COASTAL ADAPTATION DECISION SUPPORT PATHWAYS PROJECT

Climate change decision support framework and software for coastal Councils

August 2012

Prepared by:
LGA South Australia
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Front cover images:
Top right – Cliff face, Onkaparinga (photo: Adam Gray), Bottom Left – Sea Rise inundation maps for Yorke Peninsula community (Guy 2011); Bottom Right - foreshore at Thompsons Beach, Mallala (Photo: Adam Gray).

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EXECUTIVE SUMMARY

This Coastal Adaptation Decision Support Pathways project aims to assess and quantify the likely impacts to Councils from coastal inundation and erosion as a result of climate change on existing assets, and identify decision pathways for a range of adaptation options. The deliverables from the project are detailed in this report: a review of the likely climate changes and climate change impacts for the Australian coastal zone; a review of the identified policy options for addressing coastal climate change impacts both in Australia and overseas (Appendix 1 and 2); and an easy to use decision map to guide decision makers through the steps associated with determining the likely costs and liabilities associated with climate change impacts on existing coastal assets. The accompanying Excel ® financial simulation model was designed to be a generic pilot financial model for evaluating the costs associated with identified policy and investment options in the coastal zone.

As a reference for Councils and coastal managers, the report provides a succinct review of observed and expected climate changes for Australia (Chapter 3) and the likely impacts for the coastal zone as well as the tools and information currently available to quantify these impacts (Chapter 4).

Chapter 5 provides a summary of the detailed literature reviews of coastal climate change risk and adaptation policy both internationally at a federal level (Appendix 1) and here in Australia at federal and state jurisdictional levels (Appendix 2). The review both identifies the range of policy options that have been developed with respect to existing public and private property infrastructure threatened by sea level rise or erosion and examines how governments are determining who is responsible for adaptation to coastal threats.

Chapter 6 details the Decision Map developed. The tool provides a robust framework that steps the user through a detailed but straightforward process for collating and analysing the necessary data and information required to undertake a financial analysis for a range of options to adapt to coastal inundation or erosion. The accompanying Excel ® Financial Simulation Model described in Chapter 7 is linked to the Decision Map and allows user to enter data specific to their site and outputs the likely costs of implementing a range of options over the coming century including hard and soft coastal defences, retreat, accommodation, delay or doing nothing and paying the cost of damages. Options can be implemented incrementally over time, inflexibly at the start of the time period or in response to inundation or erosion events or projections.

Trials of the Decision Map and Financial Simulation Model were undertaken for two case study Councils in South Australia - City of Onkaparinga and the District Council of Mallala. Chapter 8 details the process of collating the necessary data as per the Decision Map and the outputs from the Financial Model for each location. Findings are obviously specific to the case study Councils tested but do suggest that the tools are rigorous in their approach and nationally applicable.

The project outputs provide useful tools and processes for assessing the impacts of coastal climate change on existing infrastructure and the development of adaptation strategies based on the science and impacts of climate change, the options to defend, retreat, accommodate or delay, and the possible financial and legal ramifications. Development and testing of both the Decision Map and the Financial Simulation Model with the two case study Councils and their real life situations and data constraints proved a valuable process and allowed for iterative improvements on both deliverables. Further work to expand the range of Councils that use and provide feedback on the tools developed is recommended. A range of materials to communicate to users the outputs from this research will also be developed including a two page fact sheet (Appendix 4), a poster (Appendix 5), an interactive Decision Map in PowerPoint ® and series of information papers based on this report.

1 BACKGROUND TO THE PROJECT

1.1 The Context of Climate Change

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) (IPCC 2007) states that the warming of the climate system is now “unequivocal”, and is “evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level”. It is also likely that despite current mitigation policies and related sustainable developments, the level of greenhouse gases in the atmosphere will continue to increase over the next few decades. As a result, the global climate system will very likely see changes that exceed those observed over the past century.

Over the coming decades, southern Australia is likely to experience continued increases in temperature, changes in rainfall (likely reductions in winter and spring), an increase in daily rainfall intensity but longer dry spells between rainfall events, an increase in evapotranspiration (the combined effects of evaporation and plant transpiration), an increase in very hot days and nights, a reduction in the frequency of frosts and snowfall events, a likely increase in the number of extreme fire danger days, sea level rise and increased frequency and height of storm surge events.

1.2 Local Government and Coastal Climate Change Threats

Australia’s 560 Local Government authorities are responsible for the management of assets (buildings, roads, footpaths, coastal retaining walls, beaches, etc) valued at approximately $212 billion and provide approvals under planning regulations for the construction of many more assets on private land. The “First Pass National Assessment” of the risks to Australia’s coasts from climate change identified a range of impacts over the coming decades and highlighted the fact that residential buildings valued at approximately $63 billion and significant but unquantified numbers and values of other assets, are at risk of inundation from a 1.1 metre sea level rise. Other coastal assets include commercial and recreational land and associated infrastructure such as roads, footpaths, stormwater networks, jetties and marinas – most of which are owned or under the planning jurisdiction of Local Government.

Coastal land and long-lived assets constructed close to the shore are likely to be affected by long-term shifts in climate such as sea level rise as well as changes to the return periods and intensity of extreme events that affect the coastal zone including storm surges, coastal erosion events and storm water inundation. How these changes in the climate will impact on existing Council assets and their management is not well understood.

A statewide climate change risk assessment for South Australian Councils undertaken by the Local Government Association of South Australia Mutual Liability Scheme (LGA MLS) (2009) identified risks associated with planning and development in the coastal zone as a high priority that requires adaptation response. Currently, however there is no consistent policy response across Australia, nor decision support tools or financial evaluation software to guide Councils on the most cost effective options for the management of these existing assets. Existing financial and asset management tools do not effectively incorporate climate change scenarios into municipal planning processes.

The challenge for Local Governments Australia wide is to adapt to the likely impacts of climate change in a timely and feasible way. Councils indicate that they are overwhelmed by the amount of information made available to them on climate change but do not know how to translate this information into planning processes to improve their capacity to adapt the built environment and mitigate the legal risks associated with planning policy. The research undertaken in this project has developed a framework methodology that guides Councils through the steps necessary to quantify the likely climate changes, impacts, legal implications and costs likely to be associated with the coastal climate change impacts of inundation and erosion and included the development of a financial model that calculates the cost of different policy approaches that deal with threatened coastlines. The model uses a real options analysis approach to provide comparative financial analysis for a suite of policy options relevant to Council planning guidelines in the coastal zone including actions associated with retreat, defend, accommodate and delay.

1.3 Project Aims

The project aims were to improve the decision-making capacity of Australian coastal planners and assets managers. The key outcomes of the research are the delivery of a pilot decision support framework (a decision map) and decision tool (the financial model). The pilot decision support framework has been designed to support informed policy development and decision making by coastal planners and asset managers at all levels of Government as a means of addressing coastal climate change risk and impacts. The financial model enables the user to undertake an evaluation of cost effective policy options based on real data.

Key outputs of this project, that provide nationally transferable lessons, include:

- a review of the likely climate change impacts on the Australian coastal zone;
- a review of the identified policy options for addressing the impacts both in Australia and overseas;
- the development of an easy to use decision map in printed and electronic format to guide decision makers through the steps associated with determining the likely costs and liabilities associated with climate change impacts on existing coastal assets; and
- the development of a generic pilot financial model to evaluate the costs associated with identified policy and investment options in the coastal zone.

Project outputs will optimise decision pathways through improved evaluation of the likely costs, benefits, financial liability and identified timing of actions for a suite of possible policy actions.
The decision map and financial model have been developed in close collaboration with two South Australian coastal Councils – City of Onkaparinga and the District Council of Mallala and tested by Council staff.

2 PROJECT METHODOLOGY

The project involved five main stages:

2.1 Quantification of Likely Climate Threats to the Coastal Zone

Building on work already undertaken for the Australian coastal zone (e.g. DCC 2009, Garnaut 2011) and links with other CADP and NCCARF projects, an updated review of the likely climate changes Australia wide was undertaken and key climate related threats to the coastal zone identified. Sources of data for quantifying climate change impacts were identified for the modelling team.

2.2 Review of Existing Policy Options

A review of international and Australian policy documents was undertaken to identify the range of policy options that have been developed to address climate change related threats to existing coastal property assets and infrastructure. Relevant policies include those relating to the options of maintenance, modification or abandonment of coastal property or infrastructure, private property litigation, urban planning guidelines, private property buy-back and compensation by Government. A spectrum of policies exist that range from acceptance that Government has a moral and financial duty to protect and/or compensate affected property owners through to abrogation of any financial liability for private property but acceptance that policy frameworks to deal with government owned assets are needed. Each of these policy options has been examined and the legal and financial implications explored.

2.3 Financial Modelling

A pilot financial model in Exel ® uses a real options approach to evaluate the costs associated with the various policy and investment options. The model is generic in structure and allows users to input variables that describe the likely climate change impacts as a result of sea level rise and coastal erosion and then select defend, retreat, accommodate or delayed action options for the financial analysis. The costs for each option is tested against three strategies – act now, sense and respond or predict and respond. Outputs quantify the most cost effective option for action and are considered in the context of the decision map.

2.4 Decision Support Tool

A decision pathways map has been constructed to guide the user along various pathways that lead to a policy decision. The information required for each step in the map was described and sources identified. The map incorporates the necessary inputs for the financial model. The map is provided in a user-friendly format that would be suitable for users with knowledge of the various engineering options included in the model including coastal engineers working for Local Government, risk assessors, consultants and infrastructure managers.

2.5 Policy Modelling

In consultation with project collaborators, the two case study Councils that face different threats from climate change and a range of threatened assets were selected for detailed evaluation and testing of the pilot decision support tool and financial model developed – the District Council of Mallala and City of Onkaparinga, both in South Australia. Using data from the selected case study sites a range of options were simulated using the financial model developed. Outputs including the likely costs, benefits, liability and optimal timing of action have been tested and results are provided. Recommendations for future research, capacity for improvement and extension of the model and barriers to further progress are presented in this report.

3 CLIMATE CHANGE AND THE AUSTRALIAN COAST

3.1 The Climate of Australia

On geological time scales, changes to the climate on earth and the resultant changes to sea level has both inundated currently terrestrial areas (the Nullarbor Plain, the Gulf of Carpentaria, the Latrobe Valley and the whole of the lower Murray River basin) or alternatively exposed large tracks of land that are now beneath the sea (dry land bridges between the mainland and both Tasmania in the south and Papua New Guinea in the north). During the last interglacial (120,000 to 13,000) years ago, sea levels were between four and six metres higher than the present. During the last glacial maximum (20,000 years ago) when large amounts of water were locked up in ice, the sea levels were approximately 120-140 metres lower than today. Over the past 6,000 to 7,000 years sea levels have been relatively stable and fluctuated only two to four metres at most. During this period of relative global climatic stability, the existing coastal ecosystems and human settlements around the world became established.

Compared to other regions of the world, the Australian region today experiences a stable geological coastline because of a lack of glacial rebound or seismic activity. However, it does have a variable climate that drives the pattern of droughts and flooding rains that typifies the continent. This climate variability is the result of a number of global and regional climate systems that change on the time-scale of months through decades and longer and include latitudinal migrations of the sub-tropical ridge or high pressure belt, the Indian Ocean Dipole, the El Niño / La Niña Southern Oscillation in the Pacific and the Southern Annular Mode that affects the south of the continent. These systems vary as a result of changes in atmospheric and oceanic temperatures across large areas of the globe and include those changes associated with global warming. Depending on the state of each of these climate systems, Australia may experience an above or below average frequency or intensity of various weather conditions – drought, heatwave, bushfire, flood, cold events, ex-tropical storms, cyclones etc. In addition, changes to the oceanic dimension of these systems affect the off and in shore ocean temperature, sea level and circulating currents that surround the continent.

Those climate and oceanic variables that affect the coastal zone in particular include terrestrial runoff from rainfall, the frequency and intensity of storms and associated surges, ocean in-shore water temperature, the concentration of salts and acids in the water and sea level. The scope of this project considers sea level rise (as a result of increased global temperatures) and coastal erosion (as a result of wind intensity and increased sea level rise) as the two most significant climate variables to affect change on the coastline.

Recent and projected changes in sea level rise and coastal erosion as a response to global warming for the Australian region are reviewed here in summary. The following chapter examines the recorded and expected impacts of these changes on the coastal zone, and in particular, for the two case study sites considered in this project – the City of Onkaparinga and District Council of Mallala.

3.2 Climate Change and the Coastal Zone – Recorded Trends

In 2007, the IPCC AR4 was released and provided a review of the latest findings on climate change science and impacts. Since then there has been further research on many of the key aspects of climate change that are crucial to our understanding of global warming. These aspects include recent trends, uncertainties, sea level rise, abrupt changes associated with climate thresholds, and feedbacks – natural processes that can increase or decrease the effects of global warming. Those changes of relevance to the coastal zone and the climate impacts addressed in this report are summarised in this chapter.

3.2.1 Temperature

Between 1850 and 2007 the global surface temperature had increased by approximately 0.76°C (IPCC 2007). The eight warmest years have all occurred since 1998, and the 14 warmest years have all occurred since 1990 (Scientific Committee on Antarctic Research 2009). The World Meteorological Organisation stated last year that “2010 ranked as the warmest year on record, together with 1998 and 2005” and that the decade ending 2010 was the warmest on record. Temperatures over land have increased at roughly twice the rate of ocean surface temperatures (because of an overturning of surface water with deeper levels and evaporative cooling) and the poles have warmed faster than the equatorial regions (Figure 1).

The global mean temperature has been above average every year for the past 25 years (1986-2010) and 2010 was ranked by the World Meteorological Organisation as the equal warmest year on record along with 2005 and 1998 (Bureau of Meteorology 2011). Both maximum and minimum temperatures have increased equally. The rate of warming over the last 50 years is almost double that for the last 100 years (IPCC 2007). Short-term changes (less than 10 years) in the temperature trend show natural variation and do not change the long-term observed global warming trend. There is now no credible explanation (e.g. solar activity, volcanos) for the level of observed warming except as a result of the released greenhouse gases from human activity (Allison et al. 2009).

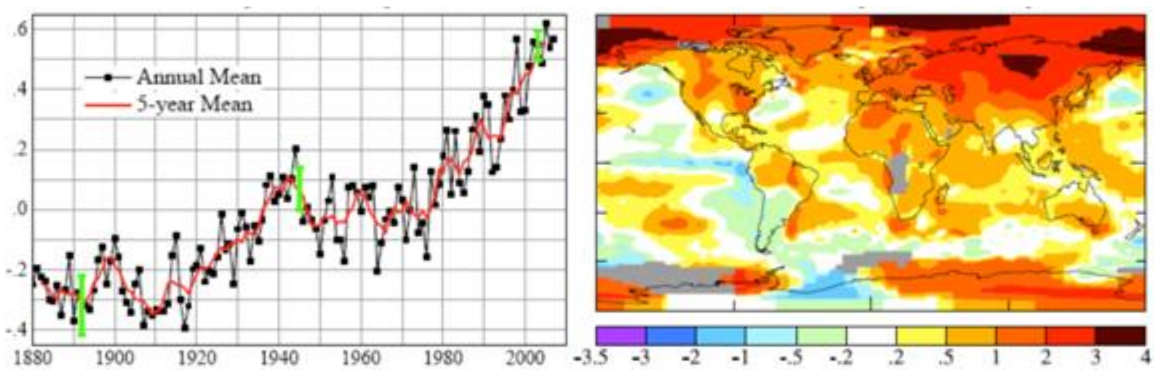


Figure 1: Global temperature change (°C) 1880 – 2007 (left) and the 2007 surface temperature difference (°C) relative to the average 1951 – 1980 temperature (right) (Source: Scientific Committee on Antarctic Research 2009).

