Box 2.2). However, the occurrence of such catastrophic changes becomes increasingly more likely as greenhouse gas concentrations continue to rise.

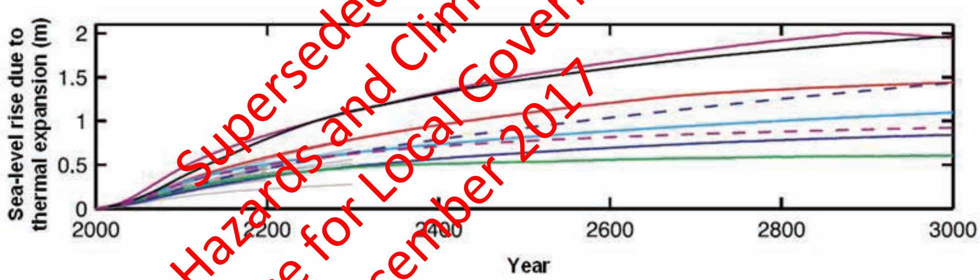

Figure 2.6: Sea-level rise beyond 2100 attributable to thermal expansion only (ie, excluding ice melting), calculated by eight climate models to the year 3000 for the A1B emission scenario. This scenario assumes that carbon dioxide equivalent concentrations[30] rise over this century to 700 ppm before stabilising beyond 2100. Source: adapted from Figure 10.34 in IPCC 2007c.

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29 Nicholls and Lowe 2005.

30 Carbon dioxide equivalent concentration is used to compare the effect from various greenhouse gases. It is the concentration of CO_2 that would cause the same amount of radiative forcing as a given mixture of CO_2 and other greenhouse gases. Source: IPCC 2007a.

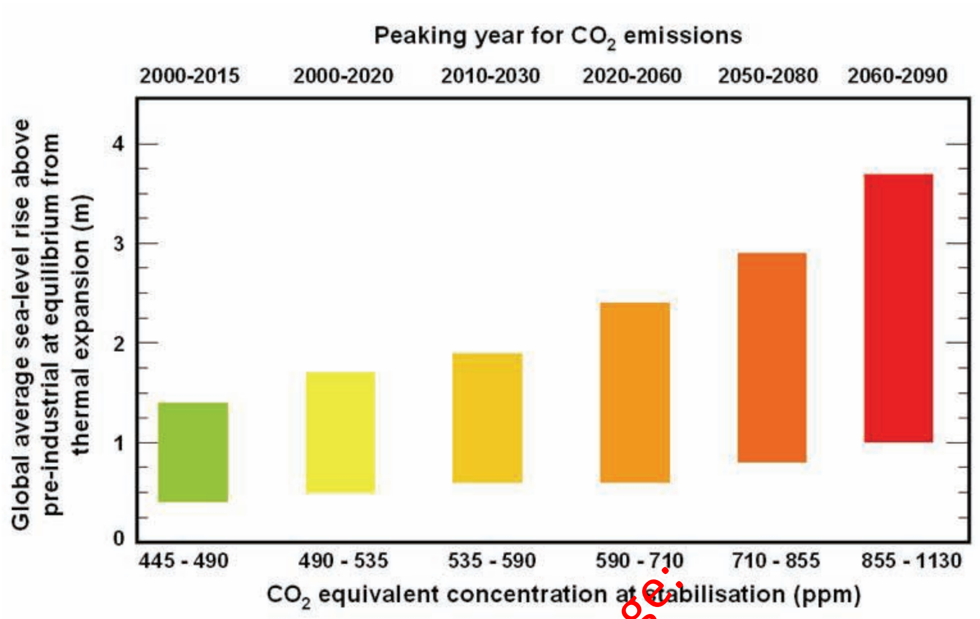

Figure 2.7: Commitment to sea-level rise beyond 2100, showing long-term equilibrium global average sea-level rise above pre-industrial levels for a range of different carbon dioxide stabilisation concentrations and assumed time periods for peaking carbon dioxide equivalent emissions. Again, these sea-level rise projections consider thermal expansion only; any contributions particularly from the Greenland and West Antarctic Ice Sheets will be additional to those shown. Source: adapted from Table 5.1 in IPCC 2007e.

Box 2.2: Loss of the Greenland and West Antarctic Ice Sheets and implications for sea-level rise (adapted from: IPCC 2007c: Chapter10, 'Frequently asked questions')

Model simulations and observations indicate that warming in the high latitudes of the Northern Hemisphere is accelerating the melting of the Greenland Ice Sheet, and that increased snowfall due to the intensified hydrological cycle is unable to compensate for this melting. As a consequence, the Greenland Ice Sheet may shrink substantially in the coming centuries. Moreover, results suggest that there is a critical temperature threshold beyond which the Greenland Ice Sheet would be committed to disappearing completely, and that threshold could be crossed in this century. However, the total melting of the Greenland Ice Sheet, which would raise global sea level by about 7 m, is a slow process that could take many hundreds of years to complete.

Recent satellite and *in situ* observations of ice streams behind disintegrating ice shelves highlight some rapid reactions of ice sheet systems. This finding raises new concern about the overall stability of the West Antarctic Ice Sheet, its collapse would trigger another 5–6 m of sea-level rise. These ice streams appear buttressed by the shelves in front of them. It is currently unknown whether a reduction or failure of this buttressing of relatively limited areas of the ice sheet could actually trigger a widespread discharge of many ice streams and, hence, a destabilisation of the entire West Antarctic Ice Sheet. Ice sheet models are only beginning to capture such small-scale dynamical processes that involve complicated interactions at the ice/ground interface (eg, friction, lubrication) and at the ocean boundary. Therefore, no quantitative information is available from the current generation of ice sheet models regarding the likelihood or timing of such a trigger.

2.2.8 Science literature subsequent to the Fourth Assessment Report

Since the cut-off point for science publications to be considered within the IPCC Fourth Assessment Report process, further scientific papers have been published. These add to the array of information on potential future sea-level rise over this century and beyond. Relevant to the guidance provided in the next section, are recent publications that relate to:

- improved quantification and confirmation that the Antarctic ice cap is shrinking (ie, losing mass).[31] This is due to ongoing and past acceleration of ice loss from glacier melting and discharge in parts of Antarctica. Overall, across the ice cap, recent ice loss is greater than the gain from snowfall. However, is as yet unclear whether this trend of increased discharge of ice from Antarctica is a response to recent climate change and will continue in to the future, or whether it is a rapid short-term adjustment that will reduce in the near future.

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[31] For example Rignot et al 2008; Shepherd and Wingham 2007; Bamber et al 2007.

- higher estimates of sea-level rise over the 21st century than suggested by the IPCC Fourth Assessment Report. These are based on a semi-empirical technique that estimates sea-level rise indirectly from changes in global-average near-surface temperature.[32] The Rahmstorf study concluded that a sea-level rise of between 0.55 m and 1.25 m is possible by 2100 (0.50 m to 1.40 m with statistical error). This was followed by the Horton study which concluded a rise of between 0.54 m and 0.89 m by 2100 (0.47 m to 1.0 m with statistical error).

  The methodology used in both these studies was based on a relationship between changes in global near-surface temperatures and sea-level between 1880 and this present decade. One half of the dataset was used to derive the relationship with the other half used to verify the predictions based on the relationship. Based on this relationship, and using temperature projections from various GCMs, sea-level rise projections were estimated. The global-average temperature projections out to 2100 used by Rahmstorf are based on IPCC Third Assessment Report GCM results for all six emission scenarios, whereas Horton et al, used global-averaged temperatures from IPCC Fourth Assessment Report GCM results, but for only three emission scenarios (B1, A1B, A1). For these three emission scenarios, sea-level rise projections by Horton et al, are around 0.1m lower than for the corresponding projections estimated by Rahmstorf.

  Temperature projections used are based on GCM simulations which do not include all processes which may influence future temperature such as carbon-cycle feedbacks. Both studies assume the historical relationship between temperature change and sea-level rise is valid to the end of this century. Implicitly this assumes that the two main components contributing to sea-level rise (thermal expansion and glacier/ice cap losses) continue to contribute in the same relative proportion as they have done since 1880. However, it is likely that ice loss will increasingly dominate over thermal expansion if greenhouse gas concentrations continue to rise particularly with the possibility of non-linear ice dynamics. The approach of using surface temperature projections to estimate future sea-level rise has resulted in substantial scientific discussion; as yet no scientific consensus has been reached over the validity of this methodology.

2.3 Future sea-level rise guidance

In its Fourth Assessment Report, the IPCC has found that "Because understanding of some important effects driving sea-level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea-level rise". While there are uncertainties associated with the science around sea-level changes, national and local governments and individuals must continue to make decisions that either implicitly or explicitly make assumptions about what this rise will be over a planning timeframe.

Adopting a risk assessment process is advocated in this Guidance Manual (Chapters 4 and 5): it is a useful approach for incorporating uncertainties such as those associated with future sea-level rise.

This requires a broader consideration of the potential impacts or consequences of sea-level rise on a specific decision or issue. Rather than define a specific climate change scenario or sea-level rise value to be accommodated, it is recommended in this Guidance Manual that the magnitude of sea-level rise accommodated (within any particular issue or decision, where it is a factor), is based on the acceptability of the potential risk. In other words, the decision on what sea-level rise value to accommodate is based on a *balanced consideration* between:

[32] Rahmstorf 2007; Horton et al 2008.

- the possibility of particular sea levels being reached within the planning timeframe or design life
- the associated consequences and potential adaptation costs, and
- how any residual risks would be managed for consequences over and above an accepted sea-level rise threshold, or if the accommodated sea-level rise is underestimated.

This is shown conceptually in Figure 2.8.

Where sea-level rise is a potential factor in a decision making process, this Guidance Manual recommends that sea-level rise considerations within such a risk assessment are based on the IPCC Fourth Assessment Report sea-level rise estimates, including consideration of the potential consequences from higher sea-levels due to factors not included in the current global climate models.[33]

To provide some guidance on this assessment process, this Guidance Manual recommends for planning and decision timeframes out to the 2090s (2090–2099):

1. *a **base** value sea-level rise of **0.5 m relative to the 1980–1999 average**[34] should be used,* **along with**
2. ***an assessment of the potential consequences from a range of possible higher sea-level rises** (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise* **of at least 0.8 m** *relative to the 1980–1999 average. Guidance is provided in Table 2.2 to assist this assessment.*

For longer planning and decision timeframes where, as a result of the particular decision, future adaptation options will be limited, an allowance for sea-level rise of **10 mm per year beyond 2100** is recommended (in addition to the above recommendation).

33 Such factors not included in the GCM models relate to uncertainties associated with increased contribution from the Greenland and Antarctica ice sheets, carbon cycle feedbacks, and possible differences in mean sea level when comparing the New Zealand region with the global average.

34 Assuming an average rate of mean sea-level rise of 1.6 mm/yr, sea levels have risen on average by about 27 mm between the midpoint (1990) of the 1980–1999 IPCC reference timeframe and 2007. This should be accounted for when using recent observed sea level measurements.

Table 2.2: Summary of sea-level rise projections and contributions, uncertainties and recent (2007–2008) science publications to guide the risk assessment process

Sea-level rise factors	Projected sea level rise by 2090s (2090–2099) (m)
IPCC Fourth Assessment: Model projected sea level rise based on 6 emission scenarios and accounting for:	0.18–0.59 m
• Thermal expansion	
• Land glaciers and ice caps	
• Greenland and Antarctic ice sheets contributing at the same rate as over the period 1993–2003.	
IPCC Fourth Assessment: Consideration of additional contributions to the above:	
• Greenland and/or Antarctic Ice Sheets if contributions to sea-level rise were to grow linearly with global average temperature change	0.1–0.2 m
• Potential differences in the NZ region from the global mean sea-level rise due to ocean density and circulation change, based on an ensemble mean from 16 GCMs forced with the A1B emission scenario.	Up to 0.05 m
Consideration of additional contributions / recent science in defining the potential full range of sea level:	
• Climate carbon cycle feedbacks	Positive likely, magnitude unknown
• Further differences in the New Zealand region from the global mean sea-level rise	Direction unknown, magnitude unknown
• Accelerated contribution from Greenland and/or Antarctic Ice Sheets	Positive, magnitude unknown
○ Increased evidence of Antarctic losing mass faster than considered in IPCC (eg, Rignot et al 2008; Shepherd and Wingham 2007)	
• Higher sea-level rise ranges in the literature subsequent to IPCC AR4:	
○ Rahmstorf (2007) based on GCM TAR simulations of all six emission scenarios	**By 2100:** 0.55–1.25 m (0.50–1.40 m with statistical error)
○ Horton et al (2008) based on GCM AR4 simulations of three emission scenarios (B1, A1B and A2)	**By 2100:** 0.54–0.89 m (0.47–1.0 m with statistical error)
○ Hansen (2007): Commentary that sea-level rise likely to rise more than 1 m this century if greenhouse gas emissions follow an IPCC business-as-usual scenario.	> 1 m by end of century

Table 2.3 summarise these baseline sea-level rise recommendations to guide the risk assessment processes for shorter planning and decision timeframes over this century.

Table 2.3: Baseline sea-level rise recommendations for different future timeframes

Timeframe	Base sea-level rise allowance (m relative to 1980–1999 average)	Also consider the consequences of sea-level rise of at least: (m relative to 1980–1999 average)
2030–2039	0.15	0.20
2040–2049	0.20	0.27
2050–2059	0.25	0.36
2060–2069	0.31	0.45
2070–2079	0.37	0.55
2080–2089	0.44	0.66
2090–2099	0.50	0.80
Beyond 2100	10 mm/year	

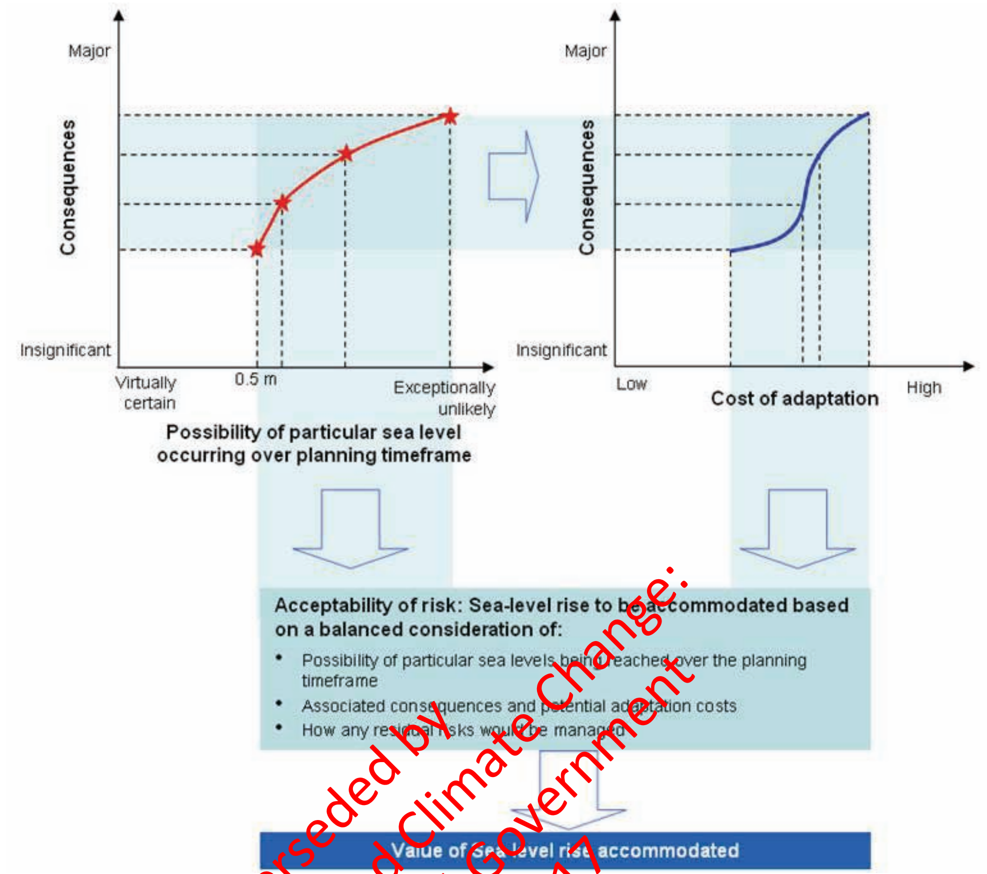


Figure 2.8: Conceptual representation of accommodating sea-level rise (SLR) based on an understanding and balanced consideration between the possibility of a particular sea-level rise occurring, the potential consequences and associated adaptation costs, and the potential residual risks associated with the accommodated sea-level rise being exceeded.

2.4 Impacts of climate change on other physical drivers influencing coastal hazards

Since the Third Assessment Report (2001), there has been little progress, both globally and in New Zealand, in understanding the effects that climate change is having, and will have, on the other drivers of coastal hazards such as tides, storms, waves, swell and coastal sediment supply. Some indicative guidance on the possible effects on these drivers is provided below.

2.4.1 Tide range and relative frequency of high tides

FS 4, 5

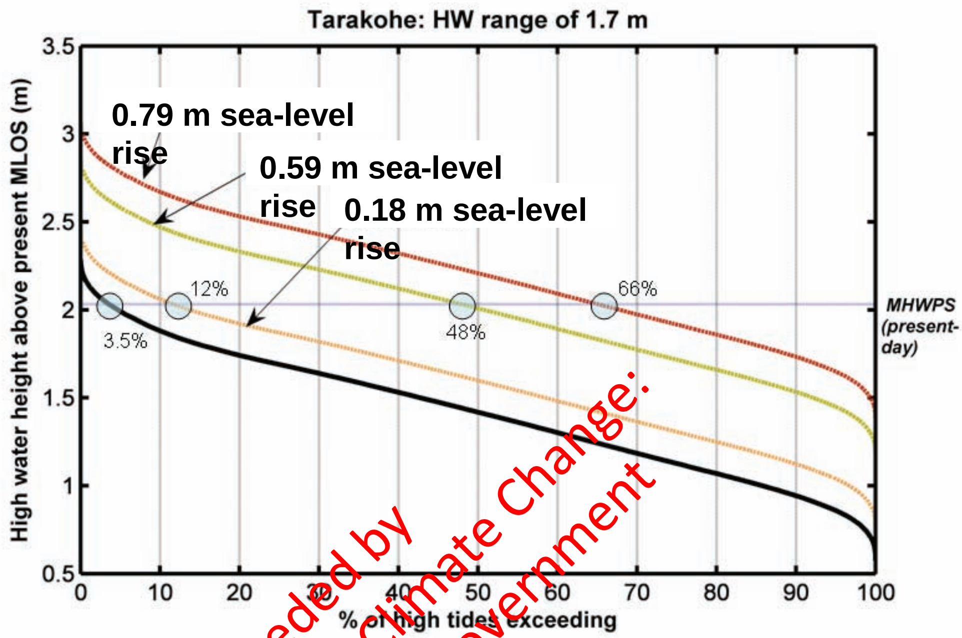
Deep ocean tides will not be directly affected by climate change. However, tidal ranges (and the timing of high and low water) in shallow harbours, river mouths and estuaries could be altered by changes in channel depth. These changes could occur through either the deepening of channels where sea-level rise exceeds the rate of sediment build-up, or conversely by the formation of shallower channels where rates of sediment build-up (from increased run-off due to more intense rainfall events) exceeds sea-level rise.

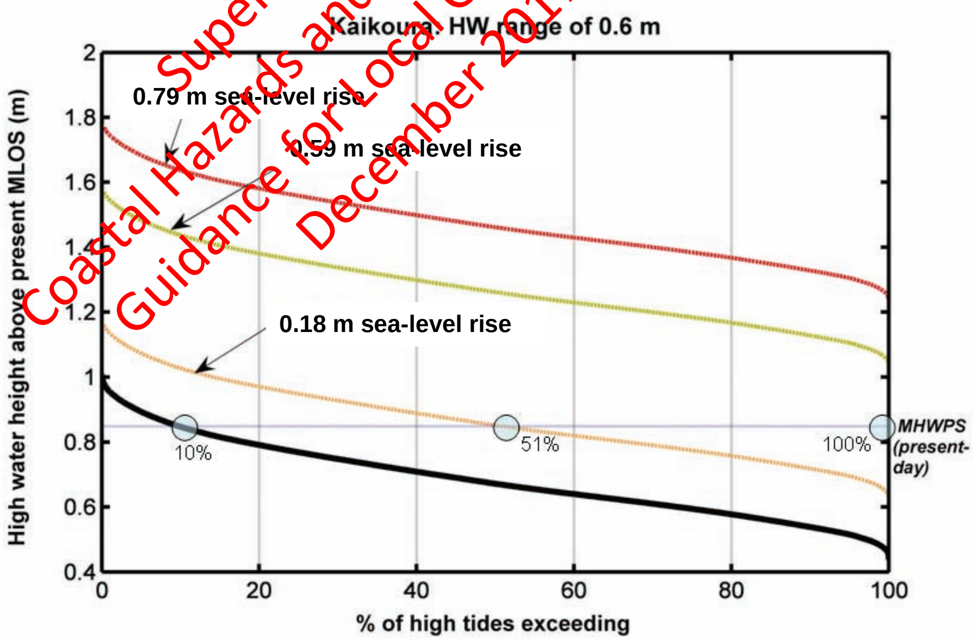
Further, around the New Zealand coast, the relative frequency of high tides that exceed a given land level will change depending on the relative magnitude of tide range around New Zealand (Box 2.3). Problems will be exacerbated for coastlines with smaller tidal ranges in proportion to sea-level rise, where high tides will more often exceed current upper-tide levels, thus allowing more opportunity to coincide with storms or large swell.[35] For the central east coast and Cook Strait / Wellington areas, this means that sea-level rise will

[35] Bell 2007.

have a greater influence on storm inundation and rates of coastal erosion than it will on coastal regions with relatively larger tidal ranges (eg, west coast).

Box 2.3: Future frequency of high tides





The plots above show a comparison between the frequency of high tides at Tarakohe in Golden Bay, which has a high tide range of 1.7 m (top), and Kaikoura on the east coast of the South Island, which has a smaller high tide range of 0.6 m (bottom). For each plot, the heavy black line shows the percentage of high tides that exceed certain levels above Mean Level of the Sea (MLOS) for present-day sea levels. If we consider the Mean High Water Perigean-Spring (MHWPS) level, at Tarakohe this is currently exceeded by about 3.5% of high tides, and at Kaikoura by about 10% of high tides. The coloured lines show this occurrence with future sea-level rises of 0.18 m (buff), 0.59 m (green) and 0.79 m (red). For a sea-level rise of 0.18 m, a present-day MHWPS level would be exceeded by 12% of the high tides at Tarakohe but by 51% of the high tides at Kaikoura. For sea-level rises of 0.59 m and 0.79 m, present day MHWPS level would be exceeded by 48% and 66% of high tides, respectively, at Tarakohe, but at Kaikoura every high tide would exceed present day MHWPS.

In a planning context, the present-day level of Mean High Water Spring (ie, the jurisdictional boundary) will be exceeded much more frequently by high tides in the future on sections of the coast where the tidal range is lower, than on sections where the tidal range is higher.

2.4.2 Storms

FS 1, 2, 4, 7, 10

Changes in storm conditions will affect coastal margins around New Zealand through possible changes in the frequency and magnitude of storm surges and storm tides, and in swell and wave conditions (see next sections). Whilst it is expected that the intensity of severe storms may increase, there remains uncertainty associated with how future climate change will influence the frequency, intensity and tracking of tropical cyclones (in the Pacific tropics), ex-tropical cyclones (which track down to the temperate regions such as New Zealand), extra-tropical cyclones (generated in the mid-Tasman) and low-latitude storms.

The Fourth Assessment Report[36] summarised the present knowledge of future changes to tropical and extra-tropical cyclone conditions, where there is confidence in the direction of the projected change based on current scientific evidence (Table 2.4).

Table 2.4: Current known changes in global future tropical and extra-tropical cyclone conditions (adapted from Table 11.2 in IPCC 2007c).

Change in phenomena	Projected change
Tropical cyclones:	
• Increase in peak wind intensities	• Likely over most tropical cyclone areas
• Increase in mean and peak precipitation intensities	• Likely over most tropical cyclone areas
• Changes in frequency of occurrence	• Decrease in number of weak storms but increase in number of strong storms (medium confidence based on some GCM projections) • Globally averaged decrease in number, but specific regional changes that will depend on sea-surface temperature change (medium confidence based on several climate model projections)
Extra-tropical cyclones:	
• Changes in frequency and position	• Likely decrease in the total number of extra-tropical cyclones • Likely slight poleward shift of storm track and associated precipitation, particularly in winter
• Change in storm intensity and winds	• Likely increased number of intense cyclones and associated strong winds (particularly in winter over the South Island)

Global climate models are presently most suited for considering changes in large-scale dynamics of the atmosphere–ocean system. Hence, there is a reasonable level of confidence that atmospheric pressure gradients during winter will increase over the South Island, implying an increase in the mean westerly wind component of flows across New Zealand expected by 2090s. Climate model downscaling to New Zealand shows this shift in bias to winds more often coming from a westerly direction but overall increased wind speeds in all directions may not change significantly.[37] However, in general the spatial resolution of GCMs is less suited to assessing variability in more transient phenomena such as intense storms, although progress is being made in addressing such issues.

[36] IPCC 2007c: Chapter 11.

[37] MfE 2008a.

The limited assessment of changes in tropical cyclone behaviour in the Southwest Pacific, provides no clear picture of changes in frequency and tracking, but indicates increases in intensity. Because El Niño-Southern Oscillation (ENSO) fluctuations have a strong bearing on tropical cyclone behaviour, uncertainties associated with climate change impacts on ENSO compound the uncertainties associated with changes in tropical cyclones.

2.4.3 Storm surge and storm tides

FS 4, 7

From the viewpoint of coastal flood and erosion hazards, any change in the magnitude or frequency of storm-tide levels is of greater concern than a rise in mean sea level. Storm-tide levels depend on the magnitude and frequency of storm surges and the timing of the storm surge with high tides.

At a global level, there have been few studies of long-term changes in extreme (high) sea levels.[38] Most have found considerable variation from year to year associated with periods of increased storminess; there is little evidence (yet) for an increase in storm-tide levels relative to the underlying upward trend in mean sea level.

Changes in storm surge (produced by low barometric pressure and adverse winds) will depend on changes in frequency, intensity and/or tracking of atmospheric low-pressure systems, and occurrence of stronger winds. Changes in the pattern of tracking of low-pressure systems, ex- and extra-tropical cyclones may also have an effect on extreme water levels due to the complex way that they interact with the continental shelf and coastline.

Changes, particularly in intensity, of individual storm conditions are likely. Much less certain is how these changes translate into changes in the magnitude or frequency of storm surges, and hence how storm-tide levels will change. Until further research and monitoring suggests otherwise, it is assumed that storm-tide levels will rise at the same rate as mean sea-level rise.

Recommendation: Assume that storm-tide (ie, extreme) levels will rise at the same rate as the rise of mean sea level – until more certainty emerges on likely changes to wind and central pressures associated with storm systems.

2.4.4 Wave climate

FS 10

Changes in wind and atmospheric pressure patterns, in storms and in cyclones around New Zealand and the wider Southwest Pacific and Southern Ocean regions also have the potential to change the wave climate experienced around New Zealand. Changes in wave climate (mean and extreme wave heights and prevailing directions) can influence the occurrence of coastal inundation though wave run-up and overtopping of coastal barriers, and can significantly influence the patterns and rates of coastal erosion.

FS 11

In harbour and estuary locations protected from conditions associated with open-ocean swell waves, changes in the occurrence and magnitude of wave conditions will be directly related to changing wind climate over New Zealand and, in shallow-water locations, increases in sea levels. Such changes will be highly localised and will require specific studies to quantify the changes in wave climate. For example, modelling of the wave climate of the city frontage of Wellington Harbour suggested that an increase in wave height of up to 15% was possible by 2050 and up to approximately 30% by 2100.[39]

On open-coast locations, changes in the swell wave climate (ie, wave conditions generated within the wider South Pacific and Southern Oceans) will dominate.

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[38] IPCC 2007c: Section 5.5.2.6.

[39] Gorman et al 2006.

Regional models of deep-water wave climate of the Southwest Pacific[40] have shown that waters off New Zealand have a correlation with the Southern Oscillation Index. In general, there is a slight increase in the average wave heights affecting the southern half of the FS 12 South Island during El Niño phases; on the northeastern coast of the North Island, slightly larger wave conditions occur during La Niña phases. With an increasing westerly wind component, wave climates experienced presently during El Niño phases may provide an indication of general wave climates in the future. However, future wave climate will also depend on changes in storm conditions in the Southwest Pacific and Southern Ocean that generate swell on New Zealand coasts.

Given the lack of present knowledge of how such phenomena (especially swell) may change, little guidance can be given on how wave climate may change and what this may mean for coastal erosion and inundation – other than through specific investigations that include 'what if' scenarios that are consistent with some of the general results from GCMs (Box 2.4). Such an approach may provide an indication of the sensitivity of wave climate to potential changes but will certainly not be definitive.

Type of environment:	Recommendations for 2050–2100:
• Harbour and estuarine coastlines sheltered from oceanic swell	• For wave modelling, assume a 10% increase in the mean westerly wind component[41] over current values.
• Open coast: All of the North Island, Tasman, Marlborough and eastern South Island coastline to Banks Peninsula.	• Assume a 10% increase in the extreme deep-water wave climate (above 1% Annual Exceedence Probability significant wave height). • For nearshore wave modelling, assume also a 10% increase in the mean westerly wind component.
• Open coast: Western and southern coast of the South Island, eastern coast of the South Island south of Banks Peninsula.	• Assume a 10% increase in the westerly component of the deep-water wave climate. • For nearshore wave modelling, assume also a 10% increase in the mean westerly wind component.

2.4.5 Sediment supply to the coast

FS 1 The effects of climate change will also influence both the episodic and mean annual supply of sediment via rivers and streams to the coast. Fluvial sources contribute much of the present-day sediment to many parts of the New Zealand coast.

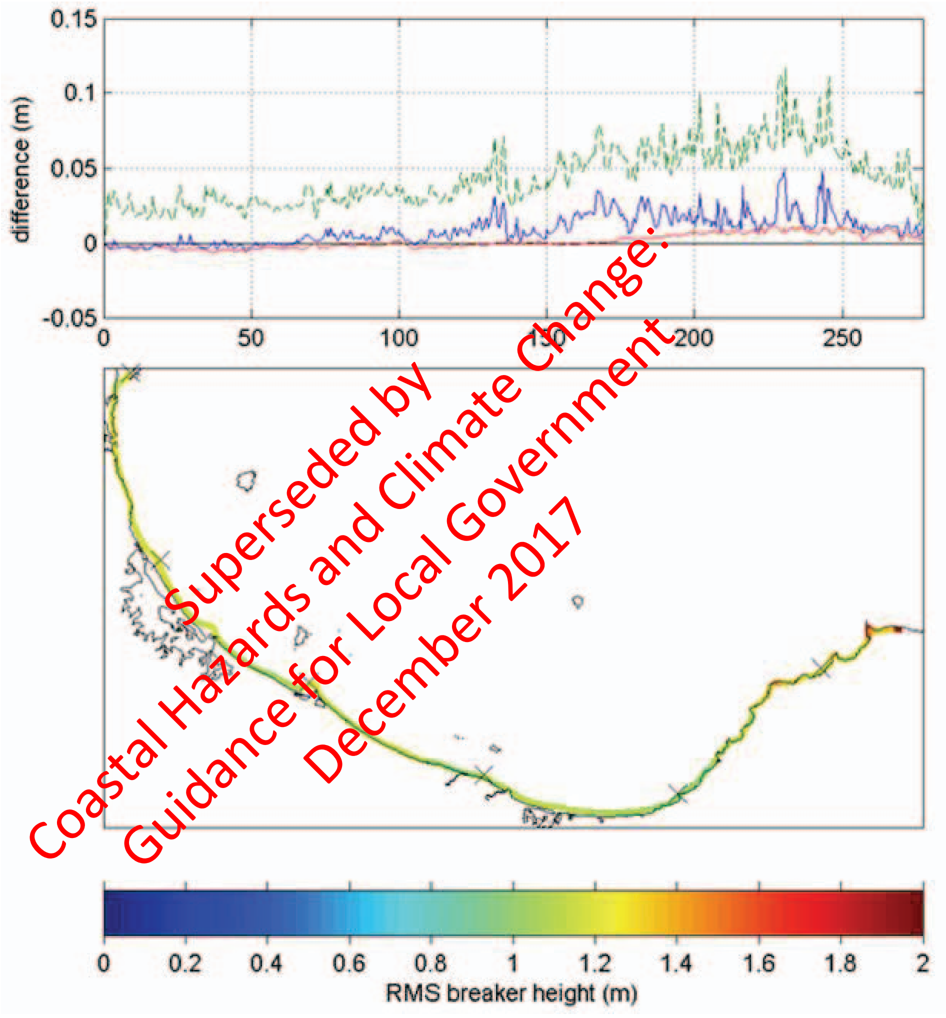
In some situations, climate change could lead to more sediment delivery. For example, changes in rainfall, and increases in rainfall intensities, will increase the potential for soil erosion from catchments – including the potential for landslips – and alter the run-off and river sediment transport capacity. Others changes could lead to less sediment delivery – for example, the likelihood of more droughts in eastern areas (apart from rivers draining the main divide in Canterbury). Hence, the potential for change will vary with location around New Zealand, with changes in the west–east gradient in rainfall (wetter in the west and drier in the east) likely to be a significant factor along with increased rainfall intensities during severe rain storms.

40 Gorman et al 2003.

41 This means an increase in frequency of winds from the westerly sector but not necessarily changes in wind speed.

Assessing changes in sediment supply and what it may mean for specific coastal regions will rely on detailed specific investigations. For example, studies[42] in the Bay of Plenty region estimated that a projected future annual rainfall between a 15% decrease to a 2% increase[43] would result in a 25% reduction to a 3% increase in average annual sediment supply from rivers (Box 2.4). However, for the Bay of Plenty, this change was relatively small compared to large interannual variability in sediment yield, which could vary by over a factor of ten.

Box 2.4: Effects of climate change on mean wave conditions in the Bay of Plenty



Example using a scenario-based approach to assess the potential effects of climate change on wave conditions in the Bay of Plenty based on adjusting wave hindcast data (in a number of different ways) to account for plausible climate change effects.

The figure shows root-mean-square (RMS) breaking wave height along the coast of the Bay of Plenty. Values for the existing climate are plotted in the lower panel in colour-scaled form. The top panel shows changes in values of breaking wave height relative to the present climate for the different assumptions used, which included changes in local winds over New Zealand (red line) and two possible scenarios of changes in swell and local winds (blue and green lines). While the changes in the average (RMS) breaking wave height look relatively small, the compounding effect on other processes such as wave set-up and run-up was significant, especially for adverse storms (see Box 3.1). Crosses in the colour-scaled plot are longshore distance tick marks for every 50 km.

Source: Bell et al 2006; Acknowledgement: Environment Bay of Plenty

42 Bell et al 2006.

43 Based on MfE 2004.

3 Implications for New Zealand’s Coastal Margins

3.1 Introduction

FS 1, 2

Climate change will not create any new coastal hazards, but at many locations it will exacerbate existing coastal erosion or inundation problems. Impacts on New Zealand’s coastal margins due to sea-level rise and possible climate change impacts on other physical drivers that shape the coast will include: increased coastal erosion; more extensive coastal inundation; higher storm surge flooding; increased drainage problems in adjacent low-lying areas; landward intrusion of seawater in estuaries and coastal aquifers; changes in surface water quality, groundwater characteristics and sedimentation; and increases in seawater temperatures (which may affect ecosystems).

The magnitude of the impacts on coastal margins will differ between regions and even between localities within regions. Such impacts will depend on the complex interaction between the localised impacts of climate change on the physical drivers that shape the coast, the natural characteristics of the coast, and the influence that humans have had or are having on the coast.

3.2 Coastal inundation

The frequency, extent and magnitude of coastal (saltwater) inundation will be substantially altered by climate change effects and by interactions between the following drivers:

FS 2, 4

- mean sea-level rise
- long-term sea-level fluctuations
- tide range
- changes to the frequency and magnitude of storm surges
- changes in storminess and wave conditions.

An increase in mean sea level will allow a gradual encroachment of seawater at high tides on low-lying coastal and estuarine land. If not constrained by coastal protection works, the inundations of such low-lying areas will transform them into coastal marsh and they will eventually become a permanent part of the coastal or estuarine system.

FS 7

Episodic inundation will still occur, being caused primarily by storm events coinciding with reasonably high tides. Irrespective of any changes in the frequency or magnitude of storm surges, in storminess or wave conditions, increasing mean sea levels will increase the chance of inundation during such storm events. Specifically:

- for existing areas prone to coastal inundation, climate change means that coastal inundation during storms could become more likely relative to the present day, given the same specific ground level or barrier height. Coasts with smaller tide ranges will be more vulnerable (eg, east coast on both the North and South Islands and Cook Strait / Wellington) than coasts with higher tide ranges
- the extent of the area at risk of inundation may well increase relative to the present day (although this will depend on the specific site).

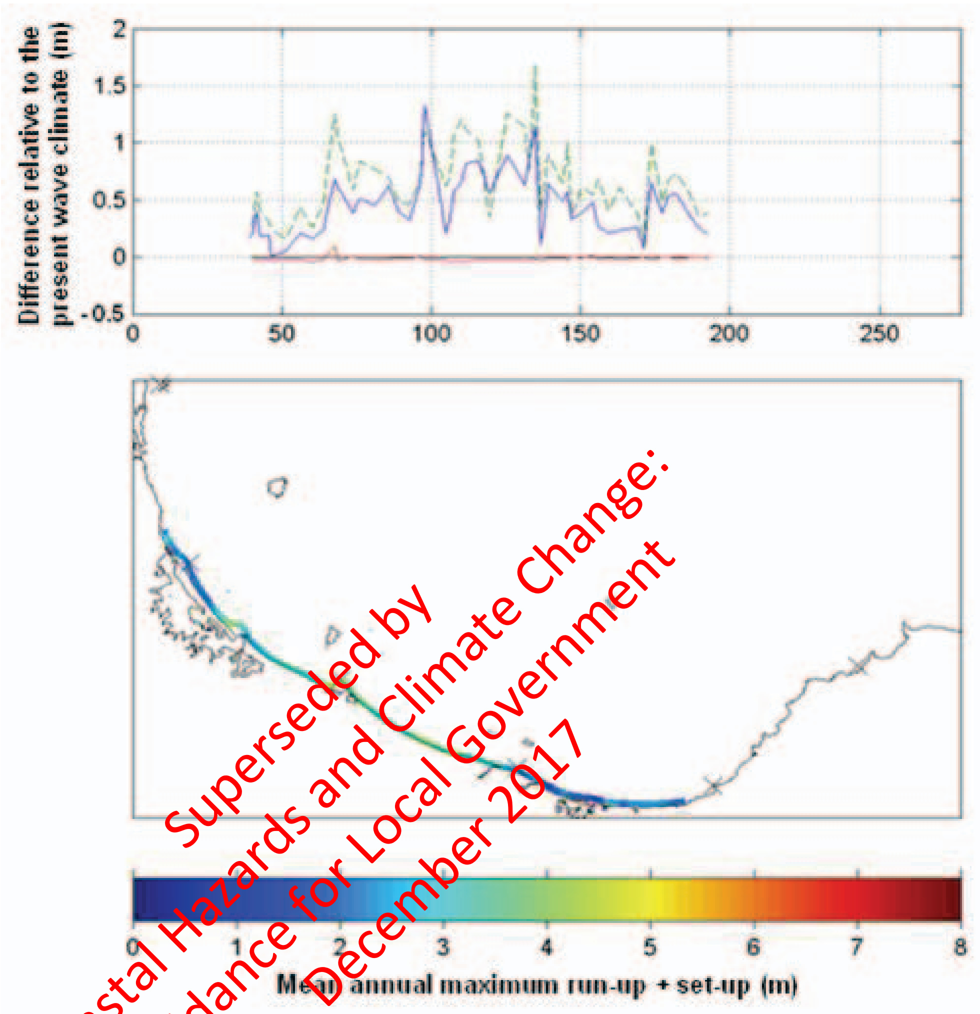
Increased sea levels will also affect rivers and streams, surface and storm water drainage, and sewer systems in low-lying coastal areas. The performance of these systems may be compromised by a back-up of flow due to increased downstream sea levels. Increased rainfall intensities may further exacerbate the problem. Low-lying urban areas will be particularly susceptible. Figure 3.1 indicates potential areas around New Zealand’s coastal margins where inundation may be influenced by changes in the coastal hazard drivers.

Figure 3.1: Indicative areas that will require risk analysis to establish their likely vulnerability to coastal inundation as a result of sea-level rise – either directly (eg, inundation during storm events) or by the impact of sea-level rise on the drainage of low-lying coastal lands. The shaded red and orange areas show approximate land levels less than 5 m and 10 m above sea level, respectively: they have been extracted from reprocessed topography data collected by the Space Shuttle Radar Topography Mission (NASA). Accuracy of the topography is around 5–8 m.

FS 10, 11

Where overtopping of a coastal barrier is a primary pathway for inundation, in addition to changing sea levels, small changes in swell wave conditions may have a significant impact on wave set-up and run-up during storms (Box 3.1). The water tables along coastal margins may also be higher in response to sea-level rise, which may increase inundation directly or potentially increase wave run-up and overtopping.

Box 3.1: Effects of climate change on the annual maximum of combined wave-induced set-up and swash run-up in the Bay of Plenty



This example is based on a scenario approach to assess the potential effects of climate change on the annual maximum of combined wave set-up and swash run-up along the sections of the Bay of Plenty coast where beach profiling is conducted. The approach involves adjusting wave hindcast data (in a number of different ways) to account for plausible climate change effects.

Average values for annual maximum wave set-up and run-up for the existing climate are plotted in the lower panel, with colour indicating metres of run-up and set-up. The top panel shows indicative differences in the annual maximum wave set-up and run-up relative to the present climate for the different assumptions used, which included changes in local winds over New Zealand (red line) and two possible scenarios of changes in swell and local winds (blue and green lines). Crosses in the colour-scaled plot are longshore distance tick marks for every 50 km.

Source: Bell et al 2006; Acknowledgement: Environment Bay of Plenty

The potential for inundation may also be exacerbated by coastal erosion (see next section) where erosion leads to a loss of either human-made or natural coastal defences (such as dune systems or gravel barriers: Figure 3.2), or where loss of beach increases the exposure during storm conditions (a particular issue in front of hard coastal defences).

Figure 3.2: Wash-out of the gravel barrier on the west coast of the South Island during a storm in 2006 has significantly increased the risk of inundation due to wave run-up and overtopping to the properties that back the beach.

3.2.1 Assessing the effects of climate change on inundation risk

There have been no peer-reviewed studies on how climate change will affect coastal inundation risk in New Zealand. In part, this is owing to the lack of high-resolution topography for coastal margins. This is now changing, with an increasing area of coastal regions being mapped with LiDAR[44] providing high-quality topography datasets on which to base such assessments (see Box 3.2).

Where some level of quantification of the potential effects of climate change on inundation is required, the approach adopted in any area will very much depend on the characteristics of the area, the level of detail required for the issue under consideration, and the availability and suitability of datasets such as topography and beach profiles. Any quantifiable assessment will need to give due consideration to the:

- interactions between the various coastal hazard drivers, the effects of climate change on these drivers, and how these interactions and effects influence inundation. Coastal inundation is rarely caused by one factor alone (eg, storm surge); it is normally due to some combination of tide level, storm surge and wave conditions (and, in certain cases, exacerbated by river or land drainage contributions). These factors are typically correlated in some way but very rarely does an extreme high tide level coincide with both high storm surge and high wave conditions. Understanding how these different drivers are correlated (known as 'joint probability') is important in assessing coastal inundation.[45] Simply assuming that extreme water levels will always occur at the same time as extreme wave conditions will tend to overestimate inundation risk.

FS 2, 4

- dynamic nature of inundation over land, particularly the mechanism of how seawater inundates a certain area (flood pathways) and the storage potential of a flood area relative to the volume of inundating water flowing into the area. For example, in an overtopping situation, swell will generally contribute a greater volume of seawater to inundation than will shorter-period wind waves. Assuming a 'bathtub' approach – in which a water level is extrapolated landward until it reaches the equivalent contour height on land (based on a combination of extreme wave and water levels) – will tend to overestimate inundation. However, where inundation is primarily a result of waves overtopping a barrier, this approach may underestimate inundation levels.
- availability, and length of record, of sea-level, weather and wave datasets for the locality or region.

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44 Light Detection and Ranging – an airborne laser scanning system that determines ground levels at a very high density (often as little as 1-m spacing between measurements) along a swathe of land underneath the track of the airplane. Most systems used in New Zealand collect data only on land above water levels, but systems are available that can also determine shallow water bathymetry levels.

45 Ramsay and Stephens 2006.

- uncertainties associated with the assessment methods used, future greenhouse gas emission scenarios and the associated magnitude of their impact on coastal hazard drivers, the lack of knowledge of how some of these coastal drivers will change with climate change, and hence how sensitive inundation risk is to these uncertainties.

Box 3.2: Assessing coastal inundation risk in the Otago Region

Otago Regional Council was one of the first regional councils in New Zealand to collect LiDAR topography data for its entire coastal margin. Collected in 2004, the dataset specifies the level of the land approximately every 1 m in the horizontal direction, with a vertical accuracy of around ± 0.15 m. The availability of the dataset has enabled a detailed hydrodynamic model study to be undertaken of the risk of tsunamis and storm-related inundation for the entire region, including an assessment of the potential effects of future sea-level rise. The detailed topography permits inundation flow paths over land to be modelled dynamically, providing a much more realistic representation of the extent and magnitude (depth and volume) of inundation.

3.3 Coastal erosion

FS 1

In many locations, climate change will influence changes in the position of the coast (and the Mean High Water Spring (MHWS) boundary) through changes to, and interactions between, the following drivers:

- relative sea-level rise
- long-term sea-level fluctuations
- the frequency and magnitude of storm surges
- tide range (coasts with relatively small tide ranges could be more vulnerable)
- storminess and wave and/or swell conditions
- rainfall patterns and intensity, and their influence on fluvial and cliff sediment supply.

Coastal erosion is not only dependent on the above hazard drivers, and changes to them, but also on the geomorphology and geological makeup of the coast, including the modifications that humans have made (perhaps indirectly) to the coast. Although these factors all influence the rate of coastal erosion, in general terms, the rate is predominantly determined by the natural drivers – waves and water levels. (Other drivers, such as rainfall and drainage patterns, can be significant for certain types of coast, such as soft cliffs.)

Despite the huge diversity of geomorphology found around the New Zealand coast, the generic sensitivity of different physical coastal environments to the likely effects of climate change is relatively straightforward. This is summarised for a range of landforms in Table 3.1, discussed for the main coastal geomorphological types in the following sections, and summarised in Figure 3.3. It is important to realise that both regional and local influences, such as variability in and interrelationships between geomorphology, coastal sediments and human influences, will result in significant local deviations from the generic response, producing variations in the rate of coastal change.

Table 3.1: Relative sensitivity of coastal landforms to changes in different climate change drivers. Sea-level rise = sensitivity to accelerations in sea-level rise; storm surge = sensitivity to changes in the frequency and/or intensity of storm surge; precipitation = sensitivity to changes in the pattern and/or intensity of precipitation; wave height = sensitivity to changes in wave height (storms); wave direction = sensitivity to changes in wave direction (eg, changed longshore sediment transport patterns). Source: adapted from Jay et al 2003.

Landform type	Climate change sensitivity				
	Sea-level rise	Storm surge	Precipitation	Wave height	Wave direction
Simple cliff	High	Moderate	Moderate	High	Low
Simple landslide	High	Low	High	High	Low
Composite cliff	Moderate	Low	Moderate	High	Low
Complex cliff	Moderate	Low	High	High	Low
Relict cliff	High	Low	High	High	Low
Embryonic dunes	High	High	Low	High	Low
Foredunes	High	High	Moderate	High	Low
Climbing dunes	Moderate	Moderate	Moderate	Moderate	Low
Relict dunes	Low	Low	Moderate	Low	Low
Parabolic dunes	Moderate	High	Low	High	Low
Transgressive dunes	Moderate	Moderate	Low	Moderate	Low
River delta	High	High	Moderate	High	Moderate
Tide dominate delta	High	High	Low	High	Moderate
Wave dominated delta	High	High	Low	High	Low
Shore platform	High	Moderate	Low	High	Low
Sandflats	High	High	Low	High	Low
Mudflats	High	High	Low	High	Moderate
Pioneer saltmarsh	High	High	Moderate	High	Low
Saltmarsh	High	High	Moderate	High	Low
Sand beach	Moderate	Moderate	Low	Moderate	High
Gravel beach	Moderate	Moderate	Low	High	Moderate
Mixed beach	Moderate	Moderate	Low	High	Moderate
Composite beach	Moderate	Moderate	Low	High	Moderate
Boulder beach	Low	Low	Low	Moderate	Low
Barrier island	High	High	Low	High	High
Barrier beach	High	High	Low	High	High
Spit	High	High	Low	High	High
Cuspate foreland	Low	Low	Low	High	Low

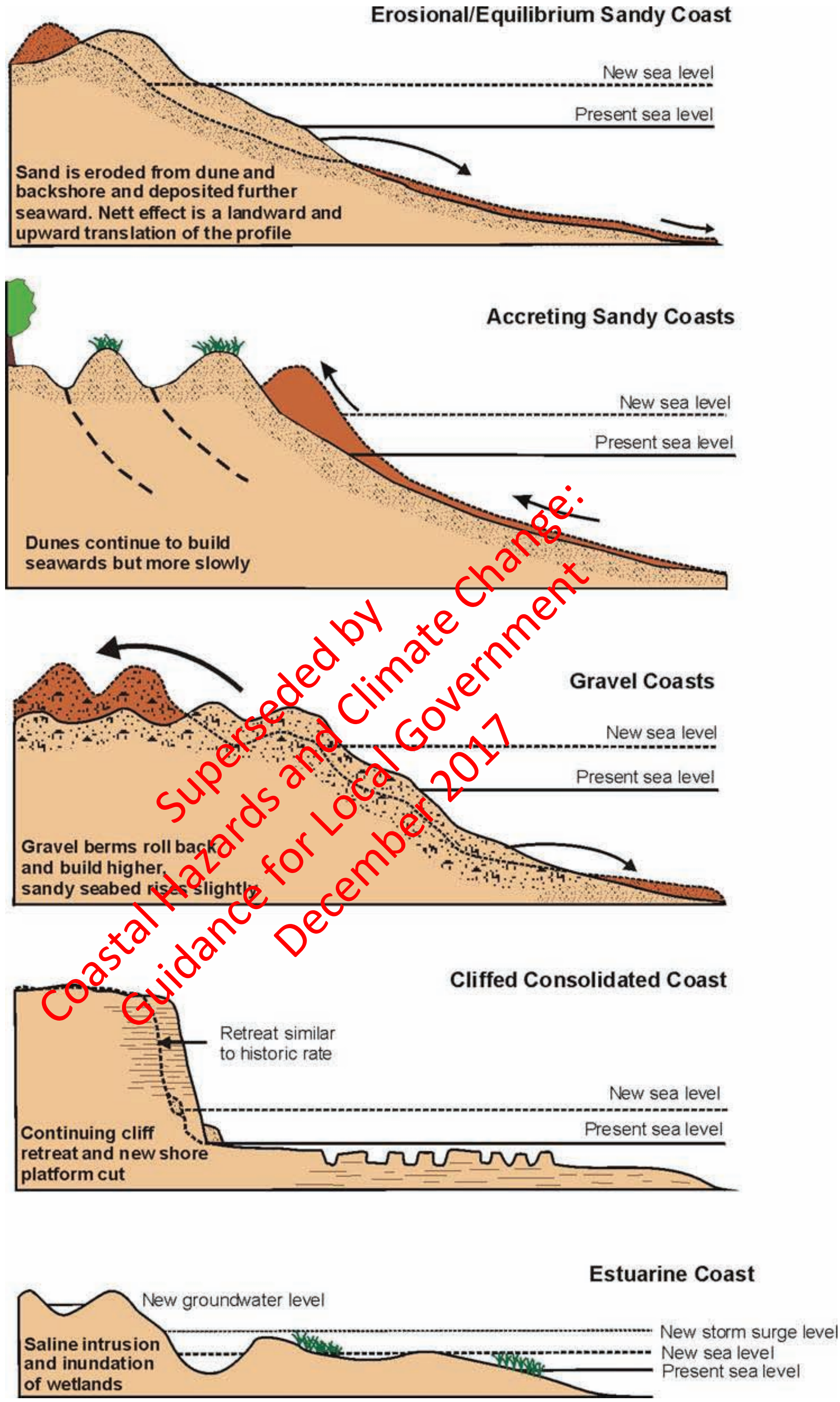

Figure 3.3: Generalised impacts of sea-level rise on different types of coastal morphology. These illustrations are only indicative, as local geomorphology, human impacts and changes to the sediment supply may produce different responses.

3.3.1 Sandy coasts

FS 1 Sandy open coasts that have been relatively stable over time are likely to show a bias towards erosion with rising sea levels, unless the supply of sand to the beaches can keep pace with erosion. In some parts of New Zealand, it is quite possible that erosion will be balanced by the rate at which sediment is supplied. With sea-level rise, accreting open coast beaches, eg, the Manawatu coast, may continue to accrete, but more slowly – the rate being highly dependent on sediment supply.

Sea-level rise will permit waves to attack the backshore and foredunes more readily in many localities (Figure 3.4) than at present, particularly on coasts with relatively small tide ranges (irrespective of whether there are changes in wave climate or storminess). If an increase in the frequency or heights of storm waves also occurs, then this combination (sea-level rise and more frequent or higher storm waves) would tend to have greater adverse effects on sand beach systems than at present. Where the present width of the back or foreshore of the beach is not sufficient to accommodate this erosion, dunes backing the beach will be eroded. Locations with higher dunes may suffer less retreat than locations with low dunes, although more frequent mass slumping could occur if high dunes are oversteepened.

Figure 3.4: Sea-level rise will provide increased opportunity for waves to attack the backshore and foredunes in many localities.

The elevation of the water table within a beach profile has an influence on erosion. Higher water tables increase wave run-up and the velocity of backwash, therefore increasing both run-up elevations and sediment losses to the nearshore. Coastal water tables may rise as a consequence of sea-level rise, increasing the potential for beach erosion. However, these effects are dependent on how the beach profile adjusts to the higher water table regime, and cannot be easily quantified.

FS 10 On long open sections of sandy coast, longshore sediment transport potential could increase due to changes in wave climate, particularly wave direction. This may change the patterns and rates of both retreat and advance of the shoreline. Subtle changes in wave direction may also have a significant effect on pocket sand beaches by moving sand from one end of the beach to the other. Spit features that are built and maintained by longshore transport are also likely to be sensitive to changes in the wave climate; they will also be subject to increases in tidal flow volume passing through tidal inlets due to higher sea levels.

FS 12 Any changes in storminess will also alter the natural recovery of beach systems, with more short-term erosion of sand (and gravel) beaches likely at many locations. The potential recovery of foredunes (or gravel ridges) between storms could be more limited than at present, particularly during certain El Niño-Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) phases.

On both sand and gravel beach systems, where catchment-derived sources of sediment provide an important supply to the coast, increases in rainfall intensity will increase upper catchment erosion and sediment transport. In some locations, the additional supply (excluding silts, muds, clays) may be sufficient to offset other climate change effects. However, in areas where there is decreased rainfall (eg, some east coast areas), ongoing sediment supply may be reduced (even with episodic storms), with shoreline erosion likely to be exacerbated even further.

It is important to remember that sea-level rise will continue for several centuries beyond 2100, even if greenhouse gas emissions are eventually stabilised. Erosion of sandy beaches is, therefore, likely to continue well beyond this century.

3.3.2 Gravel beaches

FS 1

Gravel beaches (Figure 3.5) tend to respond in two ways to ongoing sea-level rise and changes in storminess and wave height:[46]

- where there is a wide and well-nourished gravel barrier (ie, sufficient sediment supply), the barrier will retreat slightly and increase in height (Figure 3.3) in response to the rising sea level, increase in wave height or increase in the frequency or magnitude of extreme storms.
- where the gravel barrier system has a net deficit in sediment supply, as is the case of many New Zealand gravel beaches (particularly on the west coast of the South Island), the barrier will experience an increased rate of retreat, or there may even be a breakdown of the gravel ridge (Figure 3.2). As most of these systems are recessional, future sea-level rise or increases in wave conditions will accelerate this present-day trend.

Figure 3.5: Gravel barriers will tend to retreat, but where there is sufficient gravel, the barrier will increase in height.

FS 10

Gravel beaches are most sensitive to changes in storm and wave conditions and less sensitive than sand beaches to changes in sea level. As with sand beaches on long open sections of coast (eg, the Canterbury and southern Hawke Bay gravel coastlines), retreat or advance of the gravel beaches will be sensitive to changes in the rates of longshore transport of gravel caused by any long-term changes in wave direction.

3.3.3 Cliffs

FS 1

The effects of climate change on cliffs will be highly dependent on how resistant their geology is to erosion (Figure 3.6). Erosion of cliffs that comprise sedimentary rocks and clays/silts is a complex one-way erosional process: moderate to high cliffs will mostly continue at similar or slightly higher rates with higher sea levels or minor changes in wave conditions. Rates of undermining are, in general, unlikely to increase markedly, except for low cliffs of several metres' height. The rate of erosion of sedimentary cliffs will be much more sensitive to changes in drainage and moisture processes, such as extremes of drought and heavy rainfall.

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46 Carter and Orford 1993.

For alluvial (unconsolidated) cliffs fronted by a gravel barrier beach at their base, such as found along the South Canterbury and North Otago coastline, changes in the rate of retreat of the cliff will be linked to changes of the gravel barrier. For such cliffs, it is unlikely that there will be significant changes in the rate of retreat.

Figure 3.6: Cliffs will tend to retreat, but the rate of retreat will be highly dependent on their geological characteristics.

3.3.4 Estuarine coasts

FS 1

The effects of sea-level rise on estuarine erosion will depend on a complex interrelationship between the topography of the estuary, the increase in tidal prism volume (ie, the amount of water that flows in and out of an estuary during each tide), the estuary's sediment storage, river and open coast inputs of sediment, and the erosion of adjacent beaches (Figure 3.7).

Sedimentation rates in most North Island estuaries have been 2–4 mm per year thus far, keeping up with the present rise in sea level. Eventually, however, the acceleration in sea-level rise is likely to exceed sedimentation. This may occur more quickly in urban areas where catchments are developed and restrict sediment supply.

Figure 3.7: Retreat of estuarine shorelines will be highly variable.

Estuary and harbour shorelines will retreat as a result of both inundation and erosion, but the rate and extent of retreat will be highly variable within any estuary. In general, estuary systems have a low-energy wave climate and limited exposure time (around high tide) for waves to develop and to erode the shoreline. However, raised water levels will permit larger waves on high tides to reach the estuary shoreline, potentially increasing the rate of erosion. Once erosion or loss of land occurs, recovery – if it occurs – will be a much slower process than on open coasts. Again, estuaries with a comparably smaller tide range will be more vulnerable for a given sea-level rise (eg, most of the east coast and Wellington/Porirua area). Along low-lying areas bordering estuaries, erosion may be relatively rapid owing to regular, and leading to permanent, high-tide inundation of areas that presently may experience only episodic inundation.

Where the landward retreat of the high-water mark is constrained due to morphology, geology (eg, rock outcrop) or coastal defences, intertidal areas and their associated ecosystems may be reduced and potentially 'squeezed out'.

In spite of the compensating effect of sedimentation, sea-level rise is likely to cause an increase in the amount of water that flows in and out of estuaries during each tide (the 'tidal prism'), along with larger increases in freshwater run-off during heavier rainfall events. Changes in increased flow volumes may be quite significant given the shallowness of many of New Zealand's estuaries; they will correspond to increases in tidal velocities and scour in the main channels and, particularly, at tidal entrances. It is at river, harbour and estuary mouths and inlets that coastal changes tend to be the most dynamic, particularly those associated with a spit morphology. The influences of such inlets can extend for up to approximately 4 km along the open coast adjacent to the mouth. The dynamics of coastal and estuarine / river processes and multi-year cycles of sand exchange between the estuary, ebb and/or flood deltas and the adjacent coastline are very complex. Thus any reliable statement about how individual inlet systems may respond to climate change effects is extremely difficult to make.

3.3.5 Assessing the effects of climate change on coastal erosion risk

Quantifying how the retreat and advance of coastlines will be influenced by climate change is extremely difficult. Coastal change is a complex process in which coastal hydrodynamics, morphology, geology, sediment supply and deposition and, in some cases, human modifications all interact over multiple timescales. Further complicating matters are both positive and negative feedbacks within the coastal system, again all of which operate on a number of different spatial and temporal scales.

Owing to this complexity, assessments of future coastal erosion, and the effects that climate change may have on erosion rates, tend to rely on relatively simplistic empirical approaches. Most commonly, they provide a relationship between past erosion rates, the characteristics of the beach profile, and the relative difference between past and future sea levels (typically based on the 'Bruun rule'[47] or a variant of it).

Strictly speaking, such approaches are more suited to providing broad estimates of relative erosion potential along a coastline rather than location-specific assessments of potential change. Their use in predicting the coastline position at some time in the future should be treated with caution, and tends to imply a level of certainty that is rarely justifiable. As with assessments of inundation, such approaches require a much more robust incorporation of uncertainties and hence of the sensitivity of future coastal changes to these uncertainties. For example, consideration needs to be given to:

- uncertainty related to past erosion rates owing to insufficient monitoring data
- the assessment methods
- future emission scenarios and the associated magnitude of their impacts on the various coastal hazard drivers
- the lack of knowledge of how some of these coastal drivers will change with climate change.

Such uncertainty also needs to be communicated more effectively.

However, such approaches, and application of expert judgment, will continue to form the basis of coastal erosion assessments in the foreseeable future. More rigorous approaches of simulating coastal change at the timescales relevant to the planning of development are still relatively limited due to two main factors.[48] Firstly, the potential for process-based models to simulate sediment dynamics and the effects climate variability has on these processes over large spatial and temporal scales is limited: this requires that new types of modelling approaches be developed and adopted. Secondly, there are few high-quality, long-term coastal datasets over the multi-decadal timescale of interest to enable refinement, calibration and validation of such models.

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47 Bruun 1962, 1988.

48 Hinton et al 2007.

3.4 Salinisation of surface freshwaters and groundwater

FS 2

Climate change effects on coastal hazard drivers will also influence the present-day balance between fresh and saline water in coastal margins. Effects will include:

- sea-level rise causing saline water to encroach further up the river and creek watercourses
- longer parched or drought periods in eastern areas leading to reduced river flows, which in turn will enable saline water to encroach further up river
- sea-level rise causing higher water levels at the coast, within estuaries and lower reaches of rivers, which will exert a higher hydraulic head of saline water on unconfined groundwater aquifers.

3.5 Tsunami inundation

FS 3

The geological causes of tsunamis (such as earthquakes, underwater landslides and volcanic activity) will not be directly affected by climate change. However, the coastal effects of tsunamis will be altered somewhat by sea-level rise, through increasing the risk of coastal inundation. Estuaries and harbours may also become more vulnerable to tsunamis as entrance channels deepen in response to greater tidal water volumes (tidal prism). The most important determiner of the magnitude of tsunami impact will continue to be the height of the tide at the time the peak tsunami wave reaches the coast.

3.6 Coastal defences

Climate change impacts on coastal hazard drivers will also have a significant effect on the integrity and performance of existing human-made coastal defences (Figure 3.8). In the United Kingdom, it has been estimated that by 2080, the structural improvements required to maintain existing coastal defences to provide protection equivalent of their present standards will cost between 1.5 and 4 times that of today, depending on the emission scenario.[49]

Climate change is likely to reduce the effectiveness of coastal defences for a variety of reasons,[50] including:

FS 4

- higher sea levels will increase the frequency with which defences are overtopped by waves or very high tides (more so for coasts with smaller tide ranges). This increased overtopping will affect the inundation risk, but is also important to all coastal structures as it can increase erosion of the protected area behind the defence and can lead to failure of the defence itself

FS 7

- an increase in storm-tide levels (due to sea-level rise and/or changes in storm surge) will produce greater water depths at the defence, increasing the magnitude of overtopping during storms and exacerbating the problems detailed in point 1 above
- greater water depths at the structure will increase the exposure of the defence to larger waves. This increased exposure will increase the risk of damage and failure. For example, with rock structures, the size of rock required for stability is directly proportional to the cube of the significant wave height. Therefore, even a small increase in wave conditions at the defence can result in a large increase in the size of rock armour required to achieve the same stability
- with larger waves at the defence, there is likely to be greater reflection from defence structures and increased scour of the beach at the structure's toe. This increases the potential for undermining and/or failure of the defence

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49 Burgess and Townend 2004.

50 Burgess et al 2007.

- steepening of the foreshore in response to sea-level rise where a defence constrains the position of the high water mark but the landward retreat of the low-water position continues (coastal squeeze). This can further increase the vulnerability of defences to overtopping and structural failure through the processes described above.

Figure 3.8: The standard of protection provided by coastal defences will decrease due to the effects of sea-level rise and other climate change impacts on coastal hazard drivers.

Given that many existing coastal defences in New Zealand have not been engineered to provide a high standard of protection, the impacts of climate change could result in substantially increased damage to these defences and lower standard of protection to the land backing it. Similarly, if defences have been designed with a particular lifetime, defences are unlikely to endure if climate change considerations have not been factored into the design.

4 Responding to Climate Change: Future-proofing Decision-making

4.1 Introduction

Effectively managing the effects of coastal hazards and the progressive changes to the occurrence and magnitude of such hazards associated with climate change is fundamental to maintaining or developing sustainable and resilient coastal communities.

Climate change impacts are occurring now. Future changes are inevitable, irrespective of mitigation efforts to reduce greenhouse gas emissions. However, climate change considerations alone are unlikely to stimulate or engender local government action. Rather, through a risk management approach (chapter 5), an assessment and prioritisation of possible responses to coastal hazard and climate change effects can provide the impetus to change policy, planning and resource consenting outcomes and to develop a proactive approach to adapting to climate change (Figure 4.1).

The emphasis in this Guidance Manual is on understanding the scope and variation of climate change, and using risk assessment as a method to determine adaptation responses appropriate to the risks. Climate change will impinge on a wide range of local government functions. The most effective approach to incorporate climate change impacts into decision-making is to include it alongside the range of coastal hazard and other factors that local government already takes into account as part of its planning and consenting functions. That way, climate change can be assimilated across the wide range of local government functions rather than applied as a separate exercise.

This chapter outlines general adaptation principles that will help ensure that climate change considerations are taken into account appropriately (Box 4.1). It also sets out some key concepts relating to local government's roles and responsibilities that are aligned to incorporating adaptation principles into local government functions.

Box 4.1: Key terminology

Adaptation to climate change	Undertaking actions to minimise threats or to maximise opportunities resulting from climate change and its effects. Various types of adaptation can be distinguished: *anticipatory* – adaptation that takes place before impacts of climate change are observed; *autonomous* – adaptation that does not constitute a conscious response to climate stimuli but is triggered by other factors such as ecological change in natural systems or market changes in human systems; *planned* – adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to or maintain a required state.
Adaptive capacity	The ability of a human system or an ecosystem to: adjust or respond to climate change (to both variability and extremes); moderate potential damages; take advantage of new opportunities arising from climate change; or cope with and absorb the consequences.
Low-regrets adaptations	Low-cost policies, decisions and measures that have potentially large benefits
No-regrets adaptation	Adaptations that generate net social, economic and environmental benefits irrespective of anthropogenic climate change, or adaptations that at least have no net adverse effects.

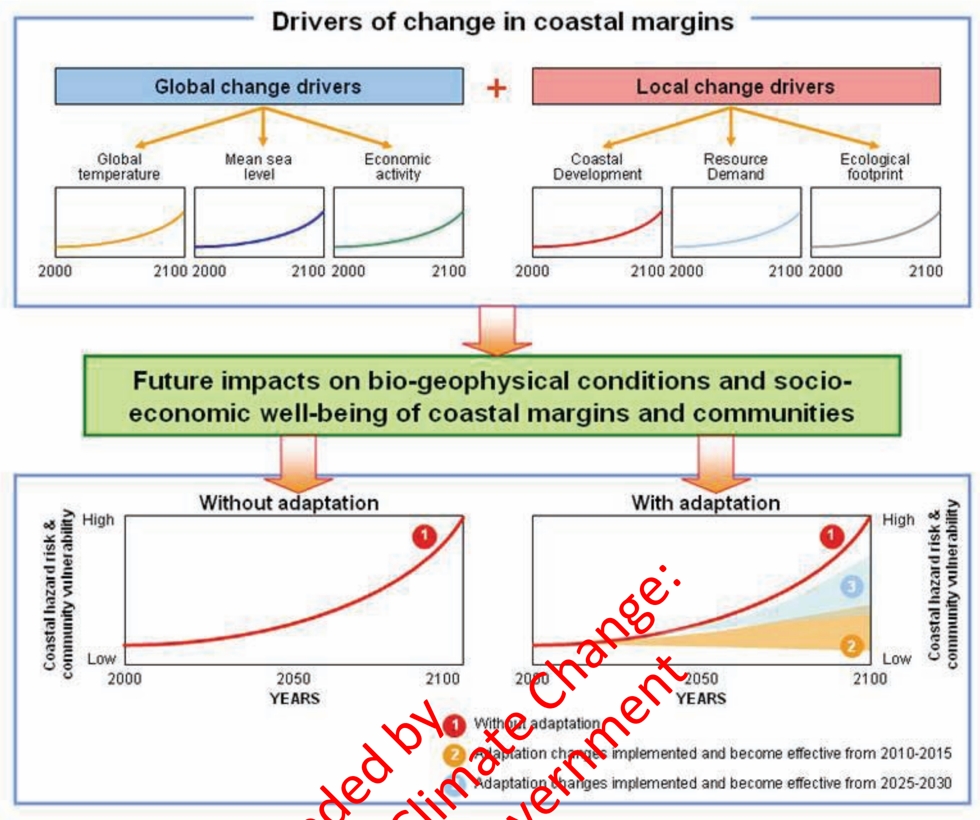

Figure 4.1: Conceptual representation of the drivers of change in coastal margins and the implications for coastal hazard risk and vulnerability of coastal communities: when no adaptation occurs, and when adaptation is implemented in the near term and mid term. Source: adapted from Box 16.4 in IPCC 2007d and from Harvey et al 2004.

4.2 Adaptation principles

Planned adaptation is part of a balanced and prudent response to climate change. Adaptation has been, and continues to be, an integral part of how natural and human systems have developed and evolved in response to climate and its variability. Fundamentally, it is about proactively enhancing our capacity to adapt to the future effects of climate change (ie, building adaptive capacity) through minimising, adjusting to or taking advantage of the consequences of climate change.[51]

A number of common themes and characteristics have led to good adaptation. Many of these principles are consistent with good participatory decision-making and hence apply more widely than to just climate change considerations (see next section). Principles include:[52]

- work in partnership with coastal communities
- understand existing risks and vulnerabilities to coastal hazards and climate change and their critical thresholds
- identify the most adverse coastal hazards and compounding climate change risks and focus on actions to manage the most vulnerable areas
- seek opportunities to incorporate adaptation into all new and existing developments within the coastal margin
- incorporate flexibility (ie, adaptive management) to deal with changing risks and uncertainties. Recognise the value of a phased approach to adaptation (Figure 4.2)

[51] UKCIP 2005.

[52] Adapted from UKCIP 2005; Shaw et al 2007.

- recognise the value of no-regrets, low-regrets and win–win adaptation options to managing climate change risks:
  - no-regrets: policies and decisions that will pay off immediately under current climate conditions
  - low-regrets: low-cost policies, decisions and measures that have potentially large benefits
  - win–wins: policies, decisions and measures that help manage several coastal hazard or climate related risks at once, or bring other environmental and social benefits, eg, preservation of natural character.
- adopt a sequential and risk-based approach to decision-making regarding coastal development
- avoid actions that will make it more difficult to cope with coastal hazard and climate risks in the future
- review the effectiveness of adaptation measures and planning processes through continual monitoring and evaluation.

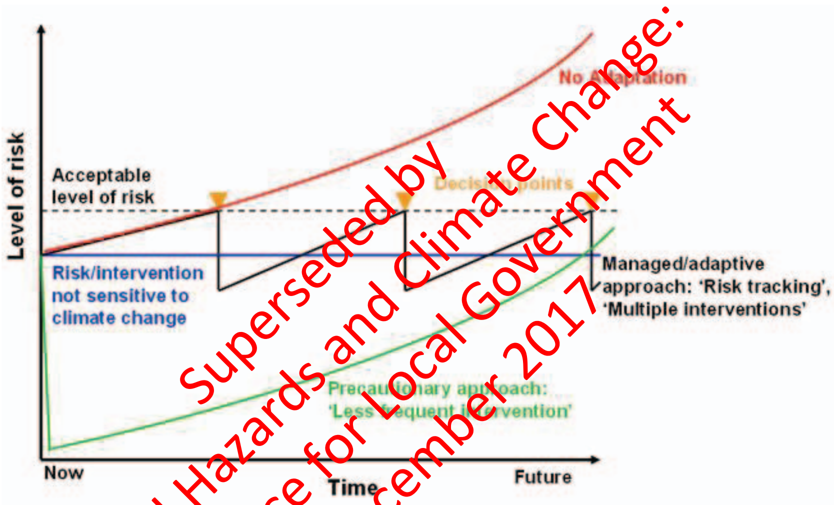

Figure 4.2: Different approaches to adaptation and their effect on the level of risk over time. Source: adapted from Donovan et al 2007.

4.3 Key principles for local government

Local government actions are undertaken in the context of a range of principles that are set out in law, or have evolved through good practice and case law.[53] All of these are integral to successful adaptation, and must be kept in mind when dealing with climate change effects.

4.3.1 Sustainability

The concepts of sustainable development under the Local Government Act 2002, and sustainable management of an area's natural and physical resources under the Resource Management Act (RMA) 1991, imply the ongoing ability of communities and people to respond and adapt to change in a way that avoids or limits adverse consequences. Since 2004, the purposes and principles set out in Part 2 of the RMA include a requirement that people making decisions in terms of the Act must give particular regard to the effects of climate change.

[53] Adapted from MfE 2008a.

Over the past decade or more, during which time people have become more aware of climate change and its causes and effects, the causes of climate change have begun to be tackled at an international level. At the same time, local communities have been encouraged to adopt no- or low-regrets responses to adapt to climate change. Such responses fit within the concept of sustainability. They involve applying adaptive responses (and sometimes limitation responses) that will not be regretted irrespective of the eventual nature and magnitude of climate change effects. Examples are: a range of energy efficiency and conservation practices; forest planting; and avoidance of new development in areas already or potentially hazard-prone.

More recent is an understanding of the variability of climate change effects, and of the possible implications of decisions made in a framework of uncertainty. This has required a shift such that local authorities undertake risk-based assessments of climate change effects and their responses before they make decisions in the interests of long-term sustainability.

4.3.2 The reasonably foreseeable needs of future generations

The phrase 'reasonably foreseeable needs of future generations' means taking into account the interests of future communities, and the direct and indirect costs that future generations may bear as a result of decisions made in the present. The concept is found in key sections of the Local Government Act and the RMA, and is the fundamental basis for international, national, regional and local responses to climate change.

Even where the need for a response to climate change is not yet apparent, this principle applies. It integrates the concepts of research and of forecasting of trends and potential biophysical impacts with the present expectations of future community needs. This principle requires responsible action in the context of balancing the needs of the present with those of the future.