Aerosols such as dust, smoke and haze both absorb and reflect heat in the atmosphere. The net effect of aerosols to date has been to cool the earth and so they have masked some of the warming from the greenhouse gases (Garnaut 2011 a and b). It is likely that over the coming years the concentration of aerosols in the atmosphere will be decreased by measures to reduce the associated health risks and so the cooling effect will be reduced. In addition, an increase in clouds and water vapour in a warmer world (because of increased evaporation and humidity) are now known to create “positive feedbacks” that will warm the planet further.

The global oceans have warmed approximately 0.7°C since 1870, mostly in the top 1000 metres (Roemmich and Gilson 2011) and sea levels have risen as a result of thermal expansion. Analysis by many groups around the world now confirms that the oceans have so FAR absorbed more than 90% of the increased heat associated with global warming (Church 2011) (Figure 2).

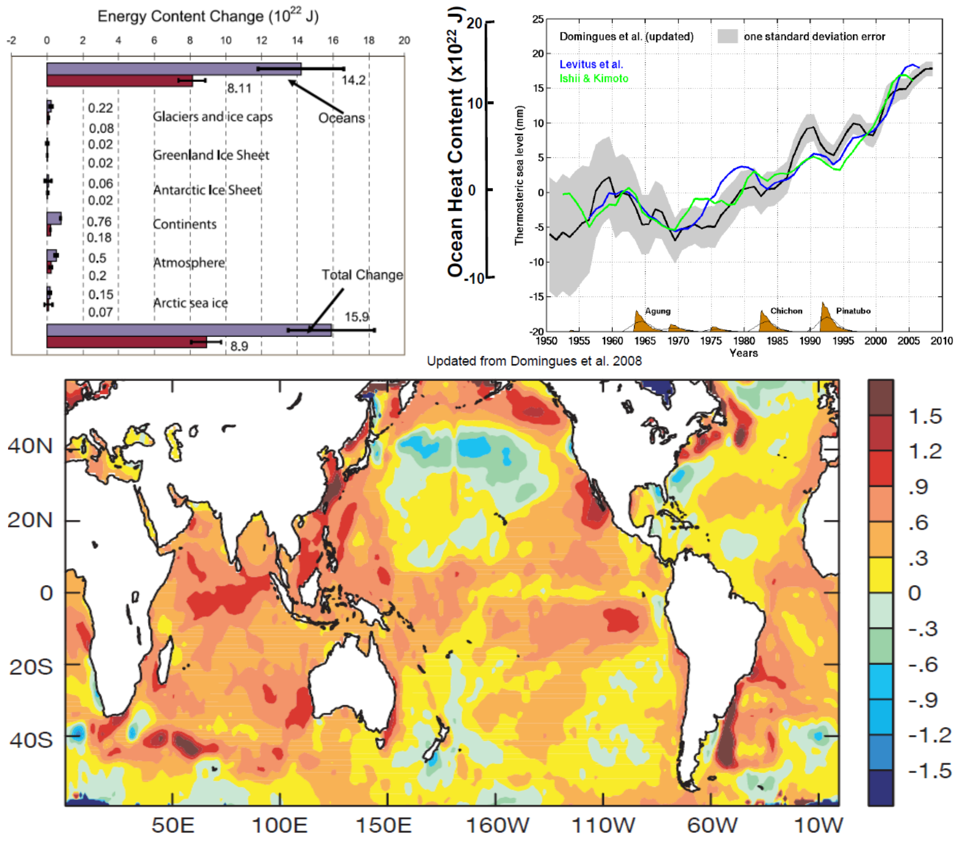


Figure 2: (Top left) Measured change in the energy content for each of the earth's surfaces between 1961-1990 and (Top right) ocean heat content for the years 1950-2010 (Source: Church 2011); (Bottom) pattern of linear warming (^{o}C/50 years) between 1950-2006 (Source: CSIRO and BoM 2007).

From 1950 to 2007, the average terrestrial temperature of Australia increased by 0.9^{o}C. The frequency of hot nights had increased and cold nights decreased (CSIRO and BoM 2007) (Figure 3). The decade spanning 2001 - 2010 was the warmest on record (Bureau of Meteorology 2011).

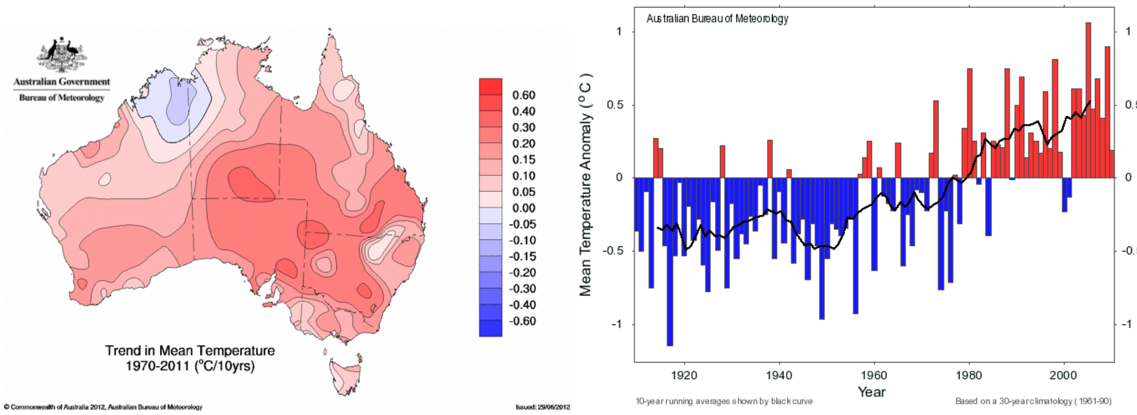


Figure 3: Increase in Australian mean (average) temperature (left) in ^{o}C/decade and (right) the long term annual mean temperature change from 1961-1990 average (Source: Bureau of Meteorology 2011).

The sea surface temperature of each of the three oceans surrounding Australia has also increased (Figure 4). Most of the warmer water appears to be pooling around the south / south-east of the continent because of the way the ocean currents flow (Karl Braganza, National

Climate Centre *pers. comm*. June 2010). During 2010, the sea surface temperatures in the Australian region were 0.54°C above the 1961 to 1990 average - the highest on record (Bureau of Meteorology 2011).

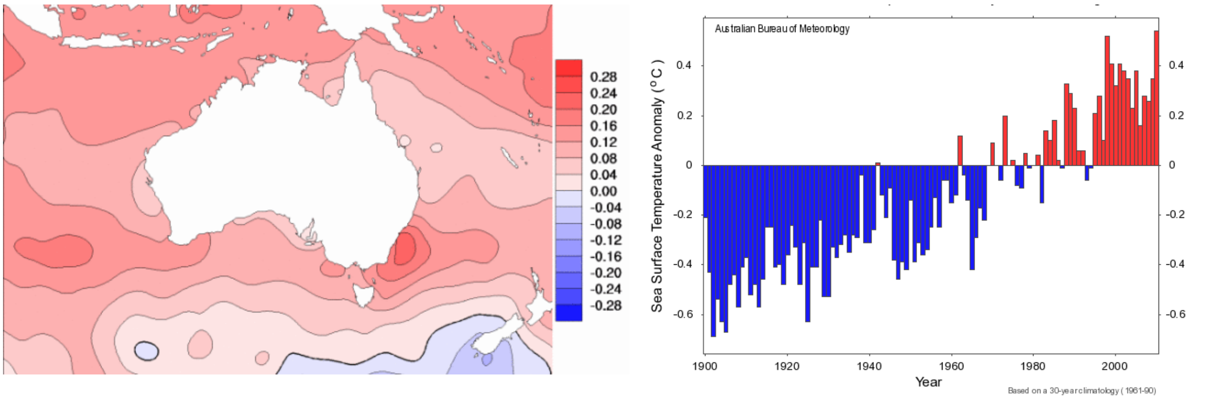


Figure 4: Measured annual change in the sea surface temperature in the Australian region 1970-2010 displayed in (left) map of change in °C/10 years; and (right) annual average temperature anomaly compared to the 1960-1990 baseline (Source: National Tidal Centre 2011).

3.2.2 Ice melt

As expected in a warming world, ice reserves in all forms have been melting. In the Arctic the temperature increased by 1.5°C between 2000 - 2006 and, as a result, the Greenland ice sheet has thinned dramatically, especially along the coastline. The rate of Greenland glacier flow has also accelerated. The ice-melt area across Greenland increased by 30% between 1979 and 2008 (Allison et al. 2009). Arctic sea ice extent in January 2011 was the lowest since satellite records began in 1979 and has shown a "precipitous" decline in over the last two years, particularly during summer (Garnaut 2011) (Figure 5). The measurements suggest that this is one aspect of the climate system that is responding to warming in a non-linear way and at a rate much faster than predicted in the IPCC AR4 (Allison et al. 2009). At the other end of the planet, measurements of the Antarctic ice sheet also show a net loss and acceleration of ice loss since 2003 (Figure 5). The largest losses have occurred in the West Antarctic Basin and there have now been seven ice shelf collapses in the past 20 years (Allison et al. 2009).

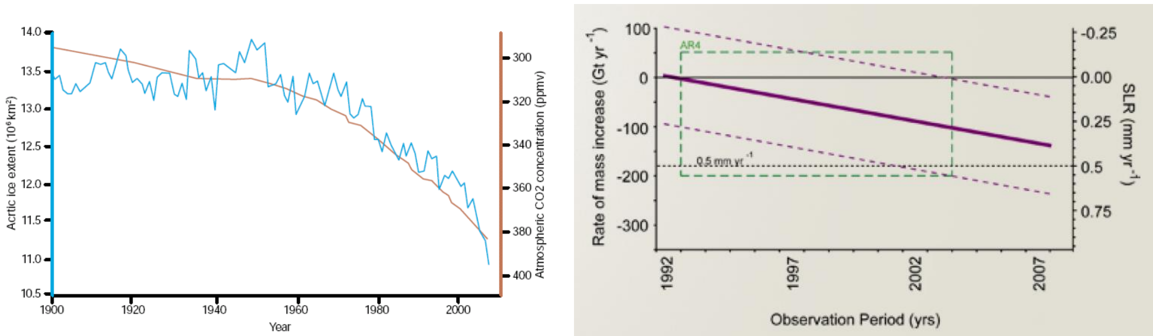


Figure 5: (Left) Arctic sea ice extent and CO2 concentration 1900 – 2007. Note the CO2 scale is inverted (Source: Steffen 2009); and (Right) the net Antarctic ice sheet mass balance since 1992 (Source: Antarctic Climate and Ecosystems Cooperative Research Centre 2008). The solid purple line approximates the mid-point of a number of different estimates made for different periods and using different techniques, and the dashed purple lines show the approximate error range in the estimates. The green box represents the estimate made by IPCC AR4 for the period 1993–2003, and its uncertainties.

Glacier status is well regarded as a high-confidence climate indicator for early changes in the Earth's energy budget. The World Glacier Monitoring Service measures annual changes in over 30 reference glaciers worldwide. The recorded ice mass balance for the period 2008 - 2009 was equal to that lost on average for the years 2000 - 2009 and 165% greater than for that lost in the

1980s and 1990s (World Glacier Monitoring Service 2011). There has been no positive mean mass ice balance at any time in the past two decades (Figure 6).

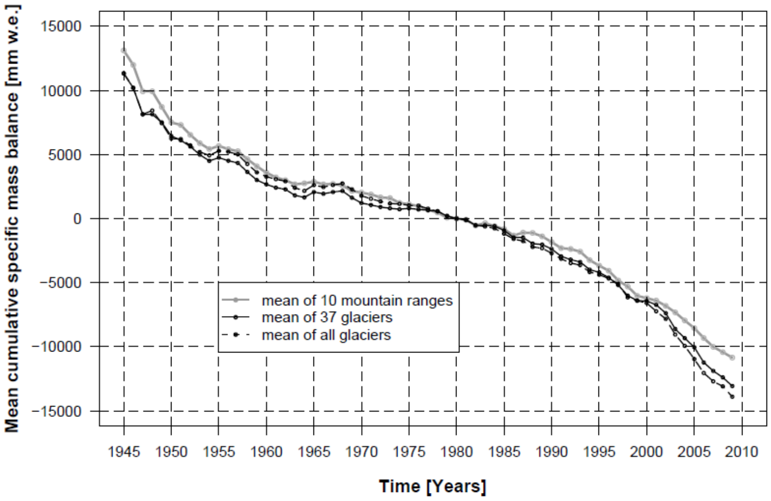


Figure 6: Mean specific mass balance (top) and mean cumulative specific mass balance (down) since 1945/46 (Source: World Glacier Monitoring Service 2011).

3.2.3 Sea level rise

The combination of thermal expansion from a warming ocean and the melting ice sheets and glaciers has resulted in an increase in global sea levels since 1970 of about 1.7 mm per year, or 17 cm in the past century as recorded by tidal gauges and satellite altimeter data (Church 2011). The most rapid increase (3.1 mm/year) has occurred since 1993 and was the result of thermal expansion (about 45%) and land-based ice contributions (about 40%) (Steffen 2006; Church 2011). Sea level rise is currently tracking at or near the upper limit of the IPCC worst-case projections (Figure 7).

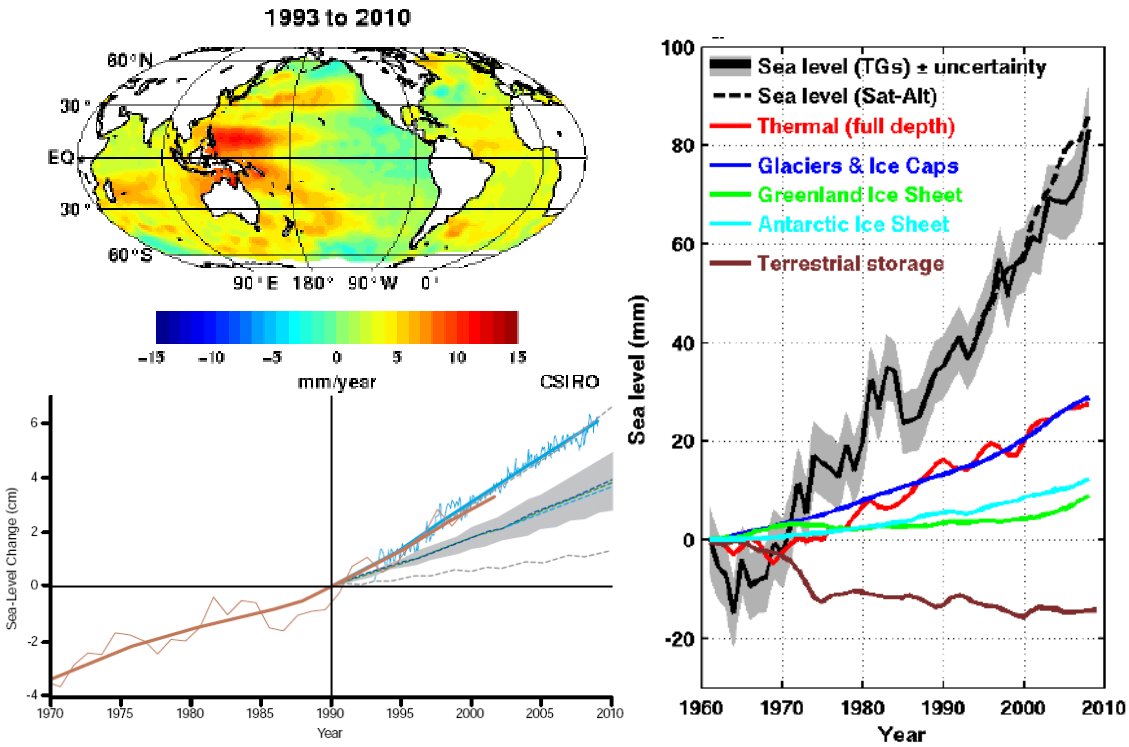


Figure 7: (Top left) Global sea level rise for the years 1993 to 2010 (Source: CSIRO Marine and Atmospheric Research 2012); (Bottom left) Global sea level changes in centimetres from 1970 – 2008. The envelope of IPCC scenario projections are shown for comparison (Source: Steffen 2009); (Right) contributing sources to sea level rise between 1960 and 2010 (Source: White et al in prep).

As with most large coastlines, the measured increases in sea level along the Australian coast vary by location as a result of tectonic movement, climatic influences including the El Niño Southern Oscillation (ENSO), and anthropogenic changes such as subsidence due to the draining of wetlands and other modifications. On average, sea levels around Australia rose by about 17 cm over the period 1920 - 2000 or 1.2 mm per year, a change close to that recorded globally (CSIRO and BoM 2007). Data from the early 1990s to June 2011 show increases in sea level around Australia of between 2.9 - 9.0 mm/year (Figure 8). All measurements are adjusted for tectonic movement, seasonal climate variations and anthropogenic land changes (National Tidal Centre 2011).

In South Australia, there has been a sea level rise at the Thevenard tidal gauge (considered the most accurate and with the longest record) of 4.3 mm/year between 1992 and 2010 (National Tidal Centre 2011).

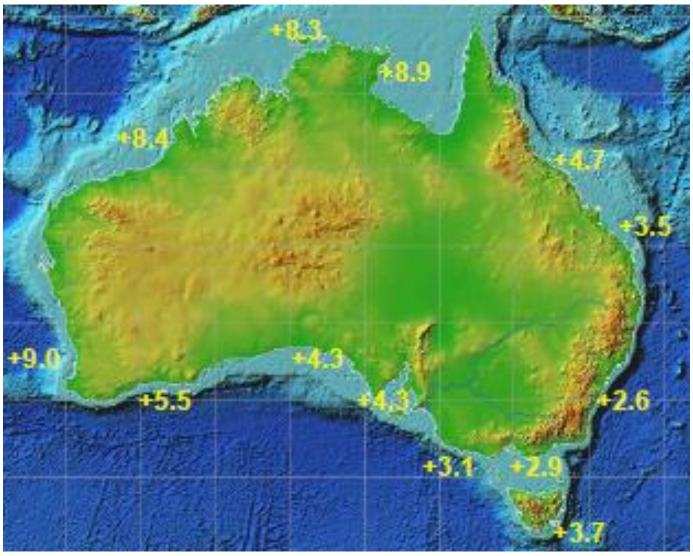


Figure 8: (Left) Australian sea level changes (mm/year) from the early 1990s when the National Tidal Centre Sea Level Rise project started to end June 2011. The measurements take into account changes due to tectonic subsidence and uplift and seasonal climatic influences (Source: National Tidal Centre 2011).

3.2.4 Extreme coastal events

Wind and wave actions associated with extreme weather events including cyclones, intense low pressure systems and storms induce the greatest short-term erosive and flood impacts on the coastal strip. In conjunction with eustatic sea level rise and tidal components, wind driven waves cause coastal erosion and resultant infrastructure and ecosystem damage (Figure 9). The frequency, intensity and distribution of wind, wave and storm surge events associated with cyclones in the north of the continent, thunderstorms nationally and intense lows (‘cut-off’ low pressure systems) in the south are described in this section.

As can be seen from Figure 9, an extreme coastal erosion or flood event is a function of a number of different factors: global and regional sea levels, regional land movements, regional sea level variability and tidal ranges constitute the oceanic component of the event, while storm surge and storm tide events are isolated events that are driven by the climatic variables of wind and atmospheric low pressure. In this section of the study we examined each of the climatic and weather related events that generate high winds and low atmospheric pressure of a significant intensity to cause a storm surge or storm tide event.

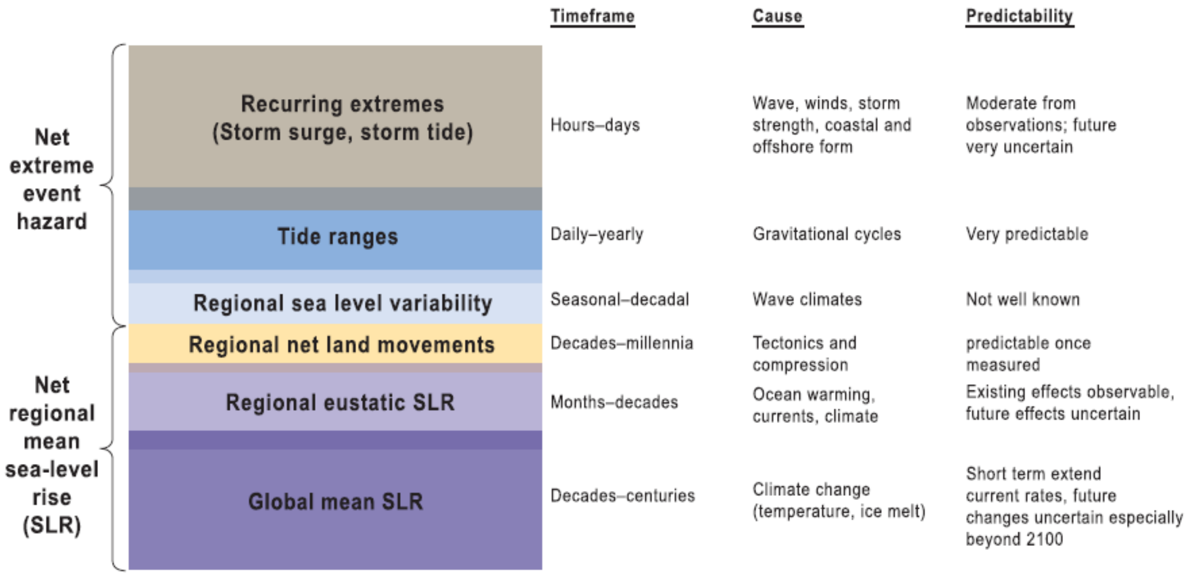


Figure 9: The main contributors to extreme event hazard and regional mean sea level rise (Source: Department of Climate Change and Energy Efficiency 2009).

Tropical cyclones

Apart from a tornado, tropical cyclones are unmatched in their capacity to produce severe wind speeds and intense low pressure and can grow to a size of over 1000 km in diameter. Tropical cyclones form and intensify over warm oceans to have a sustained gale force wind (63 km/hr) or greater surrounding the central eye and gusts in excess of 90 km/hr) that persist for at least six hours. Severe tropical cyclones sustain winds at the centre in excess of 118 km/hr and gusts above 165 km/hr. In the Australian region and average of 13 cyclones form over the warmer months of each year, about half of which become severe. Cyclone frequency and intensity are predominantly affected by changes in ocean temperatures driven by seasonal and large scale climate cycles and are highly variable at all time-scales.

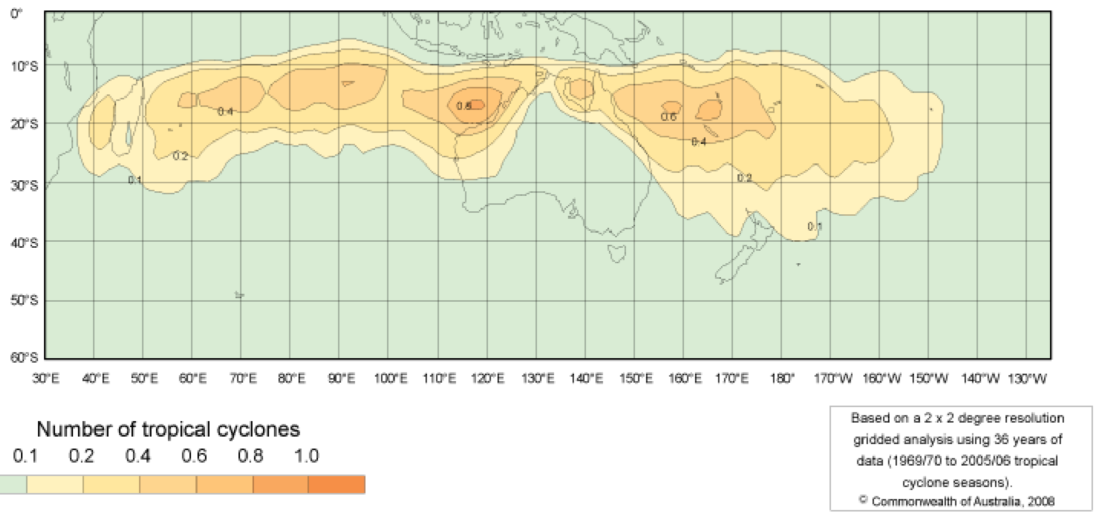


Figure 10: Average annual number of tropical cyclones in the Australian region each year (Source: BOM 2011).

Over the past thirty years, the incidence of tropical cyclones to the Australian region has not significantly changed (Kuleshov et al. 2010). However, there has been a likely decrease in the annual number of cyclones affecting the east coast of the continent, probably due to an increase in the number of El Niño events over the same period and associated cooler ocean temperatures and easterly prevailing winds in the Coral Sea. Analysis of cyclone data for Western Australia indicates that as with the east coast, patterns of cyclone intensity are likely affected by ENSO and that there has been an increase in the cyclones intensity and the proportion of cyclones in the highest intensity categories between 1968/69 and 200/01 for all data sets tested. However, these trends reduce from the mid-1980s and so earlier estimates may be the result of instrument bias (Harper et al. 2008).

Mid-latitude lows

Intense ex-tropical low pressure systems, also described as ‘cut-off lows’ in the south of the continent and ‘east coast lows’ on the east coast are significant drivers of wind and wave driven coastal erosion in the southern latitudes.

‘Cut-off lows’ are low pressure systems that have become cut off from the prevailing westerly winds while still exhibiting a closed circulation at the surface and the 500 hPa level. The lows usually develop within a deep trough, are often accompanied by a Southern Ocean cold front and usually bring moderate to heavy rainfall and occasional severe weather (Qi et al. 1999). Qi *et. al.* examined 14 years of data (1983-1996) and identified 1483 cut-off low days between the latitudes of 25-40^{o}S. Most events occurred in the winter months and all months between May and October exhibited an above average number of cut-off low days (Figure 11).

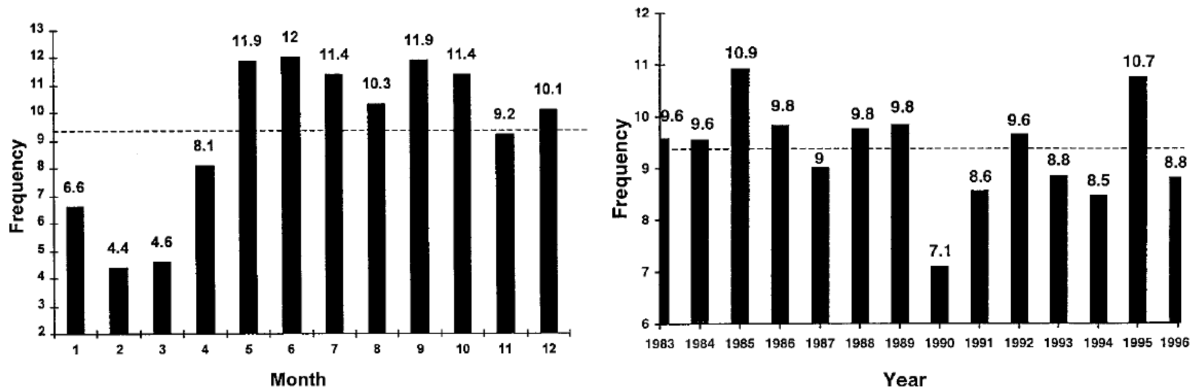


Figure 11: (Left) Average monthly number of cut-off low pressure system days, and (Right) the monthly mean number of cut-off low days for each across southern Australia (1983-1996) (Source: Qi et al. 1999).

‘East coast lows’ are a particular type of cut-off low and are defined by the BOM as an ‘’intense low-pressure systems which occur on average several times each year off the eastern coast of Australia, in particular southern Queensland, NSW and eastern Victoria. Although they can occur at any time of the year, they are more common during autumn and winter with a maximum frequency in June. A study by Hopkins and Holland (1997) identified a doubling in the number of east coast lows over the 30 years to 1990, followed by a decline from 1990 to 2006. The number of east coast lows is closely related to patterns of ENSO and so exhibit strong interannular variability. Analysis of data on east coast lows between 1973 and 2004 showed no trends (BOM 2011).

Severe thunderstorms

Severe thunderstorms occur across the country, usually in the summer months or in association with cold fronts across the south during winter and spring. Thunderstorms are localised events that include hail with a diameter of two centimetres or more, wind gust of 90 km/hr or more, flash flooding, or any combination of the three (BOM 2011). Although severe thunderstorms usually affect an area less than that impacted by a cyclone or intense low, they are more common and result in more damage (as measured by cost) than cyclone, earthquake, flood or fire each year in Australia (BOM 2011).

The incidence of severe thunderstorms as measured by the average number of thunder days each year (considered by the BOM to be the most reliable measure of storm activity) is shown in Figure 12 as recorded by a network of 300 quality tested sites nationwide. The map highlights the higher frequency of storm activity across the north of the continent. Thunderstorms are less frequent in Victoria, Tasmania and southern areas of Western Australia and South Australia than they are in the north of the continent. An assessment of the data over the years available does not show any evidence of a ‘widespread temporal trend in thunderstorm activity’ (BOM 2011). However, there has been a poleward displacement of the jet streams and storm tracks. There has also been a 20% reduction in the strength of the sub-tropical jet over Australia and a reduction in the frequency of synoptic disturbances over south-west Western Australia (CSIRO and BOM 2007). General trends such as these are likely associated with global warming and would indicate that an expansion of the tropics, increased subsidence over southern Australia and a poleward migration of cold fronts and lows would bring conditions that are less conducive to thunderstorm development over Southern Australia in the future *(pers. comm. Darren Ray, Bureau of Meteorology, Adelaide, 16 April 2012).*

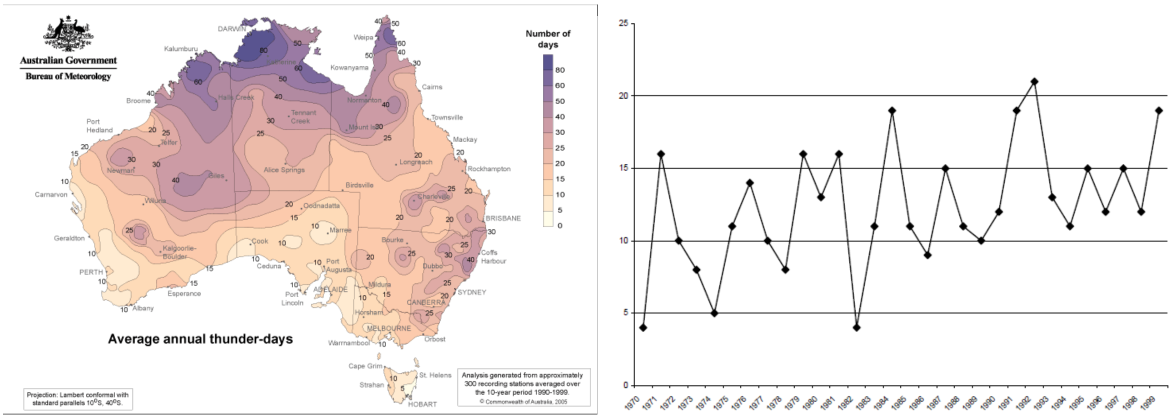


Figure 12: (Left) Average annual thunder day map of Australian based on station recorded from 1990 to 1999; (Right) Time series graph of the total number of thunder days for Adelaide (Source: Kuleshov et al. 2011).