4.3.3 Avoid, remedy and mitigate adverse effects

This duty from the RMA, to 'avoid, remedy and mitigate adverse effects' applies to the preparation of plans by local authorities under that Act, to every decision made under that Act, and to everyone who carries out an activity or development under that Act. 'Effect' is defined to include temporary or permanent effects, present and future effects, cumulative effects over time, and potential impacts of high probability, or of low probability with high potential effects. Therefore, through reasonable understanding and analysis of future environmental change, climate change impacts can and should be taken into account when contemplating new activities and developments.

Questions of scale and type of change, and implications of specific decisions, can best be worked out through a risk assessment process that takes into consideration the realistic permanency of the decision and the anticipated future impacts. The process may result in decisions to avoid future effects (such as 'no go' areas for development), or at least to mitigate them by specific design responses (such as minimum floor levels). If a future remedy is to be an option (such as relocatable buildings in coastal locations), the implications for present and future owners and the community need to be clearly identified at the time of consent; and conveyed into the future by long-standing mechanisms (such as consent notices on titles).

4.3.4 Precautionary principle and the cautious approach

This concept of 'precautionary principle' is implied in the RMA (and stated in the New Zealand Coastal Policy Statement prepared under that Act) and is directly stated in the Civil Defence Emergency Management Act 2002. It requires an informed but cautious approach to decisions where full information on effects is not available, particularly when there is high level of uncertainty and where decisions are effectively irreversible.

A precautionary approach is also particularly relevant where effects are of low probability but high potential impact, such as the effects of infrequent but high flood levels in developed flood plain areas. Section 32 of the Resource Management Act requires an analysis of a plan provision to consider the risks of 'acting or not acting' if there is uncertain or inadequate of information.

This principle is directly relevant to addressing climate change effects in plans.

4.3.5 The ethic of stewardship / prudent stewardship / kaitiakitanga

The Local Government Act and the RMA both contain the concepts of stewardship / kaitiakitanga. In the Local Government Act, prudent stewardship is to be applied to the efficient and effective use of a community's resources in the interests of the district and region. In the RMA, the ethic is applied to the wider environment.

The concepts underpin sound planning decision-making in the interests of the community, to avoid or minimise loss of value or quality over time. Its relevance to climate change is to asset management, landcare and watercare, biosecurity and biodiversity, but also to natural character, amenity and public access values.

4.3.6 Consultation and participation

Principles of consultation with communities and affected people lie at the heart of local government decision-making. Consultation implies informed input into decision-making processes. For decisions with outcomes likely to be influenced by climate change, those being consulted must have sufficient information to understand the likely scenarios and associated risks for their communities. Ensuring that adequate information is available within a community for consultation to be effective is a responsibility for regional and local government. It involves the translation of international and national knowledge and projections to local levels, with indications of degree of certainty and uncertainty.

Consultation and participation can also raise awareness of risk and appropriate responses – for example, tsunami risk and how people should respond when it happens in their locality.

4.3.7 Financial responsibility

Local government is expected to act within normal codes of financial responsibility on behalf of the community. In terms of local government activities, particularly asset provision and management, the Local Government Act sets out requirements that the reasons for any changes to current provisions, and their cost, be identified in detail. For infrastructure enhancements due to future effects of climate change, both an evaluation of risks and the costs of different levels of service need to be expressed in a transparent way.

4.3.8 Liability

Local government can be financially liable for the consequences of decisions that are shown to have been in breach of statutory or common law duties. This is a difficult area of law, and councils use a range of techniques to reduce their risk of liability. For example, where decisions regarding single properties are involved, instruments such as covenants or consent notices attached to titles may be used to identify risks. Care should be taken when using such devices as they may not limit the owner's (or future owner's) expectations of further capitalisation, and do not appear to have any effect on land values.

Broader climate-related issues, such as frequency of inundation of a developed area, may be less likely to result in direct liability unless the area becomes uninhabitable as a result. However, community costs in enhancing or retrofitting infrastructure can become considerable, and questions of equity in relation to wider community interests also arise.

5 Understanding Changing Coastal Hazard Risk

5.1 Introduction

A sound risk assessment process is fundamental to ensure that coastal hazards, and the effect that climate change has on coastal hazards, are appropriately taken into account in local government policy, planning and resource consent decision-making. The process has the advantage of being conducive to building in the sensitivity of outcomes to different levels of uncertainties in climate change drivers.

To implement effective approaches to managing coastal hazard risk, such risk must first be appraised through:

- identifying the coastal margins and describing the associated assets located there that are at risk from coastal erosion, storm and tsunami inundation
- considering how such risk may be induced or exacerbated by climate change or by changing development in coastal margins
- evaluating the likelihood and consequences of such risk over the timeframes of interest.

This process also allows the climate change risks and subsequent adaptive responses to be prioritised and compared equitably with other risks, resource availability and cost issues (including works) that the local authority faces.

The risk assessment framework described in this chapter provides an overall framework for carrying out risk assessment at a range of levels, permitting a structured way to think about, or work through, coastal hazard and climate change issues and associated uncertainties. It is intended that the framework can be used to assist both proactive policy and planning, and assessing and determining resource consent applications. This process is not the only one that can be used: where a local authority has an existing risk assessment process, climate change should simply be added into it. For the purpose of this Guidance Manual, the terminology used is outlined in Box 5.1.

Box 5.1: Key terminology

Risk	The chance of an 'event' being induced or significantly exacerbated by climate change, which will have an impact on something of value to the present and/or future community. It is measured in terms of consequence and likelihood.
Hazard	A source of potential harm to people or property. Examples are coast erosion or inundation.
Event	A coastal hazard incident that occurs in a particular place during a particular interval of time. It is distinct from merely a 'storm event', although it could be an event that occurs during a storm (eg, erosion that results in loss of private property).
Consequence (or impact)	The outcome of an event, expressed qualitatively in terms of the level of impact. Consequences can be measured in terms of direct or indirect economic, social, environmental or other impacts.
Likelihood	Likelihood is a qualitative (and possibly quantitative) measure of the probability or chance of something happening.

5.2 Fundamental concepts in risk assessment

There are several fundamental concepts that should be incorporated in any assessment of coastal hazard risk, and how such risk may change as a result of climate change effects.

5.2.1 Risk varies over time

Risk varies over time and, for coastal margins, the risk is invariably increasing. This reflects both the changing probability of the underlying hazard occurring, and the changing scale of consequence should the risk occur. For example:

- climate varies because of its natural variability and longer-term climate change, both of which will influence the occurrence or magnitude of the hazard
- natural defences change (eg, a narrowing of beach or dune width), influencing the occurrence or magnitude of the hazard
- land use, subdivision and development change, usually intensifying, thereby increasing the extent and therefore the magnitude of the consequences
- the value of assets at risk changes. It usually increases, influencing the direct losses and, therefore, the magnitude of the consequences.

Time is a fundamental consideration in any risk assessment of coastal hazards and the effect climate change may have on these risks. A risk may not exist now but may evolve, owing to climate change, during the lifetime of development, service or infrastructure. The time factor or horizon that must be considered is the lifetime of the decision, development, service or infrastructure (Figure 5.1).

In this context, risk assessment can recognise the evolution of risks over time by introducing a planning horizon and considering the risk at various points in the lifetime of the decision, development, etc.

For example, for a lifetime of 100 years, the risk may be evaluated as it is now and as it will be in 25, 50, 75 and 100 years' time. This approach allows local government to plan for response options to evolve over time – that is, it allows latitude to be incorporated in the response options to address the risk. If the risk is not addressed now, despite it being likely to occur in the future, the question arises: Is the community locked into a position where it cannot avoid or adapt to the risk?

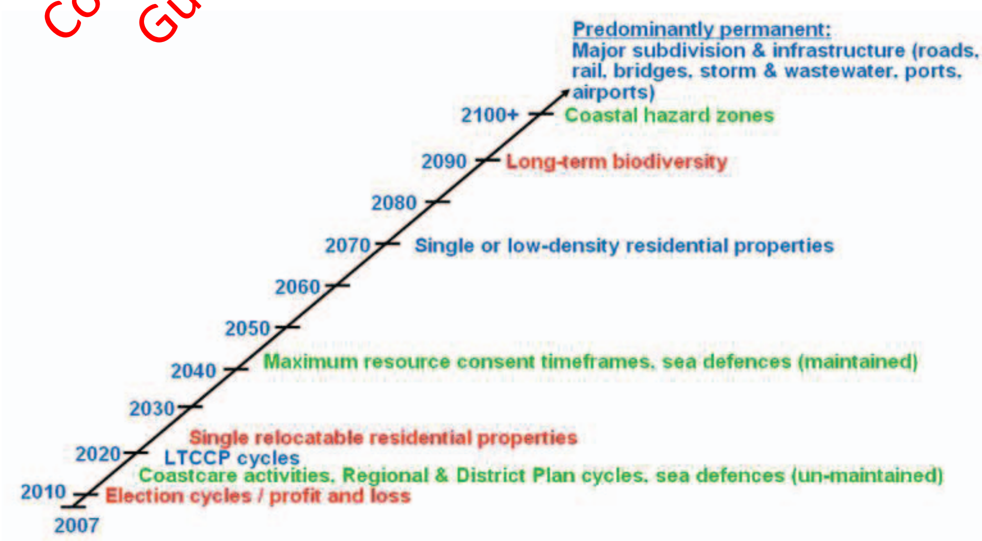

Figure 5.1: Example timeframes for various decisions and development.

5.2.2 Risk varies spatially

Coastal hazard risk can be extremely variable, even over relatively short distances. This spatial variability in risk can again be due to both spatial variability in the probability of hazard occurrence and variability in the hazard consequence. Factors that affect the spatial variability of risk include:

- changing coastal morphology (ie, coastal characteristics) or changing exposure to coastal hazard drivers (eg, waves) along a coast, resulting in differing erosion rates, storm response, etc
- differing hinterland elevations and the influence of inundation pathways, eg, variation in inundation risk
- varying land use, subdivision density and value of human assets
- cultural and environmental assets.

5.2.3 Risk assessment needs to be appropriate

Any risk assessment needs to be:

- conducted at a level of detail appropriate to the scale of the risk and nature of the decision (Table 5.1)
- consistent with the level of data or information available.

Table 5.1: The tiered approach to determining the level of detail for the risk assessment

Tier	Description	Scope	Nature	Scale
1	Risk screening	Broad	Qualitative	Policy, national, regional, local, project
2	Qualitative and semi-quantitative risk estimation	Specific	Qualitative	Policy, regional, local, project
3	Quantitative risk assessment	Specific, detailed	Quantitative	Local, project

This Guidance Manual is aimed primarily at local government staff involved in policy, planning or resource consenting, and those who need to be able to assess the risks posed by coastal hazards and to identify when a more detailed assessment may be required. As such, it is qualitative in nature and should be able to be conducted by local authority personnel, although some input from coastal hazard specialists is generally desirable. Where available, coastal hazard personnel from the regional council should be consulted.

The approach outlined in this Guidance Manual assumes that local government staff using the process have a reasonable knowledge of the characteristics of the coastal margins, are aware of past coastal hazard issues, have access to aerial photographs, and have reviewed previous relevant studies and reports.

However, the risk assessment framework used here is also amenable to more detailed levels of risk assessment. As the level of detail increases, input from suitably qualified and experienced specialists in coastal hazards (possibly available in the regional council) may be required.

5.2.4 Risk needs to be communicated

The purpose of the risk assessment process is to aid decision-making. Therefore, there is a need to communicate the risk assessment process in language that is as clear and concise as possible. Within all risk assessments, there is a need to:

- define the overall approach
- clearly define all key assumptions made
- identify all uncertainties and their potential impact of the overall decision
- outline the scope and impact of any sensitivity testing

- be accountable and transparent
- report in a way that the non-specialist can understand the significance of the results.

5.2.5 Uncertainty needs to be considered

All local government business contends with uncertainty. Nevertheless, local government has developed a range of mechanisms and approaches to deal with uncertainty through all its planning and review processes.

In terms of coastal hazards and climate change, uncertainty defines the quality of our knowledge concerning risk.[54] Uncertainty may affect both the likelihood of hazard conditions occurring and the consequences of those hazard events (Figure 5.2). The extent of the impact that future climate change will have is also uncertain. For example, we cannot predict with any degree of certainty the quantity of greenhouse gases that will be emitted over the coming century. While ongoing research typically aims to reduce uncertainties, adopting a risk-based approach allows uncertainty to be accommodated and treated accordingly within decision-making.

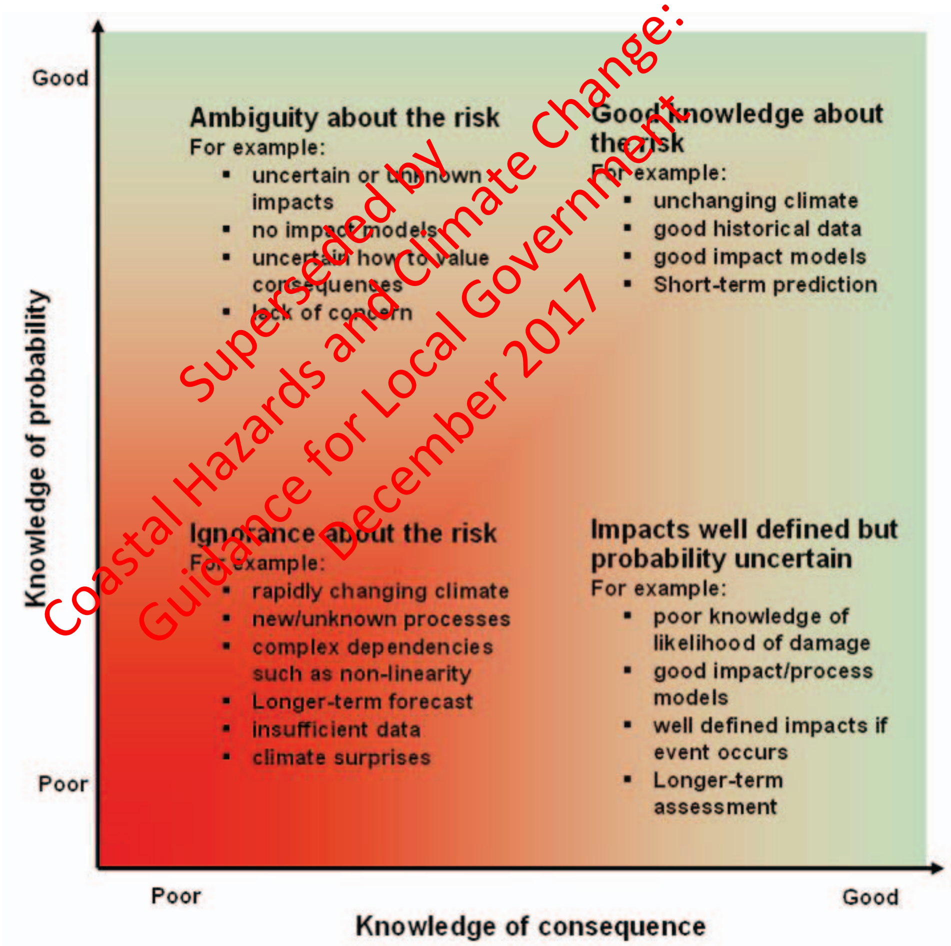

Figure 5.2: Summary of different sources of uncertainty and some of their contributing factors relating to hazard risk and climate change. Source: adapted from Willows and Connell 2003.

It is important to appreciate and clearly define where uncertainty exists, which uncertainties have the most impact on the decision to be made, and the possible steps that could be taken to reduce uncertainty. It may be that the scale of the decision does not warrant detailed investigation to reduce such uncertainty, or that adopting a precautionary approach is appropriate. More detailed approaches to risk assessment allow more robust methodologies for incorporating uncertainty into the assessment procedure.

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[54] UKCIP 2003.

Irrespective of the level of detail of the risk assessment process, the number of uncertainties that are involved with future climate change will require use of a mixture of quantitative and qualitative information. While the risk assessment process provides a systematic process, judgement (based on a range of information sources) will still need to applied.

5.3 The risk assessment process

The risk assessment process described in the following sections is based on the New Zealand Standard for Risk Management, AS/NZS4360[55] (see Figure 5.3). The process can be used to:

- identify and characterise the nature of the risk
- identify qualitative or quantitative estimates of the risk
- compare the sources of risk
- assess the impact of uncertainty within the context of the overall decision
- assess and compare the potential effectiveness of solutions to manage the risk.

This section considers steps 1 to 5 of the risk assessment process detailed in Figure 5.3, with step 6, on managing the risks, being covered in chapter 6.

5.3.1 Step 1: Define the problem and establish the context

This first step 'sets the scene' within which the risk assessment process takes place and the context within which coastal hazards and climate change effects fit. Defining the issue will assist with selecting the level of risk assessment required (Box 5.2). The significance of the risk and the appropriateness of the adaptation measures can then be judged against these considerations.

Box 5.2: Establishing the context – key considerations

What is the problem or objectives that need(s) to be addressed?

Where does the need to make a decision come from?

What are the primary drivers behind the problem?

What is the planning timeframe and/or realistic 'permanency' timeframe?

What are the boundaries, both spatially (ie, potential area affected by the hazard or decision, and temporally (ie, the period) over which the decision will be applied?

What constraints and decision criteria can be identified?

What is the extent and quality of data and information available?

What is the level of risk analysis to be adopted?

What legislative or policy constraints or requirements may apply?

What information on similar decisions and other guidance is available for this issue?

Have coastal hazards and climate change been incorporated within the decision-making process before, or been accounted for at a higher level (eg, policy or strategic)?

How will the risk assessment be used within the decision-making process?

What is the approach to risk, eg, should a precautionary approach be adopted?

What resources are available to aid the risk assessment and decision-making?

55 Standards New Zealand 2004.

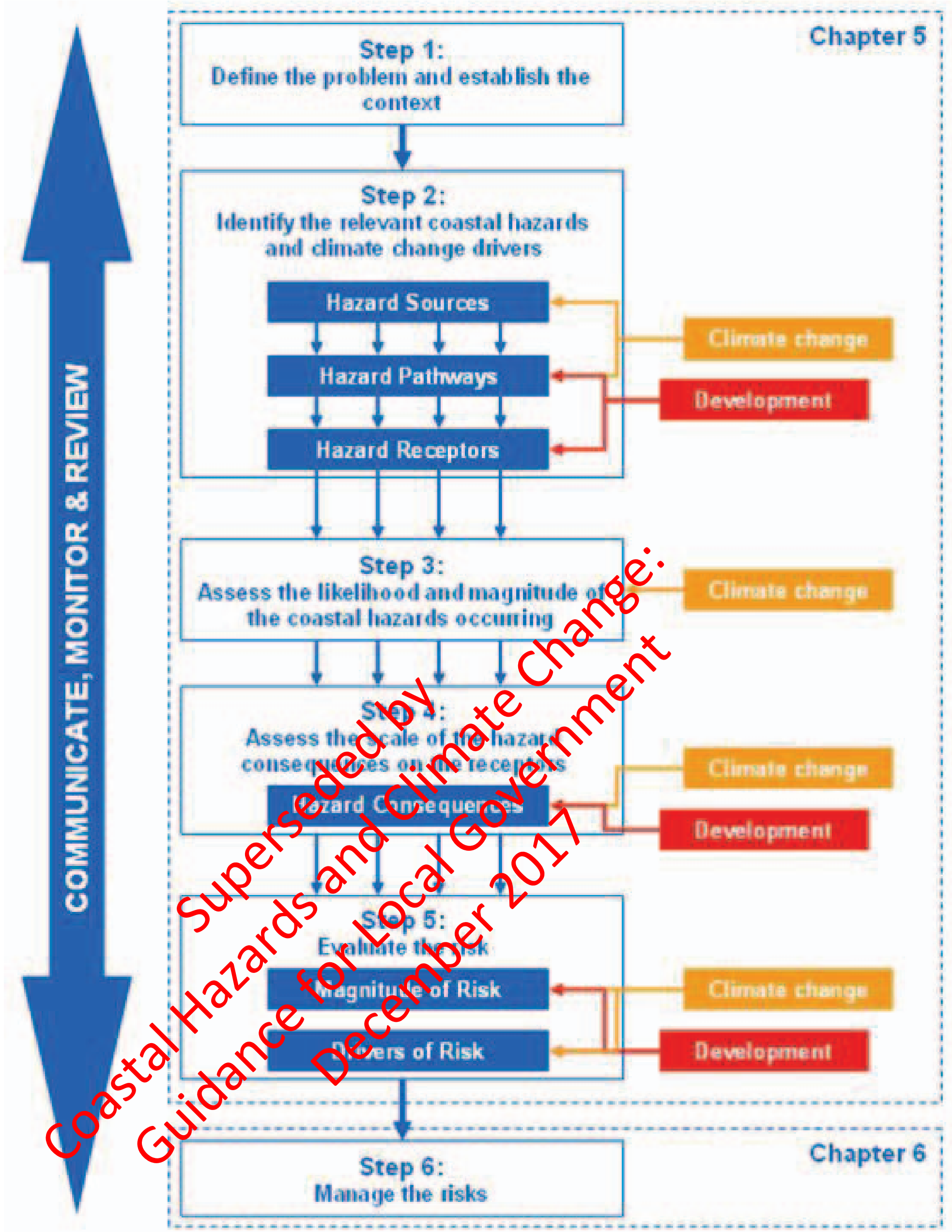

Figure 5.3: A process of coastal hazard risk assessment showing how the Source-Pathway-Receptors-Consequences framework, and consideration of the effects of climate change and future development, fit in to the risk assessment process. Source: adapted from Standards New Zealand 2004.

5.3.2 Step 2: Identify the relevant coastal hazards and climate change drivers

FS 1, 2, 3

Understanding a community's coastal hazards, vulnerability and exposure to damage, and how these may change over time, is the foundation for developing effective and appropriate risk-management and -reduction measures. For a coastal hazard risk to occur, there needs to be a 'driver' (such as a storm), a 'receptor' (such as property within the coastal margin), and an erosion or inundation pathway between the two, created by the driver. However, a driver or hazard does not necessarily lead to a harmful impact, only the possibility of harm occurring.

Coastal hazards and their consequences often have multiple sources, pathways and receptors (eg, people, infrastructure, property), which may or may not be related and interacting, may or may not occur at the same time, may occur over different timescales (eg, an event such as a tsunami compared to slow coastal erosion), resulting in the overall consequence. Appreciating these interactions is important.

The Source-Pathway-Receptor-Consequence (SPRC) framework (Figure 5.4) is a convenient way to consider the key drivers of coastal hazards and how they impact on the range of the human and built environment within particular coastal margins. Example sources, pathways and receptors for different coastal hazards are shown in Table 5.2.

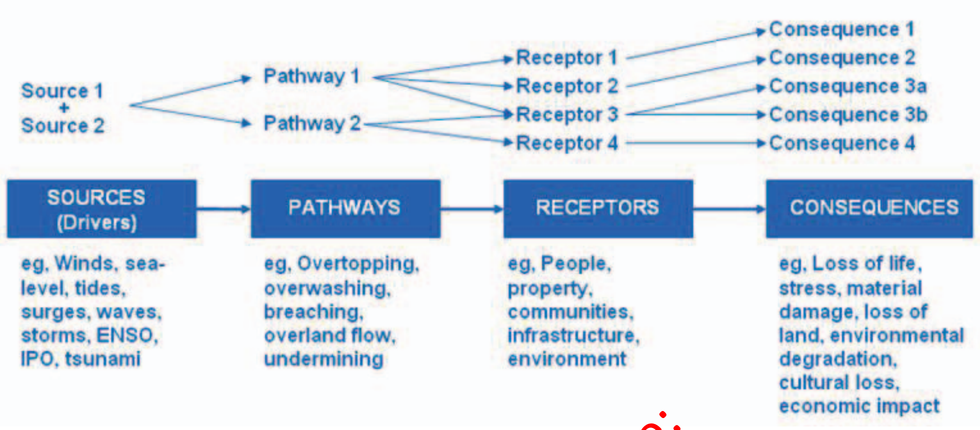

Figure 5.4: Source-Pathway-Receptor-Consequences (SPRC) framework for assessing coastal hazard risk. A conceptual example of how different source-pathway-receptor-consequence combinations can form is shown at the top of the figure.

Identification of the hazards and what is exposed to these hazards focuses on the first three components (Sources, Pathways and Receptors) of the SPRC framework.
To apply the framework:

1. For the present day, consider the combinations of hazard sources, the range of pathways they use, and the extent of the receptors (or potential receptors) each source/pathway combination impacts on, for the location and situation under consideration.
2. Consider how the different source-pathway combinations may interact. For example, coastal erosion could lead to an increased possibility of dune breaching and hence inundation.
3. Over the timeframe in question, consider the changes that climate change and natural climate variability will have on the identified hazard sources and pathways, how they interact and the resulting impacts on receptors (or potential receptors).
4. Identify whether climate change will result in new source-pathway hazard combinations that will impact on the receptors (or potential receptors).

Table 5.2: Example sources, pathways and receptors for different coastal hazards

Hazard	Sources	Pathways	Receptors
Coastal inundation	• Sea level (tides, storm surge) • Waves • River flow • Rainfall • Influence of ENSO and IPO • Wind	• Direct inundation of low-lying coastal margins • Overtopping of dunes, coastal barrier or coastal defences • Breaching or overwashing of dunes, gravel barrier or coastal defences • Via beach access points and boat ramps • Inundation via rivers and streams • Backed up stormwater systems	• People • Residential property • Commercial property • Essential services • Infrastructure • Cultural assets • Ecosystems • Landscape and natural character values
Coastal erosion: Beaches	• Sea level (tides, storm surge) • Waves • Sediment supply (rainfall and/or river flow) • River flows • Tidal prism in estuaries • Stormwater discharge • Influence of ENSO and IPO	• Continuous retreat (due to episodic storms) • Retreat (but with fluctuations in the short–medium term) • Stable (but with fluctuations in the short–medium term) • Fluctuations in coast position due to inlet and river mouth dynamics • Overstepping of coastal barrier	
Coastal erosion: Cliffs	• Sea level (tides, storm surge) • Waves • Rainfall • Temperature • Influence of ENSO and IPO	Slumping and/or slippage due to: • Undermining of cliff • Oversteepening of cliff • Removal of talus toe protection • Lowering of shore platform • Lowering of toe beach levels • Internal factors (weathering, groundwater, shrinkage)	
Tsunamis	• Local source • Regional source • Distant source	• Direct inundation of low-lying coastal margins • Overtopping of dunes, coastal barrier or coastal defences • Breaching or overwashing of dunes, gravel barrier or coastal defences • Via beach access points • Inundation via estuary margins, river and stream mouths	

Box 5.3: Identifying the risks – key considerations

Hazard sources and pathways:

- Have coastal erosion lines or zones been defined or have inundation zones been assessed?
- How does the general coastal morphology vary along the coast, eg, beach, cliff, estuary?
- What is the dominant beach type (eg, sand, shingle) and how does this change along a coast?
- What is the width of the beach or intertidal area?
- How does the exposure to particular wave conditions (eg, swell or locally generated waves) and wave directions change along the coastline?
- What is the height and width of natural frontal barriers (eg, dunes)?
- How do these natural barriers vary along the coast and how might they change over time (eg, reduction in width due to erosion)?
- What are the characteristics of the coastal hinterlands?
- Are there any known vulnerable locations (eg, access points, spits, estuaries or river mouths, levelled dunes)?
- What particular low-lying areas are there?
- Is there a history of coastal hazards affecting this location?
- What events have happened in the past?

Receptors:

- What is the land use and where does it occur?
- What is the density of development?
- How many people live within the coastal margins?
- What are the approximate/relative values of the assets?
- Is any lifeline infrastructure or critical facilities located within the area (eg, hospitals, key transportation or network utilities that provide lifeline connections and for which there is no alternative)?
- Is the value of the assets likely to rise markedly in the future (eg, because of redevelopment of residential property)?
- Are assets easily re-locatable (eg, cabins at a camping ground with no plumbing/drainage services, compared with concrete slab on-grade houses)?
- Are there particular environmental issues to be considered (eg, significant mangroves, wetlands, seabird feeding or nesting areas, dune ecosystems)?
- What level of access is available, how is this access affected?
- Are there any cultural or heritage sites?
- How may these criteria change over the period that the particular decision is to be applied?

5.3.3 Step 3: Assess the likelihood and magnitude of the hazards occurring

For each of the potential hazard sources and pathways affecting receptors located within the coastal margin, an assessment is required of the magnitude of these hazard occurrences and how likely they are to occur.

It is important to note that different coastal hazards have different characteristics. Storm and tsunami inundation tends to be episodic and inundation levels can typically be defined in a probabilistic way; for example, there is a 1% chance of a storm tide of a certain level being exceeded in any one year (see Box 5.4). Coastal erosion, on the other hand, at present tends not to be expressed probabilistically. As it is an ongoing process (a creeping hazard), it is usually defined as the expected position of the coast at a certain future point in time.

Box 5.4: Annual exceedence probabilities and return periods

For episodic hazard events such as storms and tsunami, we tend to express the likelihood of their occurrence in terms of Annual Exceedence Probability (AEP) or in terms of average return period.

'AEP' refers to the chance of a particular threshold (eg, storm-tide level) being equalled or exceeded in any one year. It is defined either as a number between 0 and 1 or as a corresponding percentage. Common AEPs used in hazard assessment include 0.01 (or 1% AEP), which means that there is a 1% chance of an event of a given size or larger occurring this year, or any year. An AEP of 0.02 (or 2% AEP) means that there is a 2% chance of an event of a given size or larger occurring this year, or any year.

In general for extreme probabilities of less than 0.1, the average return period for an event is the reciprocal of the AEP. Hence 0.1 (or 10%) would have an average return period of 10 years; 0.01 (or 1%) an average return period of 100 years.

The use of AEP to define the likelihood of hazard events is preferable to the use of return period terminology, which is often misused. It can lead to a false sense of security for non-technical people if there is not an equivalent statement qualifying the likelihood of a particular event occurring or being exceeded during a particular timeframe.

As a rule of thumb, there is approximately a 63% chance of an event with an AEP of 2% occurring in a 50-year timeframe, or a 1% AEP event occurring within a 100-year timeframe (see Figure 5.5 below).

Information and/or data on hazard probabilities for a particular location, or consideration of coastal hazard zones where data and/or information have been derived, should be used wherever they are available. For a qualitative assessment, consideration can be given to the following categories, which are based on the terminology for expressing the likelihood of occurrence in the Fourth Assessment Report.[56] Boundaries between the categories should be considered 'fuzzy'. Depending on the situation, for either each source-pathway combination creating a coastal hazard, or cumulatively for each coastal hazard, the following is considered:

- For coastal erosion: Over the timeframe of interest (eg, 100 years), consider which terminology best fits the likelihood of the different coastal erosion pathways affecting the issue or receptor under consideration:
  - Virtually certain: > 99% probability of occurrence
  - Very likely: 90–99% probability of occurrence
  - Likely: 66–90% probability of occurrence
  - About as likely as not: 33–66% probability of occurrence
  - Unlikely: 10–33% probability of occurrence
  - Very unlikely: 1–10% probability of occurrence
  - Exceptionally unlikely: < 1% probability of occurrence
- For storm and tsunami inundation: Again, select the terminology (based on the categorisation above) that best fits the magnitude of the event for each inundation hazard pathway for the planning timeframe in question.

To assist this assessment, Figure 5.5 shows the relationship between Annual Exceedence Probability (horizontal axis) and the likelihood of occurrence within certain planning timeframes (vertical axis). The coloured lines define the relationship for planning timeframes of 20, 35, 50, 75, 100 and 150 years.

[56] IPCC 2007d.

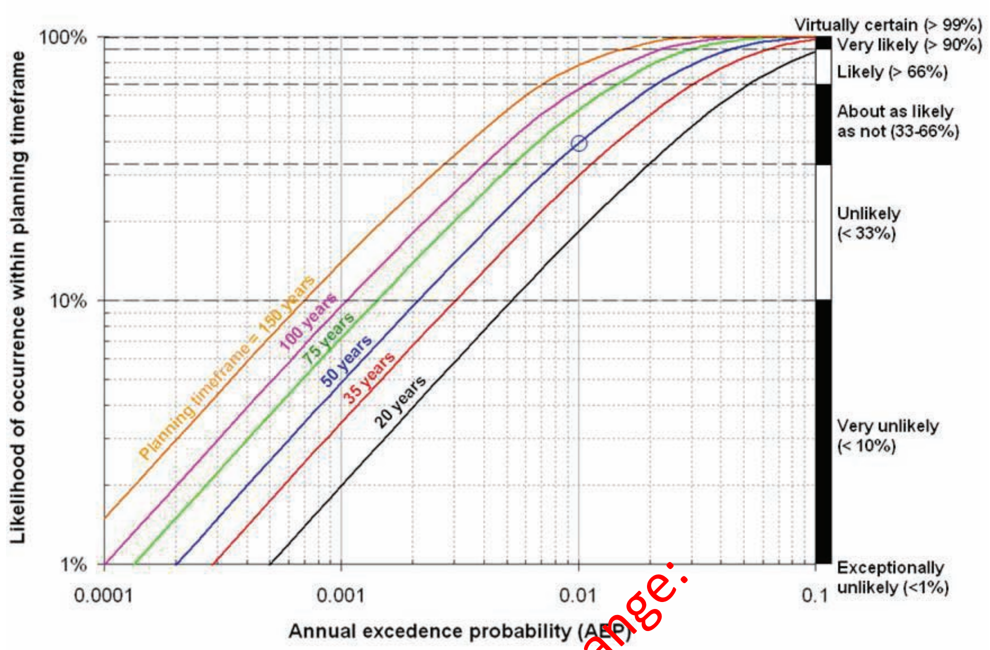

Figure 5.5: Likelihood of occurrence of different Annual Exceedence Probability (AEP) events over planning timeframes ranging from 20 to 150 years. For example, there is approximately a 38% chance of a 1% AEP event occurring within a 50-year (blue line) timeframe (blue circle). Hence, such an inundation event would be defined as being 'about as likely as not' to occur. Terminology based on IPCC 2007d.

Where the effects of climate change on the likelihood or magnitude of the hazard are significant, the table above could be used to assess how climate change may change the likelihood of the hazard. However, in many cases, the above categories may be too coarse to define the hazard changes that climate change may bring about. This is discussed further during the evaluation of the risks in Step 5 below.

5.3.4 Step 4: Assess the scale of the hazard consequences on the receptors

Just as we must consider the magnitude, and likelihood of occurrence, of the different ways coastal hazards may impact on a coastal margin and the receptors (or elements) in it, understanding the potential scale of the consequence is also necessary. To develop this understanding, we can consider the degree of vulnerability of the existing (and potential) receptors in the coastal margin.

The impact of coastal hazards can have many consequences, only some of which can be expressed in monetary (tangible) terms. The measure of consequences can include: fatalities, injuries, stress and physical disruption to people; tangible and intangible loss and damage to property, community and lifeline infrastructure, the environment and cultural assets; and direct and indirect impacts on the economy.

The range in the potential scale of the consequence depends again on the characteristic of the coastal hazard, its interaction with a particular receptor and how vulnerable that receptor is. For example, a major tsunami event has the potential to result in substantially higher numbers of fatalities compared to ongoing coastal erosion, which would rarely threaten life. Coastal erosion, on the other hand, may result in irreversible loss of significant numbers of property, or ecosystem or cultural assets. An episodic event, such as inundation due to a major storm, may cause only disruption for a period of time, or damage that can be repaired.

Again, depending on the situation, the level of consequence for each receptor is assessed: either for each source-pathway combination creating a coastal hazard risk, or cumulatively for each coastal hazard risk. Some common receptors and suggested levels of consequence are defined in Table 5.3, although alternative types of scaling can be used to suit the particular situation.

Note once again that the categorisation of the consequences in Table 5.3 may be too coarse to detect either:

1) the extent of change that climate change may bring to the level of coastal hazard consequence, or

2) the extent of change that further development may bring to the level of coastal hazard consequence.

This is discussed further during the evaluation of the risks in Step 5.

Table 5.3: An example of the level of consequences for different receptors affected by hazard occurrence. The criteria for such a table are likely to be specific to each region.

Receptor	Consequence				
	Insignificant	Minor	Moderate	Significant	Major
People displaced (no. or permanency)	< 10 Short-term inconvenience	10–50 Disruption for several days	50–100 Disruption for weeks – months	100–200 Permanent loss of some homes	> 200 Permanent loss of many homes
People (no. of injuries)	< 5	1–10	10–25	25–50	> 50
People (no. of fatalities)	0	0	1	< 5	> 5
Economic impact	Minimal financial losses	Moderate financial loss for a small number of owners	High financial losses probably for multiple owners	Major financial losses for many individuals and/or companies	Huge financial losses involving many people and/or corporations and/or local government
Essential services	Short-term inconvenience	Disruption for a day or two	Disruption for several days to weeks	Some long-term impacts	Large long-term loss of services
Infrastructure	Short-term inconvenience	Disruption for a day or two	Disruption for several days to weeks	Loss requiring reinstatement of parts of infrastructure network	Loss of significant parts of infrastructure network requiring reinstatement or relocation
Commercial services	Short-term inconvenience	Disruption for a day or two	Disruption for several days to weeks	Some long-term impacts	Extensive long-term loss of services
Cultural assets	Some minor impacts	Some impacts on significant cultural assets	Moderate impacts on significant cultural assets	Some irreversible damage to cultural assets	Complete loss of significant cultural assets
Ecosystems	Short-term impact	Some impacts on valued natural environment	Moderate impacts on valued natural environment	Major impacts on valued natural environment	Complete loss of important natural environment

5.3.5 Step 5: Evaluation of coastal hazard risk

The magnitude of risk is commonly expressed as a combination of the magnitude of the hazard occurrence and the magnitude of the vulnerability or consequence. Before making decisions on how such risks may be managed (see chapter 6), the final step requires assessing the level of risk; what is driving ongoing and longer-term changes in the level of risk; and the significance of such risk in relation to the many other factors that need to be taken into account when considering coastal margin policy, planning and resource consenting decisions. As such, this step involves assessing:

- the level of risk to the issue or receptor under consideration
- the significance of this risk
- how climate change may affect this level of risk
- what is driving the changing levels of risk.