Storm surge

A storm surge event is the result of oceanic conditions (sea level, currents and tides) and the added influence of waves driven by strong onshore winds and/or low atmospheric pressure during a cyclonic or storm event (Figure 13). Sea level rises by about 1 cm for every hectopascal fall in pressure while storm surge and wind wave setup and runup on top of a high tide can cause flooding for hundreds of kilometres along the coast in areas that would normally be above tidal influences and severe coastal erosion and damage to landforms and infrastructure.

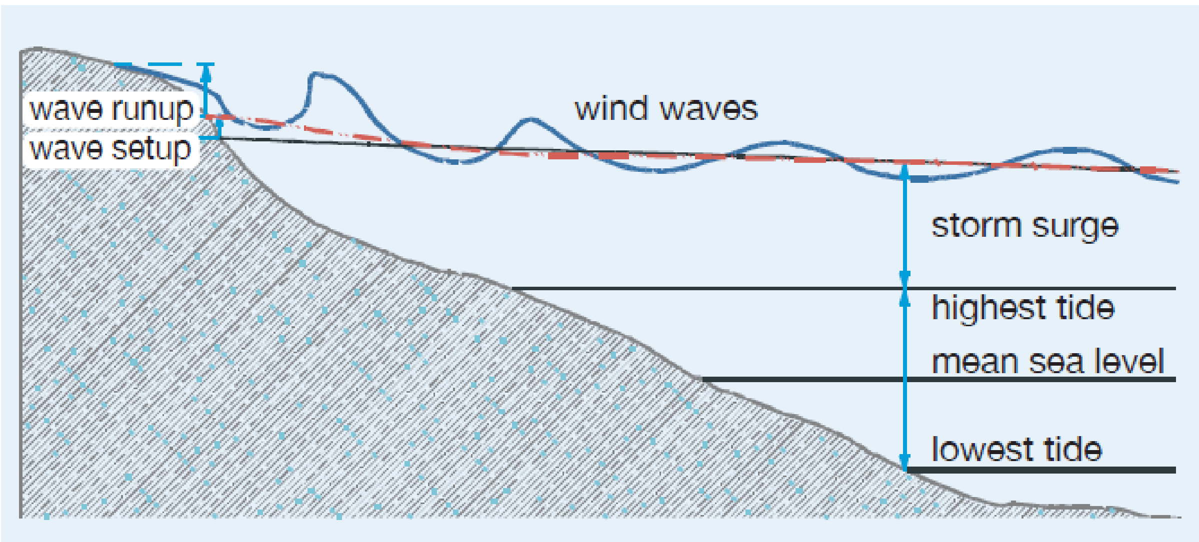


Figure 13: During an extreme storm event, storm surge and additional wave runup and setup all add to the height of the sea level and may result in flooding along the coast (Source: CSIRO and BoM 2007).

A review of the impacts of these events on a range of different substrates and locations across southern Australia is given in the following chapter.

3.3 Climate Change and the Coastal Zone – Future Projections

Regardless of efforts to reduce greenhouse gas emissions in the future, much of the climate change over the coming years will be the result of greenhouse gases already in the atmosphere – "committed warming" (IPCC 2001; Allen Consulting Group 2005). Conditions in the tropics will continue to become more humid with more frequent and intense storms and possibly cyclones, and the mid-latitudes (southern Australia) will become drier. Sea levels are expected to continue to rise as polar and continental ice sheets and glaciers melt and the warmer oceans expand (IPCC 2007).

3.3.1 Temperature

The AR4 predicted mean global temperature to increase by 1.1 to 6.4°C over the 1990 - 2100 period (IPCC 2007), although if greenhouse gas emissions continue at the high end of the scale the increase in global temperature may be as much as 7.0°C (Allison et al. 2009). Globally averaged sea surface temperatures are also expected to increase with a trend towards more 'El Niño like' conditions, although, changes to the frequency and intensity of these El Niño events is still unclear (IPCC 2007).

Projections for future temperature increases are based on a suite of scenarios of future greenhouse gas emissions. Average annual temperature in Australia is expected to increase by between 0.1°C and 2.0°C by the year 2030 and between 1.5°C and 5°C or more by the year 2070 as shown in Figure 14 (CSIRO and BoM 2007).

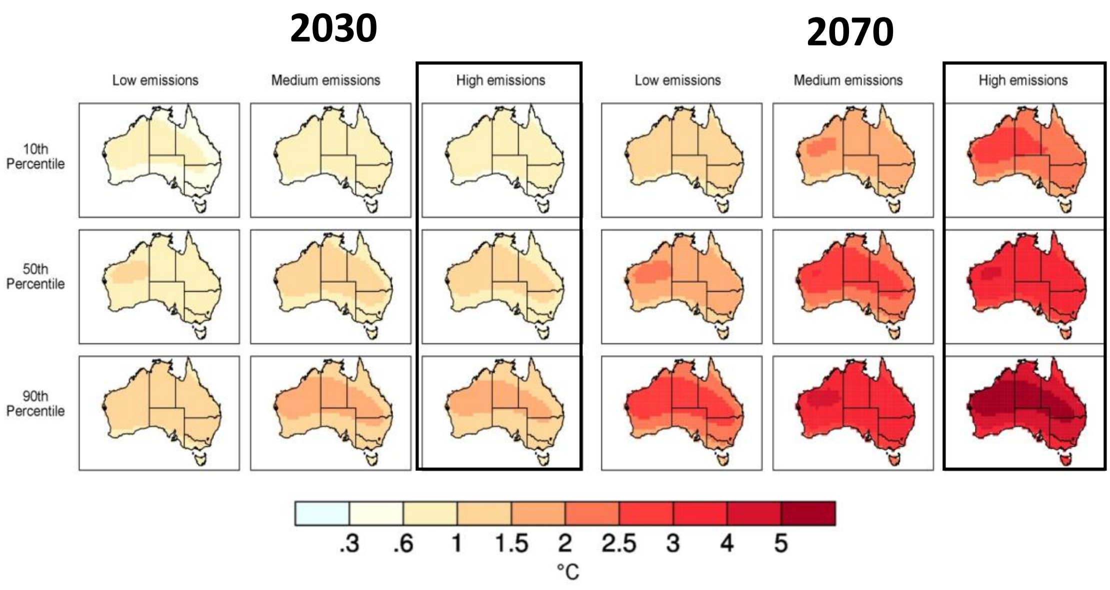


Figure 14: Expected range of changes to annual temperature (°C) for Australia as predicted by a suite of Global Climate Models under low medium and high greenhouse gas emissions scenarios for the year 2030 (left) and 2070 (right) (Source: Bureau of Meteorology 2009). The median expected change across all models is shown in the 50th percentile row. To date, greenhouse gas emissions have been "high".

An increase in average annual temperature of between 0.6°C and 2.0°C by 2030 and 1.0°C and 5°C by 2070 compared to 1990 levels is predicted for South Australia. Spatial patterns of warming are expected to be consistent with current observations - greater warming inland and less along the coastal strip.

Sea surface temperatures will rise more slowly than air temperatures as heat transfer to the oceans (and in particular the deep oceans) lags behind atmospheric warming. For this reason ocean temperatures and associated thermal expansion will continue for many centuries and perhaps millennia beyond air temperature stabilisation.

By 2030 most Australian waters are expected to have risen by 0.3°C to 0.6°C and waters off the southern Tasman Sea and north-west shelf of Western Australia by 0.6°C - 0.9°C. By the end of the century sea surface temperatures along the southern coastline may be as high as 2°C above 1990 levels depending on the emissions scenario chosen and even higher in northern and eastern waters (Figure 15) (CSIRO and BoM 2007).

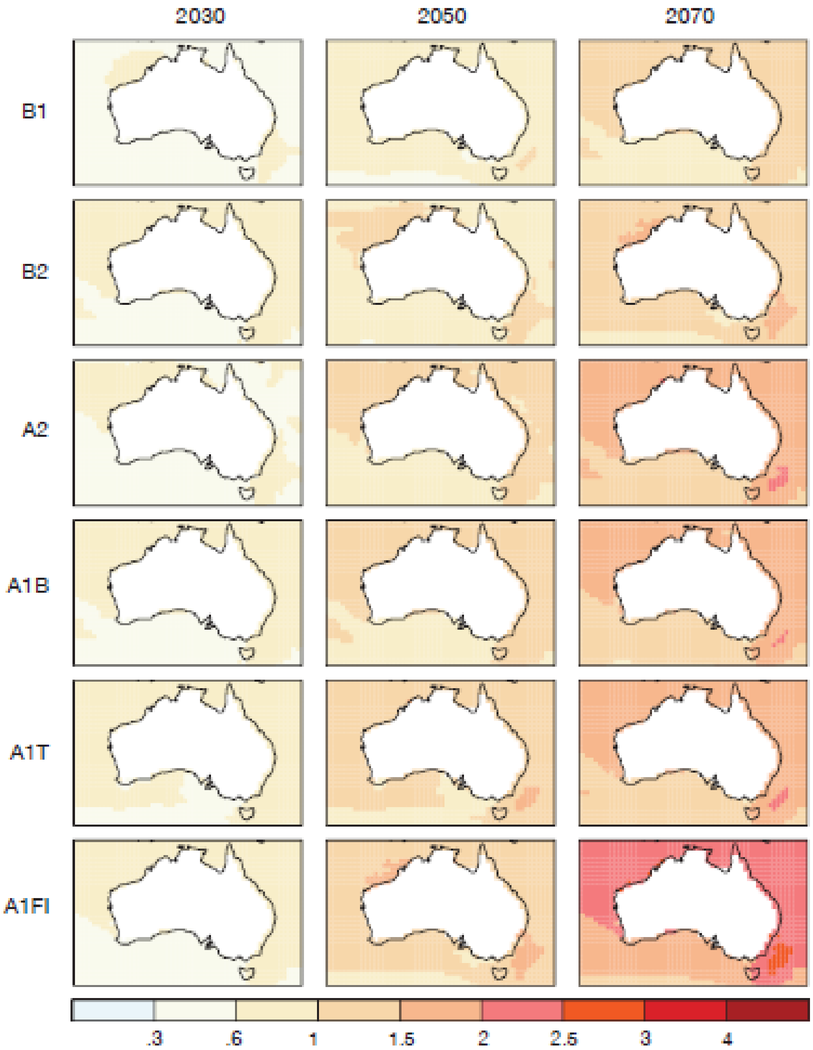


Figure 15: Expected level of sea surface temperature warming (°C) for Australia compared to the 1961-1990 baseline years for each of the SRES emissions scenarios (Source: CSIRO and BoM 2007).

3.3.2 Ice melt

Projections for future global ice melt in the IPCC AR4 were based on observed ice loss over the 1993 - 2003 period (IPCC 2007). A number of aspects of ice dynamics are not yet well represented in the current generation of models (Antarctic Climate and Ecosystems Cooperative Research Centre 2009):

- the response of floating ice shelves to climate change;
- the connection between floating ice shelves and flow in the ice sheets;
- the nature of rapid flow in ice streams and outlet glaciers; and
- the effect of water at the base of the ice sheet on ice flow.

It is important to note that the uncertainties that these limitations incur are one sided. Ice melt in a warming world will only continue to increase at rates equal to or greater than those seen already while greenhouse gas emission continue to rise. In addition, ice is likely to continue to melt for a number of centuries and perhaps millennia, after the atmospheric temperature stabilises due to heat transfer lags (Antarctic Climate and Ecosystems Cooperative Research Centre 2009).

3.3.3 Sea level rise

The AR4 projections for global sea level rise were between 0.20 and 0.59 metres by 2090 - 2099 across the range of climate scenarios (IPCC 2007). These estimates included thermal expansion from oceans and freshwater contributions as a result of ice melt from glaciers, Greenland and Antarctica, but did not include uncertainties pertaining to changes in ice sheet flow or climate-carbon cycle feedbacks (Table 1). The AR4 indicated that if the contribution to sea level rise from ice sheet flow were to increase linearly with the global temperature change (as opposed to remaining at the average 1993 - 2003 rate) then the upper range for sea level rise may be 0.1 metres to 0.2 metres higher than projected.

Table 1: Projected average surface air warming and sea level rise for the end of the 21st century.

	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Since the release of the AR4, sea level rise has increased at a rate higher than the worst case scenario predicted by the IPCC AR4, and has roughly tripled in response to the 0.8°C warming observed in the 20th century (Rahmstorf 2007). Recent research to quantify dynamic processes including ice sheet dynamics indicates that rapid melting of not only surface ice can result from contact with warming water as has been observed in Antarctica. Church *et. al*. (2011) added rapid ice melt to the IPCC AR4 estimates of sea level rise for the A1FI SRES scenario and calculated a rise of 0.8 metres (Figure 16 left). If the earth's glaciers alone were to melt, sea level rise has been calculated to increase by 0.6 metres (Radić and Hock 2010). The range of estimates for sea level rise to the end of the century now indicates levels between about 0.5 metres up to over 2 metres (Figure 16 right). As a result, it is now agreed that there is a "considerable body of evidence that points toward a sea level rise of 0.5 - 1.0 metre by 2100" and that "sea level rise… towards 1.5 metres cannot be ruled out" (Steffen 2009).

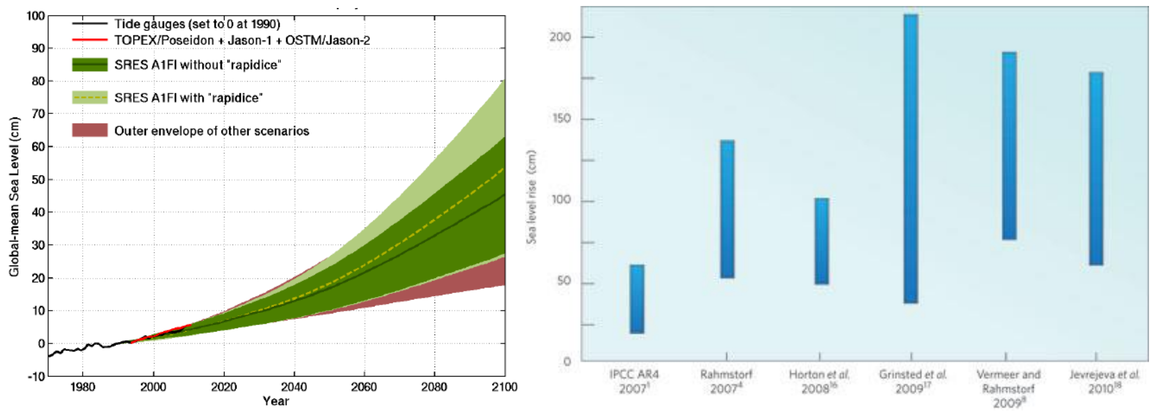


Figure 16: (Left) Modelled estimates of sea level rise as a result of all contributing sources to the year 2100 based on IPCC 2007 and Church and White 2011 (Source: Church 2011); Estimates of sea level rise since AR4 for the 21st century (Source: Rahmstorf 2010).

Beyond the end of the 21st century it has been estimated that if the West Antarctic Ice Sheet were to collapse (the currently grounded ice), sea levels could be expected to rise by between four and six metres (Oppenheimer 1998). Warming of between four and seven degrees Celsius at the end of the last ice age resulted in a sea level rise of 120 metres at rates often exceeding a metre per century (IPCC 2007). There is nothing in the data to suggest that similar rates would not be experienced in response to anthropogenic global warming should global temperatures rise as high (Pfeffer et al. 2008).

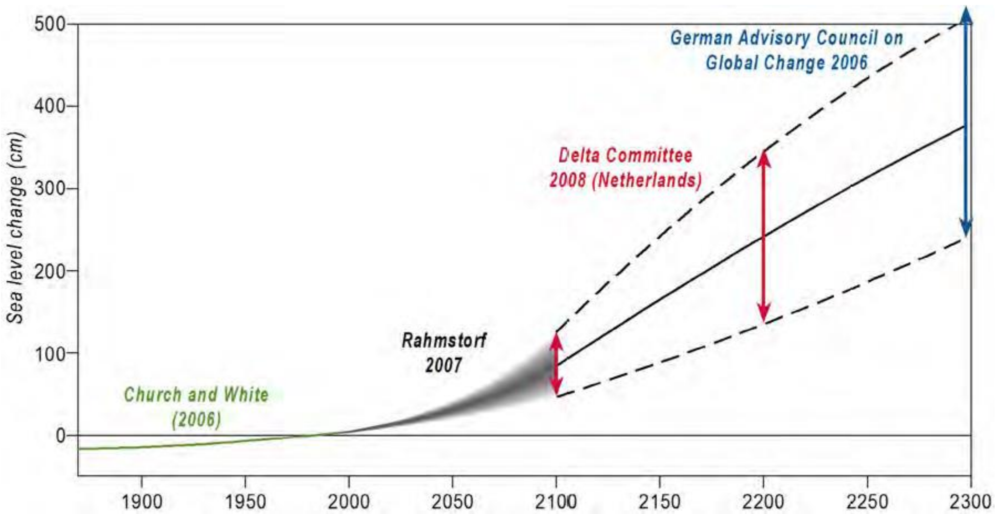


Figure 17: Estimates of sea level rise projections out to the year 2300 compared to the 1990 baseline (Source: Rahmstorf 2012).

Average sea level rise projections for Australia have been calculated by CSIRO for three scenarios for the years 2030, 2070 and 2100 (Table 2): Values for any particular location along the coast will vary from these shown because of local conditions.

> ***'Scenario 1 (B1)*** *considers sea-level rise in the context of a global agreement that brings about dramatic reductions in global emission. This scenario represents sea-level rise that is likely to be unavoidable.*
> ***Scenario 21 (A1FI)*** *represents the upper end of the IPCC AR4 'A1FI' projections and is in line with recent global emission and observations of sea-level rise.*
> ***Scenario 3 (High end)*** *considers the possible high-end risk identified in AR4 and includes some new evidence on icesheet dynamics published since 2006 and after AR4' (DCCEE 2009).*

Table 2: Projected sea level rise for Australia based on three scenarios (B1, A1FI, and high end) for the years 2030, 2070 and 2100 (Source: DCCEE 2009).

Year	Scenario 1 (B1)	Scenario 2 (A1FI)	Scenario 3 (High end)
2030	0.132	0.146	0.200
2070	0.333	0.471	0.700
2100	0.496	0.819	1.100

3.3.4 Extreme coastal events

Higher sea levels will result in an increase in the height of extreme coastal events that result in flooding and erosion regardless of changes to the drivers of those extreme events. Here we summarise the likely changes to each of the key drivers of high winds and low air pressure responsible for driving storm surge and coastal erosion and flooding events.

Tropical cyclones

Continued cyclone research and modelling has progressed our understanding of cyclone formation, frequency and intensity and how climate change is likely to affect these aspects. However, cyclones remain a difficult dimension of the climate system to predict due to their highly variable nature and small relative size. Limitations in climate change projections for cyclone behaviour are similar to those that face all future climate projections (uncertainties about climate forcing in response to increases in greenhouse gas emissions and limitations in model dynamics) but also because of the high resolution that is required for climate models to accurately calculate cyclone characteristics.

Most models used to predict cyclone activity indicate an increase in the proportion of severe cyclones (category three to five) but not necessarily an increase in the number of cyclones. Projections for changes to cyclone intensity estimate an increase in category three to five storms by 60% by 2030 and 140% by 2070 (Abbs et al. 2006) and by 2050 an increase of between 56% (Walsh et al. 2004 a) and 22% (Leslie et al. 2007). The study by Abbs et al (2006) using CSIRO simulations showed a significant decrease in the number of cyclones in the Australian region (particularly off the coast of Western Australia). However, other studies show no net change in the number of cyclones in the region.

The areas of cyclone genesis and tracks are expected expand poleward as the earth warms. By the year 2050, cyclone may be expected to form south of their current range by two degrees of latitude (200 km) (Leslie et. al. 2007) and decay up to 300 km further south by 2070 (Abbs et. al. 2006). Recent work indicates that for some scenarios cyclones are likely to affect areas as FAR south as Sydney on the east coast (Walsh 2011).

Mid-latitude lows

Downscaled models that predict the wind speeds of tropical cyclone winds also indicate that the wind intensity of mid-latitude storms may also increase. A strengthening and extension of the warm East Australian Current southwards has been observed since the 1970s, a change that and may intensify east coast lows and associated wave conditions as has happened when similar changes in the current have been observed in the past (Department of Climate Change and Energy Efficiency 2009). The frequency of stormy low pressure systems and strong wind events across southern Australia is expected to decrease by up to 20% in the winter months (McInnes et al. 2003) although the intensity of low pressure systems may be marginally higher. A combination of decreases in the frequency of deep trough patterns and an increase in the number of high pressure systems in the south-west Western Australian region suggest that the occurrence of winter low pressure systems will reduce in that area (CSIRO and BoM 2007).

Severe thunderstorms

A limited number of downscaled modelling exercises for winds in small-scale convective systems have suggested that warmer temperatures may make these systems in coastal regions more active, and result in micro-bursts of locally high winds and intense rainfall (DCCEE 2009). However, even downscaled models cannot capture thunderstorm activity and so it is not possible to model global warming impacts on thunderstorm activity. However, modelling of conditions conducive to thunderstorm activity indicates that conditions favourable to the formation of cool season tornadoes is likely to reduce by about 10-20% by the end of the 21st century (CSIRO and BoM 2007). The effect on summer tornadoes has not yet been analysed. Conditions conducive to hail formation were also modelled. For the southern Australian coastline projections indicated a general reduction in the frequency of hail events and severe thunderstorm activity in general (Figure 18) (CSIRO and BoM 2007).

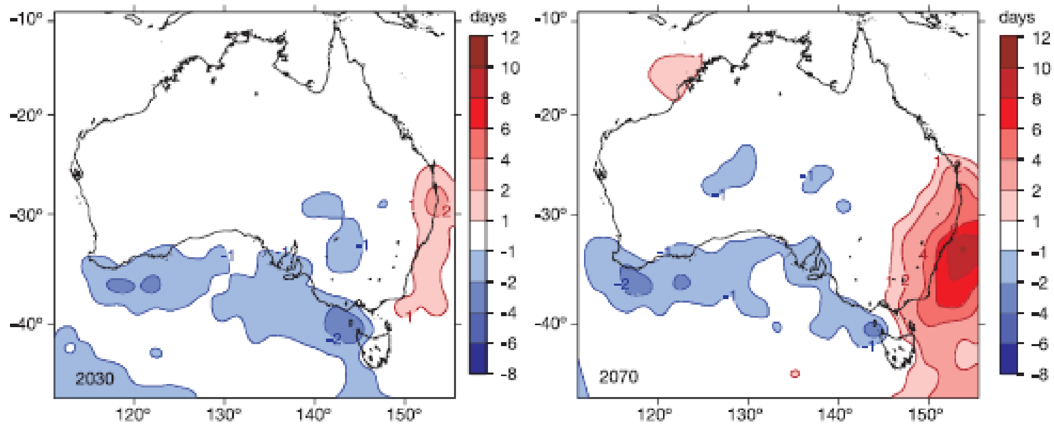


Figure 18: Projected changes in hail risk (hail-days per year) for 2030 and 2070 for the A2 scenario using the CSIRO Mark 3.5 model (Source: CSIRO and BoM 2007).

Storm surge

Detailed storm surge modelling has been undertaken for a number of discrete locations around the Australian coast including Cairns, the southern Victorian coast. McInnes et. al. (McInnes et al. 2003) identified an expected increase in the frequency of high wind events responsible for driving storm surge events in spring in across South Australia. However, it appears that changes in wind speed have a smaller effect on storm surge height than sea level rise. More recently, findings of the changes to storm tide events found that 'under future climate conditions it is found that a 1 in 100 year storm tide level estimated for the late 20th century would occur every 10 years or less under a 2030 high sea level rise scenario once every 4 years or less for a 2070 high sea level rise scenario' (McInnes et al. 2007). There has been a positive observed trend in the frequency and intensity of large wave events across the south of *t*he continent (DCCEE 2009).

4 THE COASTAL IMPACTS OF CLIMATE CHANGE

The Australian coastline is generally classified into four broad regional environments:

- the muddy north (highly tidal, cyclone influenced and muddy);
- limestone south and west (small tides, carbonate rocks, high wave and wind energy);
- eastern headlands and bays (small tides, quart sands, moderate wave energy, mainly bays); and
- the Barrier Reef (northern Queensland, including low-lying rocky mainland coasts and the Great Barrier Reef and its islands).

Each of the climatic changes described in the previous chapter will impact upon the 35,000 kilometres of coastline around Australia in different ways depending on the underlying substrate and geological characteristics of an area. Around Australia more than 85% of the population lives in coastal regions and so the impacts of sea level rise are likely to be significant (Garnaut 2011).

Sea level rise will result in the inundation of beaches, marshes, coastal wetlands and other low lying areas, salt water will infiltrate into groundwater, the concentration of salts in affected coastal soils will increase, exposed infrastructure will be damaged, and ecological systems disrupted. Coastal biota including mangroves, salt marsh / wetlands, samphire flats and estuarine ecosystems will migrate landward in response to rising sea levels.

Coastal erosion will, in most cases, increase as a result of sea level rise in combination with either seasonal changes in currents or wave climates, or as a result of extreme events including an changes to the frequency and intensity of storm or cyclonic wind and storm surge events. Beaches, dunes and cliffs will erode at speeds dependant on their composition, coastal foreshore will slump or slide, and exposed infrastructure will be damaged.

This chapter describes likely climate change impacts to the coastal zone in more detail and reviews work that has attempted to quantify both the existing and expected future scale of those impacts.

4.1 Sea Level Rise and Inundation

The risk that an inundation event will occur along a coastline is usually described in terms of the magnitude of the event and the frequency at which it has happened based on historical records. For example, a 1-in-100 year storm tide is the storm tide height that is expected to be exceeded on average once every 100 years. The height of the water will vary depending on location and is a function of average sea level, local currents, wave climate and the incidence and intensity of extreme events in the region. There are two common methods for quantifying inundation events: average recurrence interval flood curves and flood mapping.

4.1.1 Average Recurrence Interval Curves

Inundation or flood risk is defined as the likely return period for a range of tide flood heights at one location – a parameter usually quantified in an Average Recurrence Interval (ARI) curve. Usually an additional safety margin elevation is added to the 100 year ARI (the 1-in-100 year flood tide height) to determine safe areas for development. Sea level rise will increase the height of the 100 year ARI or cause the event to return more often. For locations where there are long records of sea level height, an increase in the height of the ARI curve can already be seen. For example, the change in the ARI heights in Fremantle are shown in Figure 19 and show a difference in sea level between the two curves of about 0.1 metres (DCCEE 2009).

It is important to note that the return period of an inundation event will not be linearly related to the increase in sea level rise. For example, an average sea level increase of 0.5 metres will result in a one in ten year event occurring every ten days. The change in event frequency may also be higher or lower depending on location, and the height of the event will be affected by changes in the wind speed or storm intensity as well as the increase in sea level rise. Figure 19 shows the changes to the average return interval curves for Stony Point under the high climate change scenarios for the years 2030, 2070 and each scenario.

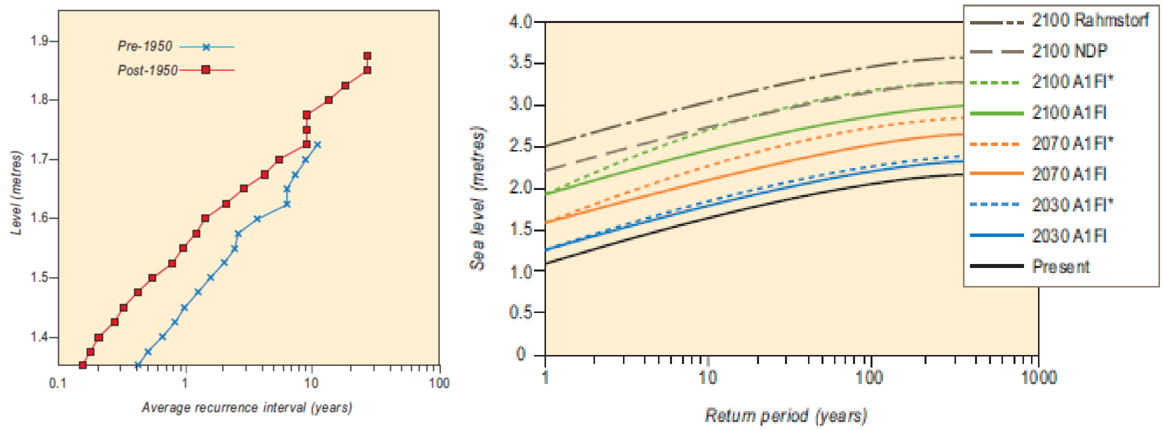


Figure 19: (Left) Changes in the average recurrence intervals of extreme sea levels, Fremantle, 1897-2004 (Source: Church et al. 2006); (Right) Storm-tide return periods for Stony Point under the high emissions scenario for the years 2030, 2070 and 2100. Asterisk scenarios include an increased wind speed allowance (Source: Department of Climate Change and Energy Efficiency 2009).

4.1.2 Flood mapping

Flood mapping of inundation along a coastline in its simplest form uses a 'bathtub' or 'bucket fill' Geographic Information System (GIS) model that uses a medium or high resolution digital elevation map (DEM) that can then be 'flooded' by entering a selected sea level. The resulting inundation map shows the areas of current foreshore that will be flooded. Additional sea level allocations may be added to include storm surge and wind driven wave setup. However, these models do not take into account whether the flooding will exacerbate erosion along the coast and so do not consider a possible breach of existing flood protections such as barrier dunes. This approach also does not include interactions between riverine and oceanic flooding should the two occur together (such as during a cyclone that causes a storm surge and localised flooding at the same time).

To date, flood risk mapping for sea level rise has been undertaken for numerous locations around the continent by State and Local Government or funded contractors for specific high interest sites. The DCCEE 'Climate Change Risks to Australia's Coast First Pass Assessment', provided the first national assessment of coastal climate change hazards and included flood mapping of the entire coastline (except Cape York) using the *High Resolution Stereoscopic Reference 3D* (SPOT) satellite derived mid-resolution DEM. The SPOT DEM has a horizontal resolution of approximately 30 metres and a vertical height resolution of one metre (i.e. the vertical slope of the coastline steps up in one metre intervals). Absolute elevation accuracy of the DEM is around 10 metres and it has a standard deviation of approximately six metres. The product was considered accurate enough for a first-pass assessment of the Australian coast. A projected sea level rise of 1.1 metres was overlaid on the DEM to indicate areas subject to inundation and then overlaid on the National Exposure Information System (NEXIS) infrastructure database developed by Geosciences Australia. The NEXIS database categorises information into residential, business (commercial and industrial), institutions and infrastructure components, on the basis of data from the best available national address dataset from the Geocoded National Address File (GNAF) and also provides the approximate total replacement cost for residential buildings.