Figure 5.6 provides a qualitative assessment of the level or risk for each of the source-pathway-receptor-consequence combinations (or cumulatively for each coastal hazard). It is based on the assessment of the magnitude and occurrence of coastal hazard risk (Step 3), and the potential vulnerability of, or consequence on, the various receptors located (or planned to be located) in the coastal margins (Step 4).

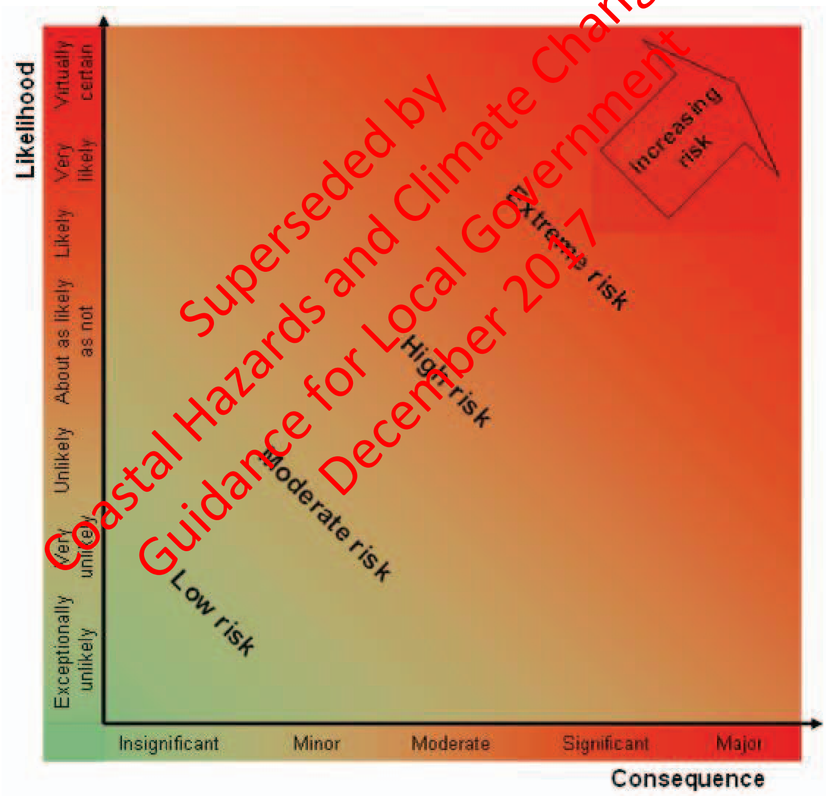

Figure 5.6: Risk matrix linking the likelihood of the hazard, scale of the consequence and resulting level of risk.

Understanding what is driving changes in the level of coastal hazard risk is the final part in this component of the risk assessment process. That understanding provides the foundation for informed decisions to be made about the acceptable level of risk, how such risk should be managed (next chapter) or whether a more detailed assessment of risk is required.

Profiles of coastal hazard risk over the next 100 years will change, driven by variations in the:

- magnitude and frequency of hazard events caused by climate change
- human and built environment that are located within coastal margins susceptible to such hazards.

Understanding the relative contribution of each of these factors to coastal hazard risk is important.

In many situations around the coast of New Zealand, changing coastal hazard risk over the next 100 years and longer will be dominated by ongoing development (or increasing value of development) in coastal margins rather than by changes in the occurrence or magnitude of hazard events.

The extent of change of coastal hazard risk (due to either a changing climate or increases in the level or extent of development) can not always be discerned using the methodology outlined above. If so, then a qualitative assessment of the relative magnitude of influence of these drivers can be made, based on Figure 5.7.

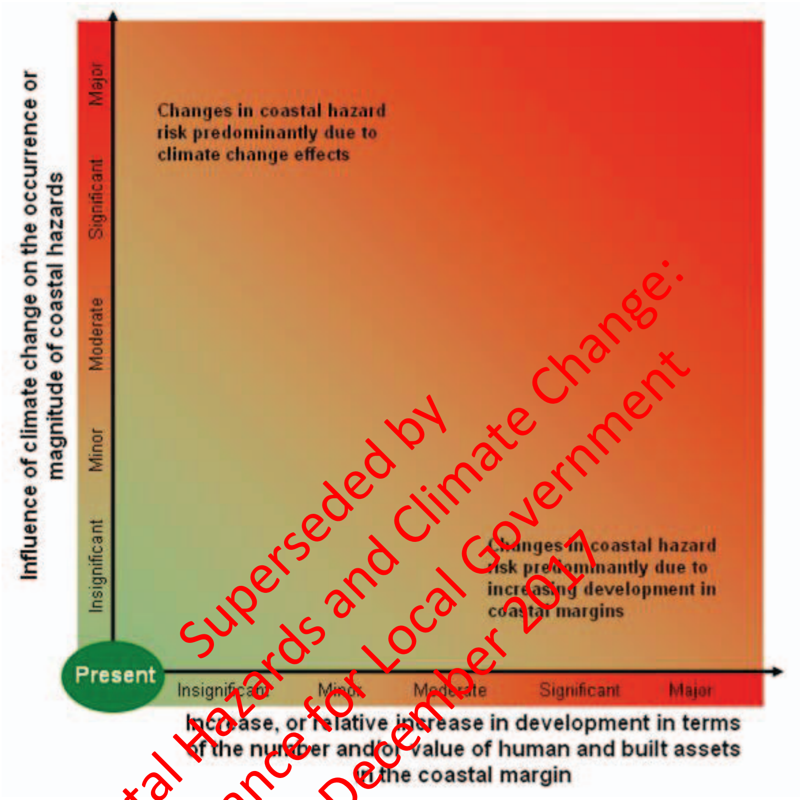

Figure 5.7: Relative influence of climate change-related and human development-related impact on future coastal hazard risk

5.4 Detailed risk assessment

Using the above risk framework permits a conceptual approach to assessing coastal hazard risk and the effect climate change may have on it. For many issues, such a qualitative assessment of risk may be sufficient; the same framework can also be used for a more detailed assessment of coastal hazard risk.

Depending on the particular situation or issue under consideration, a more detailed or quantitative risk assessment may be needed to aid the decision-making process. Such a more detailed assessment will typically involve some or all of the following:

- analysis of existing datasets or monitoring of hazard sources and receptors to collect further data
- application of quantitative approaches to hazard and risk modelling
- expert opinion.

In general, approaches to quantifying the physical aspects of coastal hazards are relatively well defined. Generally, there is much lower capability for quantitative assessment of biophysical and social, human and cultural impacts. However, whatever methods or approaches are used, there will still be inherent uncertainties or assumptions that need to be made. These, along with the uncertainties relating to projections of future climate, need to be taken into account and clearly communicated.

6 Managing Coastal Hazard and Related Climate Change Risks

6.1 Introduction

The risk assessment process and use of up-to-date knowledge of climate change can help local government and communities adapt to known climate change. The risk assessment process outlined in the previous chapter fits comfortably into the plan preparation and review required by the Resource Management Act 1991 (RMA) and Civil Defence Emergency Management Act 2002 (CDEM Act) at the stages where issues are being identified and a range of possible response options evaluated. With the advanced knowledge of general climate change effects on coastal hazards, the need for an unplanned response to climate change can be avoided.

In managing and reducing coastal hazard risks, the main purpose of this Guidance Manual is to ensure the following:

- a precautionary approach is adopted when making land-use planning decisions relating to new, and changes to existing, development in coastal margins that takes account of the level of risk; and uses existing scientific knowledge and accounts for scientific uncertainties
- new development is not exposed to, or does not increase the levels of, coastal hazard risks over its intended serviceable lifetime. Progressively, the levels of risk to existing development are reduced over time
- the role of natural coastal margins is recognised in decision-making processes, and consequently coastal margins are secured and promoted as the fundamental form of coastal defence and as an economic, environmental, social and cultural resource
- an integrated and sustainable approach to the management of development and coastal hazard risk is adopted, which contributes to the environmental, cultural, social and economic well-being of people and communities.

6.1.1 The legislative context

Successful management of coastal hazard risk and the effect of climate change on coastal development, and sustainable management and development of our coastal margins, do not take place in isolation. Rather, they are integral components of protecting the natural character, public access and amenity values of the coastal environment, as well as the significant values and perceptions for the cultural, social and economic well-being of people and communities.

Regional and territorial authorities have responsibilities and duties relating to avoiding, remedying and mitigating coastal hazard risk, primarily under the planning framework of the Local Government Act 2002 and the Resource Management Act (Figure 6.1). The RMA was amended in 2004 to include the effects of climate change as a matter for councils to have particular regard to in decision-making, including in relation to managing coastal hazards. The RMA is effects-based, with the purpose of bringing about sustainable management of natural and physical resources through planning of both land and the coastal marine area.

The other key legislation of relevance to coastal hazard risk management is the Civil Defence Emergency Management Act. The CDEM Act primarily focuses on the sustainable management of hazards, and the safety or people, property and infrastructure in an emergency, through an emphasis on risk reduction, readiness, response and recovery. Risk reduction is primarily achieved through proactive planning as required by the RMA, the Local Government Act 2002, the Building Act 2004, and the CDEM Act.

Appendix 1 provides a brief summary of the RMA, Local Government Act and CDEM Act in relation to coastal hazards and climate change, along with the associated New Zealand Coastal Policy Statement (NZCPS);[57] it also summarises other legislation of particular relevance to coastal development and hazard management: primarily the Building Act 2004, the Foreshore and Seabed Act 2004 and the Reserves Act 1997.

Figure 6.1: Planning framework under the RMA for the coastal environment.

A growing body of case law is available that is also directly relevant to managing climate change effects and local authorities' responsibilities for managing natural hazards. Summaries of relevant cases are provided in Appendix 2.

Key themes include:[58]

- recognising the reality of climate change
- clarifying the respective roles of regional and territorial authorities
- indicating principles of hazard avoidance, generally, and in areas which are already developed
- indicating timescales over which to consider effects
- clarifying the relationship between resource and building consents
- adopting climate change information and a cautious approach.

More detail on the legislative frameworks in relation to coastal development decision-making is provided in the *Coastal Development Guidance Note* on the Quality Planning website of the Ministry for the Environment,[59] in *The Community Guide to Coastal Development under the Resource Management Act 1991*[60] and (in terms of natural hazards in general) in the *Natural Hazards Guidance Note* on the Quality Planning website,[61] with a comprehensive review of coastal hazard management issues provided by Jacobson as part of the NZCPS review.[62]

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57 Under review – out for public consultation: March 2008.

58 MfE 2008a.

59 MfE 2008b.

60 Peart 2005.

61 MfE 2008c.

62 Jacobson 2004.

6.2 Principles for managing coastal hazard risks

Local government management of present-day and future risk from coastal hazards through policy development, planning and resource consenting involves a combination of inter-related risk-avoidance and risk-reduction activities. However, planning approaches will never completely nullify all coastal hazard risks that affect coastal communities.

Risk management also involves understanding and assessing the boundaries between risk-avoidance and risk-reduction activities, and risk-transfer activities – which deals with any portion of risk that is left over, after agreement is reached on levels of risk protection (Figure 6.2).

How these risk-management activities (ie, the typical relative contribution of each) relate to successful climate change adaptation in relation to coastal hazard risk is shown conceptually in Figure 6.3. The most effective adaptation will occur when the risk is avoided, but in many cases (eg, existing development), avoidance may be impractical and a mix of risk-reduction and risk-transfer approaches are required.

Figure 6.2: The risk-management triangle. Effective coastal hazard risk management is a combination of planning and resource consenting, emergency management and insurance.

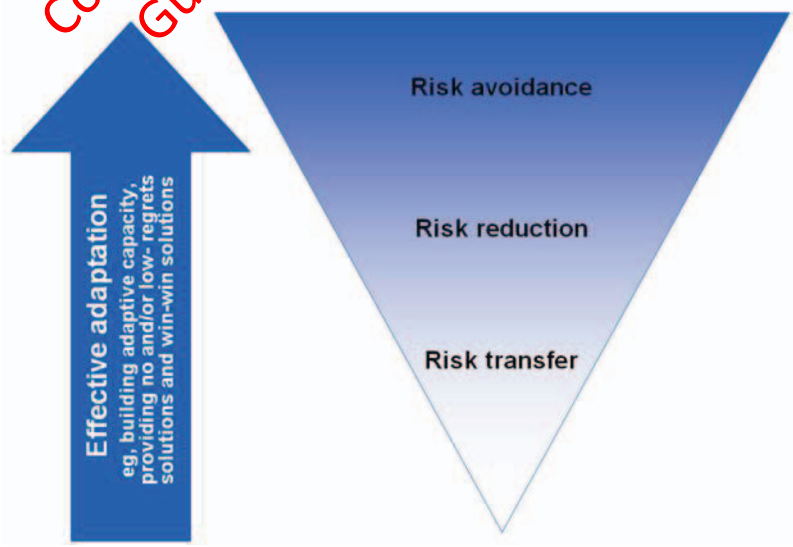

Figure 6.3: Relative contribution of risk-management activities for effective adaptation to coastal hazard-related climate change risks in coastal margins.

These risk-management activities involve a range of statutory and non-statutory measures. Some of these measures are applicable in many situations and others are suitable or effective in only exceptional circumstances. Measures include those that are well established and accepted compared to others that are relatively new, untested or trialled. The mix of measures will depend very much on: the nature of the hazard; the risk characteristics and how these are changing (specifically the duration, location, extent and nature of the issue in question); whether there is a particular driver present; and people's awareness, risk tolerance and willingness to adapt or pay to reduce risk.

The basic principles for coastal hazard risk management and how they apply to different categories of coastal development are summarised in Figure 6.4.

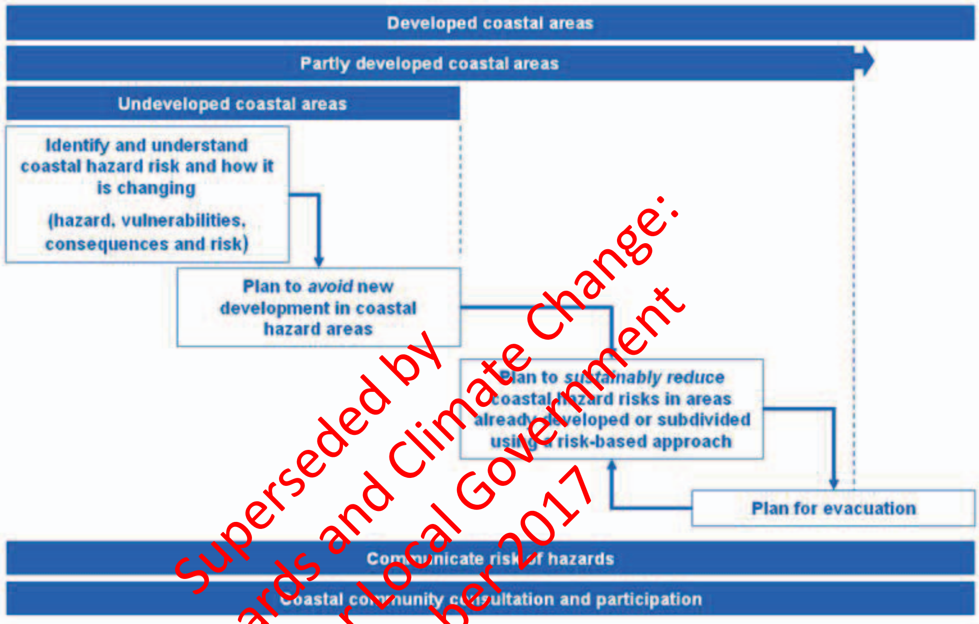

Figure 6.4: Basic hierarchy of principles relating to managing coastal hazard risk and the different levels of coastal development to which the principles apply.

Identifying and understanding coastal hazards, vulnerabilities and potential consequences within coastal margins (eg, through the risk framework detailed in the previous chapter) provides a foundation for land-use and emergency planning policies, and strategies for managing the associated risks.

These basic principles must also be underpinned by effective communication to build community awareness and public and political support for coastal hazard risk planning activities, and to support the processes of community consultation and participation for achieving effective community planning outcomes. There must also be a community acceptance of the upper threshold of risk treatment before emergency management arrangements come into play (especially for episodic events such as tsunami or storm-tide inundation).

6.3 Mechanisms for avoiding and reducing coastal hazard risks

Taking a precautionary approach to planning new development, infrastructure and services to avoid coastal hazards over their intended lifetime (see Figure 5.1 in section 5.2) is the most effective and sustainable long-term approach. This approach is relevant to all coastal development situations, from completely undeveloped coastal margins to high-density urban areas. It helps build effective adaptive capacity in permitting the human and built environment as well as natural coastal systems, to adjust or respond to climate change – thereby limiting the potential for damage, and providing opportunity for the natural coastal system to absorb much of the potential consequences.

For greenfield sites, ensuring that new development is located beyond (landward of) defined coastal hazard zones (left-hand side of Figure 6.4) should be effected through the appropriate controls in the regulatory processes of regional and district planning.

A more complex planning issue is dealing with existing development that is already located in areas identified as being susceptible to coastal hazards in the foreseeable future. This issue requires a wider mix of mechanisms for managing coastal hazard risk and promoting adaptation, which typically involve a combination of methods such as:

- information and education
- land-use planning regulation
- building consent controls
- financial mechanisms, eg, land purchase
- long-term infrastructure planning
- protection structures (soft and hard) where 'holding the line' is necessary.

Some of these methods are discussed in the sections that follow.

Box 6.1: Coastal hazard avoidance: different meanings for different coastal hazards

In the context of *coastal erosion*, avoidance means ensuring that an asset is not affected by retreat of a coastline over a specific period of time (typically 50–100 years).

For *storm inundation*, avoidance means ensuring that an asset is not significantly damaged by, or is located beyond (or above) an area prone to, inundation to a certain acceptable or defined risk level (usually expressed as an Annual Exceedence Probability) over a specific period of time. Residual risk, due to more extreme events, may be managed (depending on the asset) by adopting risk-reduction measures related to the asset's location and construction: the aim is to minimise impact and facilitate evacuation, emergency management and insurance.

For *tsunami inundation*, avoidance means ensuring that an asset is not damaged by, or is located beyond an area prone to inundation to an acceptable or defined risk level. (This may be expressed as an AEP or in terms of the magnitude, type and location of the event causing the tsunami). Residual risk due to more extreme events should be managed (depending on the asset) by adopting risk-reduction measures related to the asset's location and construction: here too, the aim is to minimise impact and facilitate evacuation, emergency management and insurance.

It is important to realise that, all other things being equal, the level of damage (consequence) experienced due to a tsunami that inundates an area to a certain level will typically be much greater than storm-related inundation to the same level. For example, a 1-m storm surge will be less damaging than a 1-m-high tsunami wave.[63]

6.4 Information and education

Public information and education on coastal hazards and risk underpins all aspects of coastal hazard risk management planning (Figure 6.4). Increased public awareness of coastal hazard risk is typically achieved through:[64]

- non-statutory approaches such as making available and/or facilitating and supporting: educational material, websites, public talks and meetings, effective use of media, Coastcare groups (to build practical community experience and 'ownership' of issues). Technical reports on the extent and significance of coastal hazards, and on options for reducing risks associated with these hazards are also important.

63 A 1-m high tsunami from a local or regional source will generally cause more direct physical damage than a 1-m high tsunami wave from a remote Pacific source. However, the latter will generally result in greater inundation volumes as the period of the wave is larger, and hence it encapsulates a larger volume of water.

64 Turbott and Stewart 2006.

- statutory mechanisms including:
  - incorporating hazard and risk information in regional and district plans, and other supporting statutory and non-statutory planning documents such as Long-term Council Community Plans (LTCCP), strategic plans and possibly annual plans
  - the Land Information Memorandum (LIM), which summarises all information that a council holds for a piece of land (see section 6.6). Among other things, it may contain information on potential erosion and inundation hazards that may affect the site, and is typically prepared for members of the public who are considering purchasing a property. An important consideration for council relates to the accuracy of the hazard information and potential liability issues (see also section 4.3)
  - placing notices of coastal hazard risk on property titles under sections 73 and 74 of the Building Act 2004.

It is well established, both in New Zealand and elsewhere, that the provision of information on coastal hazard risks does not always influence people's decision-making on purchasing or living in property within at-risk areas. Nor does it in general result in property owners proactively and sustainably reducing coastal hazard risk to their property.

Whilst education and the provision of hazard and risk information underpin all aspects of coastal hazard risk management, these are ineffective in managing coastal hazard risk on their own.

6.5 Risk management and adaptation through land-use planning

6.5.1 RMA planning framework

Coastal development and the effects of coastal hazards (and resulting effects climate change has on these hazards) is primarily managed by regional councils and territorial and unitary councils through the statutory land-use planning process:

- regional policy statements, regional coastal (environment) plans and district plans are prepared under the RMA and must give effect to national policy statements and the NZCPS[65]
- subdivision and resource consent considerations must have regard to the objectives, policies, methods and rules defined in the regional policy statement, regional and district plans, and the provisions of the NZCPS, national policy statements and Part II of the RMA.

A regional policy statement defines the regionally significant resource management issues over both land and the coastal marine area within a particular region and sets region-wide objectives and policies. It also details the methods to use in addressing and implementing the objectives and policies. The regional policy statement has a key role in integrating resource management issues. However, it does not contain rules and therefore does not control activities directly.

Under the RMA, regional councils are responsible for controlling the use of land for the purposes of avoiding or mitigating natural hazards. They may control any actual or potential effects of the use, development or protection of land within the coastal marine area (defined as the area from Mean High Water Spring (MHWS) out to the 12 nautical mile limit), for avoiding or mitigating natural hazards.

City and district councils are empowered by the RMA to control the effects of land-use activities for the purpose of avoiding or mitigating natural hazards.

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65 RMA sections 62(3), 67(3)I, 75(3).

In the context of land-use controls for avoiding or mitigating natural hazards, the functions of the regional councils and territorial authorities are similar. It is vital that a collaborative and integrated approach between the authorities is adopted to ensure that consistent structures for environmental policy and rules are developed.

The purpose of the regional policy statement is to provide an overview of the significant resource management issues of the region and policies and methods to achieve integration.[66] In regard to natural hazards, this purpose is reinforced through RMA section 62(1)(i)(i), which requires the regional policy statement to specify which local authority (region, district, city or unitary) is responsible for controlling the use of land for avoiding or mitigating natural hazards or any group of hazards.

This statement of relative responsibility will help clarify district and regional responsibilities for managing coastal hazards. Most first-generation regional coastal plans addressed only the coastal marine area, but some regional councils have developed regional coastal environment plans. These latter plans focused on the integrated management of the coastal marine area and the landward areas. Some regional coastal environment plans concern only the objective and policy level, while others also include rules controlling activities on land for hazard and soil conservation purposes (Figure 6.5 shows one regional coastal environment plan). For example, regional plans cannot control subdivision, but may state policies directing how subdivision in coastal hazard areas is to be managed.

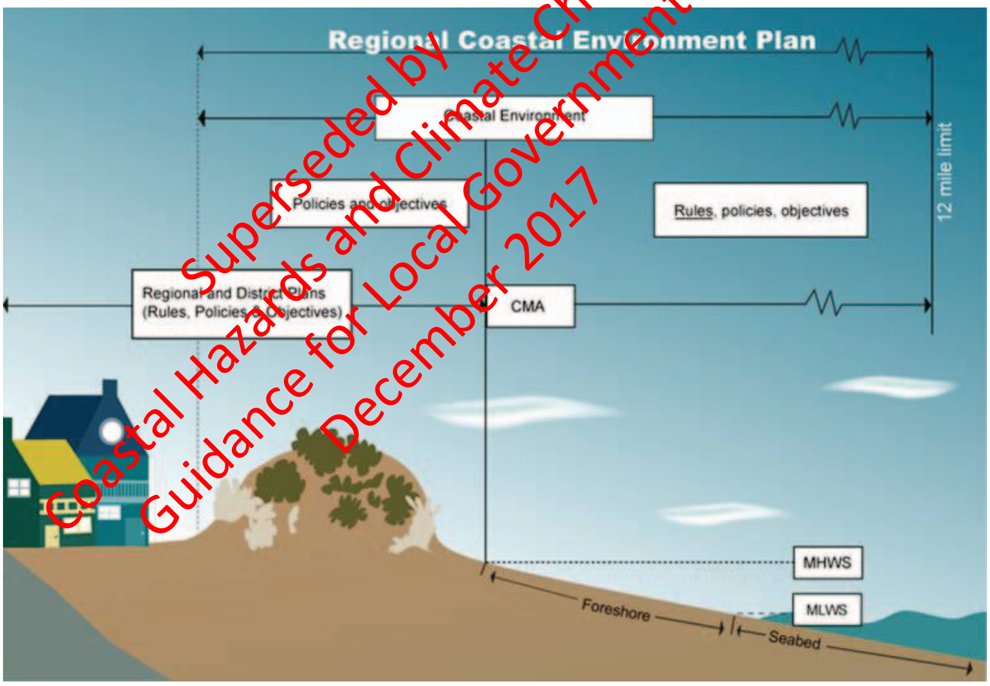

Figure 6.5: Plan boundaries as defined in Environment Bay of Plenty's Regional Coastal Environmental Plan. A number of regional coastal plans cover only the coastal marine area (ie, seaward of MHWS), whereas others also include the land–sea interface in the coastal environment. CMA=Coastal Marine Area. Source: Environment Bay of Plenty 2003.

District plans focus on the subdivision, use and development of land; they include objectives, policies, rules or other methods that guide and control related activities. District plans must give effect to the objectives and policies of the NZCPS and the regional policy statement and must not be inconsistent with any objective, policy, rules or other methods in a regional plan. Some key issues and differences relating to regional and district plans are summarised in Table 6.1.

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66 RMA section 59.

Table 6.1: Some key issues and differences between regional and district plans relevant to coastal hazard risk management and climate change. Source: adapted from Turbott and Stewart 2006.

Regional plans	District plans
• An activity *cannot occur* unless there is a rule specifically permitting the activity, or a resource consent is obtained. Note: this does not hold true in respect of RMA section 9(3) – Restrictions on the use of land.	• Activities *are permitted* unless there is a rule stating that the activity requires a consent (eg, building coastal defences above the MHWS line is a permitted activity unless there is a rule in the plan controlling it). • The exception to this is subdivision (RMA section 11), which cannot occur unless it is allowed in the district plan or a resource consent is obtained.
• Rules *cannot* be used to control subdivision.	• Rules *can* be used to control subdivision.
• Rules have potential to control both existing and new development on land. Historically, most regional councils have deferred this responsibility to the district or city councils.	• Rules cannot control activities occurring seaward of the MHWS position.
• Rules have potential to control coastal defence works both in the coastal marine area and on land.	• Rules can control coastal defence works on land only above MHWS.
• If controls on building in a hazard area are contained within the rules, then it is not possible to rely on existing use rights.	• If controls on building in a hazard areas are contained within the rules, then existing use rights will apply under section 10. • Controls on building in a hazard area with existing use rights can be applied only where substantial extension or upgrade of the building is undertaken.

6.5.2 Management of coastal hazard risk through rules in regional and district plans

The effectiveness of managing coastal hazard risk through the RMA process primarily comes down to:

- How effective are the rules in the district plan in controlling subdivision, use and development activities in coastal hazard areas?
- How well are the overarching policies and objectives – that are defined within the NZCPS, the regional policy statement and regional plans – encapsulated and specified within the district plans?

The effectiveness also depends on the degree to which compliance with the district plan is monitored and enforced. Requirements will vary between districts and regions, but effective regional and district plans that relate to managing coastal hazard risks, and the effects of climate change, must include rules and other methods that:

- are based on risk, in particular, are related to the importance or vulnerability of the specific elements (receptors) at risk (Figure 6.6 and Box 6.2)
- recognise the importance of specific and well-defined coastal setback zones for coastal hazard areas covering a lengthy planning horizon such as 100 years. They need to be periodically reviewed and redefined and may also incorporate other setback requirements, such as those related to landscape and natural character requirements
- are flexible enough (through precautionary or risk-tracking approaches) to accommodate the variability and uncertainty associated with natural coastal hazards and the uncertainties associated with future climate change and its impact on coastal hazards (see Figure 4.2)
- specify coastal hazards as a regionally significant issue and state a preference for risk avoidance for new development and risk reduction for existing developed areas

- do not lock in future generations to particular or restrictive approaches to risk management; nor do they reduce the range of risk-management approaches that are available at present (eg, constructing coastal defences typically results in the expectation that such defences will be maintained *in perpetuum*, leading to ever increasing financial commitment to maintain and upgrade such defences)
- encourage no-regrets and win–win solutions to reducing risks and building long-term community resilience
- place a strong emphasis on integrated planning across the MHWS boundary
- maintain the natural coastal defences and buffers and encourage mechanisms for their enhancement (such as Coastcare)
- strategically identify in the regional and district plans (or, where appropriate, in other non-statutory plans or strategies) where certain management approaches (such as 'hold the line' approaches) may be appropriate and acceptable
- are specific, particularly about what is not permitted in district plans in relation to: 1) new or intensified coastal development in coastal hazard areas, and 2) building new or upgrading coastal protection works within the coastal environment
- integrate the range of coastal hazard risk, rather than treating coastal erosion, storm inundation and tsunami risk independently
- identify and permit a mix of complementary statutory and non-statutory risk-reduction activities
- define transition mechanisms and timeframes for current unsustainable approaches to risk management, so as to move towards sustainable approaches
- facilitate ongoing research and understanding of coastal hazards, vulnerabilities and potential consequences within coastal margins, how these are changing and what is driving these changes. Facilitate also the subsequent incorporation of this information in: regional and district plans, strategic, community, annual and management plans, and community awareness and education activities.

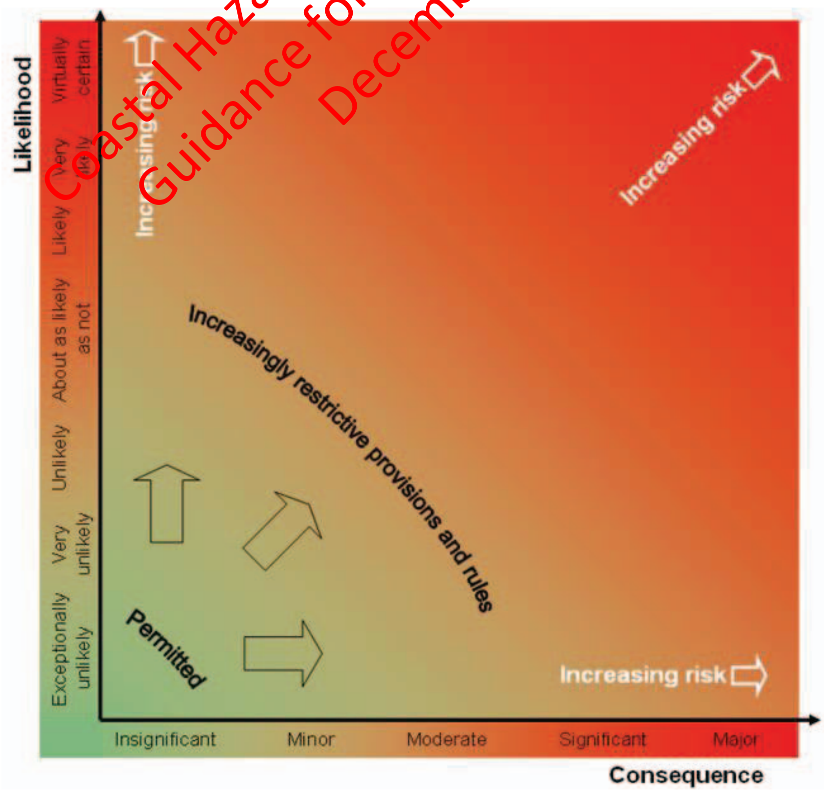

Figure 6.6: Conceptual representation of the relationship between the magnitude of the risk and the restrictiveness of resource consent category within the coastal environment.

There are some significant barriers to achieving effective risk reduction through the land-use planning framework. These relate particularly to relocating property at risk and managing existing use rights, the management of esplanade reserves on eroding coastlines, and managing the ongoing public and political pressure for coastal protection works to 'hold the line' on eroding coasts. These issues are addressed in the sections that follow.

Box 6.2: Vulnerability zoning – increasing risk standards in Europe

In many places in the world, coastal hazard risk is expressed in terms of an acceptable event return period (or AEP; see Box 5.3).

In Sweden, risk is defined this way, but the definition varies depending on the 'social tolerance' of inundation expressed in terms of the impact. Hence, inner city areas with a high level of people at risk and a high level of investment have the lowest tolerance.

Such an approach is increasingly being used elsewhere, including in Scotland, England and Northern Ireland for flood policy (which includes coastal erosion and inundation). An example of one of these risk frameworks (in simplified form) is outlined below (adapted from *Scottish Planning Policy SPP7:* Planning and flooding).

1. **Little or no risk areas:** AEP of watercourse, tidal or coastal flooding less than 0.1% (1000-year return period).

   Appropriate planning response: No constraints on planning due to flood risk

2. **Low to medium risk areas:** AEP of watercourse, tidal or coastal flooding in the range 0.1–0.5% (1000–500-year return period)

   Appropriate planning response: It will not usually be necessary to consider flood risk unless local conditions indicate otherwise. Suitable for most development. A flood risk assessment may be required at the upper end of the probability range (ie, close to 0.5%) or where the nature of the development or local circumstances indicate(s) heightened risk. Water-resistant materials and construction may be required depending on the flood risk assessment. Subject to operational requirements, including response times, these areas are generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots. Where such infrastructure has to be located in these areas or is being substantially extended, it must be capable of remaining operational and accessible during extreme flooding events.

3. **Medium to high risk areas:** AEP of watercourse, tidal or coastal flooding greater than 0.5% (200-year return period)

   Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots, schools, ground-based electrical and telecommunications equipment. The policy for development on functional flood plains applies. Land raising may be acceptable.

   Appropriate planning response (within areas already built up): These areas may be suitable for residential, institutional, commercial and industrial development, provided flood prevention measures to the appropriate standard already exist, are under construction, or are planned as part of a long-term development strategy in a structure plan context. In allocating sites, preference should be given to those areas already defended to that standard. Water-resistant materials and construction as appropriate.

   Appropriate planning response (undeveloped and sparsely populated areas): These areas are generally not suitable for additional development, including residential, institutional, commercial and industrial development. Exceptions may arise if a location is essential for operational reasons, for example, for navigation and water-based recreation uses, agriculture, transport or some utilities infrastructure, *and* an alternative lower-risk location is not achievable. Such infrastructure should be designed and constructed to remain operational during floods. These areas may also be suitable for some recreation, sport, amenity and nature conservation uses (provided adequate evacuation procedures are in place). Job-related accommodation (eg, caretakers and operational staff) may be acceptable. New caravan and camping sites should generally not be located in these areas. Exceptionally, if built development is permitted, flood prevention and alleviation measures are likely to be required and the loss of storage capacity minimised. Water-resistant materials and construction as appropriate. Land should not be developed if it will be needed or have significant potential for coastal managed realignment or washland creation as part of an overall flood defence.

Sources: Crichton 2005a; Scottish Executive 2004.

Planned or managed retreat

Given the level of existing coastal development in coastal margins around New Zealand, the use of planned or managed retreat will need to become a fundamental and commonly applied risk-reduction measure within the next few decades. The alternative would be a considerable increase in the scale of hard coastal protection works that are installed. This may be an appropriate long-term strategy in certain (exceptional) circumstances, but such an approach does not fit comfortably with the values and principles of sustainably managing coastal margins: it would impact significantly on beaches, and on natural character, amenity and public access values.

'Managed retreat' is defined as any strategic decision to withdraw, relocate (Figure 6.7) or abandon private or public assets that are at risk of being impacted by coastal hazards.[67] At present, relocation of properties tends to occur on a case-by-case, occasional basis, with no council having yet developed a district or region-wide strategic approach to reducing coastal hazard risk this way.

Figure 6.7: Relocation of a property back from the eroding coastline on the West Coast.

The various scales of managed retreat include:

- micro-retreat, where the elevation of the building floor is raised, for example, by elevating a building on piles (suitable only for inundation-related hazards)
- relocation within a property boundary
- relocation to another site
- large-scale relocation of settlements and infrastructure.

It is suggested that the most likely methods for implementing managed retreat would be a mix of some or all of the following:

- district and regional plan rules that relate to managing existing use rights and limiting or controlling the construction of protection works
- property title covenants, to prevent undesirable activities such as construction of coastal defences. Covenants may also specify where and when retreat and/or relocation is required
- financial instruments or assistance measures including:
  - purchase of property
  - subsidies for relocation
  - taxation of risk or adverse effects
  - pre-paid community relocation fund
  - transferable development rights
- relocation of infrastructure out of hazard areas
- insurance incentives or disincentives.

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[67] Turbott and Stewart (2006), from which this section has been summarised. Further consideration of managed retreat is provided in Jacobson (2004).

Financial mechanisms are likely to play a key role, but their use to date in reducing coastal hazard risk has tended to be on a case-by-case basis by councils and other agencies. If financial mechanisms are to be incorporated more fully into activities to avoid and reduce coastal hazard risk, decision tools such as cost–benefit analyses will need to be part of option appraisal processes (and include more research into aspects such as non-market valuation).

Box 6.3: Relocatable buildings – a mechanism for facilitating managed retreat?

Rules specifying that new buildings within coastal erosion hazard zones are able to be relocated are used in a number of district plans. Typically, such provisions relate to buildings in hazard zones that are likely to be impacted by erosion in the next 50–100 years (ie, not immediately) and relate to replacement of either existing buildings where existing use rights apply, or to new buildings in existing subdivisions. To be effective, a number of conditions are required; these will depend on the nature of the location but generally include:

- construction of the building so that is readily relocatable
- a 'building relocation strategy' to ensure that dwellings can be easily relocated. For example, Tauranga City Council require an alternative building site be identified that is clear of the city's defined coastal hazard zone
- a trigger point for relocation, typically related to the seaward toe of the foredune or vegetation line, and timeframe for relocation to be undertaken
- inclusion of a covenant on the land title to register the consent conditions
- inclusion of notice on title to the land of the natural hazard under sections 73 and 74 of the Building Act.

As requirements for relocatable buildings have been a relatively new development, there are no examples where relocation has yet been undertaken. Key provisions are the trigger point and ensuing timeframe for relocation. These vary with each situation, but they tend to be based on one trigger and one timeframe. In some situations, timeframes can be a matter of hours after the trigger point is reached: this may be unrealistic, particularly if there are a number of buildings to be relocated. A more effective approach would be to identify an initial trigger point (when erosion reaches it, the property owner is put on notice to relocate), and an ultimate trigger point (if erosion continues and reaches this point, removal must occur within a short timeframe).

While relocatable buildings may be appropriate in some circumstances, it is debatable whether they provide an effective balance between coastal development and managing coastal hazard risk. In essence, the provisions still permit development in areas that will likely experience coastal erosion within the next 50–100 years (and that may be at risk from other hazards such as tsunamis). As such, current provisions permit levels of risk to continue to increase in coastal margins. Rather than being viewed as a long-term option, use of such measures should perhaps be considered more as a transition mechanism until more comprehensive forms of planned retreat have been adopted and until there are tighter controls on existing use rights on development and redevelopment in coastal hazard areas.

For managed retreat to be implemented, Turbott and Stewart (2006) suggest that regulation must also include two key elements: 1) prohibiting hard protection works in the coastal marine area and adjacent land, and 2) specifying control of land-use rights for both new and existing buildings plus the trigger levels that would require relocation. Despite Turbott's and Stewart's work, significant barriers remain to managed retreat becoming a strategic and more commonly applied mechanism.

These barriers include:

- public perception, existing use rights (see next section), financial issues, and the relative involvement of central government, and regional / district councils in applying and managing retreat
- the sporadic use of more robust decision-making tools, particularly cost–benefit analysis incorporating non-market valuations
- the lack of clear processes relating to transition mechanisms and timeframes for staging a strategic approach to managed retreat.

6.5.3 Existing use rights

Issues around existing use rights[68] are a key barrier to the effective implementation of planned retreat approaches and, in general, to reducing coastal hazard risks on coastal margins where existing development is located.

Under the RMA, there are no existing use rights for structures in rivers and lakes or in the coastal marine area (except for reclamations), or for water takes and discharges. All consents are given for specific terms. Note, however, that the term of a consent, once set, cannot be changed. Reviews of conditions by a local authority can require changes to mitigate effects, but cannot extinguish the rights granted with the consent.

Land uses, if established through permitted activity status in a district plan, or through a consent, have existing use rights; they are thus effectively permanent, unless a rule in a regional plan provides otherwise (see RMA sections 9(3) and 20(2)). However, the wording of section 10 of the RMA, which provides for existing use rights, incorporates the ability to consider the effects of a use or development whenever an alteration is proposed. This may mean, for example, that building upgrades or extensions in hazard areas may not be able to rely on existing use rights. However, for coastal hazard zones, controlling existing use rights within the district plan would remain a problem where existing buildings are not altered (see Box 6.4).

Councils need to consider carefully the implications of activities permitted in a district plan, the terms of consents granted, and the extent of existing use rights in circumstances where coastal hazards may be exacerbated – or new coastal hazards may occur – within the lifetime of a development or new activity.

Box 6.4: Management of existing use rights in the *Canterbury Regional Coastal Environment Plan*

The *Canterbury Regional Coastal Environment Plan* is one of the few regional plans that currently contain specific rules controlling existing use rights within defined coastal hazard zones. The rules permit existing uses to continue, but control the reconstruction or replacement of structures within the coastal erosion hazard zone. For all reconstruction and replacement activities, rules require specifications to be similar to those of the existing structure, they control the location relative to the existing structure, and they prevent any increase in floor area of any habitable building (the exception is a number of defined areas where an increase in floor area of up to 25 square metres is permitted relative to the floor area that existed at 1 July 1994).

Where a building is damaged or destroyed by the sea, rules also control the minimum section size upon which reconstruction or replacement is permitted. Hence, the plan also provides the scope to roll existing unaltered development landward, should the need arise.

Regional land-use rules, which may relate to the avoidance or mitigation of natural hazards (enabled through the provisions of sections 30(1)(c) and 68), effectively extinguish existing use rights if those rights are incorporated in a regional plan (see section 20A(2) of the RMA) (see Box 6.4). These provisions sit alongside district plan provisions but override section 10 of the Act. Activities that are not permitted must obtain new consents once the plan becomes operative, and new consents may be of a limited duration.

6.5.4 Esplanade reserves and strips

The RMA enables territorial authorities to create esplanade reserves or strips at the time of consent for new subdivision to contribute to the protection of conservation values, to enable public access to or along the coast, and to enable public recreational use adjacent to the sea. Amendments to the RMA in 1993 gave more discretion to councils to waive or vary esplanade requirements following subdivision.

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68 This section is adapted from MfE (2008a).

There are three forms:

Esplanade reserves	extend up to a width of 20 m inland from the MHWS position, have fixed landward boundaries and are owned by the council.
Esplanade strips	are created as part of the title of the land and remain in private ownership. Boundaries are fixed only in relation to the MHWS position and move with changes in erosion and accretion.
Access strips	are used to provide access to the coast, commonly to join a road end to the coast via private land. They can be achieved only through negotiation, are not conditions on consents and are not added to land titles. They can be varied or cancelled without public input. They can also be acquired along coastal margins to join up other public lands or reserves.

Where land is subdivided adjacent to the coast into lots less than 4 ha, then local authorities can require an esplanade reserve or strip. Territorial authorities have considerable discretion to vary this requirement, but the default is that it should be taken for the purpose of protection of conservation values, public access and recreational use.[69]

Despite providing a buffer at the coast, reserves or strips do not provide a primary mechanism for reducing coastal hazard risk; they can assist in mitigating natural hazards while protecting conservation values and enabling public access and compatible recreational use.[70]

Esplanade reserve land is typically backed by residential development, or infrastructure serving residential development, so ongoing coastal erosion causes the progressive loss of the reserve, resulting in a potential loss of legal public access to the coast. In many places, there is also considerable pressure on councils from property owners backing the reserve to protect it and hence their property. There are also cases of un-consented protection works that have been constructed on public reserves by front row property owners. However, councils do not have responsibility to protect reserves as a means of protecting private property.[71]

How councils will manage loss of esplanade reserve, and hence the public values associated with such areas, is a difficult and complex issue for councils. The issue will strongly influence their approach to strategically implementing managed retreat.

6.5.5 Coastal protection structures

On eroding coastlines that have been developed, there is typically high public (and often political) demand for coast protection measures to ‘hold the line’ and protect private property, infrastructure or utilities. Such measures are often viewed by the public as ‘solutions’ to coastal erosion problems. Unfortunately, they tend to:

- be reactive
- rarely be the most effective or sustainable option in the long term
- lead to a false sense of future security and often encourage further development behind the structures (see the Development-defend-development cycle in Box 1.2)
- lead to other environmental damage and severe impacts on other coastal values
- lead to an expectation that such defences will be maintained *in perpetuum*, leading to ever increasing financial commitment to maintain and upgrade such defences.

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69 RMA sections 229, 230 and 237.

70 RMA section 229(2)(v).

71 Turbott and Stewart 2006.

Most constructed coastal defences on New Zealand's coastline that protect residential property will have a limited lifetime – at best, probably around 10–20 years. Generally they are not constructed to a standard to effectively withstand the more significant storm events that can occur. They are, in most cases, not as permanent as the residents apparently 'protected' by them assume. On coastlines that are retreating, the effectiveness of such defences is continually being reduced while the potential negative impacts caused by the defence often increase. A typical process, over a yearly to decadal timescale, in a general sense, is summarised in Figure 6.8.This process is likely to be sped up by climate change.

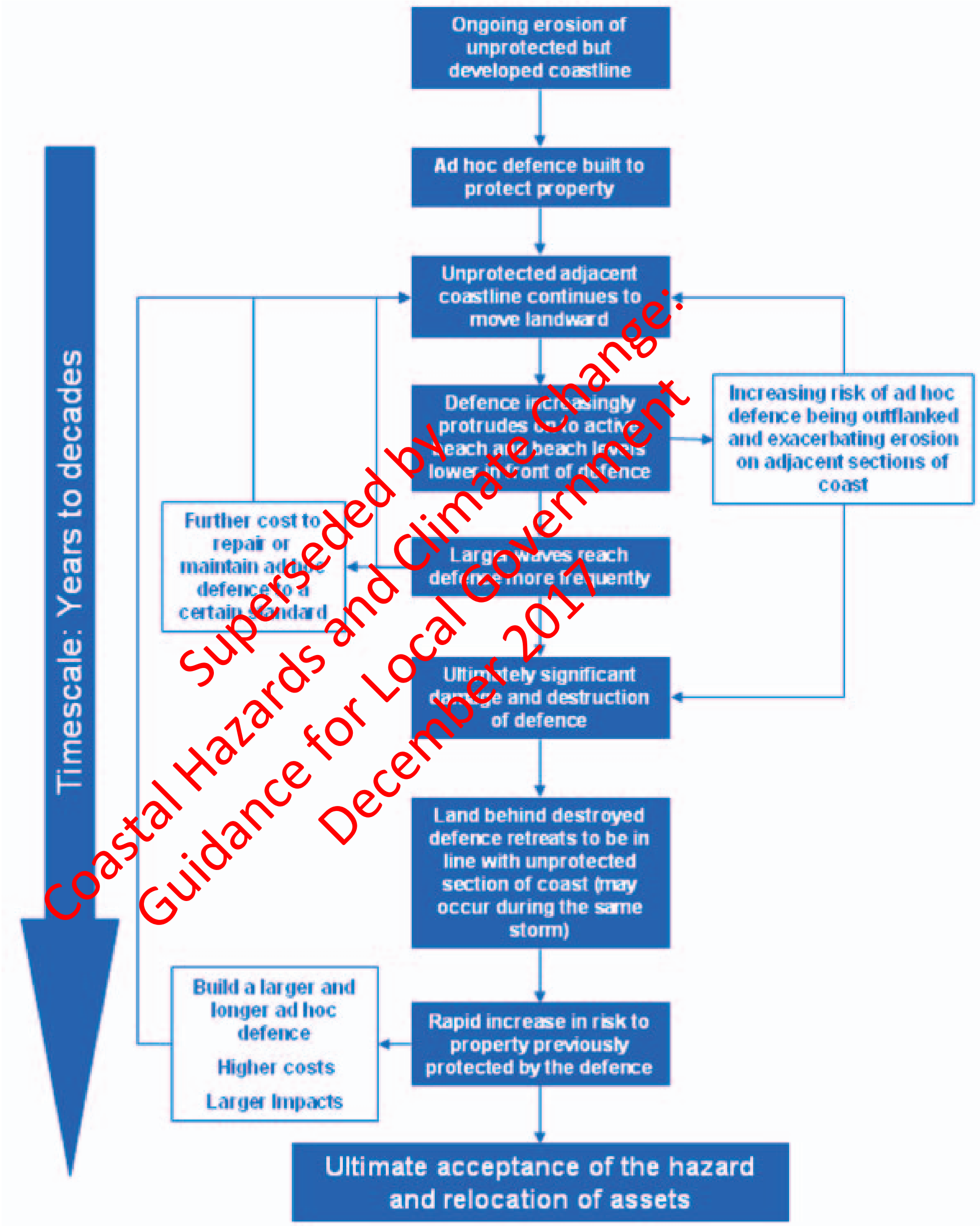

Figure 6.8: Typical timeline of the protection provided by, and effects of, ad hoc coastal defences on an eroding coastline (and to a certain extent, engineered coastal defences).

Unless – or even if – there are specific rules in regional and district plans (Box 6.5) that control the use of coast protection works, there will continue to be considerable pressure on councils to consent protection structures – particularly in the aftermath of storm events where retreat or inundation has occurred. There is a temptation to use coastal protection works as a short-term measure to 'buy some time' (to permit more long-term options to be explored and implemented); but in reality, once defence works are in place, it is extremely difficult to then remove them. Illegally constructed defences present a similar problem.

Box 6.5: Hard protection works to become non-complying activities in Whakatane District

Whakatane District Council is currently undertaking a variation to the district plan to better manage coastal hazards in the Whakatane District. As part of the variation, hard protection works to protect private or public land anywhere in the defined coastal erosion risk zone (to 2100) are classified as non-complying activities. For public roads, 'protection' is classified as a restricted discretionary activity, as are 'softer' protection options such as beach nourishment and 'sand sausages'. The provisions have resulted in considerable community concern; the district council, with support from Environment Bay of Plenty, have been working through these concerns with the communities. As part of this process, the council commissioned an assessment of the economic costs and benefits of the proposed variation as required under section 32 of the RMA.

There are locations where ongoing coastal protection is a long-term option (typically in highly developed urban areas with a long history of coastal protection). Regional and district plans can strategically identify where 'hold the line' options may be appropriate, and make hard protection works a prohibited activity outside these areas: this would send a clear signal about where such measures are acceptable and, more importantly, where they will not be considered.

The introduction of such measures can be difficult for councils and involve considerable controversy and litigation, particularly with front row property owners. Yet the complications that arise from not managing coastal development and protection works are far more complex and expensive in the long run.[72] In implementing such measures, the council can reduce much of the wider community's concern by providing good information and participation processes. Acceptability of these measures, however, will never be universal.

6.6 Building controls and consents

Section 71 of the Building Act 2004 requires district and city councils to refuse a building consent if the following applies: the land is subject to one or more natural hazards; or the building work is likely to accelerate, worsen or result in a natural hazard on that land or any other property – unless adequate provision is made to protect the land or restore the damage.

However, under section 72 of the Building Act, district and city councils must issue building consents on land that is at risk from coastal hazards, or any other hazard, provided that the building complies with the Building Code and that the building itself does not accelerate or worsen or extend the hazard to another property.

Under the Building Act, Land Information Memoranda (LIMs) and Project Information Memoranda (PIMs)[73] are key elements in providing known site and hazard risk information to someone interested in a particular piece of land. Their purpose is to help individuals decide for themselves whether to proceed with a purchase of land or development. A LIM[74] is prepared by the council on request: it is based on all the information a council holds about a piece of land and generally provides a more up-to-date and detailed source of hazard information than will be contained in a district plan. LIM information needs to be periodically updated by district and city councils when new hazard information comes available; the information provided by the LIM may become the basis for liability actions (see section 4.3).

[72] Dahm 2007.

[73] A PIM is a summary of all the information a council holds in relation to a particular project associated with a piece of land, and outlines all other consents required to complete the project.

[74] LIMs are issued under the Local Government Official Information and Meetings Act 1987 (section 44A).

The purpose of the Building Act is to ensure the safety and integrity of a structure during its construction and subsequent use, and district councils can exercise some judgement about whether to allow a subdivision or development. The RMA process is important because the outcome of it will generally decide whether a building can be sited in the relevant area in the first place. The Building Act (specifically sections 72 and 73) is particularly important where coastal (or other) hazards are discovered after titles have been created, or even after development is already established.

6.7 Non-statutory and other supporting measures

There are a range of other tools and techniques that can be used to support the main statutory measures for managing coastal hazard risks, to promote awareness and understanding among the public, and to provide integrated and effective coastal development. Their use will vary between regions and include[75] the following:

- *Coastcare initiatives* may be supported in regional and district plans and be allocated funding support in annual plans. Such programmes have proven to be highly successful in enhancing the buffer provided by the natural dune system and are an effective way of empowering communities and raising their awareness of coastal hazard issues.
- *Structure plans and growth strategies* provide direction for integrated urban growth: they can be used to avoid development and infrastructure being located in areas prone to coastal hazards. They have no legal effect in their own right to ensure this happens, unless they become part of a document such as an RMA plan (which often occurs).
- *Design guidelines* promote good practice for matters such as subdivision layout, development location and building design. Design guidelines can be used to avoid and reduce the potential impact of coastal hazards on structures, and also facilitate emergency management through designing for evacuation (eg, in areas at risk from tsunami inundation). Again, they have no legal effect unless incorporated into a RMA plan.
- *Community- or issue-based strategies* can provide long-term direction for, and identification of, the range of issues relating to coastal development. Often developed in consultation with communities, they are not statutory but are generally used to feed into regional and district planning. An example is the Mana Whenua Mana Moana paper developed by the Mana Whenua Reference Group as part of the New Plymouth District Coastal Strategy.[76]
- *Iwi management plans* or other documents identify important issues relating to Māori. Any relevant planning document recognised by an iwi authority and lodged with the territorial authority needs to be taken into account in RMA planning documents and consent processes.
- *Financial measures* can be provided by the council (eg, rating relief or grants – which may include land management agreements), by other organisations such as Queen Elizabeth II National Trust (encouraging rural landowners to maintain undeveloped coastal areas and/or to assist with land management for conservation purposes), or by the government (through reserves).

75 Adapted from MfE (2008b, 2008c) and Peart (2005).

76 Available from: www.newplymouthnz.com/NR/rdonlyres/D085B4C4-F872-49C0-91D7-C3CFACE456D0/0/ManaWhenuaManaMoana2006.pdf (30 June 2008).

6.8 Risk transfer – managing residual risk

Risk-avoidance and risk-reduction measures will never completely remove coastal hazard risks. Managing the component of risk that is left over, the residual risk, usually involves transferring that risk. This typically means living with and accepting this residual risk, and dealing with any associated consequences via emergency management and insurance arrangements.

6.8.1 Emergency management

Emergency management under the Civil Defence Emergency Management (CDEM) Act 2002 primarily focuses on the safety of people, property and infrastructure in an emergency. It puts an emphasis on readiness, response and recovery (risk reduction being the fourth component). The CDEM Act also requires a risk-management approach be taken when local government deals with hazards, considering both the hazard aspects and the resulting consequences.

Risk reduction is one of the four key components of the CDEM framework but it has generally been given less emphasis than the three other components in the first generation of CDEM Group Plans. This lack of emphasis has been recognised, along with the need for much closer integration between the CDEM framework and regional policy statements, and regional and district plans prepared under the RMA.[77,78] Upcoming reviews of regional policy statements and associated plans provide an opportunity for planners to consider and incorporate measures and actions from their region's CDEM Group Plan into the regional policy statements and plans and vice versa.

6.8.2 Insurance

The approach of insurance companies towards meeting the cost of hazard-induced asset loss has, in the past, been largely reactive. Increased insurance premiums and refusal of reinsurance are based on previous losses incurred. These can provide a disincentive for asset investment within high-risk hazard areas that have previously suffered financial loss.

This combination can result in extreme pressure on councils to provide 'protection' against the hazard. The insurance approach does not send a clear signal to property owners, as at-risk areas will not necessarily be affected by insurance premiums, unless there have already been hazard events in the past. Likewise, premiums are generally not targeted to the affected areas of a coastal margin.

However, insurance companies are becoming increasingly proactive in hazard risk management and are working in partnership with councils to identify sustainable options for mitigating hazard risks (Box 6.6). Such an approach has been adopted in the Coromandel in response to developing sustainable options for mitigating river flooding. It is likely that insurance companies will take a greater role in future coastal hazard risk management, including for hazards induced by climate change effects.

Whilst insurance could be an efficient market-based economic tool to distribute and reflect actual risk for coastal properties, it does not necessarily reflect long-term changes in risk. Its efficient application may require intervention and collaboration between councils and insurance companies – and require detailed risk assessment information, at the property level, much of which is currently not available.

[77] Saunders et al 2007.

[78] Department of Conservation 2006.

Box 6.6: Flood Liaison and Advice Groups – effective flood and coastal risk management in Scotland

Flood Liaison and Advice Groups (FLAGs) address fluvial flooding, coastal flooding and erosion. They now cover 98% of Scotland and have made substantial progress in virtually eliminating new building in flood and coastal hazard areas. The first of these groups was set up in 1995.They involve all statutory and relevant non-statutory organisations with interests in flood and coastal hazard management, to provide advice on planning and flood alleviation measures and insurance. Specifically, FLAGs have brought together planners, building control officers and the insurance industry to assess development issues in hazard areas in a non-confrontational, collaborative and 'joined-up thinking' approach. The success of the FLAGs has been recognised by the Scottish Executive: that recognition is encapsulated in a policy that every local planning authority should establish or participate in such a group.

While flood insurance becomes more difficult and costly to obtain in the UK, areas with FLAGs are experiencing fewer insurance problems.

Source: Crichton 2005a, 2005b.

6.9 Monitoring changing risk

Section 35 of the RMA delegates councils the responsibility of gathering information and undertaking or commissioning research to the extent necessary to carry out the Act's functions. Such research also needs to be made available to the public. Under the same section, councils are also responsible for monitoring the state of the whole (or any part of) the environment 'to the extent that it is appropriate, to enable the local authority to effectively carry out' its responsibilities under the RMA.[79]

In terms of managing coastal hazard risk, planning approaches need to have measurable outcomes to ensure that the risk-management activities being undertaken are effective. Several regional councils are now attempting to measure and monitor how coastal hazard risk is changing. In general, such indicators for monitoring risk need[80] to:

- be policy-relevant
- provide information on which decisions can be made
- be based on data that can be consistently gathered and consistently interpreted
- be simple and easily understood
- be readily collected without significant additional cost
- be comparable over the area under study.

The focus of these indicators is the landward component of the coastal environment, ie, that which is impacted by coastal hazards. Particularly in a context of a changing climate, monitoring the drivers of coastal hazards (eg, sea levels, waves) and the magnitude of the hazards themselves (eg, beach profiling) is also important: it can help identify which aspects are due to natural climate variability and which are due to climate change.

79 Paragraph adapted from MfE (2008a).

80 MfE 1996.

Box 6.7: Monitoring coastal hazard risk in the Bay of Plenty

Environment Bay of Plenty has investigated, developed and trialled a quantifiable process of monitoring coastal hazard risk in support of its Regional Coastal Environment Plan objective of *No increase in the total physical risk from coastal hazards*. The process began in 2003 with the development of a set of proposed indicators and a pilot trial of the indicators to assess whether they were workable. This process proved useful as it was found that there were some difficulties with collating the data required for the indicators and many were found to be too complex.

The seven core coastal hazard risk indicators that were subsequently adopted are:

1. identifiable and/or identified coastal hazard zones that have been included on district planning maps
2. district rules that support those hazard zones and that are aimed at not increasing the physical risk of coastal hazards (eg, no subdivision rules and building setbacks)
3. administrative or district plan policies that ensure that any building within the coastal hazard zones is subject to controls to mitigate risk, such as relocatability and relocation management plans
4. average building set back for the most seaward residential dwellings on residential lots in coastal hazard zones from the year 2000 datum for toe of foredune survey line
5. number of residential dwellings in the coastal hazard zones at the date of the most recent aerial photography
6. number of residential lots in coastal hazard zones from the digital cadastral database (DCDB) at a date close to the most recent aerial photography
7. percentage of new residential dwellings within coastal hazard zones subject to resource consent with building relocation conditions.

Sources: Hill Young Cooper and Eco Nomos 2003; Gordon and Fraser 2005; Gordon 2006.

7 Further Resources

7.1 Climate change

Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Reports:

- *The Physical Science Basis*. *Contribution of Working Group I.* 'Summary for Policymakers' and the full report are downloadable from: ipcc-wg1.ucar.edu/wg1/wg1-report.html (23 April 2008).
- *Climate Change Impacts, Adaptation and Vulnerability*. *Contribution of Working Group II*. 'Summary for Policymakers' and the full are report downloadable from: www.ipcc-wg2.org/ (23 April 2008).
- *Mitigation of Climate Change*. *Contribution of Working Group III*. 'Summary for Policymakers' and the full report are downloadable from: www.mnp.nl/ipcc/pages_media/AR4-chapters.html (23 April 2008).
- *Climate Change 2007: Synthesis Report*. 'Summary for Policymakers' and the full report are downloadable from: www.ipcc.ch/ipccreports/ar4-syr.htm (23 April 2008).

New Zealand guidance:

- Ministry for the Environment. 2008a. *Climate Change Effects and Impacts Assessment. A Guidance Manual for Local Government in New Zealand.* 2nd Edition. Prepared by Mullan B, Wratt D, Dean, S (NIWA); S, Allan S, Morgan, T (MWH New Zealand Ltd);, Kenny G. (Earthwise Consulting) and MfE. Available from: www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/ (30 June 2008).
- Ministry for the Environment. 2007d. *Preparing for Climate Change. A Guide for Local Government in New Zealand. ME Number 534*. Available from: www.mfe.govt.nz/publications/climate/preparing-for-climate-change-jul04/index.html (23 April 2008).

New Zealand publications:

- Chapman R, Boston J, Schwass M (eds). 2006. *Confronting Climate Change. Critical Issues for New Zealand*. Victoria University Press: Wellington. 336 p.
- Renowden, G. 2007. Hot Topic. Global Warming and the Future of New Zealand. AUT Media: Auckland. 203 p.

New Zealand websites:

- Ministry for the Environment:
  - General climate change info: www.mfe.govt.nz/issues/climate/ (23 April 2008).
  - Impacts of and adaptation to and/or preparing for climate change: www.mfe.govt.nz/issues/climate/adaptation/index.html (23 April 2008).
  - Mitigation and/or reducing your emissions; climate change solutions: www.climatechange.govt.nz/index.shtml (23 April 2008).
- NIWA National Climate Centre:
  - Information on the science being conducted to better understand climate variability and change in New Zealand: www.niwascience.co.nz/ncc (23 April 2008).
- Quality Planning website (Climate change):
  - www.qualityplanning.org.nz/qp-library/index.php?browse=subject&subjectid=307#Climate+change (23 April 2008).

7.2 The New Zealand coast and coastal hazards

Recent publications and guidance:

- Goff JR, Nichol SL, Rouse HL. 2003. *The New Zealand Coast. Te Tai O Aotearoa*. Dunmore Press and Whitirea Publishing: Wellington. 312 p.
- Dahm J, Jenks G, Bergin D. 2005. *Community based dune management for the mitigation of coastal hazards and climate change effects. A Guide for Local Authorities*. Available from: www.envbop.govt.nz/media/pdf/Report_Coastalhazardsandclimate.pdf (8 July 2008).
- Department of Conservation. 2006. *Review of the New Zealand Coastal Policy Statement. Issues and Options*. Department of Conservation: Wellington. 83 p. Available from: www.lgnz.co.nz/projects/NZCPS/DOC_CPS_Final.pdf (23 April 2008).
- Jacobson M. 2004. Review of the New Zealand Coastal Policy Statement 1994 – Coastal Hazards. A review of the effectiveness of the NZCPS in promoting sustainable coastal hazard management in New Zealand. Report prepared for The Minister of Conservation (unpublished). 121 p.
- Rossier J. 2004. Independent review of the New Zealand Coastal Policy Statement. A report prepared for the Minister of Conservation (unpublished). Available from: www.doc.govt.nz/upload/documents/conservation/marine-and-coastal/coastal-management/nzcps-review-2004.pdf (23 April 2008).
- Turbott C, Stewart A. 2006. Managed retreat from coastal hazards: Options for implementation. *Environment Waikato Technical Report 2006/048*. Environment Waikato: Hamilton. 89 p. Available from: www.ew.govt.nz/publications/technicalreports/tr0648.htm (23 April 2008).

Websites:

- Quality Planning website (Coastal hazards): www.qualityplanning.org.nz/qp-library/index.php?browse=subject&subjectid=298&keywordid=24049#HazardsCoastal+hazards (23 April 2008).

7.3 Risk and adaptation

Publications and guidance:

- Standards New Zealand. 2004. AS/NZS4360:2004 (Risk Management).
- Centre for Advanced Engineering. 2004. *Planning for Natural Hazard Risk in the Built Environment*. Centre for Advanced Engineering, University of Canterbury: Christchurch. 52 p.
- Allen Consulting Group. 2005. Climate change, risk and vulnerability. Promoting an efficient adaptation response in Australia. Report to the Australian Greenhouse Office, Department of the Environment and Heritage. Allen Consulting Group: Canberra. 159 p.

Websites:

- Ministry for the Environment: Resources and guidance for local government to aid adapting to a changing climate: www.mfe.govt.nz/issues/climate/resources/local-govt/index.html (23 April 2008).
- Quality Planning website: Natural hazard guidance note. (In prep.) Available 2008 from www.qp.org.nz/

7.4 Coastal development

Publications and guidance:

- Peart, R 2005. The Community Guide to Coastal Development under the Resource Management Act 1991. Environmental Defence Society: Wellington. 155 p. Available from: www.eds.org.nz/shop/publication/3.htm (23 April 2008).

Websites:

- Quality Planning website: Coastal development guidance note. (In prep.) Available 2008 from www.qp.org.nz/

8 References

Bamber JL, Alley RB, Joughin I. 2007. Rapid response of modern day ice sheets to external forcing. *Earth and Planetary Science Letters 257*: 1-13.

Bell RG. 2007. Use of exceedence curves for defining MHWS and future sea-level rise. *In: Coast and Ports 2007: Proceedings of the 17th Australasian Conference on Coastal and Ocean Engineering*. Melbourne, 17–20 July 2007.

Bell R, Goring D, Gorman R, Hicks M, Hurran H, Ramsay D. 2006. Impacts of climate change on the coastal margins of the Bay of Plenty. Report prepared for Environment Bay of Plenty. NIWA Client Report HAM2006-031. 134 p.

Brundtland (1987) Our common future. Oxford University Press. ISBN 0-19-282080-X . See also http://en.wikipedia.org/wiki/Our_Common_Future

Bruun P, 1962. Sea-level rise as a cause of shore erosion. *American Society of Civil Engineering Proceedings, Journal of Waterways and Harbors Division 88*: 117–130.

Bruun P. 1988. The Bruun rule of erosion by sea-level rise: a discussion on large-scale two- and three-dimensional usages. *Journal of Coastal Research 4*: 627–648.

Burgess K, Jay H, Nicholls RJ, Green C, Penning-Roswell EC. 2007. Assessment of future coastal erosion risk. Chapter 17. *In*: Thorne CR, Evans EP, Penning-Roswell EC (eds). *Future Flooding and Coastal Erosion Risk*. Thomas Telford Publishing: London. 528 p.

Burgess K, Townend I. 2004. The impact of climate change upon coastal defence structures. *In: Proceedings 39th Defra Flood and Coastal Management Conference*, July 2004. Department for Environment, Food and Rural Affairs (Defra): London.

Carter D, Bray M, Hooke J, Taussik J, Clifton J, Mitchell J. 1999. SCOPAC. *A Critique of the Past: A Strategy for the Future*. Isle of Wight: Standing Conference on Problems Associated with the Coastline. SCOPAC Secretariat: Newport.

Carter RWG, Orford JD. 1993. The morphodynamics of coarse clastic beaches and barriers: A short- and long-term perspective. *Journal of Coastal Research. Special Issue 15*: 158–179.

Church JA, White NJ. 2006. A 20th century acceleration in global sea-level rise. *Geophysical Research Letters 33*: L01602, doi:10.1029/2005GL024826.

Clough P, Duncan I. 2007. Coastal Retreat. Cost benefit approach to management of coastal land use in face of erosion. Report to Whakatane District Council by NZIER. August 2007.

Crichton D. 2005a. *Flood risk and insurance in England and Wales. Are there lessons to be learned from Scotland?* 2nd edition. Benfield Hazard Research Centre: London. 205 p.

Crichton D. 2005b. Draft PPS15 Consultation paper. Planning and flood risk in Northern Ireland. Comments from Professor David Crichton. 9 p. Available from: www.planningni.gov.uk/AreaPlans_Policy/PPS/pps15/consultation_responses/prof_david_crichton.pdf (23 April 2008).

Dahm J. 2007. Human Dimension in Managing the Coast. Presentation to the NIWA Managing Coastal Hazards short course, 20–21 March 2007. Unpublished.

Department of Conservation. 2006. *Review of the New Zealand Coastal Policy Statement: Issues and Options*. Department of Conservation, Wellington. 83 p. Available from: www.lgnz.co.nz/projects/NZCPS/DOC_CPS_Final.pdf (23 April 2008).

Donovan B, Von Lany P, Wells T, Hall J. 2007. Introducing the concept of decision-pathways to help make adaptive and robust flood risk management decisions under uncertainty. Paper presented at the 42nd Flood and Coastal Management Conference. July 2007. York, United Kingdom.

(EDS) Environmental Defence Society. 2006. Society warns against Ohiwa Spit property sale. Press release from the Environmental Defence Society, 11 January 2006. Available from: www.scoop.co.nz/stories/PO0601/S00020.htm (30 June 2008).

Environment Bay of Plenty. 2003. Bay of Plenty Regional Coastal Environment Plan. Environment Publication 2003/08. Available from: http://www.ebop.govt.nz/Regional-Coastal-Environment-Plan.asp (30 June 2008).

Environment Waikato. 2008. Coastal development at risk. Available from: www.ew.govt.nz/Environmental-information/Environmental-indicators/Natural-hazards/Coastal-hazards/co14-keypoints/ (8 July 2008).

Gordon DA. 2006. *Confirmed Coastal Hazard Risk Indicators*. Environment Bay of Plenty Environmental Publication 2006/05. 43 p.

Gordon DA, Fraser R. 2005. Pilot report of proposed coastal hazard indicators. Environment Bay of Plenty Environmental Publication 2005/21. 59 p.

Gorman RM, Bryan KR, Laing AK. 2003. Wave hindcast for the New Zealand region: deep water wave climate. *New Zealand Journal of Marine and Freshwater Research 37 3*: 589–612.

Gorman R, Mullan B, Ramsay D, Reid S, Stephens S, Thompson C, Walsh J, Walters K, Wild M. 2006. *Impacts of long-term climate change on weather and coastal hazards for Wellington City*. NIWA Client Report HAM2006-036.

Gregory JM, Church JA, Boer GJ, Dixon KW, Flato GM, Jackett DR, Lowe JA, O'Farrell SP, Roeckner E, Russell GL, Stouffer RJ, Winton, M. 2001. Comparison of results from several AOGCM's for global and regional sea-level change 1900–2100. *Climate Dynamics 18(3-4)*: 225–240.

Hannah J. 2004. An updated analysis of long-term sea level change in New Zealand. *Geophysical Research Letters 31*: L03307; doi:10.1029/2003GL019166.

Hansen JE. 2007. Scientific reticence and sea level rise. *Environmental Research Letters 2*: 024002 doi:10.1088/1748-9326/2/2/024002.

Harvey N, Rice M, Stephenson L 2004. Global change coastal zone management synthesis report. Asia–Pacific Network for Global Change Research. APN Secretariat: Chuo-ku, Kobe. 37 p.

Hill Young Cooper Ltd, Eco Nomos Ltd. 2003. *Coastal Hazard Risk Indicators*. Report to Environment Bay of Plenty. October 2003. 77 p.

Hinton C, Townend IH, Nicholls RJ. 2007. Coastal Processes. Chapter 9. *In*: Thorne CR, Evans EP, Penning-Roswell EC (eds). *Future Flooding and Coastal Erosion Risk.* Thomas Telford Publishing: London. 528 p.

Horton R, Herweijer C, Rosenezweig C, Liu J, Gornitz V. 2008. Sea level rise projections for current CGCMs based on the semi-empirical method. *Geophysical Research Letters 35*: L02715; doi:10.1029/2007GL032486.

IPCC. 2007a. Summary for Policymakers. *In*: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. (eds) *Climate change 2007: The Physical Science Basis.Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: Cambridge, UK and New York. 996 p. Available from: www.ipcc.ch/ipccreports/ar4-wg1.htm (30 June 2008).

IPCC. 2007b. Summary for Policymakers. *In*: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. (eds.) *Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. . Cambridge University Press: Cambridge, UK. 976 p. Available from: www.ipcc.ch/ipccreports/ar4-wg2.htm (30 June 2008).

IPCC. 2007c. Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available from: www.ipcc.ch/ipccreports/ar4-wg1.htm (30 June 2008).

IPCC. 2007d. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). Cambridge University Press, Cambridge, UK, 976 p. Available from: www.ipcc.ch/ipccreports/ar4-wg2.htm (30 June 2008).

IPCC. 2007e. *Climate Change 2007: Synthesis Report. 'Summary for Policymakers'* Available from: www.ipcc.ch/ipccreports/ar4-syr.htm (23 April 2008).

Jacobson M. 2004. Review of the New Zealand Coastal Policy Statement 1994 – Coastal Hazards. A review of the effectiveness of the NZCPS in promoting sustainable coastal hazard management in New Zealand. Report prepared for The Minister of Conservation, February 2004. 121 p.

Jay H, Burgess K, Hosking A. 2003. An awareness of geomorphology for coastal defence planning. *Proceedings of the International Conference on Coastal Management*, Institution of Civil Engineers, October 2003.

Local Government New Zealand 2003. *Local Government Know How. The Local Government Act 2002: An overview*. Local Government New Zealand: Wellington. 76 p.

(MfE) Ministry for the Environment. 1996. *The Monitoring Guide: A Practitioner's Guide to Section 35 of the Resource Management Act*. Ministry of the Environment: Wellington.

(MfE) Ministry for the Environment. 2004. *Climate Change Effects and Impacts Assessment: A GuidanceManual for Local Government in New Zealand.* Wratt D, Mullan B, Salinger J, Allen S, Morgan T,Kenny G. with MfE. Ministry for the Environment, Wellington, 153 p. http://www.mfe.govt.nz/publications/climate/effects-impacts-may04/index.html (2 April 2008).