High resolution DEMs are available for selected areas along the coast and usually use Light Detection and Ranging (LiDAR) data gathering processes from an aircraft to provide a vertical accuracy of about 10 - 15 cm. Figure 20 and Figure 21 show the availability of DEMs at various resolutions along the Australian coast as assessed by the National Data Elevation Audit in 2009.

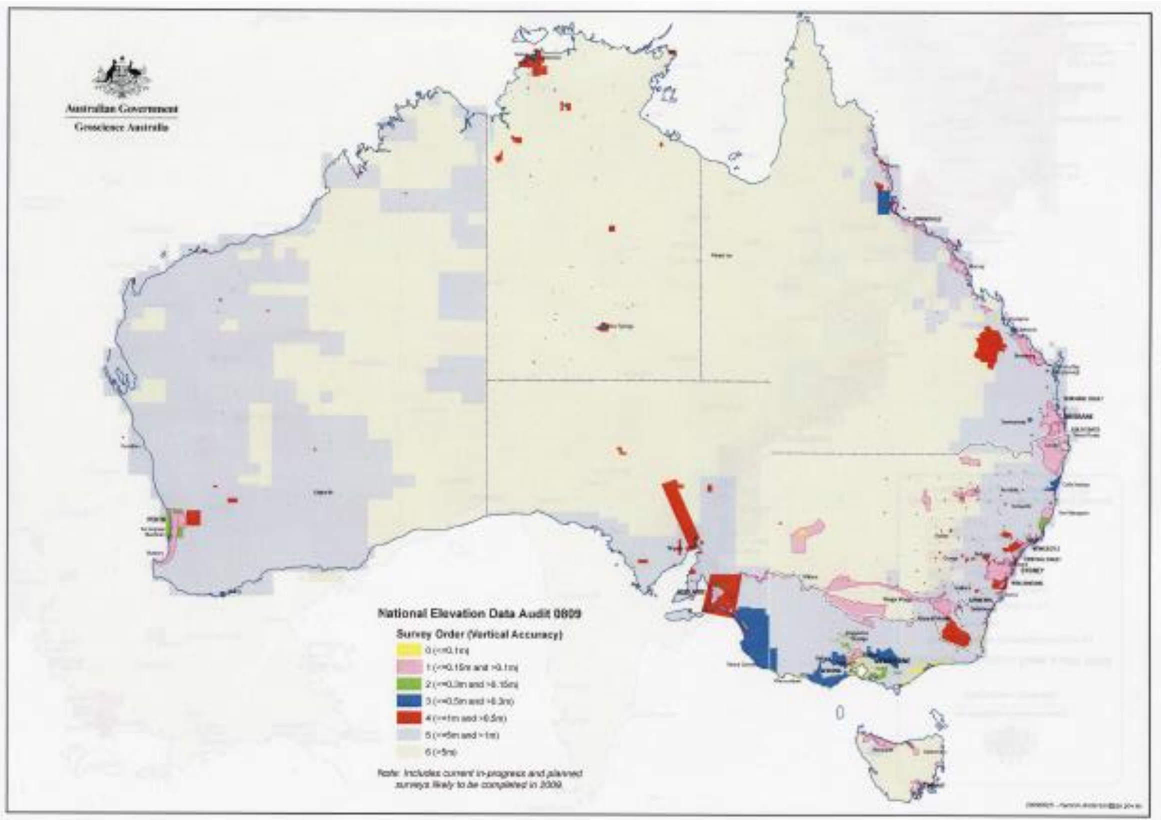


Figure 20: The National Data Elevation Audit maps show the availability of vertical accuracy elevation maps for the Australian coastline (Source: Geosciences Australia 2012).

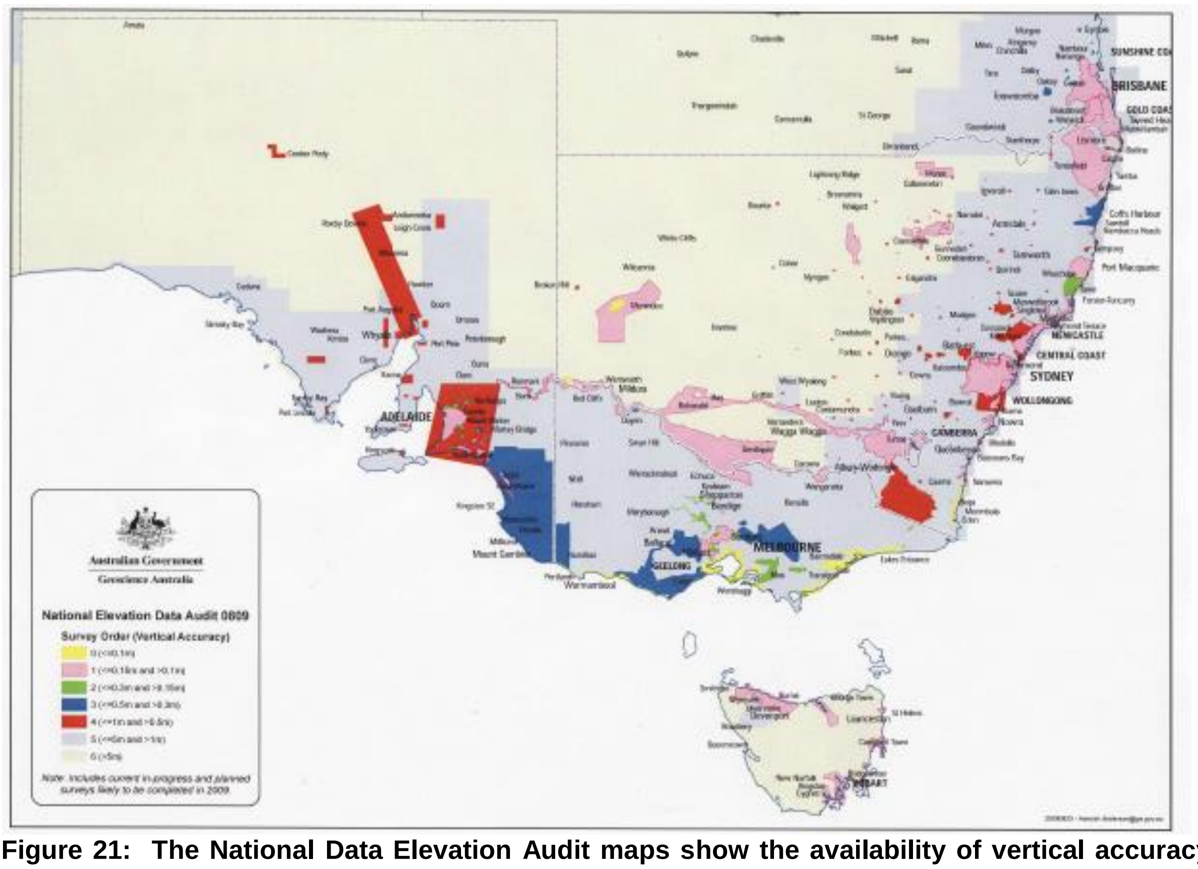


Figure 21: The National Data Elevation Audit maps show the availability of vertical accuracy elevation maps for the southern Australian coastline (Source: Geosciences Australia 2012).

A study by the Coast Protection Board (CPB) in South Australia used a simple flood risk model and high resolution LiDAR DEM to identify those settlements at risk of inundation and possible coastal erosion along the Yorke Peninsula and north-east Gulf of St. Vincent coastlines (Guy 2011). The maps indicate those areas that will be flooded in a 1-in-100 year sea flood event under the current climate and include a 1-in-100 year storm surge and 0.1 metres wave set up allowance. Maps that include areas flooded in response to an additional sea level rise of 0.3 metres and 1.0 metres above the 1990 'current climate' baseline levels were then calculated. An examination of the maps clearly shows which areas will be inundated and whether any of the settlements rely on dunes or other barriers for flood protection, and if protection of these barriers is critical for their future sustainability (Figure 22).

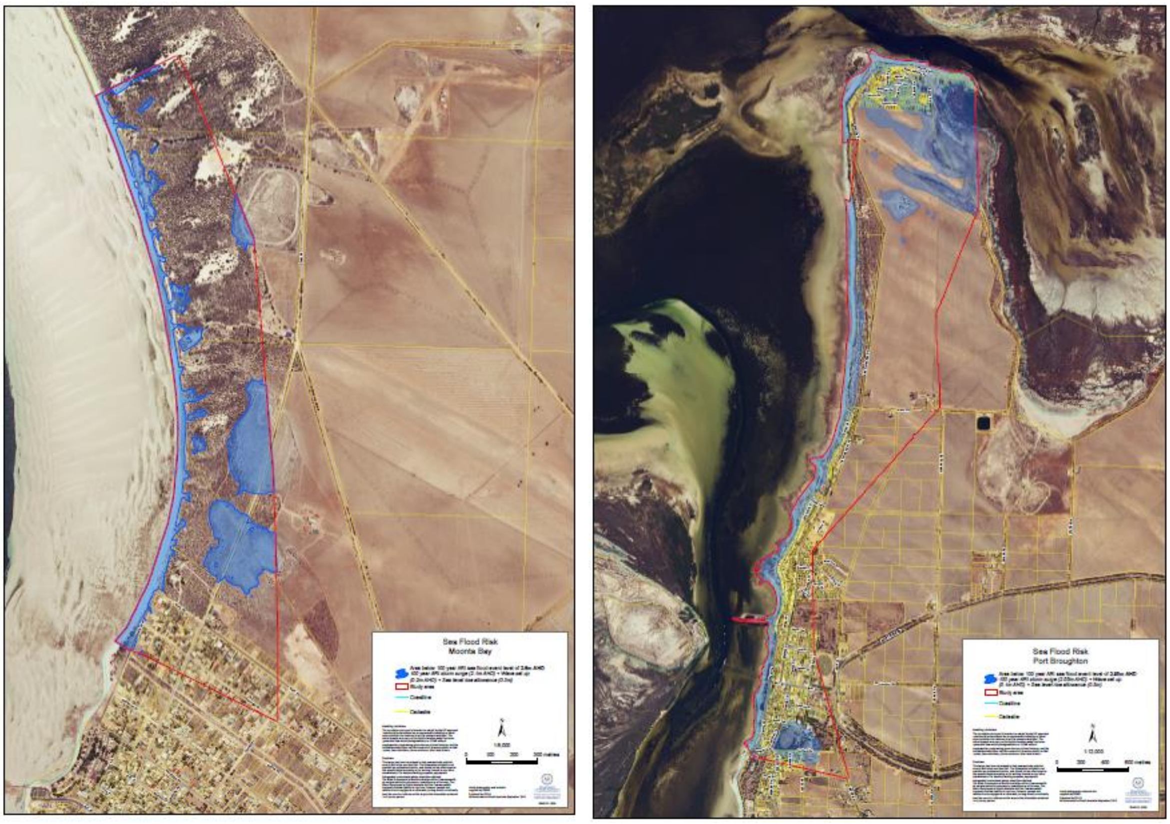


Figure 22: 1-in-100 year flood areas including a 0.3 metres sea level rise for (Left) Moonta Bay, and (Right) Port Broughton. Blue areas are projected to flood (Source: Guy 2011).

The Spatial Information Council is coordinating a national Elevation Data Framework to provide access to a range of DEM data and products to users and over time improve the quality of elevation data and DEM products.

4.2 Coastal Erosion

Even a moderate increase in sea level rise can result in a significant increase in the ARI of an extreme sea level event associated with high tides and storm surges and the associated erosion of the coast. As an example, an event that now occurs once every 100 years could be expected to occur two or three times *every* year by the end of the century. Erosion (or accretion) of a coastline is dependent on the combined effect of four factors (DCCEE 2009):

- change in mean sea level;
- changes in the frequency and magnitude of transient storm erosion events;
- realignment of shorelines due to changes in wave direction; and
- extent of supply and loss of sediments in nearby sources and sinks.

Assuming a static sea level and climatic drivers of extreme events (the first two factors), the potential rate of erosion will still vary significantly in response to wave energy and direction (factor three) - erosion on an open, exposed coast is often greater than that on a more sheltered coast, as the larger wave climate is capable of shifting more sediment from the top of the beach into deeper water, compared with a calmer, shallower environments. Finally, the substrate along the coast determines the actual erosion rates in response to the combination of the other three factors – a sandy shoreline will erode much faster than hard rock substrates. Those substrates most vulnerable to coastal erosion are those made up of 'unconsolidated sediments, such as beaches, dunes and sand cliffs on the open coast of leady embayments and on the shores of coastal lakes and lagoons… soft sedimentary and weathered cliffs, especially those formed in calcarenite' (DCCEE 2009). Sea level rise is not expected to increase the erosion of most hard coasts above current rates.

The geomorphic attributes (landform and stability) of the Australian coast were compiled into a national line map as part of the DCCEE 'First Pass National Assessment' of climate change risks to the Australian coast (Figure 23). Known as "Smartline" the database is available on the OzCoasts website (www.ozcoasts.org.au) (DCCEE 2009). Each segment of the Smartline map contains multiple data layers describing the landform types at that point of the coast extending from the High Water Mark 500 metres both inland and offshore that where can be queried through the web browse or using GIS software. 'As a 'geomorphic' map, it represents not just the topography of the coast – the planform, elevation and shape of the coastal landforms which a contour map or digital elevation model may represent - but it also indicates what the differing coastal landforms are made of – varying rock types, laterite, coral, sand, mud, laterite, boulders, beachrock and so on.

The map classifies coastal landforms into differing combinations of form (generalised shape) and constituents (or fabric – what the landform is made of) which in turn are indicative of the differing natural processes by which each coastal landform has developed' (OzCoasts 2012).

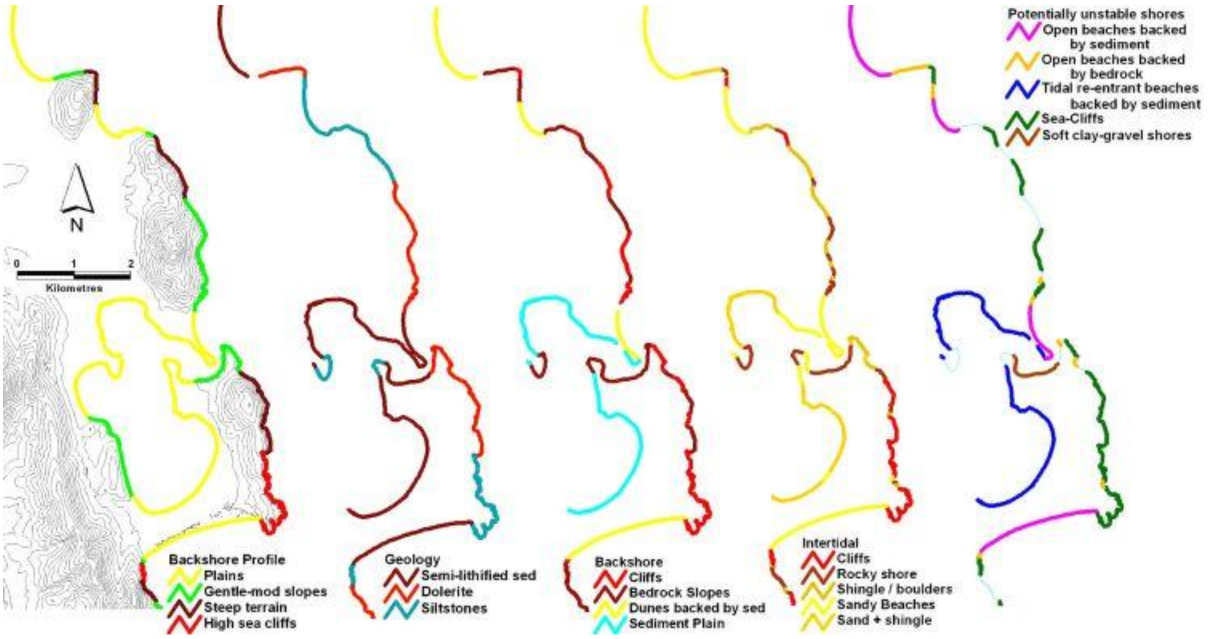


Figure 23: An example of the information provided by four of the basic geomorphic attribute fields and the coastal stability landform class (right hand side) displayed as separate line maps in the Smartline Geomorphic Map of Australia (Source: Geosciences Australia 2012).