(MfE) Ministry for the Environment. 2008a. *Climate Change Effects and Impacts Assessment. A Guidance Manual for Local Government in New Zealand*. 2nd Edition. Mullan B, Wratt D, Dean S, Allan S, Morgan T, Kenny G, and MfE. Available from: www.mfe.govt.nz/publications/climate/climate-change-effect-impacts-assessments-may08/ (30 June 2008)

(MfE) Ministry for the Environment 2008b. *Coastal Development Guidance Note*. Quality Planning website (In prep.) Available 2008 from www.qp.org.nz/

(MfE) Ministry for the Environment 2008c. *Natural Hazards Guidance Note*. Quality Planning website (In prep.) Available 2008 from www.qp.org.nz/

Nicholls RJ, Lowe JA. 2004. Benefits of mitigation of climate change for coastal areas. *Global Environmental Change 14*: 229–244.

Nicholls RJ, Lowe JA. 2005. Climate stabilisation and impacts of sea-level rise. Pp. 195–202. *In*: Schellnhuber HJ, Cramer W, Nakicenovic N, Wigley T, Yohe G (eds). *International Scientific Symposium: Avoiding Dangerous Climate Change*. Cambridge University Press: Cambridge, UK.

NIWA and the Royal Society of New Zealand. 2008. *Climate change. IPCC Fourth Assessment report. Impacts: New Zealand and the South Pacific*. Information leaflet. Available from: www.niwascience.co.nz/ncc (23 April 2008)

Paert R. 2005. *The Community Guide to Coastal Development under the Resource Management Act 1991*. Environmental Defence Society: Auckland. 155 p. Available from:www.eds.org.nz/shop/publication/3.htm (23 April 2008).

Rahmstorf S. 2007. A semi-empirical approach to projecting sea-level rise. *Science 315*: 368–370.

Ramsay D, Stephens S. 2006. Double trouble: How often do large waves occur with high water levels? *Coastal News 32*: 4–5. [Published by the New Zealand Coastal Society.]

Rignot E, Bamber JL, Van der Broeke MR, Davis C, Li Y, Van der Berg WJ, Van Meijgaard E. 2008. Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. *Nature Geoscience 1*: 106–110.

Saunders W, Forsyth J, Dohnston D, Becker J. 2007. Strengthening linkages between land-use planning and emergency management in New Zealand. *The Australian Journal of Emergency Management 22 (1)*: 36–43.

Scottish Executive. 2004. Scottish Planning Policy SPP 7. Planning and flooding. Scottish Executive Development Department, Edinburgh.

Shaw R, Colley M, Connell R. 2007. *Climate Change Adaptation by Design: A Guide for Sustainable Communities*. TCPA, London. 52 p.

Shepherd A, Wingham D 2007. Recent sea-level contributions of the Antarctic and Greenland ice sheets. *Science 315*: 1529–1532.

Smith RK. 1976. Ohiwa Spit erosion. Unpublished report. 16 March 1976.

Standards New Zealand 2004. AS/NZS4360:2004 (Risk Management).

Turbott C, Stewart A. 2006. *Managed Retreat from Coastal Hazards: Options for Implementation*. Environment Waikato Technical Report 2006/048. 89 p. Available from: www.ew.govt.nz/publications/technicalreports/tr0648.htm (23 April 2008).

(UKCIP) UK Climate Impacts Programme. 2005. Identifying Adaptation Options. UKCIP Technical Report. UKCIP: Oxford, UK. 34 p.

Willows RI, Connell RK (eds). 2003. Climate adaptation, risk, uncertainty and decision-making. UKCIP technical report, United Kingdom Climate Impacts Programme: Oxford, UK. 154 p. Available from: www.ukcip.org.uk/index.php?option=com_content&task=view&id=322&Itemid=9#risk(23 April 2008).

9 Glossary

Adaptation to climate change	Undertaking actions to minimise threats or to maximise opportunities resulting from climate change and its effects.
Adaptive capacity	The ability of a human system or ecosystem to: adjust or respond to *climate change* (including both variability and extremes); moderate potential damages; take advantage of new opportunities arising from climate change; or cope with and absorb the consequences.
Adaptive responses	See *Adaptation to climate change*.
Aerosols	A collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 microns, which reside in the atmosphere for at least several hours. Aerosols may be of either natural or *anthropogenic* origin.
Anomaly	A difference from the long-term average climate (eg, of a climate element). For example, the El Niño summer rainfall anomaly is the difference between the rainfall averaged over summers when El Niño conditions are present and the rainfall averaged over all summers.
Anthropogenic	Produced by human beings or resulting from human activities.
Anthropogenic emissions	Emissions of *greenhouse gases*, greenhouse gas *precursors* and *aerosols* associated with human activities. These activities include burning fossil fuels for energy, deforestation, and land-use changes that result in a net increase in emissions.
AOGCM	Acronym for *atmosphere–ocean general circulation model*.
AR4	Acronym for the three volume IPCC *Fourth Assessment Report, 2007*.
Atmosphere–ocean general circulation model (AOGCM)	A comprehensive *climate model* containing equations representing the behaviour of the atmosphere, ocean and sea ice and their interactions.
Bruun Rule	A simple mathematical relationship that states: as sea-level rises, the shoreface profile moves up and back while maintaining its original shape.
Carbon dioxide (CO_2)	A naturally occurring gas, also a by-product of burning fossil fuels. It is the principal anthropogenic greenhouse gas.
Carbon dioxide equivalent (CO_2-e)	Carbon dioxide equivalent concentration is used to compare the effect from various greenhouse gases. It is the concentration of CO_2 that would cause the same amount of radiative forcing as a given mixture of CO2 and other greenhouse gases. Source: IPCC 2007a
City and district councils	The management bodies of territorial authorities, of either predominantly urban or predominantly rural character.
Climate	The 'average weather', over a period of time ranging from months to thousands or millions of years. The classical period for calculating a 'climate normal' is 30 years.
Climate change	A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer).

Climate model	A numerical representation (typically a set of equations programmed into a computer) of the *climate system*. The most complex and complete climate models are known as *General Circulation Models* (below).
Climate prediction	An attempt to provide a most likely description or estimate of the actual future evolution of the *climate*.
Climate projection	A potential future evolution of the climate in response to an emission or concentration *scenario* of *greenhouse gases* and *aerosols*. Often based on a simulation by a *climate model*.
Climate system	The interacting system comprising the atmosphere, hydrosphere (liquid water in lakes, rivers, seas, oceans), cryosphere (snow, ice, permafrost), land surface and biosphere (ecosystems and living organisms) that determines the earth's *climate*.
Climate variability	Variations of the *climate* (eg, of the mean state, standard deviations and extremes) on all temporal and spatial scales beyond those of individual weather events.
Coastal accretion	A long-term trend of shoreline advance and/or gain of beach sediment volume over several decades. In many cases, accretion is beneficial and creates a buffer against future coastal hazards.
Coastal erosion	A long-term trend of shoreline retreat and/or loss of beach sediment volume over several decades. 'Cutback' is a more suitable term for a dynamically 'stable' shoreline to describe the temporary loss of beach volume or shoreline retreat during a storm (before the volume gets replenished over ensuing weeks and months).
Coastal margin	Aquatic and land environments that are potentially affected by coastal hazards, including the long-term impacts of climate change, in which the coast and any dune or cliff system is a significant element or part, and includes the coastal marine area.
Coastal Marine Area (CMA)	That area of the foreshore and seabed of which the seaward boundary is the *outer* limits of the territorial sea (12 nautical miles) and the *landward* boundary is the line of mean high water spring, except where that line crosses a river. There, the landward boundary is whichever is the lesser of: 1 kilometre upstream from the mouth of the river, or the point upstream that is calculated by multiplying the width of the river mouth by five. (*Resource Management Act 1991)*.
Consent notice	A condition on a subdivision consent, under section 221 of the Resource Management Act 1991, which must be complied with on a continuing basis by the subdividing owner and any subsequent owner. A consent notice is issued by a territorial authority and is deemed to be an instrument creating an interest in the land and a covenant on the land.
Downscaling	Deriving estimates of local climate elements (eg, temperature, wind, rainfall), from the coarse resolution output of *global climate models*. Statistical downscaling uses present relationships between large-scale climate variables and local variables. Nested regional climate modelling uses the coarse resolution output from a global climate model to drive a high resolution *regional climate model.*

El Niño
A significant increase in sea surface temperature over the eastern and central equatorial Pacific that occurs at irregular intervals, generally ranging between 2 and 7 years. Associated changes occur in atmospheric pressure patterns and wind systems across the Pacific. These can lead to changes in seasonal rainfall and temperature in parts of Australia and New Zealand.

El Niño Southern Oscillation (ENSO)
Term coined in the early 1980s in recognition of the intimate linkage between *El Niño* events and the *Southern Oscillation*, which, prior to the late 1960s, had been viewed as two unrelated phenomena. The interactive global ocean–atmosphere cycle comprising El Niño and La Niña is often called the 'ENSO cycle'.

Extreme weather event
An event that is rare at a particular place. 'Rare' would normally be defined as rare as or rarer than the 10th or 90th percentile.

ENSO
Acronym for *El Niño–Southern Oscillation*.

General Circulation Model (GCM)
A global, three-dimensional computer model of the *climate system*, which can be used to simulate the general circulation and climate of the atmosphere and ocean, and particularly human-induced climate change. GCMs are highly complex and they represent the effects of such factors as reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures and ice boundaries. GCMs include global representations of the atmosphere, oceans and land surface.

GCM
Acronym for *General Circulation Model* or *Global Climate Model*.

Global Climate Model (GCM)
The same as *General Circulation Model*.

Global surface temperature
The global surface temperature is the area-weighted global average of:

(i) the sea surface temperature over the oceans (ie, the subsurface bulk temperature in the top few metres of the ocean), and

(ii) the surface-air temperature over land at 1.5 m above the ground.

Global warming
Generally used to refer to the rise of the earth's surface temperature predicted to occur as a result of increased emissions of *greenhouse gases*.

Greenhouse effect
An increase in the temperature of the earth's surface and the lowest 8 km or so of the atmosphere, caused by the trapping of heat by *greenhouse gases*. Naturally occurring greenhouse gases cause a greenhouse effect at the earth's surface of about 30°C. Further temperature increases caused by *anthropogenic emissions* are termed the enhanced greenhouse effect.

Greenhouse gases
Gases in the earth's atmosphere that absorb and re-emit infrared (heat) radiation. Many greenhouse gases occur naturally in the atmosphere, but concentrations of some (such as *carbon dioxide*, methane and nitrous oxide) have increased above natural levels because of *anthropogenic emissions*.

Hazard
A source of potential harm to people or property. Examples are coast erosion or inundation. Note a hazard does not necessarily lead to harm or damage.

Interdecadal Pacific Oscillation (IPO)
A long timescale oscillation in the Pacific Ocean–atmosphere system that shifts climate every one to three decades. The IPO has positive (warm) and negative (cool) phases. Positive phases tend to be associated with an increase in *El Niño*, and negative phases with an increase in *La Niña events*.

Intergovernmental Panel on Climate Change (IPCC)
The body established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to objectively assess scientific, technical and socioeconomic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.

IPCC
Acronym for *Intergovernmental Panel on Climate Change*.

IPO
Acronym for *Interdecadal Pacific Oscillation*.

Kaitiakitangi
Stewardship, or the awareness of and care for natural and cultural resources, according to customary principles.

Kyoto Protocol
The Kyoto Protocol to the *United Nations Framework Convention on Climate Change* (UNFCCC) was adopted at the Third Session of the Conference of the Parties (COP) to the UNFCCC, in 1997 in Kyoto, Japan. It contains legally binding commitments on countries included in Annex B of the Protocol (most OECD countries and some others) to reduce their *anthropogenic greenhouse gas emissions* to some (negotiable) value below 1990 levels in the commitment period 2008 to 2012.

Different countries have different targets to achieve. New Zealand's target is to reduce its greenhouse gas emissions to the level they were in 1990, or take responsibility for excess emissions. Negotiations are now under way on further commitments for developed countries under the Kyoto Protocol.

La Niña
A significant decrease in sea surface temperature in the central and eastern equatorial Pacific that occurs at irregular intervals, generally ranging between 2 and 7 years. La Niña is the cool counterpart to the *El Niño* warm event, and its spatial and temporal evolution in the equatorial Pacific is, to a considerable extent, the mirror image of El Niño. Like El Niño, there are associated changes in atmospheric pressures and wind systems across the Pacific, and related changes can occur in temperature and rainfall in parts of Australia and New Zealand.

Lifelines
Key networks for communication and survival during emergency conditions, including connected links and operating facilities in electricity, telecommunications, roading, water supply and wastewater systems. They may also include key emergency services such as ambulance, fire and civil defence services, and facilitates such as hospitals and medical centres.

Limitation adaptations
Adaptations aimed at lessening or minimising the consequences of the most adverse effects of climate change as they arise over time.

Low-regrets adaptations
Low-cost policies, decisions and measures that have potentially large benefits.

LTCCP
Acronym for Long-term Council Community Plan.

Mean High water Spring (MHWS)	Mean high water spring is traditionally the level of the average spring tides just after full or new moon. In central–eastern regions, a 'pragmatical' MHWS or perigean-spring tide level (MHWPS) is a better hazard measure of upper-level high tides than the traditional MHWS, because the spring-neap effect is weak.
Mean Level of the Sea (MLOS)	The actual level of the sea over a certain averaging period (days, weeks, years, decades) after removing the tides (not to be confused with mean sea level or MSL, which usually refers to a set vertical survey datum).
Mean Sea Level (MSL)	Mean sea level survey datum generally set down in the 1930s to 1950s for different regions. Because of the sea-level rise since then, MSL datum values around New Zealand are usually several centimetres below the current mean level of the sea.
Mitigation (of climate change)	Activities undertaken to reduce the sources or increase the sinks of *greenhouse gases.*
Natural character	The qualities of the coastal environment that together give the coast of New Zealand recognisable character. These qualities may be ecological, physical, spiritual, cultural or aesthetic in nature, whether modified or managed or not.
Natural hazard	Any atmospheric or earth or water-related occurrence (including earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire or flooding), the action of which adversely affects or may adversely affect human life, property or other aspects of the environment. (*Resource Management Act 1991).*
Natural variability	Non-anthropogenic climate variability that may be irregular or quasi-cyclic. *El Niño-Southern Oscillation* is probably the best-known example of a natural oscillation of the climate system, but there are many others. Changes caused by volcanic eruptions and solar variations can also be considered 'natural'.
No-regrets adaptation	Those adaptations that generate net social, economic and environmental benefits whether or not there is anthropogenic climate change, or adaptations that at least have no net adverse effects.
Percentile	Used to give an observed value a ranking within the historical record. For example, only 5% of observations lie *below* the 5th percentile (ie, the coldest 5% of the temperature record) and 5% of observations lie *above* the 95th percentile (ie, the warmest 5% of that record).
Regional Climate Model (RCM)	A *climate model* that is run at high resolution over a 'region' (eg, the eastern part of Australia, Tasman Sea plus New Zealand) to describe climate at the regional scale. RCMs are typically driven with data from *Global Climate Models*, which run at lower resolution and therefore do not accurately simulate, for example, the effects of the Southern Alps on New Zealand's climate.
Regional councils	Constituted under the Local Government Act 2002 with the functions and responsibilities that relate to defined local government regions.
Relative sea level	Sea level measured by a tide gauge with respect to the land upon which it is situated. Mean Sea Level (MSL) is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transient fluctuations such as waves.

Return period	The average time period between repetition of an *extreme weather event*, such as heavy rainfall or flooding, in a stationary climate (that is, a climate without global warming or other trends). In the case of rainfall, a return period is always related to a specific duration (eg, 50-year return period of 24-hour extreme rainfall).
Risk	The chance of an 'event' being induced or significantly exacerbated by climate change, that event having an impact on something of value to the present and/or future community. Risk is measured in terms of *consequence* and *likelihood*.. It also has an element of *choice* by humans.
RPS	Acronym for Regional Policy Statement – a mandatory policy statement prepared under the RMA by a *regional* or *unitary council*.
Scenario	A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces.
Sea-level rise	Trend of annual mean sea level over timescales of at least three or more decades. Must be tied to one of the following two types: *global* – overall rise in absolute sea level in the world's oceans; or *relative* – net rise relative to the local landmass (that may be subsiding or being uplifted).
Significant wave height	The average height of the highest one-third of waves during a short recording interval (typically 10–20 minutes). Generally, considered the height that a trained observer would report for a given sea state.
SOI	Acronym for *Southern Oscillation Index*.
Southern oscillation	A multi-year low-latitude seesaw in sea level pressure, with one pole in the eastern Pacific and the other in the western Pacific/Indian Ocean region. This pressure seesaw is associated with a global pattern of atmospheric *anomalies* in circulation, temperature, and precipitation. Its opposite extremes are the *El Niño* and *La Niña* events.
Southern Oscillation Index (SOI)	An index calculated from *anomalies* in the pressure difference between Tahiti and Darwin. Low negative values of this index correspond to *El Niño* conditions, and high positive SOI values coincide with *La Niña* episodes.
SRES scenarios	A set of *greenhouse gas* and *aerosol* emissions *scenarios* developed in 2000 by Working Group III of the *IPCC* and used, among others, as a basis for the climate projections in the IPCC's 2001 Third Assessment Report.
SST	Acronym for *Sea Surface Temperature* (see *Global surface temperature*).
Storm surge	The temporary excess above the level expected from the tidal variation alone at a given time and place. The temporary increase in the height of the sea is caused by extreme meteorological conditions such as low atmospheric pressure and/or strong winds.
Storm tide	The total elevated sea height at the coast above a datum during a storm combining storm surge and the predicted tide height. Note that *wave set-up* and *wave run-up* need to be added to the storm tide level at any locality to get the final storm inundation level.

Sustainability	'... development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Bruntland Report, *Our Common Future, Report of the World Commission on Environment and Development* 1987).
TA	Acronym for *Territorial Authority*.
Territorial authorities	Constituted under the Local Government Act 2002, comprising *city and district councils* and (for some functions) *unitary authorities*.
Unitary authorities	Territorial authorities that also have regional council responsibilities.
United Nations Framework Convention on Climate Change (UNFCCC)	The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all parties. Under the Convention, parties included in Annex I aim to return greenhouse gas emissions not controlled by the *Montreal Protocol* to 1990 levels. The convention entered into force in March 1994. See also *Kyoto Protocol*.
Wave run-up	The ultimate height reached by waves (storm or tsunami) after running up the beach and coastal barrier (see also *wave set-up*).
Wave set-up	The super-elevation in water level across the surf zone caused by energy expended by breaking waves (see also *wave run-up*).
Weather generator	Weather generators produce multiple time series of numbers with statistical properties resembling those of historical weather records. The most common weather generators produce output representing daily time series of maximum and minimum temperature, rainfall and solar radiation. The numbers preserve observed characteristics such as persistence of temperature (eg, one hot day is often followed by another), as well as inter-relationships (eg, wet days tend to have lower solar radiation and lower maximum temperature but higher minimum temperature).

10 Appendix 1: Relevant legislation

Disclaimer: This appendix has been prepared for the Ministry for the Environment by external contractors, as noted on the verso of this document's title page. To the extent that this Guidance Manual deals with legal matters, it does not necessarily represent the views of the Ministry for the Environment; readers should not rely on it as legal advice.

10.1 Resource Management Act 1991

The Purpose (section 5(1)) of the Resource Management Act 1991 (RMA)[1] *is to promote the sustainable management of natural and physical resources*. The RMA imposes a hierarchy of planning instruments (Figure A1.1) for:

> *managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well-being and for their health and safety.*

The Act requires particular attention be paid to avoiding, remedying or mitigating the actual or potential adverse effects of activities on the environment (section 5(2)).

The RMA recognises the special significance of the coastal environment in Part II (Purpose and Principles) and various other sections of the Act[2] as well as through the mandatory New Zealand Coastal Policy Statement (NZCPS) (sections 56–58). Regional policy statements and regional and district plans must be prepared to give effect to the Act and the NZCPS. While there is no specific part within the Act itself that deals with coastal management and coastal hazards, the functions that are stipulated for the regional and district councils require avoidance or mitigation of natural hazards. Coastal hazards are clearly a subset of natural hazards.

Some relevant principles prescribed in the RMA for achieving the purpose of the Act include:

- recognising and providing for 'Matters of national importance' (section 6), such as: (a) *The preservation of the natural character of the coastal environment (including the coastal marine area)…;* (b) *The protection of outstanding natural features and landscapes from inappropriate subdivision, use, and development;* (d) *The maintenance and enhancement of public access to and along the coastal marine area, …;* and (e) *The relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga;*
- having particular regard to 'Other matters' (section 7), such as: (a) *Kaitiakitanga (the ethic of stewardship);* (c) *The maintenance and enhancement of amenity values;* (g) *Any finite characteristics of natural and physical resources;* and (i) *The effects of climate change*.

The latter principle, which states that particular regard must be given to the effects of climate change (section 7(i)), came into effect on 2 March 2004 as a result of the RMA (Energy and Climate Change) Amendment Act 2004 (2004 No. 2). This amendment has relevance to the increasing need to plan for the effects of climate change that can exacerbate coastal hazards and also the effects of adaptation measures put in place to protect natural and physical resources at the coast to alleviate the risks from climate change.

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1 Consolidated RMA at: www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html?search=gs_act_resource+management_resource__ac%40acur&sr=1 (23 April 2008).

2 Refer to sections 30 (1)(c)(iv), 30(1)(d)(v), 31(1)(b)(i).

Under the RMA, regional (or unitary) councils are responsible for managing the effects of activities within the 'coastal marine area' via a regional coastal plan, whereas territorial local authorities are primarily responsible for managing activities on the landward side of the coastal marine area through a district plan. Regional councils can also manage some land uses through a regional plan. The coastal marine area is defined in the RMA (section 2) as the foreshore, seabed, coastal water and air space above the water between:

- a seaward boundary (territorial sea limit, which is presently 12 nautical miles offshore) and
- a landward boundary (the line of Mean High Water Spring (MHWS), except where that line crosses a river – in which case it is generally upstream as determined by the given criteria).

Note that this landward boundary moves somewhat with natural cycles of shoreline erosion and accretion on sedimentary coasts (if not artificially constrained). However, as climate change effects increase, the mean high water spring boundary will change more extensively, with an increasing encroachment of land (brought about by sea-level rise) and potential increasing erosion of vulnerable sedimentary coasts. Any dispute of where MHWS lies requires a formal boundary survey to be undertaken.

Although this coastal delineation suggests a concise management regime, coastal issues invariably cross the landward jurisdictional boundary of the coastal marine area, and thereby require an integrated management approach. Integrated management is fundamental to the RMA and is specifically required under sections 62(1)(b), 62(1)(i)(i), 65(3)(c), 67(2)(f) and 75(2)(f). The use of integrated management is reinforced in the New Zealand Coastal Policy Statement (under review – out for public consultation: March 2008), which applies to the 'coastal environment' and refers to both the coastal marine area and the land adjacent to the coast up to the nearest coastal hills or prominent feature (developed by case law but not otherwise defined in the Act).

The RMA requires that levels of authority in a region consult with each other (and with adjacent regional and territorial councils) when preparing plans and regional policy statements under the RMA; and that they consider the extent of consistency required between plan or policy statement provisions.

There are some key issues of how district and regional plans give particular regard to the effects of climate change (as required by RMA section 7). These include:

- only regional policy statements, district plans and regional coastal plans are mandatory. Although regional councils may prepare other plans to fulfil their functions under RMA section 30, including those to control the use of land in relation to natural hazards, such plans are not mandatory for land outside the coastal marine area[3]
- an activity cannot occur within the coastal marine area unless there is a resource consent or rule in a plan permitting it. This contrasts with most land-use activities (RMA section 9), where an activity is permitted unless a rule controls or prohibits it.[4] Therefore, it is critical that policies and particularly rules in district plans are carefully constructed to achieve intended community outcomes for land use in the coastal environment, in relation to the managing the effects of coastal hazards and climate change

[3] Section 65(3)(c) states that a regional council must consider the desirability of preparing a regional plan where any threat from natural hazards is likely to arise.

[4] Harris, R 2004. The coastal and marine environment. *In*: Harris, R (ed.) *Handbook of Environmental Law*. Royal Forest and Bird Protection Society of New Zealand: [Wellington] 235–267.

- even if controls on building in a hazard area are contained in district plan rules, existing use rights generally apply to buildings constructed before the coastal hazard rules came into effect providing the building was 'lawfully established' (RMA section 10). Even when a building has been partially or completely destroyed by coastal hazards or a new replacement is to be built for other reasons, 'existing use rights' usually still apply as long as the building is re-built on the same general footprint. On the other hand, if controls on building in a coastal hazard area are contained in a regional plan, then existing use rights should not be relied on to allow reconstruction of the building.[5] Section 20A also limits these rights when a new regional rule becomes operative.[6]

The issue of hazard management within district and regional planning documents was considered in the case of *Canterbury Regional Council v Banks Peninsula District Council* [1995] 3 NZLR 189, [1995] NZRMA 452 (CA) in which McKay J. Court of Appeal noted:

> *It is true, ... that natural hazard is not defined as being the consequence of the occurrence, but as the occurrence itself which has or potentially has the adverse consequence. What can be avoided or mitigated, however, is not the occurrence but its effect. Neither in s 30 nor in s 31 are the words 'effects of' used in connection with 'natural hazards'. This is for the simple reason that they would be otiose,*[7] *as the definition of 'natural hazard' incorporates a reference to effects. The word 'effects' would also be inappropriate in respect of s 30(1)(c)(i)-(iii). It is unnecessary and inappropriate to explain the language by reference to some subtle distinction between the respective functions of regional councils and territorial authorities.*
>
> *It follows that the control of the use of land for the avoidance of [sic] mitigation of natural hazards is within the powers of both regional councils and territorial authorities. There will no doubt be occasions where such matters need to be dealt with on a regional basis, and occasions where this is not necessary, or where interim or additional steps need to be taken by the territorial authority. Any controls imposed can be tested by appeal to the (Environment Court), and inconsistencies are precluded by s 75(2).*

A regime for managing hazards in the coastal environment works best when clear working agreements have been stated in the regional policy statement, which clarify the regional councils' and territorial authorities' respective responsibilities. Regulatory plans are the main vehicle for managing effects of activities but councils are generally required to select the most effective, efficient and appropriate methods to achieve the purpose of the RMA (section 5).

However, there is potential to improve the management of the coastal environment through amending various planning instruments to formally recognise overlap and jurisdictional exclusivity, and through reviewing daily activities. Some regional councils (eg, Environment Bay of Plenty, Environment Canterbury) have extended the geographical coverage of their coastal plan, called a 'Regional Coastal Environment Plan', by providing policies and objectives to guide activities (eg, natural character, public access and hazards) on land adjacent to the sea, as well as the coastal marine area. Environment Canterbury's Regional Coastal Environment Plan goes one step further as it also has rules that control building and other activities within coastal hazard zones (or setbacks). These rules allow existing uses to continue, but buildings damaged or destroyed by the action of the sea may not necessarily be rebuilt as of right.[8]

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5 *McKinlay v Timaru District Council C 24/2001* – refer to chapter 11 (Appendix 2) for case notes.

6 See also the Court of Appeal case: *Rodney Distict Council v Eyres Eco-Park Ltd* (CA87/07).

7 'Otiose' means functionless.

8 Environment Canterbury. 2005. Regional Coastal Environment Plan for the Canterbury Region, Report No. R04/13/1, November 2005. Available at: www.ecan.govt.nz/Plans+and+Reports/Coast/ (23 April 2008).

In these regions, regional rules for a coastal hazard zone are expected to have the long-term effect of progressively rolling development back on a retreating shoreline – a managed retreat approach somewhat similar to that used in some states of the USA.[9]

10.2 The New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS; gazetted in 1994) is a guiding policy under the RMA (sections 56–58) for managing the coastal environment. The NZCPS is required to be 'given effect to' when district or regional plans are being drafted, and must be given 'regard to' when decisions on resource consent applications are being made. Regional policy statements, regional coastal plans and district plans must give effect to the NZCPS (section 67(3) and 62(3) and section 75(3) RMA).

The NZCPS advocates a precautionary approach for decisions affecting the 'coastal environment'. It addresses the effects of activities on the coastal environment through a number of guiding principles and specific policies. The policies highlighted below are particularly pertinent to the assessment of response options to coastal hazards, including sea-level rise, and other climate change impacts:

- Policies 1.1.1 to 1.1.5 – address features and components of natural character
- Policies 3.2.1, 3.2.2, 3.2.4 – consider appropriate subdivision, use and development of the coastal environment
- Section 3.3 policies – address the precautionary approach towards proposed activities
- Section 3.4 policies – recognise natural hazards, and outline provisions for avoiding or mitigating their effects
- Section 3.5 policies – for maintenance and enhancement of public access.

The NZCPS is currently under review (out for public consultation: March 2008). Hence, any reference in this Guidance Manual to specific policies may change as a result of this review process.

As part of the review, a survey showed that the NZCPS has been effectively implemented into regional coastal plans and regional policy statements, but only partially effective in influencing district plans and subsequent land-use planning decisions within the coastal environment. While the NZCPS has assisted management of subdivision and land-use changes within the coastal environment, there are some concerns about the degree to which the principles and policies are reflected in the content of district plans and their implementation. However, it was also acknowledged that there are other factors, beyond the NZCPS, that determine land-use outcomes. The NZCPS alone cannot determine sustainable management outcomes in the coastal environment.[10]

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9 Turbott, C, Stewart, A 2006. Managed retreat from coastal hazards: Options for implementation. Environment Waikato Technical Report 2006/048. 89 p. Available from: www.ew.govt.nz/publications/technicalreports/tr0648.htm (23 April 2008).

10 Rosier, J 2004. Independent review of the NZ Coastal Policy Statement. Report to The Minister of Conservation. Massey University: Palmerston North. 135 p.

Jacobson, M 2004. Review of the New Zealand Coastal Policy Statement 1994 – Coastal Hazards. A review of the effectiveness of the NZCPS in promoting sustainable coastal hazard management in New Zealand. Report prepared for The Minister of Conservation, February 2004. 121 p.

10.3 National policy statements

National policy statements enable central government to prescribe objectives and policies on resource management matters of national significance. Such statements guide subsequent decision-making under the RMA at the national, regional and district levels. National policy statements can, therefore, significantly affect resource management practices in New Zealand.

The Minister of Conservation is required to prepare a New Zealand Coastal Policy Statement, but other national policy statements (prepared by the Minister for the Environment) are optional. National policy statements have broad scope. They can state policies and objectives on any issue that is of national importance and that is also relevant to promoting the sustainable management of natural and physical resources. Regional policy statements and plans and district plans must give effect to all national policy statements.

10.4 National environmental standards

National environmental standards are regulations made under sections 43 and 44 of the RMA 1991. Standards can be numerical limits, narrative statements or methodologies that are in a legally enforceable form. They may include (but are not limited to) standards relating to:

- land use
- noise
- contaminants
- water quality, level or flow
- air quality
- soil quality in relation to the discharge of contaminants
- methods of implementing such standards.

This means that each regional, city or district council must enforce the same standard. In some circumstances, councils can impose stricter standards. There are national environmental standards around air quality and human drinking water sources.

10.5 Building Act 2004 and Building Regulations 1992

The Building Act 2004 addresses building work in the interests of ensuring the safety and integrity of the structure through its construction and subsequent use. This focus is distinct from that of the RMA, which addresses the effects of that structure (or any activity within it) on the environment, and of the environment on that structure (or activity within it). The Building Act is administered by the Department of Building and Housing[11] through district councils.

Under section 7) of the Building Act, a building consent authority must refuse to grant a building consent for construction of a building, or major alterations to a building, if:

1. the land on which the building work is to be carried out is subject or is likely to be subject to 1 or more natural hazards; or
2. the building work is likely to accelerate, worsen, or result in a natural hazard on that land or any other property.

However, these conditions do not apply if the building consent authority is satisfied that adequate provision is made to protect the land and building work from natural hazards (section 71(2)). Natural hazards include coastal erosion and inundation from tides and storm surge (section 71(3)).

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[11] http://www.dbh.govt.nz/building-index (23 April 2008).

Buildings may require a land-use consent under the RMA (where a building: is located in an area in which building needs to be controlled; breaches a permitted activity condition in relation to bulk or location; or is associated with a type of activity not envisaged for a particular area) as well as a building consent under the Building Act. If controls are imposed under both the RMA and the Building Act, the more stringent control prevails. In this regard, section 71(2)(a) of the Building Act is often counter to the provisions developed under the RMA, and regional and district plans, in terms of the need for or appropriateness of coastal defences to protect buildings or property.

Section 72 of the Building Act allows for the granting of building consents if the work does not accelerate, worsen or result in a natural hazard, and if it is reasonable to grant the consent in respect of the natural hazard. If this waiver occurs, the Registrar-General of Land must be notified (or on behalf of the crown, the relevant Minister and Surveyor-General must be notified, or in case of Māori land, the Register of the Māori Land Court) (section 73). Any notification must include the project information memorandum for the building consent, and the natural hazard(s) must be identified. Following this notification, an entry must be recorded on the certificate of title, noting that a building consent has been granted under section 72, and any particulars that identify the natural hazard concerned (section 74) must also be noted there. This record-keeping allows for any future owners of the land to be aware of the risk that may not be apparent at the time of purchase.

Building regulations, including the mandatory Building Code, are made under and in accordance with the Building Act. Under the present Building Act, the only part of the Building Regulations 1992 still in force is Schedule 1 containing the Building Code. Clause E1[12] is aimed at safeguarding people from injury and property from damage by surface water (which can be fresh water or water from the sea). Clause E.1.3.2 states that *surface water*, resulting from an event having a 2% probability of occurring annually, shall not enter *buildings*. The clause is usually applied in the form of a minimum building floor level for housing and residential-communal buildings, and it is a minimum standard – some councils have adopted a 1% annual exceedence probability (AEP) which equates to an average return period of 100 years.

The Building Code is currently under review. Some of the relevant suggestions in a discussion document by the Department of Building and Housing (not finalised) are:

- considering a change of the requirement to 1% AEP for flooding because it reflects the planning controls already being adopted by some territorial authorities, and provides a precautionary approach to managing the impact of climate change
- considering a requirement that particular types of building should be protected from tsunamis such as Performance Group 4 buildings (ie, those essential to post-disaster recovery or those associated with hazardous facilities eg, hospitals, fire, police, fuel storage) and Group 5 buildings (eg, major dams or extreme hazard facilities).

Finally, the theme throughout RMA and Building Act case law appears to be that, although district councils can exercise some judgement about whether to allow a subdivision or development, councils cannot abrogate responsibilities for avoiding or mitigating the effects of natural hazards and merely rely on the controls under the Building Act. The RMA process is important because the outcome of that process will generally decide whether a building can be sited in the relevant area in the first place. The Building Act, specifically sections 71–74, is particularly important where coastal (or other) hazards are discovered after titles have been created, or even after development is already established.

12 Copies of the Building Code are available at: http://www.dbh.govt.nz/building-code-compliance-documents (23 April 2008).

10.6 Local Government Act 2002

The Local Government Act 2002 (LGA) outlines administrative and management responsibilities for regional and district councils, including for matters such as land management, utility services, recreation assets, transportation and the associated provision of services.

The Local Government Act-1974 (LGA-1974) requires stopped[13] roads along the margins of the coast (along MHWS) to be vested in council as esplanade reserves (section 345(3)). The Local Government Act also establishes the means by which territorial local authorities may collect financial contributions for funding the acquisition, maintenance and development of reserves.

Section 650A of the LGA-1974 allows for district councils to undertake various works in the coastal environment, including the erection and maintenance of: quays, docks, piers, wharves, jetties, launching ramps and any other works for *the improvement, protection, management, or utilisation of waters within its district (subject to the controls established by the RMA).*

Community planning is a cornerstone of the LGA, which requires communities to prepare Long-term Council Community Plans (LTCCP) that set out desired community outcomes and longer term financial planning. There are also specific consultation requirements that local governments must meet when preparing plans or bylaws under the LGA. These requirements are particularly significant for coastal strategies, or other management plans that are adopted as part of the adaptation response to coastal hazards, including climate-induced impacts.

10.7 Civil Defence Emergency Management Act 2002

The Civil Defence Emergency Management Act 2002 (CDEM Act) is intended to:

- promote sustainable management of hazards
- encourage and enable communities to achieve acceptable levels of risk
- provide for planning and preparation for emergencies, and for response and recovery
- require local authorities, through regional groups, to coordinate planning and activities
- provide a basis for the integration of national and local civil defence emergency management
- encourage coordination across a wide range of agencies, recognising that emergencies are multi-agency events
- focus on reduction, readiness, response and recovery.

The CDEM Act requires that a risk-management approach be taken when dealing with hazards. When the risks associated with a particular hazard are being considered, both the likelihood of the event occurring and its consequences must be addressed. The CDEM Act is largely an enabling mechanism, which can complement both the Building Act and the RMA, particularly in managing residual risk (eg, where emergency arrangements, such as evacuation, are used when buildings are likely to be overwhelmed or when the hazard poses an intolerable risk to public safety). In particular, integration between regional and district councils is achieved with the formation of CDEM Groups comprising representatives from each of the territorial local authorities and the regional council within a region.

[13] Legal procedures can 'stop', or dispose of, a portion of legal road (eg, unformed road), where historically the margins along waterways and the coast were designated as 'roads'.

The CDEM Act (section 17(1)) outlines the functions of a CDEM Group in relation to relevant hazards and risks. These include:

- *identify, assess, and manage those hazards and risks;*
- *consult and communicate about risks; and*
- *identify and implement cost-effective risk reduction ...*

The CDEM Act (section 48) provides that each CDEM Group must provide a CDEM Group plan and that plan must state the hazards and risks to be managed by the Group and the actions necessary to do so.[14] The CDEM Act, therefore, anticipates that regional and territorial authorities will cooperate in the management of hazards and risk, including coastal hazards.

10.8 Reserves Act 1977

The Reserves Act 1977 makes provision for the acquisition, control, management, maintenance, preservation, development and use of public reserves, and makes provision for public access to the coastline and rural areas. Administering bodies are required to prepare management plans for their reserves, which are open for public comment and review (except management plans for most government and local purpose reserves).

While the Reserves Act is aimed at providing public use areas and access, these reserve areas may also be useful as providing buffers from coastal hazards. However, councils must manage reserves to fulfil their purpose(s) under the Reserves Act (whether historic reserve, scientific reserve, scenic reserve, etc.). If buffer functions are not specifically mentioned in a reserve management plan, it is questionable whether reserve areas can be treated in this way by territorial authorities, as their buffering function may have an effect on their specified use for reserve or open space recreation. For example, the purpose of an esplanade reserve is defined in the RMA, but the primary purpose is not to reduce coastal hazard risk. There is some debate whether managing an esplanade reserve to reduce the hazard on adjoining land is actually within the scope of the Reserves Act. One option is to refer to a reserve's hazard buffer functions within a reserve management plan. However, at this stage there is no case law to support this approach.

10.9 Public Works Act 1981

The Public Works Act 1981 deals with the rights of central and local government to acquire private land for public purposes including for reserves (within the meaning of the Reserves Act), and the procedures for acquiring and disposing of this land. The acquisition of land for reserve purposes is one way of providing for buffer mechanisms.

10.10 Foreshore and Seabed Act 2004

The object of the Foreshore and Seabed Act 2004 is to preserve the public foreshore and seabed in perpetuity as the common heritage of all New Zealanders in a way that enables the protection by the Crown of the foreshore and seabed, including protection of the association of whanau, hapu and iwi with areas of the public foreshore and seabed (section 3).

The 'foreshore and seabed' (section 5) collectively have the same offshore and landward boundaries as the coastal marine area defined in the RMA. The relevant purposes of Foreshore and Seabed Act are (section 4):

- providing recognition and protection of ongoing customary rights to undertake or engage in activities, uses, or practices in areas of the public foreshore and seabed
- providing for general rights of public access and recreation in, on, over and across the public foreshore and seabed.

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14 Section 49(2) of the CDEM Act.

Some of the issues covered by the Foreshore and Seabed Act that may be relevant to coastal hazard management and adaptation to developing climate change impacts include:

a) rights of owners of roads located in the public foreshore and seabed (section 15)

b) status and ownership of reclamations (sections 18–20)

c) provisions for land title where a portion is located below the line of mean high water spring (section 23).

11 Appendix 2: Relevant case law

Disclaimer: This appendix has been prepared for the Ministry for the Environment by external contractors, as noted on the verso of this document's title page. To the extent that this guide deals with legal matters, it does not necessarily represent the views of the Ministry for the Environment; readers should not rely on it as legal advice.

11.1 Introduction

The following sections summarise a selection of case law relating to coastal hazards and the effects of climate change on coastal hazards (listed in Table 11.1). For this revision of the Guidance Manual, the case law summary has not been updated from 2004 to 2008, except that *Fore World Developments Ltd v Napier City Council W029/06* has been included.

Table 11.1: Case law summarised in Appendix 2

Section	Case	Issues under consideration
11.2	*Maruia Society v Whakatane District Council 15 NZPTA (1991)*	Interpretation of section 106 of the RMA
11.3	*Bay of Plenty Regional Council v Whakatane District Council A 068/94*	Timescales for consideration of effects
11.4	*Opotiki Resource Planners v Opotiki District Council A 15/97*	Further development in existing developed areas where appropriate hazard mitigation measures had been undertaken
11.5	*Judges Bay Residents Association v Auckland Regional Council and Auckland City Council A 72/98*	Hazard protection measures and port development
11.6	*Auckland City Council v Auckland Regional Council A 28/99*	Relevance of climate change information
11.7	*Kotuku Parks Ltd v Kapiti Coast District Council A 73/00*	RMA Section 106 and catastrophic events.
11.8	*Lowry Bay Residents Association v Eastern Bays Little Blue Penguin Foundation Inc W45/01*	Relationship between Building Act 1991 and RMA in avoiding coastal hazards
11.9	*Save the Bay v Canterbury Regional Council C6/2001*	Hazard zone provisions within regional coastal environmental plan
11.10	*McKinlay v Timaru District Council C 24/2001*	Existing use rights and the role of rules in regional and district plans
11.11	*Bay of Plenty Regional Council v Western Bay of Plenty District Council A 27/02*	Principles of hazard avoidance. Relationship between resource and building consents
11.12	*Skinner v Tauranga District Council A 163/02*	Reasonable timeframe for coastal planning, use of precautionary approach for managing uncertainties
11.13	*Fore World Developments Ltd v Napier City Council W029/06*	Climate change information and use of the precautionary approach to account for uncertainties

11.2 Maruia Society v Whakatane District 15 NZPTA (1991)

High Court, Judge Doogue presiding.

This case was decided under section 274(1) of the Local Government Act 1975, which was a similar provision to section 106 of the RMA. The case involved subdivision of land fronting Ohiwa Harbour at Port Ohope. The minimum ground levels imposed by the Council had been based on the effects of the 1968 Wahine storm. The Council's engineer considered that section 274(1) of the Local Government Act did not allow Council to recognise the possible effects of rising sea levels in determining conditions relating to the subdivision. This was a judicial review of the Council's decision. In relation to interpreting section 274(1), the Court said:

> *I find it difficult to see ... that any decision-making body faced with that particular language is meant to put aside what it is known by it to be likely to occur within the immediate or foreseeable future, regardless of the fact that the event may not have occurred in the historical past.*
>
> *That is now to say that an authority would have to go to any particular lengths to determine what are clearly difficult areas in respect of likely future changes in sea or ground level. Whether the evidence at present available in respect of matters such as the 'greenhouse' effect is anything more than conjectural I do not know. ... It would be a matter entirely for the council or the Planning Tribunal as to the extent to which it took such information into account.*

The Court also held that the council does not have to protect every part of the land in the subdivision from inundation. Section 274(1) gives the council discretion to determine whether there is sufficient protection against inundation suitable for subdivision. This is important case law for interpreting section 106 of the RMA.

11.3 Bay of Plenty Regional Council v Whakatane District Council A 003/94

Environment Court, Judge Bollard presiding.

11.3.1 Overview

This case was decided under the provisions of the Local Government Act 1975 because the proceedings were initiated before the RMA came into force. The case also concerned a subdivision at Port Ohope. The Regional Council appealed the District Council's decision to grant the subdivision based on the effects of sea-level rise.

The Regional Council's witness (Professor Kirk) referred to sea-level rise predictions published by the Intergovernmental Panel on Climate Change (IPCC) and by the New Zealand Climate Change Programme (Ministry for the Environment). The Court said:

> *We were told that the IPCC estimates are expected to be reviewed in the next year or two. Be this as it may, Professor Kirk asserted that the climate models used to make predictions in country-wide, let alone global, terms are 'crude in respect of ocean/atmosphere interactions and spatial resolution, especially in the southern hemisphere'. In short, he considered that reliance placed on IPCC global estimates by other witnesses was misconceived.*

Professor Kirk recommended a forecasting period of 2050 in preference to 2100 on the basis that reliable predictions cannot be made much past the year 2050. He noted that the IPCC projections for global average sea level have an uncertainty range of +50%.

The Regional Council's witness (Professor Healy) referred to the IPCC's (1990) best estimate for sea-level rise: 66 cm by the year 2100. He said that shoreline retreat would likely be accelerated by the 'Bruun' effect. He recommended a coastal hazard zone line. Other Regional Council witnesses (Dr Gibb and Mr Pemberton) regarded the IPCC best estimate data as important for reference purposes.

11.3.2 Court's decision

... we are of the view that, in this case at least, a forecasting period to 2050 AD is reasonable. Given the present state of understanding of the factors causing global and regional sea level changes, we accept the 2050 AD time horizon for present purposes – that being, in our view, as far as the 'foreseeable future' may reasonably be extended, allowing for the uncertainties of scientific knowledge and balancing the interests of the applicant and succeeding landowners. By adopting such a time frame in this instance, it should not be thought that in another planning context a different time frame ought not to apply. We simply say that, on the evidence before us and against the background of this particular case, such a forecasting period seems to us appropriate. We thus adopt Professor Kirk's evidence on this aspect. On the other hand, we are persuaded by Dr Gibb and others that the IPCC 'best estimate' for general sea-level rise of 0.3 m as at 2050 AD should be taken heed of.

We accept ... that it is notoriously difficult to make a reliable prediction as to the sea-level change that will affect the subject land as far ahead as 2050, let alone beyond that. Nevertheless, we consider that the best prediction currently available of the likely sea-level rise that will affect the country generally as at 2050 should be adopted.

The Court accepted Dr Gibb's evidence on predicted rates of coastal erosion over the evidence of the Regional Council witnesses. The Court adjourned the proceedings to allow the developer to prepare an amended scheme plan with a scaled-down proposal with an amended minimum building platform.

11.4 Opotiki Resource Planners v Opotiki District Council A 15/97

Environment Court, Judge Bollard presiding.

This case involved an appeal against a consent granted to construct a new integrated primary health care centre in the main shopping street of Opotiki. It was argued that the proposal should be rejected for a number of reasons, including the site's susceptibility to flood risk (sea-level rise, aggradation of local rivers over time, lack of a guarantee that the stopbanks would not fail during a major flood event).

The Court did not consider that this hazard risk warranted declining the consent.

One cannot overlook that, in reality, the district has a considerable investment incorporated in the commercial area, of which the former post office building, in itself a relatively modern and substantial building, forms part. We do not regard upholding the proposal as some sort of unreserved and final endorsement of the town being located in perpetuity where it is. Rather, our decision recognises the substantial infrastructure of present urban development and associated facilities/ services – including the stopbank protection works and the ongoing scheme directed to their maintenance and improvement.

Much of the evidence we heard was really pertinent to the basic question whether the location of the town itself is appropriate on account of the flood risk element, despite the measures taken to protect the town. It lies well beyond the realm of this appeal to draw so bold a conclusion on an 'across the board' footing, and then go on to illustrate such a finding by rejecting the proposal.

The consent was granted with a condition relating to the floor level of the new building.

11.5 Judges Bay Residents Association v Auckland Regional Council and Auckland City Council A 72/98

Environment Court, Judge Sheppard presiding.

Resource consents had been granted by the Auckland Regional Council and Auckland City Council for extension of the Fergusson Container Terminal the Ports of Auckland. Five parties appealed the decisions.

The Proposed Auckland Regional Policy Statement contained provisions regarding natural hazards – identified as including erosion, inundation of low-lying areas, land instability, rising sea levels and tsunami. Policy 11.4.1(10) stated that location and design of new subdivision, use or development should be such that the need for hazard protection measures is avoided. Policy 11.4.1(12) required a 'precautionary approach' to be used in avoiding, remedying or mitigating the adverse effects of natural hazards on development.

Expert evidence presented at the hearing addressed matters of extreme events such as sea-level rise and tsunamis. The witness for Auckland Regional Council gave the opinion that the proposed wharf level would be adequate for extreme events. The extension was proposed to have the same levels as the existing built port environment, and therefore the same protection from natural hazards.

The opinion was given that the standard design (particularly in regard to possible sea-level rise) was appropriate and that inundation and erosion were not relevant risks to a built port environment. The Court found that the proposal would not cause any adverse wave effects or any other adverse effects in extreme events.

11.6 Auckland City Council v Auckland Regional Council A 28/99

Environment Court, Judge Sheppard presiding.

This case involved appeals against refusal of resource consents required for the proposed Britomart underground transport and parking centre in central Auckland.

The proposed five-level underground development involves construction below groundwater level and thus diversion was required. The appeals opposed the consents for earthworks and the diversion of groundwater, based on potential damage to land and buildings in the vicinity from ground movement resulting from excavation and groundwater diversion.

A submitter urged that consideration be given to the possibility of tsunamis and storm surges causing the water of the harbour to overtop seawalls and flood the Quay Street underpass, although acknowledging that it would be unlikely that seawater would enter the Britomart transport centre itself. The Court held that sea-level and climate change issues were relevant only to the extent that the bases for ground water modelling had been properly prepared, having regard to contingencies.

The key witness explained that effects on groundwater levels would fully manifest themselves within 10 years of the start of construction, which is a relatively short period within the context of sea-level rise. Sea-level rise due to climate change would have no effect on the validity of the groundwater model predictions.

11.7 Kotuku Parks Ltd v Kapiti Coast District Council A 73/00

Environment Court, Judge Sheppard presiding.

This was an application for consents for subdivision and earthworks and involved an appeal against some of the conditions imposed by Kapiti Coast District Council. Ultimately, the consents were declined by the Court on grounds that included failing to protect significant habitat or indigenous fauna, adverse visual effects and impairment to kaitiakitanga.

It was argued by the Waikanae Estuary Guardians that the land proposed to be subdivided would be likely to be subject to material damage by subsidence as a result of earthquake, and by inundation and erosion from the sea in conditions of storm surge, tsunami, and sea-level rise. This was relevant for consideration under section 106 of the RMA.

The Court found that although a major event causing extensive inundation or erosion could occur on this coast at any time, it was not standard practice to design for such extreme events as those described by witnesses for the Waikanae Estuary Guardians. The evidence about catastrophic events had been in relation to the next hundreds of years, and would have effects along the entire Kapiti Coast. Another witness gave evidence of catastrophic events having a return period of at least every 250 years, and of larger saltwater inundation events occurring one every 400 years.

Sufficient provision to avoid or mitigate the likelihood of damage was made by the building platform levels that had been set by the Council. This building platform level had been based on a:

- river flooding event of 1% probability combined with a storm sea-surge event of 5% probability; or
- storm sea- surge event of 1% probability with a similar allowance for future sea-level rise.

This was considered to be sufficiently conservative to avoid or mitigate the likelihood of damage.

11.8 Lowry Bay Residents Association v Eastern Bays Little Blue Penguin Foundation Inc W45/01

Environment Court, Judge Kenderdine presiding.

This case involved appeals against consents to establish a facility for the reception, recovery and rehabilitation of wild birds for release back into the wild. The Court said:

> *It was the Association's case that the applicants and respondents appear to have studiously ignored the fact that the proposed buildings will be located in an area having an obvious natural hazard. It is not sufficient to say that buildings will be built in accordance with the Building Code. The evidence of the witnesses for the Association demonstrate that location of any buildings on the site proposed is unwise and courting disaster.*

The Hutt City Council's witness said that any reference to the potential for the proposed facility to be affected by severe storms, salt deposits and spray drift was not relevant to the consideration of the grant of the consent sought, because the design and construction of the buildings was a matter to be considered under the Building Act 1991.

The Court said:

> *We do not understand how a dwelling house (large enough to hold small children), an educational facility (which will include small children), and a cafe for 54 visitors could be approved for this site ...*

> *We concluded that the location of all aspects of the proposal and the activities it imports, is not commensurate with the principles of sustainable management. The last word on natural hazard goes to Mr Churchman who submitted it is impossible to say that siting this proposal in an area demonstrably subject to coastal hazards is in accordance with the plan or commonsense – a submission we endorse.*

11.9 Save the Bay v Canterbury Regional Council C6/2001

Environment Court, Judge Jackson presiding.

11.9.1 Overview

The reference related to provisions of the Proposed Regional Coastal Environment Plan (PRCEP) dealing with coastal hazards as they relate to Taylor's Mistake and Hobson's Bay (Banks Peninsula). The plan contained:

- Hazard Zone 1 – land at risk from coastal erosion within 50 years (its boundary, the 'hazard line', runs approximately parallel to the shoreline)
- Hazard Zone 2 – inland from Hazard Zone 1; land at risk from coastal erosion within 50 to 100 years.

These zones were defined only by reference to coastal erosion. Other natural hazards were not dealt with by the rules but were to be the subject of further plan reviews. These included tsunami events and the possible effects of global warming (on sea level, coastal sediment supply and storm generation).

The plan stated:

> *There is a need to undertake more investigation on the magnitudes frequencies and possible effects of these events. The results are to be used in future reviews of coastal hazard management policies and methods. In the absence of consensus as to the precise effects of global climate change, the wisest course is to adopt a precautionary approach when considering developments in the coastal area.*

Save the Bay was concerned about storm damage by wave action and rockfall.

11.9.2 Court's decision

The Court was concerned that the objectives and policies in the plan related only to coastal erosion and inundation and not to other natural hazards and, for inundation, the objectives policies were not followed through with rules (because the hazard zones related only to coastal erosion risk). Outside the natural hazard zones, the reconstruction of those buildings damaged by the sea was not controlled by the plan at all.

The Court considered that there was totally inadequate recognition of catastrophic natural events. 90% of damage to the environment caused by natural hazards occurs in 10% or less of events.

> *If resource management has a significant function in relation to natural hazards – and it seems important enough to Parliament to give functions in respect of natural hazards to the regional and territorial authorities – then surely authorities should recognise that inverse relationship in the preparation and wording of their plans.*

The Court heard evidence about the location of the hazard line and said:

> *In our view drafting a hazard line is not as scientific as ascertaining where the MHWS is (although that too is fraught with difficulty). The task is to draw a line as an administrative boundary which is conveniently ascertainable.*

The boundary line for Hazard Zone 1 at Taylor's Mistake was amended.

11.9.3 Conclusions on the case

This case provides guidance on the interpretation and administration of sections 30 and 31 of the RMA:

- regional and territorial authorities need to recognise the significant function of resource management in relation to natural hazards in the preparation and working of their plans
- councils need to recognise serious, but infrequent, events when planning
- dealing with only one coastal hazard in the plan rules is not an integrated management approach.

11.10 McKinlay v Timaru District Council C 24/2001

Environment Court, Judge Jackson presiding.

The Canterbury Regional Council controlled the use of land in relation to natural hazards through its regional policy statement. In relation to the site in question, the regional policy statement did not contain any rules relating to natural hazards. Nor were there in the proposed regional coastal plan. However, there were rules governing natural hazards at the site in the Timaru Proposed District Plan. Under those rules, construction of a residential building was prohibited at the site (because it was within the 'Coastal Inundation Line').

The Court was asked to decide what would happen if an existing residence at the site was destroyed by a natural hazard such as a flood, and whether reconstruction would be prohibited by the proposed district plan. This relates to 'existing use rights' (sections 10 and 20 of the RMA). The Court said that the property owner would have existing use rights to rebuild provided that the dwelling rebuilt was the same or similar in character, intensity and scale as the present building (section 10). However, if there had been regional rules governing the reconstruction, then the situation would be different (sections 10(4) and 20(2)(c)). So, although regional rules can 'override' existing use rights, district rules do not.

11.11 Bay of Plenty Regional Council v Western Bay of Plenty District Council A 27/02

Environment Court, Judge Bollard presiding.

11.11.1 Overview

This reference related to provisions of Variation No. 1 to the Western Bay of Plenty District Council's proposed plan – development controls affecting coastline areas at Waihi and Pukehina beaches. The referrers were the Regional Council and the Waihi Beach Protection Society.

The plan contained a 'Coastal Protection Area' line, based on a 1993 study. (The Regional Plan also contained an 'Areas Sensitive to Coastal Hazards' line, which was compatible but not identical to the coastal protection area line).

The coastal protection area was split into 'high risk' and 'low risk' areas. Within the 'high-risk' areas, new buildings and alterations were a discretionary activity. In 'low-risk' areas, such activities were permitted, subject to conditions. Subdivision was discretionary in both areas. The Regional Council sought discretionary activity status for buildings in both areas. The Society sought permitted activity status for buildings in both the areas.

The District Council pointed out that, for permitted activity status, further conditions on building could be imposed under the Building Act 1991.

The plan variation was supposed to be an interim solution, providing adequate protection until 'future options for coastal management are known'. These include coastal protection works, but the Council did not want to proceed with those until other options had been investigated.

11.11.2 Court's decision

The Court considered that the planning instruments had properly recognised coastal erosion, inundation, dune stability and sea-level rise issues.

The Court considered that the Regional Council's approach should be accepted. It was sound to plan for a 100-year predicted risk period. The District Council argued that only a 50-year risk period should be planned for, but this was rejected, particularly considering the principles in the New Zealand Coastal Policy Statement. The areas should be categorised as 'primary' and 'secondary' areas of risk rather than 'high' and 'low', as both areas carry significant risk. Potential adverse effects through changed climate conditions and sea-level rise were accepted as existing. In secondary risk areas, buildings and extensions should be a limited discretionary activity.

The argument from the Society was rejected as follows:

> *... it was argued that the voluntary assumption of risk by private property owners does not abrogate the Council's responsibility of controlling the use of 'at risk' land for the purpose of avoiding or mitigating natural hazards. We accept that submission … Failure to manage known actual and potential effects of natural hazards at Waihi and Pukehina Beaches under the Act's regime would not, in our view, be consistent with the legislative purpose of sustainability.*

The Court commented on the evidence and the uncertainty inherent in this area of planning. These, together with the New Zealand Coastal Policy Statement, pointed to a precautionary approach to planning.

It commented on the interface with the Building Act:

> *... the respective means of control under the RMA and the Building Act should not be narrowly construed as merely amounting to alternatives available to a Council to achieve the same ends. Rather they should be viewed in a broader light, both individually and in combination, of assisting to serve the public good. Were the contrary contention sound, Parliament's recognition of the two separate Acts' frameworks of authority and control might be seen as unnecessarily repetitious. Each in fact serves its particular purpose – that under the RMA of promoting the sustainable management of resources in the context of the wide environmental perspective that the Act embraces; and that under the Building Act by focussing on the integrity and safety of buildings wherever they are located. Logically, any relevant controlling provisions that govern a development proposal under the holistic management regime of the RMA will generally fall to be invoked initially, with the application of controls under the Building Act following as appropriate in terms of that Act.*

11.11.3 Conclusions on the case

- Given the uncertainties in this area of planning, a precautionary approach should be taken.
- The Building Act should not be relied on completely – the RMA's purpose of sustainable management should still be fulfilled.

(The final plan provisions for this case were resolved in *Bay of Plenty Regional Council v Western Bay of Plenty District Council* A 141/02.)

11.12 Skinner v Tauranga District Council A 163/02

Environment Court, Judge Bollard presiding.

11.12.1 Overview

The reference related to provisions of the Tauranga District Council's proposed plan – development controls affecting coastline areas at Papamoa Beach. The referrers were residents represented by a Mr Skinner.

The plan contained a 'Coastal Hazard Erosion Policy Area' (the Area). Within the Area were the following hazard risk zones:

- an extreme risk erosion zone (the area immediately susceptible to notable adverse effects from coastal hazards) – any development a prohibited activity
- a high-risk erosion zone (erosion predicted 2050–2100, taking into account global warming predictions) – development is limited discretionary
- a moderate-risk erosion zone (erosion predicted 2050–2100, taking into account global warming predictions) – development is limited discretionary
- a buffer zone – (an 'at risk' area should parameters used to arrive at the other zones should be too low) – has an in-built safety factor of 30%.

The Area had been developed by a coastal hazards expert Mr Gibb. Mr Skinner (resident) sought the Area to be relocated seaward of the residences. He had already commissioned a report from a Mr Smith. In response, the Council had asked a Mr Reinen-Hamill and experts at the Auckland Regional Council (Mr Brookes) to review the Smith report and the Gibb report – concluding that the Gibb report should be preferred.

There was much expert evidence on the assessment of coastal hazard risk. The Tauranga District Council called as witness Mr Gibb, Mr Reinen-Hamill, and Mr Brookes, supported by Dr Bell (NIWA) and Dr de Lange (Waikato University). Some of these witnesses applied the 'Bruun rule'.

Mr Skinner called evidence from Mr Smith (NIWA), supported by Dr Abbott, Dr T Lustig and Mr Oldham (NIWA). Mr Smith considered it unlikely that cutback from a one in 100-ear storm would cause sufficient damage to endanger beachfront houses, even allowing for future climatic uncertainties and sea-level rise. The use of the 'Bruun rule' was rejected by these witnesses.

11.12.2 Court's decision

The Court concluded that the beach was susceptible to erosive cutback when major storm events occur, and to continual dune line change. The 100-year period was deemed reasonable for coastal planning. Predictions were difficult but a lack of field data meant that the Area should not be moved as Mr Skinner wanted:

> *In the absence of such data, it would not be prudent to adopt an approach that postulates that the future dynamics of the beach profile will carry no hazard risk to seaward-facing parts of properties immediately proximate to the beach during the next 100 years.*

Also:

> *Of major import in arriving at a determination in this instance in the face of the conflicting evidence, is the lack of certainty as to future climate change and how such change will affect the various 'drivers' that lead to shoreline movement.*

In relation to sea-level rise, the Court noted the 'most likely' mid-range predicted by the IPCC.

Bearing in mind the precautionary element in the New Zealand Coastal Policy Statement, the Court found in favour of the witnesses who considered the 'Bruun rule' (which applied to 'closed systems' –

> *we find that the notion of an 'ample cushion' of sediment supply cannot be endorsed with [a] degree of confidence ...).*

Economic evidence was put forward on development potential and on the decrease in property values of beachfront properties. However, the evidence was not sufficient to override the need for the Council to plan ahead for coastal hazard risk.

The Area was upheld, with the extreme, high and moderate risk zones in it, but the Court considered the safety buffer zone could be removed as it was ultra cautious.

> *The effect is to place a zone restriction on the properties affected beyond the extent necessary to ensure sufficient and appropriate recognition of coastal hazard risk to those properties during the 100-year forecasting period.*

However, the Council was directed to monitor trends so that the plan could be refined based on continuing experience and additional data.

11.12.3 Conclusions on the case

- The District Council had appropriately fulfilled its function in relation to natural hazards.
- It was correct to take a precautionary approach, given the uncertainties involved.
- The IPCC predictions on sea-level rise were endorsed.
- The case is interesting because of the large number of coastal hazard expert witnesses that were called.

11.13 Fore World Developments Ltd v Napier City Council W 029/06

Environment Court, Judge Thompson presiding.

In this case, appellants sought to have land zoned residential to enable subdivision, despite coastal erosion concerns.

The Court acknowledged that sea-level rise would result in wave action occurring at a higher elevation on shore and thus cause coastal erosion. In order to calculate the rate of coastal erosion, the Court accepted the sea-level rise estimates of the IPCC.

In its overall assessment, the Court stated that climate change aspects such as increased storminess require the consideration of an additional buffer allowance. This was explained as follows:

> *It is not a situation where it is necessary to be overly cautious but it would be prudent to provide for a buffer in addition to the estimated extent of the coastal erosion to make some sort of allowance for the factors that have not been estimated and included. ... That buffer should be in the order of 25% of the sum of the estimated distance.*

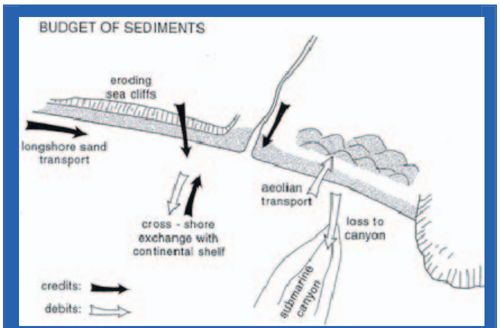
The decision further described the inland extent of the coastal hazard zone based on the information before it and the buffer area.

11.13.1 Conclusions on the case

- A 100-year timeframe is appropriate for considering coastal issues.
- The 'Bruun rule' was accepted as an adequate method for assessing the effects of sea-level rise on coastal retreat.
- A graduated coastal hazard zone was not favoured in this case owing to difficulties of application and enforcement with a relatively small overall width of land.
- Adoption of a precautionary approach, based on weighted consideration of the level of knowledge of the risk, its likelihood of occurrence and the consequences, was accepted.
- The case is interesting because of the large number of coastal hazard expert witnesses that were called.

12 Factsheet 1: Coastal erosion

Coastal erosion becomes a hazard where human activity or settlement is threatened by a **temporary or permanent cutback of the shoreline**. (Coastal accretion is the opposite, where the shoreline builds out over time.)



Typical sediment sources to nearshore coastal systems in New Zealand:

- Longshore transport into area
- Input from rivers
- Wind transport onto beach
- Erosion of sea cliffs upcoast
- Onshore transport
- Beach nourishment
- Trapping of sand by dune vegetation

Typical sediment losses from nearshore coastal systems in New Zealand:

- Longshore transport out of area
- Wind transport away from beach
- Offshore transport
- Abrasion
- Sand mining

Source: Komar, P 1998. *Beach Processes and Sedimentation*. Prentice-Hall Inc. New Jersey.

Changes in the position of the coastline result from a complex interaction of different natural factors and processes, including:

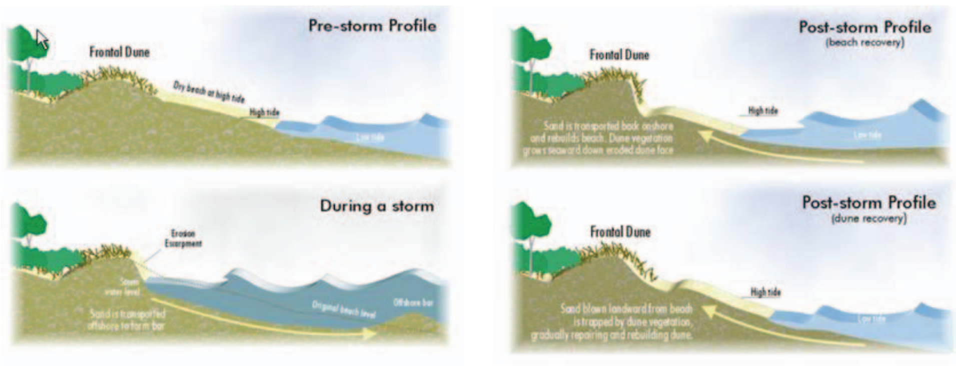
- the interactions and influences of the hydrodynamic driving processes. These include swell, waves, tides, storm surge, currents, storm sequences and the effect of climatic variability, ie, El Niño-Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO). Climate change may have an effect on each of these processes
- the geomorphology – ie, the characteristics of the coastal margin (eg, beach and barrier type, sediment characteristics, geological controls, such as headlands and islands) – and how these characteristics respond to, and interact with, the hydrodynamic processes. For example, spits are often extremely unstable and prone to large changes in the position of the coastline
- the rate and relative balance of sediment supply and losses to coastal margins (see figure)
- crustal loading and tectonic factors influencing coastal uplift or subsidence.

Because there are so many factors involved in coastal erosion, shoreline change from sediment 're-distribution' within a nearshore beach system will *not* be consistent year after year in the same location.

Erosion and accretion can occur in a cyclic pattern ranging in timeframes from seasonal up to several decades (particularly on sandy coastlines). They can also occur in a series of episodic steps related to storm events; there may be little change for many years and then rapid cutback may occur during a storm, or sequence of storms. Even over short distances of coast, patterns of erosion and accretion can vary, producing, for example, erosion hotspots linked to the occurrence and movements of nearshore sand bars.

There is a wide range of timescales over which coastal erosion occurs, ranging from individual storms, through annual and El Niño cycles, up to long-term retreat at decadal or century scales. Therefore, normal practice is to deal with erosion on two timescales*: short-term fluctuations* (days to a few months, including storm cutback) and *long-term trends* (seasonal to decades or centuries).

The complexity of processes related to coastal erosion means that it is very difficult to estimate future coastal erosion at a specific locality without adequate data and historic information on shoreline position and changes.



Typical response of a natural sand beach–dune system to erosion during a storm event and the subsequent build-up of the beach and dunes over the following months (and even years).

Typical ranges of coastal erosion rates

	Storm response (short term)	Long-term erosion rates
Sandy beaches	Highly variable even within a locality and can be 10+ m during an extreme storm.	Highly variable even in a locality but generally less than 5 m/yr.
Spits	Extremely variable, with storm-related movements of 100+ m at the ends of unstable spits.	Extremely variable, with storm-related fluctuations typically dominating long-term trends. Fluctuations can be of the order of 200+ m.
Gravel	Can be up to 5–10 m during extreme storms, with stable periods between storms.	Generally < 1 m/yr on average but can be 2–3 m/yr in more vulnerable locations, particularly where the land backing the gravel barrier is low-lying or where the longshore supply is interrupted.
Estuarine shores	Highly variable, dependent on storm wave direction and timing with high tides. Changes can be of the order of 10s of metres during storm conditions but can vary substantially over short distances.	Variable over short distances, with erosion tending to occur as a series of storm-related steps. On average, < 2 m/yr and up to 5 m/yr at some vulnerable locations, eg, where channels cut in.
Cliffs	Highly variable depending on the geological characteristics and hydraulic processes. Negligible for hard rock cliffs but can be substantial on unconsolidated cliffs, particularly if landslipping also occurs.	On unconsolidated cliffs, average rates tend to be up to 1–2 m/yr.

Human intervention can also markedly alter natural coastal sediment processes through:

- catchment activities eg, land-use practices, urbanisation, dams, water abstraction (affects sediment supply from land sources via rivers and streams)
- dredging of tidal entrances and harbour channels (affects sediment movements within coastal systems)
- sand or gravel extraction from the coastal marine area (removes sediment from the nearshore system)
- coastal protection works eg, groynes, breakwaters, artificial reefs, seawalls (affects the natural movement and distribution of nearshore and beach sediments)
- beach nourishment (adds sediment to the beach and nearshore system)
- permanent modification of coastal margins eg, dune removal, vegetation removal or change, reclamations, waterways, wharfs and marinas (affects the natural movement of beach and nearshore sediments).

13 Factsheet 2: Coastal inundation (storms)

Storm inundation is an *acute* natural event arising from extreme weather events (storms), in which normally dry, but low-lying coastal land is flooded occasionally. Storm-related coastal inundation is caused by high tides (normally during spring or perigean tides), combining with:

- storm surge – the temporary (hours to days) increase in sea level over and above the predicted tide height due to a combination of strong winds and low barometric pressure
- waves, through a combination of wave set-up (an increase in the water levels landward of where waves are breaking) and wave run-up over the upper beach, which can overtop low coastal barriers.

'Storm tide' is used to describe the total sea level formed from the combination of tide and storm surge during storm conditions. During storm events, the likelihood and magnitude of coastal inundation is highly dependent on the occurrence or timing of high tides, storm surge and wave conditions. For example, the peak of the storm surge will not always coincide with the highest wave conditions and the time of a high spring tide. Around New Zealand, they will be correlated in some way, owing to the following:

- certain weather conditions, such as the tracking of extra-tropical cyclones or low-pressure systems close to New Zealand's coast, could produce both high wave conditions and high storm surge. However, as storm surge in New Zealand is relatively modest compared to the astronomical tide (which is completely independent of meteorological conditions), any correlation with extreme wave conditions may not be that high (particularly on the west coast where the tide range is higher)
- wave heights that are limited by water depth in shallow water. In such a case there may well be a high correlation between high water level and higher wave conditions.

The biggest storm-tide events last century occurred close together in 1936 and 1938. The Great Cyclone of 1–2 February 1936, with barometric pressures down to 970 hPa and ferocious winds and waves, came on the back of a very high perigean-spring tide and caused widespread coastal inundation damage along the east coast of the North Island. Coastal roads were washed away, a house fell into the sea at Te Kaha, while the sea swamped houses 100 m inland at Castlepoint (the sea broached the coastal dunes). A month later, on 25–26 March 1936, an easterly gale produced by a low depression combined with extremely high 100-year high tides and together they caused damage and sea flooding in the Auckland region.

Two years later, on 4–5 May 1938, 35,000 ha of the lower Hauraki Plains (pictured) were flooded through a combination of spring tides and northeast gales that caused a large storm surge and accompanying waves. There were several breaches of the shoreline stopbank from Waitakarau to Kopu. The inundation was exacerbated by heavy rainfall.

Source: Brenstrum E. 1998. *The New Zealand Weather Book*. Craig Potton Publishing: Nelson.

The extent and magnitude of inundation also depends on how the high storm tide and wave conditions actually inundate an area (ie, their flow path). This depends on the physical characteristics and topography of the upper parts of the beach or estuarine shoreline and immediate coastal hinterland. Typical flow pathways include:

- direct inundation, where the storm-tide level exceeds the level of the land. This typically occurs where waves have not built up a coastal barrier, such as along estuarine and sheltered coastlines or along the margins of rivers and streams

- inundation due to the breaching of a barrier. This may be related to the breaching of a natural barrier such as a gravel ridge or narrow dune field (with low-lying land behind it) or a human-made defence such as a stopbank. Coastal flooding due to breaching of a barrier is more likely to occur on open sections of coast exposed to larger waves
- overtopping of a barrier. Again this may be either a natural barrier such as a gravel ridge or narrow dune field or a human-made defence such as a stopbank. Overtopping typically occurs due to wave or swell conditions during a high tide or storm tide on more exposed open sections of coast.


Coastal inundation at East Clive, south of Napier on 16 August 1974 was caused by persistent heavy swell coinciding with high tides. This resulted in the gravel barrier being overtopped and the low-lying land behind being inundated and 200 homes affected.

Source: Ministry of Works and Development collection, Napier.

River flooding of coastal and estuarine margins, and stormwater flooding of low-lying areas, can be exacerbated by high tides or storm tides. In relatively flat low-lying coastal margins (eg, Lower Heathcote at Christchurch, South Canterbury Plains, Hauraki Plains), land may stay flooded with seawater for several days after an extreme event. This type of inundation has a dramatic effect on vegetation and pasture production, and can sometimes curtail pasture growth for a year or more.

Human interventions can also exacerbate storm inundation hazards through:

- river training works (straightening, stopbanks) that increase river levels at the coast
- poorly designed coastal protection structures that exacerbate loss of the beach adjacent to the structure or increase wave run-up and overtopping potential
- coastal property development in inundation-prone areas (low-lying estuary margins or shore-front areas without an adequate buffer), or roads or other infrastructure that blocks overland flows
- physical removal, reduction or damage to natural coastal barriers such as sand dunes and gravel barriers (eg, lowering access ways, removing vegetation, trimming or removing dunes)
- permanent modification of coastal margins (eg, by constructing waterways, canals, marinas and boat ramps, and carrying out reclamation).

High tide ´red alert´ days

www.niwascience.co.nz/rc/hazards/dates – Dates in the present year when high tides reach the highest levels. Hence storm surge or large wave conditions on top of such high tide levels during these dates will likely result in inundation of exposed low-lying coastal areas.