The stability maps show a range of 'Stability Classes' that describe characteristics of particular landform types or groupings that 'have potential to physically respond to sea-level rise and other coastal processes in distinctive ways (including differing styles of erosion, accretion or stability)' (Ozcoast 2012). The main stability classes are: muddy shores, sandy shores, sand dune and beach ridge coast, coarse sediment shores, undifferentiated soft sediment shores, "Soft Rock" shores, "Hard Rock" shores, undifferentiated rock shores, coral coasts, and those sections of the coast that have no stability classification. However, 'the stability classes do not attempt to predict the rates or degrees of instability likely to affect particular potentially unstable shores' because to do so requires additional data relating to the oceanic processes including sea level rise, currents, tidal movements, wave setup, and other factors (Ozcoast 2012).

Once the geomorphology and stability of the coastline has been determined and the oceanic and climatic components quantified, the coastal erosion / recession rates can be calculated using a coastal erosion model. The Bruun rule is a simple model often used to calculate the ratio between sea level rise and coastal erosion. On a sandy coast, erosion is often 50 to 100 times the amount of sea level rise as the coastline adjusts to maintain near shore depth (Figure 24). Calculated erosion rates are driven by local mean sea level and the Bruun ratio will be different for each section of the coast depending on shore-face profile, height of the dune or friable cliff, shoreward or alongshore sediment flux, and local sediment sources. In all cases, a coast backed by large sediment supplies, such as sand major dunes, will mitigate the erosion to some degree.

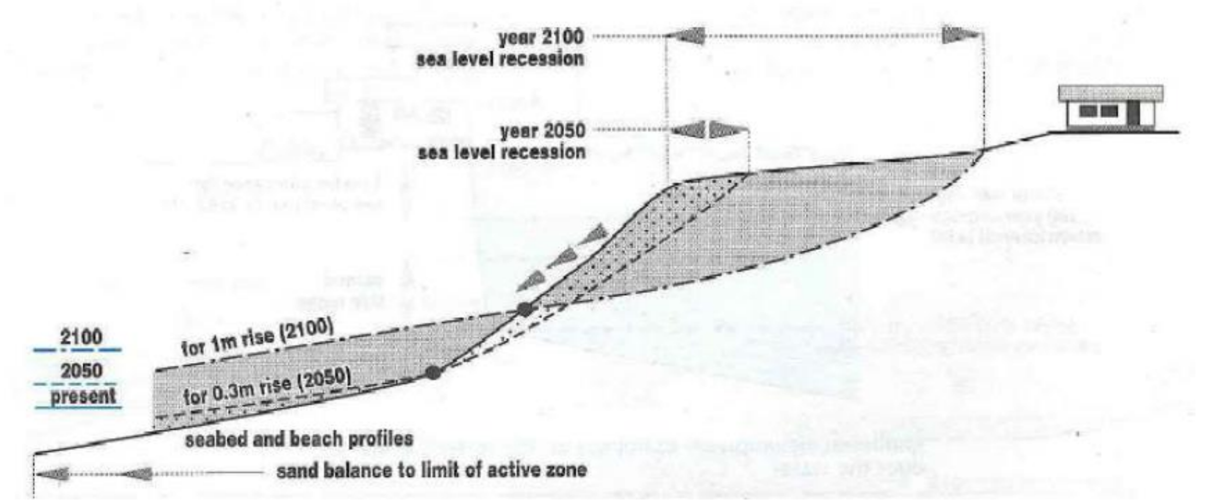


Figure 24: The "Bruun" rule predicts recession of sand coasts with changed water levels (Source: South Australia Coast Protection Board 1992).

For South Australia, if sea level rise continues at the current rate (4.3 mm per year), levels would be approximately 0.5 metres higher than 1990 levels by the end of the century. Erosion of a sandy shore for this much sea level rise would mean the coastline could be expected to recede by between 25 metres and 50 metres over the same time frame. The increase in sea level rise at Thevenard if current rates of 4.3 mm per year continue by the year 2030 would be approximately 0.18 metres by the year 2030. Sea level rise of 15 to 20 cm above the baseline level would result in recession of sandy shores from erosion of between 10 to 20 metres.

However, this estimation of expected erosion rates from sea level rise is generally imprecise. The Bruun Rule relies on many assumptions and is rarely able to be applied without breaching at least one. However, it does provide "ball-park" estimates that are often reasonable. Because of this imprecision, many of the recently conducted coastal vulnerability assessments do not include the impacts caused or exacerbated by erosion (e.g. the South Australian Department of Environment and Natural Resources (DENR) / Department of Planning and Local Government Yorke Peninsula study (Guy 2011).

To obtain more accurate estimates of coastal recession / erosion, each section of the coast needs to be modelled by taking into account mean trend recession due to accelerated sea-level rise, increased storm erosion demand, imbalance in the alongshore and sand transport budget, and presence / length of rock reefs and seawalls. This level of modelling has only been undertaken for some locations (e.g. Manly Beach in NSW and Lake Macquarie Beach, NSW (Figure 25).

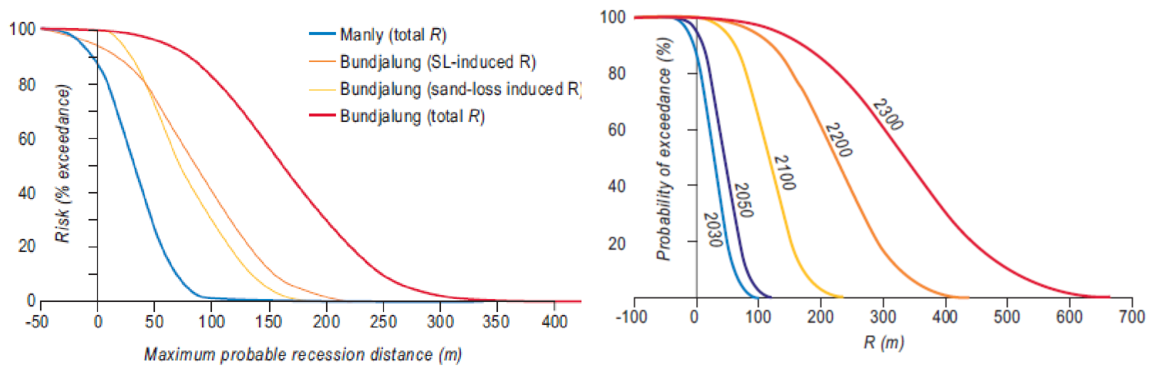


Figure 25: (Left) Maximum probably recession to 2100 for Manly Beach, Sydney and Bundjalung Beach on the NSW north coast between Iluka and Evans Head; and (Right) potential long-term coastal recession in Lake Macquarie Beach NSW (Source: Cowell et al. 2006).

In summary, although reasonable estimates of future inundation and coastal recession can be made on the basis of medium resolution assessments of coastal geomorphology and oceanic patterns, at the local scale high resolution mapping and monitoring are required to more accurately describe the likely changes. In all cases there is a significant degree of uncertainty associated with not only future projections of climate change and related sea level rise and changes in the climatic drivers of extreme events but also the complex interactions between local processes and the geomorphology of the area. In this study we have used the highest resolution data available for each of the case study areas selected.

5 REVIEW OF INTERNATIONAL AND AUSTRALIAN COASTAL CLIMATE CHANGE POLICY

5.1 Introduction

Management of the range of risks from climatic impacts on existing infrastructure and property poses significant policy questions for government. While the project encompasses both privately owned, Council owned and other government owned assets, the principal focus is on the decisions that Councils have to make in relation to projected coastal climatic changes.

This section of the report reviews coastal policy in Australia and a number other countries around the world – the United States, Canada, the United Kingdom, Denmark and New Zealand as examined in detail in Appendices 1 and 2 to this report. The desktop literature review identified the range of policy options that have been applied to existing public and private property infrastructure with respect to climate change related coastal threats. Because decision making also carries with it the potential for liability, this aspect was also summarised for the policy documents reviewed. In summary, the aim of the review was to:

- Identify the range of policy options that have been developed to address climate change related threats to existing coastal property assets and infrastructure.
- Examine the policy options identified and quantify the legal and financial implications of each.

5.2 Research Approach

The research approach was to conduct a desktop literature review in the following manner:

1. an online document search identified key websites and associated policy documents and these were organised into national groupings;
2. an initial scoping of the national groupings identified those countries with more advanced climate change adaptation strategies. For example, while South Africa raised some adaptation issues in 2007, a preliminary review of government websites reveals that the emphasis of South Africa is still focused on mitigation rather than adaptation strategies;
3. subsequent to this initial scoping, countries with similar coastal situations to Australia were identified. For example, while the Netherlands have a long history of dealing with the threat of inundation from the North Sea, hard engineering options have been used in the construction of dikes covered in concrete and rock, and metal barriers that can close off deltas and estuaries. These approaches are unlikely to be implemented in Australia;
4. other than Australia, the following countries were identified to have developed adaptation strategies of relevance to Australia were: Denmark, New Zealand, United Kingdom, Canada and the USA;
5. as adaptation policy tends not to be ‘stand-alone’ but rather embedded within other policy, the approach was to ‘drill down’ through legislation and policy documents that related to sea level rise to obtain the full picture. An appropriate picture of adaptation policy is only obtained by reviewing the broader legislative and policy environment and therefore this review takes a comprehensive approach to the review of legislation and policy environments within each jurisdiction; and
6. within each of the countries examined the following research questions were asked:
    - What is the nation’s perceived attitude to climate change science?
    - Who does the government see as responsible to adapt to coastal impacts?
    - How does insurance play a role in climate change adaptation?
    - What has been the government’s adaptive approach so FAR in relation to legislation, policy, and response?
    - What tools or case studies are relevant to this study?

5.3 A Summary of the Review Findings

The full, detailed review of international policies relating to coastal impacts and climate change is provided in Appendix 1 for the United States, Canada, the United Kingdom, Denmark and New Zealand. The detailed review of Australian coastal climate change policy is provided in Appendix 2. A summary of the findings for each of the questions posed in Step 6 of the methodology for the review is provided here.

5.3.1 What is the nation's perceived attitude to climate change science?

All of the nation states in the sample studied accepted that the global climate is changing at a more rapid rate than in recorded human history and that sea levels are rising as result. All were active in developing policy to address how their governments and communities might address a range of climate driven changes including sea level rise. Even the USA, which internationally is sometimes regarded as a laggard on climate change related matters, was observed to be actively developing adaptation plans at a federal level and encouraging scientific research into climate processes and impacts. While all nations recognised the fact of rising sea levels some viewed the issue as more urgent than others. The UK for example, perceives the associated risks from rising sea levels as 'high' while the New Zealand government tends to see these risks as longer term and considers that there is an adequate window of about 40 years before urgent action is necessary. The Australian federal government regards the risks relating to climate change and sea level rise in particular as 'serious and persuasive' (Australian Government 2010, p. 4).

5.3.2 Who does the government see as responsible to adapt to coastal impacts?

Responsibility for the development and implementation of coastal climate change policy varied across international jurisdictions. In those nations that operate a federal system of government such as the USA and Canada, it was common to find federal reports and initiatives that attempt to set an overall strategy. However, because of differing state legislation, wide variations in climatic conditions and the location of critical industries that depend on specific natural resources such as fisheries or water, localised responses to climate related issues varied. Elsewhere, for example in Denmark, New Zealand and the UK, there was evidence of central governments addressing climate change adaptation and coastal issues specifically through the formation of various committees to examine these problems. However, in the case of these latter countries action in terms of the development of detailed policy and action in respect of particular cases and locations tends to be devolved to the Local Government level.

In the European case, this approach to move responsibility to the local level may be seen as an example of the application of the subsidiarity principle, which states that powers should be allocated to the level of government that can best exercise them. In the case of the UK, recent government policy has produced a sharp localisation of powers across government, justified by central government as part of a broad process of empowerment of local communities. Not only does this shift imply that local Councils may carry financial responsibility for any future policy on protection or otherwise of coastal communities, but central government policy statements suggest that empowerment brings responsibility down to the level of individual property owners. So current UK policy argues:

> *'Flooding and coastal erosion cannot be entirely prevented and the relevant legislation is largely permissive. This means that there is no general right to be protected from flooding and coastal erosion, and no right to be protected to any particular standard where risk management action is taken.'* (DEFRA 2011, p. 35)

The Danish government likewise argues for a process of 'autonomous adaptation' that effectively places the onus of responsibility for climate change adaptation on the individual citizen or owner of the assets under threat who are expected to respond within the existing legislative and policy environment. 'Planned adaptation' only follows 'autonomous adaptation' where it becomes evident that existing legislation and policies are inadequate or where the threat is of a magnitude that requires a national response.

In Australia, the federal government policy statement *Adapting to Climate Change in Australia* (Australian Government 2010a) notes that individuals, communities and businesses need to take responsibility for adaptation to climate induced risks. Elsewhere, the Natural Disaster Relief and Recovery Arrangements (NDRRA) outline the scope for federal government assistance in the case of extreme climate disasters. However, while there is scope for federal intervention in extreme circumstances, gradual encroachment and small scale coastal losses would not be regarded as a federal responsibility. Overall therefore, there appears to be a move by governments across the world to both clarify policy and divest responsibility to protect vulnerable communities, though the degree of urgency with which this process is viewed varies.

5.3.3 How does insurance play a role in climate change adaptation?

Attitudes to insurance and detailed arrangements vary around the world. For example, in the US the Federal Emergency Management Agency's (FEMA) National Flood Insurance Program provides federally backed flood insurance to home and business owners located in communities that participate in the NFIP' (FEMA 1991). Although not explicitly related to the impacts of climate change, and primarily designed for floodplain (not coastal) areas, the NFIP is under investigation to better incorporate sea level rise, storm surge and associated phenomenon.

In the UK flood insurance is standard in most household and small business insurance but flood cover is offered in accordance with a set of Statement of Principles between the Government and the insurance industry. The current agreement will expire in 2013. The basis of the agreement is that if the Government agrees to work toward managing the risks then the insurance companies will continue to cover for flood events. As early as 2004, the Association of British Insurers (2004) were calling for large upgrades in expenditure on flood defence systems, with the veiled threat that insurance cover could not be assured unless this was done.