14 Factsheet 3: Coastal inundation (tsunami)

The word *tsunami* is used internationally, and is a Japanese word meaning 'harbour wave' or waves. Tsunamis are generated by a variety of geological disturbances, particularly:

- large seafloor earthquakes in which significant uplift or subsidence of the seafloor or coast occurs
- submarine landslides (which may be triggered by an earthquake)
- volcanic eruptions (eg, under-water explosions or caldera (crater) collapse, pyroclastic flows and atmospheric pressure waves
- large coastal-cliff or lakeside landslides
- very occasionally, meteorite (bolide) impact.

The last major remote source tsunami to hit our shores was the Chile tsunami of 1960 that reached 5.5 m high in Lyttleton Harbour, thankfully around low tide. It caused damage at many locations along the east coast.

Tsunamis can be classified either by the distance from their source to the area impacted or, more relevant for emergency management purposes, the travel time to the impacted area and the length scale of impact. For New Zealand, three categories are typically defined:

- local source/local impact event – within 60 minutes travel time and affecting several tens of km of coast
- regional source/regional impact event – within three hours' travel time and likely to affect a region or several regions
- distant (remote) source/national impact event – longer than three hours' travel time and likely to affect many regions.

The remains of a four-room house north of Gisborne that was destroyed by a 10-m local source tsunami in March 1947. Three people rode out the tsunami in the house, while two others ran across the road and up the hill with water at their heels. Pouawa, where the bridge was destroyed, is in the distance. Source: Weekly News, *2 April 1947.*

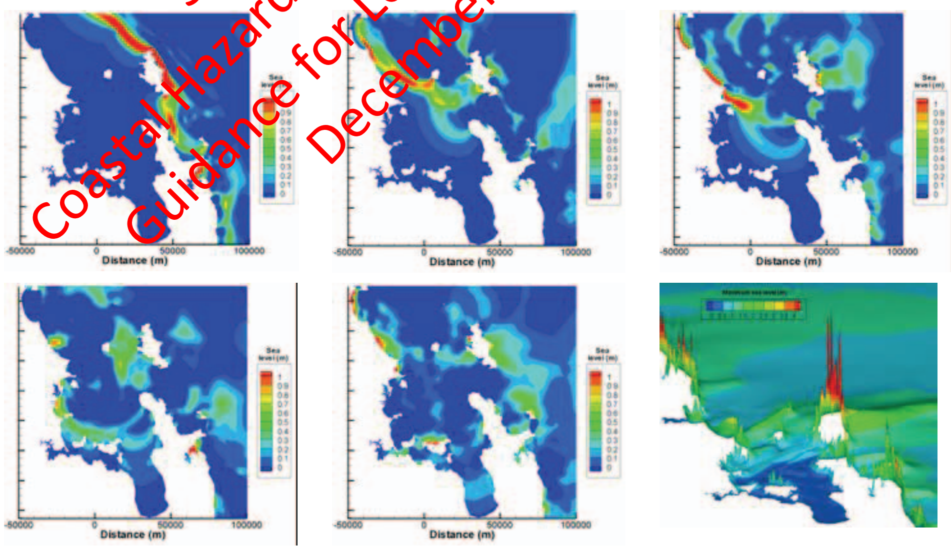
Tsunami wave characteristics at any location can vary substantially, depending on several factors, including: the generating mechanism; the location, size and orientation of the initial source (disruption); source-to-locality distance; and local seabed and coastal margin topography. The timing and height of high tide are also critical factors in determining the extent and magnitude of inundation.

Tsunami waves differ from the waves we see breaking on the beach or in the deep ocean, particularly in their length between wave crests. In a tsunami wave-train, the distance between successive wave crests (the wavelength) can vary from several kilometres to over 400 km, compared to around 50–100 metres for waves at the beach. The time between successive tsunami wave crests can vary from several minutes to an hour, rather than several seconds. As tsunami waves reach shallow coastal waters, they slow down and steepen rapidly, sometimes reaching heights of 10 m or more. Shallow bays and harbours tend to focus the waves and cause them to be amplified (or resonate) and slosh back and forth. Tsunami waves that overtop or breach natural coastal beach ridges and barriers can surge considerable distances inland in low-lying areas (100s of metres to a kilometre or more, depending upon the wave height at the shoreline, the wave period and the geographical characteristics of the coastal margin).

Key tsunami definitions

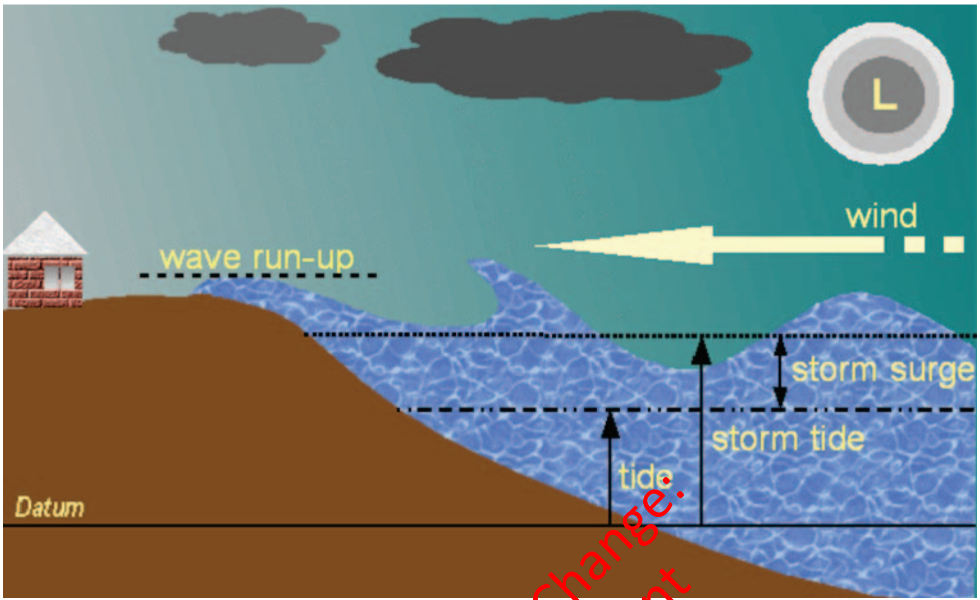
- *tsunami period* (minutes) – the time between successive wave peaks. This can fluctuate during a single event and vary between different locations within the same region. Periods are usually in the range of a few minutes (eg, 'local source/local impact' tsunami) to an hour or more for a 'distant source/national impact' tsunami
- *tsunami height* (m) – taken as the vertical crest-to-trough height of waves, but it is far from constant, and it increases substantially as the wave approaches the shoreline. It is generally used only in conjunction with measurements from a sea-level gauge to express the maximum tsunami height near shore
- *tsunami amplitude* (m) – the height difference between a wave crest and the instantaneous sea level at the time of arrival. It is used in tsunami warnings
- *tsunami run-up* (m) – a more useful measure; the *vertical* inundation elevation the seawater reaches above the instantaneous sea level at the time of the tsunami (including the tide). This measure still has the drawback that it depends markedly on the type of wave (rapidly rising and falling, a bore, a breaking wave, the wave period) and on the local slopes of the beach and foreshore areas, so it is site-specific
- *inland penetration* (m) – the maximum *horizontal* distance inland from the shoreline or mean-high-water mark inundated by the tsunami (inundation line). It depends on the tsunami run-up and local topography, barriers and slopes within the coastal margin.

The arrival of a tsunami wave-train (ie, it typically isn't just one wave) is often manifested by an initial draw down of the level of the sea (much faster than the tide). However, the first sign may instead be an initial rise in sea level. The waves that propagate towards the coast seldom break before reaching the nearshore area, and appear to have the whole ocean behind them. Inundation of the coastal margin continues until maximum run-up height is reached before the water temporarily recedes. Other tsunamis occur as an advancing breaking wave front or bore, which is the type of wave most people associate with a tsunami. For the same wave height at the shore, a longer-period tsunami wave-train, such as generated by a remote source (eg, from South America), will cause greater inundation volumes than a shorter-period wave (eg, a local source).



Modelling tsunami waves approaching the Coromandel and Hauraki Gulf coasts: Modelling tsunami inundation requires complex computer models that can simulate: the generation of the tsunami; the way the waves propagate over the ocean; the waves' interaction with the continental shelf, nearshore seabed and coastline; and ultimately their flow over and retreat from the coastal margin. Such modelling requires detailed nearshore bathymetry information and topography, such as LiDAR data.

15 Factsheet 4: Components of sea level



The elevation that the sea reaches at a shoreline is made up from the following components:

1. At any given time, there is a ***predicted astronomical tide*** level above a datum (eg, Chart Datum or Local Vertical Datum). The tide oscillates about the mean level of the sea (MLOS).

2. The mean level of the sea (MLOS) is influenced by longer-term climate fluctuations relating to ***seasonal effects*** (annual cycle), the ***El Niño-Southern Oscillation*** and the ***Interdecadal Pacific Oscillation (IPO)***. Seasonal sea levels are a few centimetres higher in late summer/early autumn (and a few centimetres lower in winter/early spring). During El Niño phases, sea levels tend to be depressed, and during La Niña phases, sea levels tend to be higher. IPO in its negative phase can increase sea levels by up to 5 cm. MLOS is increasing owing to global warming.

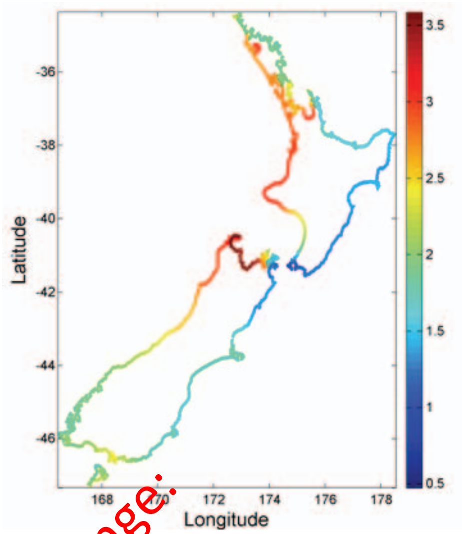
3. ***Storm surge*** is the increase in regional ocean level (excluding the effects of waves) due to low barometric pressure and winds blowing either onshore or alongshore over the ocean (with the coast on left). Conversely, high pressure and winds blowing offshore, or alongshore with the coast on the right, tend to decrease ocean level.

4. In New Zealand, ***storm tide*** is the term used to describe the temporary rise in level of the sea offshore of the wave breaker zone. Storm tide is the combination of the above three components (MLOS, the predicted tide at the time of the event and the storm surge height).

5. At the shoreline, the maximum vertical elevation reached by the sea is a combination of the ***wave set-up*** that is induced landward of the wave breaking zone and ***wave run-up*** (or swash). These act on top of the storm-tide level. Wave run-up is highly variable even over a short length of coast, varying according to the type of beach, the beach slope, the backshore features and presence of any coastal defence structure.

16 Factsheet 5: Tides

Tides are generated by gravitational forces exerted by both the Sun and Moon on the Earth's oceans. Ocean tide waves then propagate onto the continental shelf and into estuaries and harbours, being modified by wave shoaling (where the tidal wave slows down and increases in tide range as the water becomes shallower), friction from the seabed and constrictions such as estuary entrances, river mouths and straits.

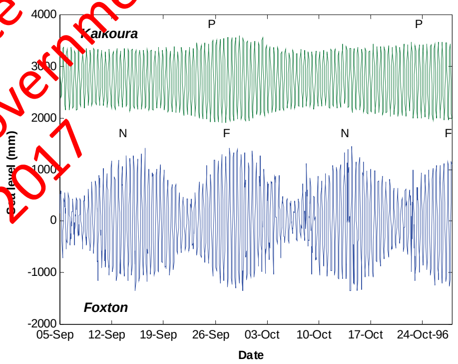


Spring tide range (in m) around the coast of New Zealand

Tides are entirely predictable and can be predicted for any day or period many years in advance.

The tide range (the difference between high and low waters) varies around New Zealand, reaching 3.5–4 m on the west coast but only 1–2 m on the east coast.

A tide mark commonly used to characterise high tides is mean high water spring (MHWS), which is also used to define the coastal planning boundary. MHWS is traditionally calculated for nautical purposes as the long-term average of the highest high tide that occurs just after every new [N] and full [F] moon (ie, spring tides). Normally, only about 10–20% of all high tides would exceed such a MHWS mark.



Comparison of tide range characteristics between Kaikoura (east coast) and Foxton (west coast). P=perigee, N=new moon and F=full moon.

MHWS is a simple concept and values for it are widely available. Yet, New Zealand tides along the central-eastern coasts don't easily fit with the commonly-used nautical MHWS definition. For example, at Kaikoura, c. 50% of high tides exceed the nautical MHWS level. The reason is that there is little difference between the fortnightly neap and spring tides along the central–eastern region. Instead, the highest tides occur once a month (every 27.5 days), when the Moon's elliptical orbit takes it closest to the Earth (ie, when the Moon is in its perigee [P]). Therefore, in estuaries and open coast locations on the east coast from Otago to Bay of Plenty, a better 'hazard' definition of the peak monthly tides is to use a 'pragmatical' MHWS, such that only 10% or 12% of local high tides exceed it; or use the mean high perigean-spring tide level (a higher tide that occurs in clusters peaking about every 7 months, often referred to as a 'king tide', when a perigean and spring tide combine).

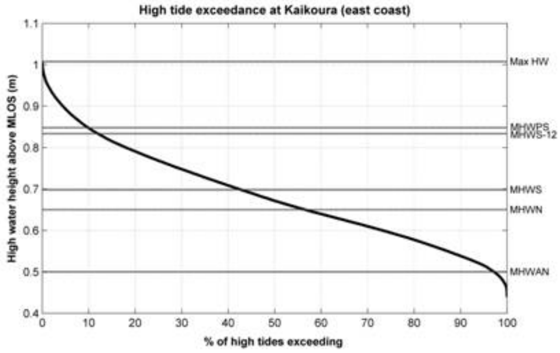
Tide prediction resources

www.niwascience.co.nz/services/free/tides. Open coast tide predictions at any location around New Zealand for any time period since 1830.

www.hydro.linz.govt.nz/tides/majports/index.asp. Tide predictions at standard and secondary ports for the following 12 months.

17 Factsheet 6: Mean High Water Spring (MHWS)

Defining the position of MHWS is important as it is used to delineate the landward jurisdictional boundary of the Coastal Marine Area (CMA) under the Resource Management Act 1991 and the Foreshore and Seabed Act 2004. However, defining MHWS is not a straightforward task, particularly if an accurate definition is required. There are a variety of quantitative and qualitative definitions of what constitutes a MHWS level in use:



An exceedence curve of high tides for a 100-year period at Kaikoura showing the different levels relative to mean level of the sea (MLOS) for different definitions of MHWS – MHWS (traditional approach); MHWS-12 – level exceeded by 12% of high tides; MHWPS – mean high water perigean-spring tide. Also shown are neap high tide markers (MHWN, MHWAN).

- MHWS: The traditional nautical approach is based on a quantitative 'tidal harmonic' definition of MHWS typically[1] as the average of pairs of successive high waters in a 24-hour period in each semi-lunation (approximately every 14 days) at New and Full Moon (or in mathematical terms the sum of M_2 (lunar) and S_2 (solar) tide constituents. However, for central areas of the eastern coast of New Zealand, such a definition results in high tides that exceed such a MHWS level much more frequently than would be pragmatic for defining the boundary of the CMA.
- *MHWPS*: This upper-level MHWS is related to the higher perigean-spring tides that occur in clusters for a few months, peaking approximately every 7 months when a Full or New Moon coincide closely with the Moon's perigee (king tides). Around New Zealand, such a tide height is exceeded by between 3% and 12% of high tides.
- *MHWS-10* and *MHWS-12*: These definitions are based on an appropriate percentile of the high tides that would exceed a MHWS level. So, 10% of high tides exceed MHWS-10 and 12% of high tides exceed MHWS-12.
- *Practical application of natural indicators*: A range of natural indicators can be used to provide an qualitative assessment of MHWS, including toe of the dune, toe of the cliff, edge of vegetation, highest line of driftwood, tide marks on fence posts and, for estuaries, the seaward edge of glasswort (*Salicornia australis*) or other salt marsh plants.[2]

Both Land Information New Zealand and the Environment Court have emphasised that there is no single definitive method that can be used to establish a natural boundary such as MHWS; the method used will have to depend on the particular issue under consideration and natural characteristics of the location.

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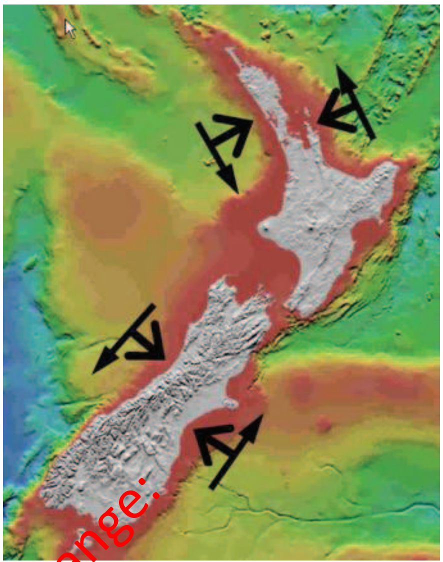
1 Bell RG. 2007. Use of exceedence curves for defining MHWS and future sea-level rise. *In: Coast and Ports 2007: Proceedings of the 17th Australasian Conference on Coastal and Ocean Engineering*. Melbourne, 17–20 July 2007.

2 Baker RF, Watkins M. 1991. Guidance notes for the determination of mean high water mark for land title surveys. Report published by the Professional Development Committee of the NZ Institute of Surveyors. 12 p. + Appendices. www.surveyors.org.nz/Documents/ MeanHighWaterMark-LandTitleSurveys(1).PDF (23 April 2008).

18 Factsheet 7: Storm surge

Storm surges are temporary increases in ocean and estuary water levels associated with storm conditions that last a few hours to a few days. Storm surge is produced by a combination of two processes:

- low barometric pressure allows sea level in a region (100 km^2 or more) to rise above the pre-storm sea level. This is known as the 'inverted-barometer' effect and results in approximately a 1-cm rise in sea level for every 1-hPa drop in barometric pressure below the mean annual barometric pressure. In central and northern New Zealand, mean annual barometric pressure is about 1014 hPa; in southern New Zealand it is about 1012–1013 hPa
- strong persistent winds blowing either onshore or alongshore, with the coast on the left, cause water to 'pile up' against the coast.

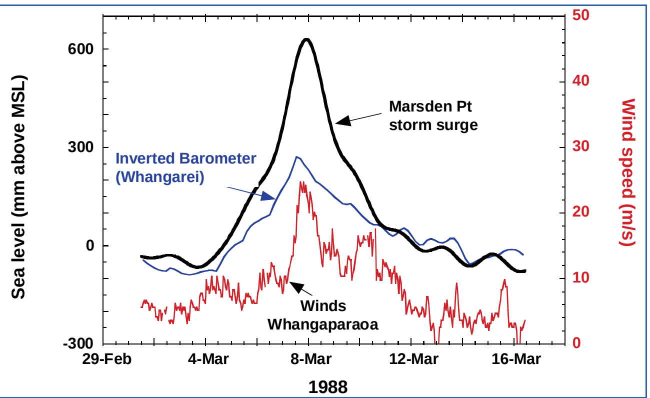


Alongshore and onshore wind directions around New Zealand that contribute to storm surge at the coast

The mix of both the wind and inverted barometer effects can vary widely, depending on the track of the low-pressure system and the clockwise rotation of the winds around the pressure system. However, generally, the inverted barometer effect contributes at least 50% or more to the storm surge height.

Storm surge height rarely gets larger than 1 m on open coasts around New Zealand but it may be higher in certain estuaries and harbours. Hence, the coinciding of storm surge with high tide, and the spring-neap or perigean tidal cycle, is the dominant factor in determining whether a high storm surge will result in inundation problems.

Cyclone Bola, one of the most damaging cyclones to hit New Zealand in recent years, tracked southwards over New Zealand in early March 1988. At Marsden Point, the storm surge measured over 600 mm (black line). At the peak of the storm surge, approximately 50% was due to the inverted barometer effect (blue line) with the remainder due to the influence of the strong winds (red line).



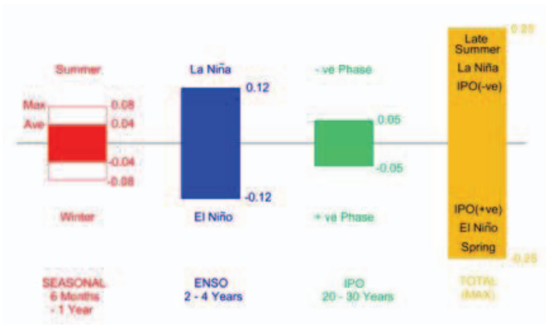
Storm surge monitoring

www.niwascience.co.nz/services/free/sealevels. Monitored sea level and storm surge data for the last 5 days at sea level monitoring sites co-ordinated by NIWA.

www.mulgor.co.nz/. Storm surge data for the last 5 days at Port Taranaki and Marsden Point.

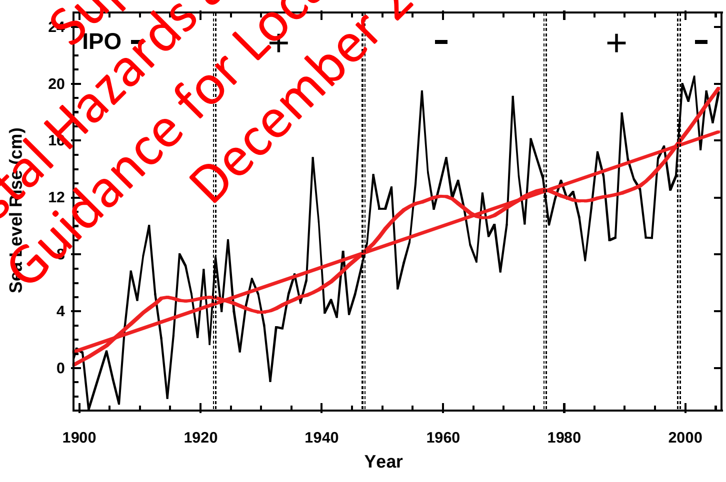
19 Factsheet 8: Long-term sea-level fluctuations

Longer-term fluctuations (lasting at least a month) in the mean level of the sea are important components when assessing inundation and erosion hazards. These fluctuations are typically related to:



Long-term fluctuations could alter the mean level of the sea by up to ±0.25 m when all longer-period sea-level cycles of at least 6 months are included. However, such a combination would occur infrequently and last for only a short period of time (ie, mean annual sea level would not fluctuate by as much).

- the annual heating and cooling cycle caused by the influence of the sun on the ocean. Mean sea levels tend to be higher in late summer and autumn and, over a year, can fluctuate around ± 0.04 m on average, but up to ± 0.08 m in some years
- interannual 2–4 year El Niño-Southern Oscillation (ENSO) cycles. Mean level of the sea is depressed during El Niño phases, and is higher during La Niña phases, with fluctuations of up to ± 0.12 m on both east and west coasts of the upper North Island. An analysis of the magnitude of fluctuations further south is currently underway
- interdecadal 20–30 year Interdecadal Pacific Oscillation (IPO) cycles. The rate of sea-level rise tends to be higher during negative phases of IPO and tends to flatten out during the positive phases of IPO. The IPO facilitates sea-level fluctuations of up to ± 0.05 m. The IPO has been in a negative phase since about 1999.



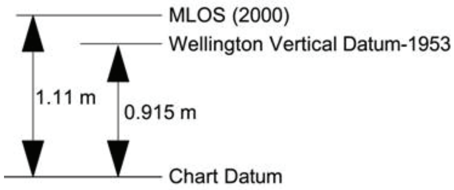
Variations in mean annual sea level (black line) from the Port of Auckland sea-level gauge. The line suggests that long-term fluctuations since 1899 have resulted in a variation in mean annual sea level of about 0.17 m relative to the linear trend in sea-level rise (straight red line).

The influence of IPO can also be seen in the Port of Auckland data, with higher sea levels generally occurring during negative phases (smoothed red line showing the 20-year moving average).

20 Factsheet 9: Datums – Mean Sea Level and Chart Datum

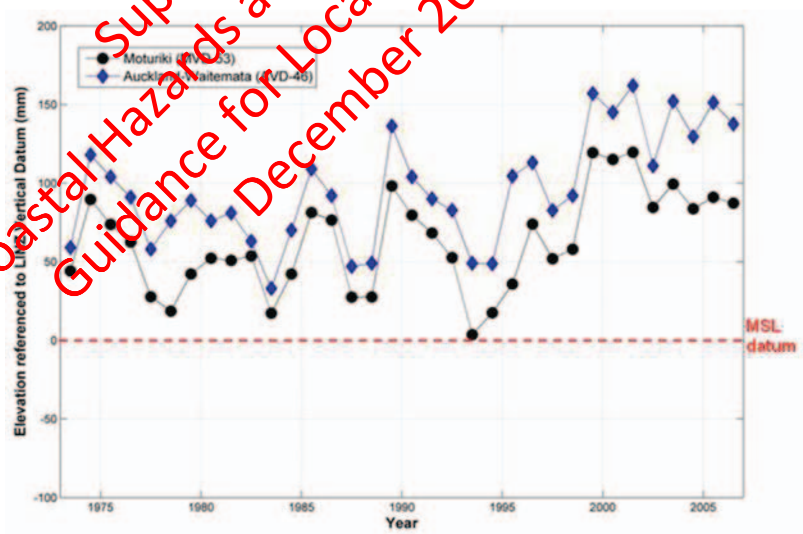
Several different vertical datums that are used for navigational purposes and on land for surveying and engineering purposes. Two are most common:

- *Chart datum* is used for navigation and for hydrographic charts. It typically refers to a level below which tides do not fall (often defined by the lowest astronomical tide). Standard port tide gauges are usually set to read zero at chart datum.
- *Mean Sea Level* (MSL) is a land-based vertical survey datum. The regional vertical or MSL datums were based on sea level data collected over several years (mostly the 1910s to 1940s, but sometimes later, depending on the region). For example, the local vertical datum in Auckland is defined as 'Auckland Vertical Datum-1946', which means that its definition in 1946 was based on the mean level of the sea over a period of time prior to that year (1909 to 1923).



Relationship between chart datum, MSL (Wellington Vertical Datum-1953) and MLOS in the year 2000 for Wellington. The difference between MSL and MLOS is due to the effects of long-term fluctuations and sea-level rise over the period between 1953 and 2000.

Caution: MSL is not to be confused with *Mean Level of the Sea*: MLOS is the average actual level of the sea measured over a defined period of time (eg, 1 year or several years). MLOS also includes sea-level rise. Hence it is MLOS, not MSL that equals the present level of the sea.



Plot of annual mean level of the sea (MLOS) comparing the sea level above the relevant LINZ vertical datum at Auckland (AVD-46) and Mt Maunganui (Moturiki MVD-1953) from 1972 to 2006. Zero on the vertical axis is the MSL datum. Present-day MLOS is higher than the MSL datum owing to the effects of sea-level rise over the last 50–80 years since the measurements used to define MSL datum. MLOS relative to MSL datum is also higher at Auckland than at Mt. Maunganui because MSL was defined independently and approximately seven years earlier at Auckland. Note that although sea levels can be physically higher between locations (especially east versus west coasts), the difference is mostly due to the datums being established at different times.

Tide marks for cadastral and engineering design purposes

www.linz.govt.nz/core/surveysystem/geodeticinfo/datums-projections/verticaldatums/tidalinfo/index.html

LINZ provides tide marks at standard ports for navigational purposes and for engineering and surveying. Marks for the latter are based on tide predictions for the next 19 years and should be used for all relevant surveying and engineering work, whereas the nautical tide marks are based on predictions for the coming year only.

21 Factsheet 10: Waves

Waves around New Zealand's open coast derive from two sources:

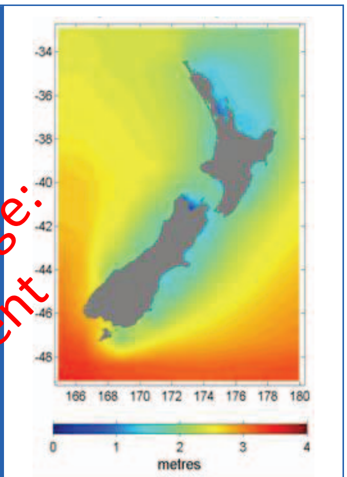
- locally generated waves caused by local winds
- distantly generated (swell) waves formed within the wider Pacific Ocean or Southern Ocean.

Waves tend to be defined by their *significant wave height* (H_s), which is the average height of the highest 33% of waves over a certain period; the *wave period* (T_m), which is the average time between successive waves; and the wave direction.

Offshore wave conditions around New Zealand can be subdivided into four major zones in terms of open-coast wave exposure:

- *south-facing coasts, (Fiordland to Catlins, South Island):* an extremely high-energy wave zone (mean H_s = 3–4 m; T_m = 10–12 s; SW–W). Waves are typically steep, indicating a zone of active wave generation, but also contain a sizable swell component from the Southern Ocean
- *western New Zealand coasts*: a high-energy wave zone (mean H_s = 2–3 m; T_m = 6–8 s; SW–W). The waves are steep and respond to the regular passage of weather systems across the Tasman Sea
- *eastern New Zealand, up to East Cape*: a moderate to high-energy wave zone (mean H_s = 1.5–3 m; T_m = 6–9 s; S). Sheltered from prevailing westerly winds by the New Zealand landmass but exposed to southerly winds and swell. Wave steepness is variable, indicating a mixed swell and local sea

  northeastern North Island (East Cape to North Cape): a low–energy, lee shore (mean H_s = 1–2 m; T_m = 5–7 s, N–E). Wave steepness is variable. Highest waves occur during ex-tropical cyclones, or as swell that is generated by Pacific cyclones well out to the northeast of the North Island.

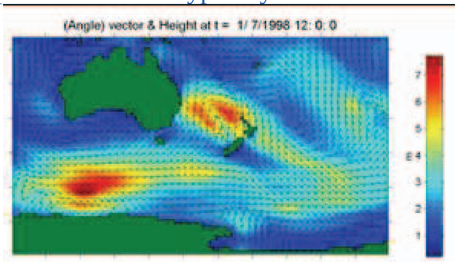


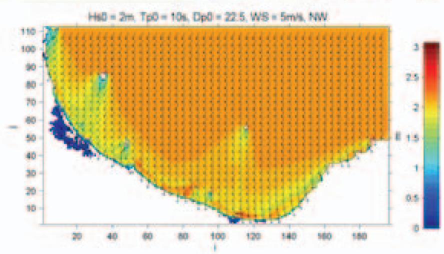
20-year average of the significant wave height (H_s) around New Zealand, based on a deep-water wave model. Note: results are only approximate in coastal areas.

In estuaries and harbours, waves are mostly generated by local winds and their height is limited by the wind fetch and the depth of water. Fetch is the distance downwind of continuous open water, with long fetches allowing the wind to build up larger waves. Wind waves in estuaries and harbours can still cause erosion and inundation hazards, particularly during very high tides or storm tides.

Very little monitoring of wave conditions has been carried out around New Zealand. Consequently, to assess wave climate and derive probabilities of extreme wave conditions, use is made of computer models to *hindcast* wave conditions from past wind conditions over a sufficient period of time (decades). Two types of model are typically used:

- deepwater wave models that simulate oceanic wave conditions over a large part of the Southern and Southwest Pacific oceans (right, upper figure) based on global wind fields
- nearshore wave models that simulate the changes in deepwater wave conditions as the waves approach the shore brought about by wave refraction, diffraction and shoaling. These models cover a small regional area and are driven by deepwater wave conditions on the offshore boundary and local winds over the region being modelled (eg, right, lower figure for the Bay of Plenty).

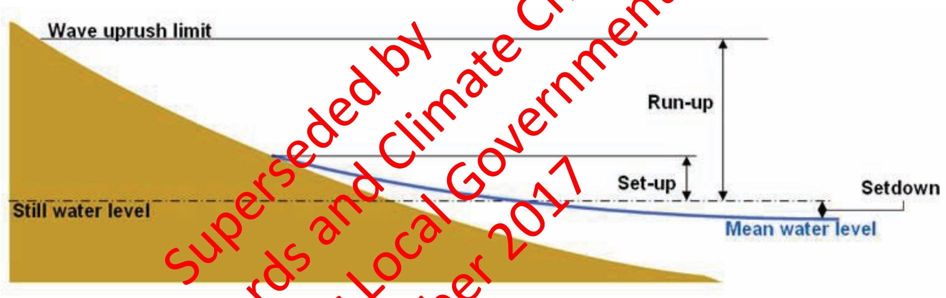




22 Factsheet 11: Wave set-up, run-up and overtopping

Waves contribute to coastal inundation hazards by three consecutive processes:

- wave set-up – after incoming waves break, the average level of the water inside the surf zone to the beach is set up higher than the sea level offshore from the breaker zone
- wave run-up – the extra height that broken waves reach as they run up the beach and adjacent coastal barrier (natural or artificial), until the wave energy is finally expended by friction and gravity
- overtopping – the spill-over of waves as they reach the crest of the coastal barrier or defence structure, resulting in flooding of the land and properties behind the barrier. Depending on the overtopping flow and character of the barrier, the barrier may breach, increasing the potential for further inundation. Wave spray or splash over a coastal defence structure can be hazardous for transport networks, but inundation volumes are relatively small.



Wave set-up and run-up.

Wave set-up is influenced by the offshore wave height and wave period, together with the nearshore seabed slope. These factors may be similar over large stretches of coast in the district, which is why wave set-up is sometimes included in the storm-tide level.

Wave run-up and overtopping at any coastal locality is usually quite site-specific, depending on factors such as beach slope, roughness of the beach (sand, gravel or large rocks), wave height, exposure to ocean swell, how close inshore waves can penetrate before breaking, and the characteristics of the land above the beach (eg, dunes, seawall, low cliffs).

Waves also play a major role in causing coastal erosion, by:

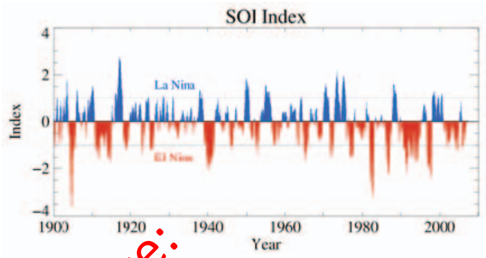
- the run-up of high-energy storm waves resulting in erosion of the dune or cliff toe
- large quantities of sediment being de-stabilised and moved back and forth between the beach and nearshore bars. Gentle swell and more quiescent waves following a storm usually assist in 're-stocking' a beach by slowly combing sediment back onto the beach, helping the beach to recover. Sequencing of moderate to severe storms that generate high wave activity is also an important factor in the susceptibility of a beach or cliff to severe coastal erosion
- variations in the rate of longshore movement of sediment (the movement is due to waves approaching the coast at an angle to the shoreline). Erosion can occur in this situation, especially if the drift is predominantly in one direction when any structure or natural feature traps sediment behind it, 'starving' the down-drift coast.

23 Factsheet 12: ENSO and IPO

Natural fluctuations in New Zealand's climate are influenced by two key natural cycles, operating over timescales of years, the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO). Both these natural phenomena operate over the entire Pacific Ocean and beyond, and cause fluctuations in the prevailing Trade Winds and in the strength of the subtropical high-pressure belt. El Niño events occur irregularly, about 3–7 years apart, and there can be large variability in the intensity of individual events. They typically become established in April or May and persist for about a year thereafter.

During El Niño conditions New Zealand experiences:

- more westerly winds
- slightly high wave conditions off the southwest coast of the South Island
- depressed sea levels
- lower likelihood of ex-tropical cyclones affecting New Zealand.



ENSO is measured in terms of the east–west pressure difference, the Southern Oscillation Index (SOI), which is a scaled form of the difference in mean sea-level pressure between Tahiti and Darwin. The plot above shows monthly SOI values for the last 20 years. El Niños occur when the SOI is persistently lower than –1 (and La Niña when the SOI is persistently greater than +1), ie, above or below the shaded grey area.

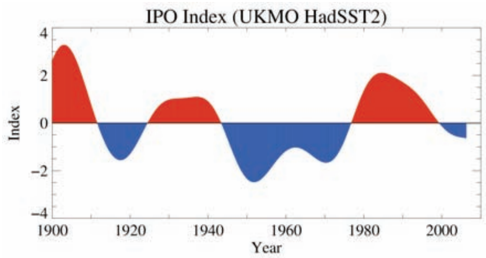
During La Niña conditions New Zealand experiences:

- more northeasterly winds
- slightly higher wave conditions off the northeast coast of the North Island
- higher sea levels
- higher likelihood of ex-tropical cyclones affecting New Zealand.

The IPO is a long-lived Pacific-wide natural fluctuation that causes relatively abrupt 'shifts' in circulation patterns within the Pacific Ocean that can last for two to three decades. It is strongest in the northern Pacific but affects New Zealand's climate. There are two phases of IPO, a negative phase and a positive phase. Three phases have been identified since the 1920s: a positive phase (1922–44), a negative phase (1946–77), and another positive phase (1978 to possibly 1998).

Positive IPO phases are characterised by:

- an increased tendency for El Niño events
- a decreased rate of sea-level rise
- increased westerly winds and anticyclones in the north Tasman
- a tendency for beaches on the northeast coastline of the North Island to accrete



IPO is defined by an index based on sea-surface temperatures (SST). The IPO changes phase every 20–30 years.

- possibly less frequent and smaller storm surge events
- drier conditions in the north and east.

Negative phases of IPO are characterised by:

- an increased tendency for La Niña events
- an increased rate of sea-level rise
- weaker westerlies, more easterlies and northeasterlies over northern New Zealand
- a tendency for beaches on the northeast coastline of the North Island to erode
- possibly more frequent and larger storm surge events.