Denmark has a public scheme of insurance that is collected through tax levies but that does not provide 100% cover and so individual asset owners also take out insurance cover (Hallegatte et. al. 2008). However, Denmark has not yet completed any systematic research into the insurance related impacts of climate change and the report notes that new financial insurance instruments will be needed to cover incidents relating to climate change. Insurance premiums in New Zealand are largely driven by previous losses incurred in respect of specific risks. So far this approach does not send clear messages to property owners about future risks. In Canada there is clear evidence of rising insurance premiums resulting from severe storm damage.

In Australia it is clear that insurance costs are being used as price signals to produce behaviour change. Not only do Australian household policies normally exclude 'storm surge', 'action of the sea' and 'erosion and subsidence' from general insurance cover, but insurers may exit areas of the market where they believe risks and costs are excessive. Also, since insurance normally prices risk on the basis of discrete addresses, there is little appetite or scope for cross subsidisation of risk across regions and high risk addresses will carry higher premiums, if they can access insurance at all. In summary therefore, insurance has a clear role either to support or disincentivise continued occupation of coastal areas, but the details of its application are significantly different across nation states.

5.3.4 What has been the government's adaptive approach so far in relation to legislation, policy, and response?

The system of common law that applies in the USA, Canada, Australia, New Zealand and the UK, implies that governments must have regard to issues of negligence, nuisance, strict liability and occupiers liability. Thus, as a general principle, failure by a public agency to act on climate related risks of which that agency was well aware could trigger action for negligence. Recognition of this aspect has triggered a response in several countries where governments have sought to limit their liability with respect to climate change driven phenomena.

The shift to localisation and the statement in policy that there is no general right to protection, and no absolute right to be protected to a particular standard, has already been noted in the UK. New Zealand displays a reticence in respect of hard engineering solutions such as groynes and sea walls since these may be seen as trigger for public liability should they fail or be overtopped by severe storms. Canada too has noted the potential liability issue that could arise from inadequate attempts at protection of coastal property and infrastructure. The Australian federal government has not introduced any new legislation with respect to climate change adaptation but rather relies on the States to develop their individual responses. The federal government has nevertheless established a DCCEE, co-ordinated the Council of Australian Government (COAG) co-operative action on climate adaptation and funded the National Climate Change Adaptation Research Facility. Meanwhile, several Australian States have sought to amend their legislation to protect Councils from liabilities resulting from coastal inundation and erosion as sea levels rise. A detailed discussion of these amendments and the report on *Local Council Risk and Liability in the Face of Climate* Change (Baker and McKenzie 2011) is included in Appendix 2. All of the different countries studied discuss the relative merits of hard versus soft defences and there is general recognition that different situations demand a range of solutions. Soft defences are broadly seen as preferable in that they work with nature rather than seek to resist it and they are less likely to have unwanted repercussions such as changes to longshore drift or erosion elsewhere along the coastline. The issue of who has the right act to protect coastal assets is a contested area. In the USA questions relate to the unconstitutional taking of common law property rights where home owners have sought to protect their beach front properties with hard protection measures such as rock armour on the shoreline. Legal challenges have also occurred in the USA where public bodies have sought to buy back private coastal land to secure other coastal properties.

Most of the countries studied have set up committees and working groups to examine climate related adaptation as an issue. The USA and Canada are notable in this respect, though as indicated above, action tends to be more regional or local since impacts vary a great deal across such large countries. New Zealand stands out in that it has sought to integrate climate related risks into existing frameworks. If a global trend is apparent it would seem to be towards localisation of policy and responsibility. For example the UK has recently moved from a centralised to a localised response. Denmark has provided centralised co-ordinating bodies but makes it clear that responsibility for action rests with individual landowners whether public or private. Similarly there is a broad international trend towards clarification of government liability, with the intention of limiting this wherever possible.

5.3.5 What tools or case studies are relevant to this study?

A range of advice notes, climate adaptation tools and case studies are discussed under the various countries reviewed and included in Appendix 1 and 2. Tools range from risk management based approaches developed in Canada, to Denmark's coastal planning screening tool that uses interactive mapping to evaluate risk to specific assets and the UK's Adaptation Wizard that takes the user through a process of determining vulnerability, identification of key risks and development of adaptation strategies. A useful case study is evident in NSW where some mechanisms of planned retreat are now embedded into policy but counter-balanced recently with the Coastal Protection and Other Legislation Amendment Act 2010 (NSW) that gives some rights to land owners to protect their properties from the sea. These changes result from a specific case at Byron Bay that is reported in detail in Appendix 2.

5.4 Adaptation Options Identified

The first of the broad aims of the review was to identify the range of policy options that have been developed internationally in and Australia in respect of the threat to existing public and private property infrastructure in climate change threatened coastal zones. This section summarises the findings of the review with respect to the identification of adaptation options. In most cases *adaptation options* in coastal areas are categorised in the following three ways:

- Protect: use various means such as construction of sea walls, beach sand replenishment or improved drainage to protect existing developments from loss or damage by tidal encroachment;
- Accommodate: use means such as raising buildings on stilts, or redesigning lower floors to allow flooding to take place without significant damage and consequent cost; and
- Retreat: abandon settlements and move development inland in the face of rising sea levels. The concept of 'retreat' is also known as 'planned retreat'. Where it exists it is usually contained in planning policy which seeks to restrict new development and set temporal limits on existing properties in threatened zones.

As described in the previous chapter, coastal zone *risks* can be categorised under two main headings: erosion risks and inundation risks. A recent report by the Local Government Association of Tasmania (2011) provides a comprehensive list of adaptation options for development and infrastructure in the coastal zone under these two main risk headings (Table 3 and Table 4 below).

Table 3: Range of works to address erosion and inundation risks (Source: Local Government of Tasmania 2011 (p. 3-39)).

Works to address erosion risks	Works to address inundation risks
Sand dune stabilisation and vegetation	Dykes and levees
Beach nourishment	Flood barriers
Groynes	Detention basins
Artificial Headlands	Raise land levels
Offshore breakwaters and reefs	
Coastal hardening	
Seawalls	
Revetment	
Training walls	

Table 4: Works to defend individual assets from coastal hazards (Source: Local Government of Tasmania 2011 (p. 43-71)).

Works to defend individual assets	Works to defend public infrastructure assets
Flood skirts	Sealed sewer systems
Flood barriers	Raised road and services
Lifting existing dwellings	Liftable bridges
Raised slab or floor	Alternative routes
Stilt house (pole house)	Independence from connection to services
Water proof ground floor	
Modular homes and removable dwellings	
Floating houses	

It is sometimes the case that Governments will not publish specific adaptation policies for particular areas due to the potential this causes for litigation. A specific policy of planned retreat in Byron Bay, NSW, for example, resulted in property owners threatening legal action against the Council (Munro 2011).

Protect
The following trends are evident in the implementation of protection strategies:

- Soft protection options, such as sand nourishment and revegetation are preferred rather than hard protection options such as sea walls. There are a number of reasons for this trend. First, hard protection options often cause new problems at another point on the coastline. Second, the initial implementation cost of hard protection works is usually high. Third, a new range of liabilities emerges when a Council installs a hard protection option. Structures need to be maintained and renewed and defaulting on these responsibilities may be the catalyst for future litigation when a defence structure is over topped and damage is suffered. Finally, an intervention such as a sea wall may infer to a purchaser that a settlement is safe from inundation. The NSW and UK Governments have recognised this fact and both have instituted legislation to eliminate the liability the Government might have in relation to the functioning of protection works. The UK Government is currently undertaking an audit of all of its protection structures to ascertain the level of its current liability.

- The right to protect private property from actions of the sea is likely to be supported in Australia. Already policy exists in the three states reviewed that allows for private protection works provided it can be demonstrated that the works will not adversely affect other sections of the coast, and that the cost of implementation and maintenance will be borne by the owners of the land in perpetuity. The NSW Government has now legislated to give rights to land owners to protect their properties but also defines the limits of those rights. It is unlikely that any government in Australia will be politically able to let houses fall into the sea while prohibiting owners from protecting their assets. The Byron Bay scenario is a test case for what might happen if this is tried. This is not to say, that in the 30-50 year time frame that these actions might become more enforceable as sea level rise increases and appropriate legislative and policy frameworks are introduced to cater for future development. Internationally, the US has stronger property rights and is contending the right to protect property, whereas in the in UK it is more likely that the Government will take a harder line. New Zealand will be more likely to offer adequate compensation should such an event occur.
- It is probable that existing coastal settlements, even smaller ones, will be defended against rising sea levels, providing that the change is incremental. There are two main reasons for this probability. The first is that the cost of compulsory acquisition of water-front properties places this option out of reach of most Governments and secondly it is very difficult to achieve politically. In South Australia, the CPB of the DENR are not opposed to development where a commitment is evident from the Council that it intends to defend the line. Most national and state policy states that development of significant economic or cultural value could be protected with hard defence options. The Adelaide Metropolitan Beaches is an example where an esplanade road will very likely be defended into the indefinite future. Should sea level rise accelerate or a series of catastrophic inundations occur, this trend may change. The choice to protect is ultimately related to community values and financial cost. Where the community values access to a sandy beach and there are related economic benefits, decision makers will ensure that the beach is protected.
- All jurisdictions reviewed gave allowance for the costs of the installation and maintenance of protection works to be levied on those who benefit from the works. In the longer term, these costs may provide a disincentive to live in sea front locations.

Retreat

By far the greatest advances in policy development have been in planned retreat. The State Governments reviewed in this report have all instituted policy to deal with the planning of future development and this policy has been adopted by local Councils into local development assessment plans.

However, the main thrust of this policy development relates to new development. New development is best discussed under two main categories - new settlements and infill development. In relation to new settlements, Councils have taken a more stringent line, and courts have supported Council decisions where developers have not properly taken into account potential sea level rises (Baker and McKenzie 2011). However this doesn’t mean that governments are adopting blanket ‘no development’ zones. NSW State policy is careful not to prohibit development outright in areas that may be vulnerable to future inundation, but rather it places the onus on the developer to demonstrate how they intend to cater for the threat. Another strategy NSW uses for dealing with land that might be subject to coastal impacts is to designate such areas as ‘investigation lands’. These two strategies are likely to be effective in mitigating the possibility of litigation by owners and developers of large land holdings and with the latter strategy, act as a warning flag to any potential purchaser.

One of the downsides of planned retreat is that it can create a number of different classes of residents in the same street. This was observed in Byron Bay where one landowner may be allowed to maintain a rock sea wall, while another adjacent is prohibited from repairing a sandbag wall. One landowner may have positioned his house at ground level, while another may be elevated by a metre or more, or may be required to ensure that their house is made to be relocatable.

There are two versions of planned retreat. The first adapts to sea level rise through planning mechanisms included in development plans and covenants on titles, and allows for appropriate protective measures as well. The second version provides for the planning mechanisms in the development plans and covenants on titles, but prohibits the land owner from protecting his assets. The case study of Byron Bay provides one insight into how this strategy may play out with the potential for the influence of political pressure outweighing development controls, especially if the saga is played out in the media. The planned retreat approach looks at the long time frame of 30-50 years in catering for sea level rise. New Zealand is a jurisdiction that appears to be taking the stance that it has time to cater for sea level rises through its planning system.

Accommodate

Policies in relation to accommodation options are less developed with the exception of those that exist in planning schemes. Raising floor levels within infill development is a simple strategy to accommodate future sea level rises. Trigger conditions on approvals are another method of accommodation. In Byron Bay Shire, in areas of higher risk from erosion or inundation, conditions of development ensure that the proposed development can be relocated within 24 hours. Accompanying these conditions, trigger points are mandated that insist that development is moved further away from the erosion escarpment and are enforced. These trigger points and conditions are noted in covenants on the title to ensure that future purchasers are warned. Despite, Byron Shire’s recent legal battles, this approach still seems to be an effective way to accommodate development within coastal zones at risk from erosion or inundation. Other accommodation strategies may be the retrofitting of houses and infrastructure to allow flood waters to pass by without causing too much damage.

Finally, it is likely that governments intend to change preferences for where people live by introducing policy settings that allow for greater insurance premiums to be charged in coastal regions, and by ensuring that residents in locations at higher risk share the cost of installing and maintaining protection works.

5.5 Responsibility and Liability

The second broad aim of the review was to assess how governments are reacting to the issue of who is responsible to adapt to coastal threats. The flip-side of who is responsible to adapt is the question of who is liable when the impacts of these coastal threats are felt. These issues are summarised in this section.

Each of the countries reviewed have at least two, and usually three tiers of government. State or provincial governments were not reviewed internationally, but in Australia the States take a similar role to the National Government in providing legislative and policy environments and also take a direct role in influencing Local Government planning legislation. National governments in this review tended to take responsibility for providing a framework for coordinated action. This action includes instituting legislation, broad policy setting, the provision of funding, and establishing scientific advisory boards. Generally, the national governments reviewed did not bear the direct liability of potential coastal impacts, although indirectly they may when disaster assistance funding is required.

Direct liability in relation to potential court action and cost of adaptation options is most keenly felt at the Local Government level and is the nub of Local Government concern (Australian

Government 2010b; Parliament of Commonwealth of Australia 2009). Councils may be liable for the following:

- loss of service and function in coastal zones as a result of inundation;
- damages from nuisance and negligence claims although only one case has been brought to date (Baker and McKenzie 2011, p. 26); and
- legal costs when defending decisions. Land owners and developers are likely to appeal when Council decisions decrease development potential, and green groups or other citizens may challenge the validity of a planning decision that has not properly taken into account climate change science. Cases relating to this are FAR more prevalent in Australia and absorb a significant amount of financial resources (see Baker and McKenzie 2011, p.25).

Furthermore, as one of their general functions, local Councils in Australia have a general responsibility to provide protection for their constituents (See for example, Section 7, Local Government Act of South Australia 1999). However, advances in science research have meant their capacity has strengthened in relation to predicting and quantifying the effects of climate change, including sea level rise. For example, in the past, a larger than normal storm surge may have been treated as an unforeseeable natural disaster and therefore no attribution of liability would be made. Now, predictions about sea level rise and associated storm surges are based on scientific collection of data, analysis, and modelling. However, in spite of these advances, and while the weight of the evidence may be compelling, the science is still imprecise and open to challenge (Baker and McKenzie, 2011, p. 25, 26). Therefore, local Councils are operating in a grey area between their general responsibilities to provide protection for their constituents, and a known, but still imprecise threat in coastal zones due to climate change. Local Councils are balancing these factors with other competing interests and limited resources.

Government responses to cope with potential liability

Governments included in this policy review have all responded in some way to address potential liability from increased sea levels. The following summarises the various responses:

- Some governments have categorised the risk of sea level rise as ‘business as usual’. In other words, by treating the risk from sea level rise in the same way as before (albeit with the qualification that the risk might be increased). With this approach, legal frameworks, policies, and procedures remain the same and are as valid as before. New Zealand and Denmark are examples of jurisdictions that have adopted this approach.
- Associated with the first approach, is the affirmation from Governments that adaptation responses should be handled within normal risk management approaches. Most jurisdictions recommend this approach to some degree, but again New Zealand and Denmark were the most overt.
- A necessary dimension of risk management is the ability to accurately describe the vulnerability or the characteristics of the likely impact in a given location. All jurisdictions reviewed were funding increased capability for conducting vulnerability or impact assessments. In Australia, the Federal Government continues to fund adaptation projects and States like Victoria, are developing high resolution mapping techniques to increase their capacity to make accurate assessments.
- Some governments have also responded by limiting the responsibilities of the respective levels of government and at the same time shifting the responsibility of adaptation to the individual landowner. The UK and the State of NSW in Australia are two examples of jurisdictions that have legislated to reduce their exposure, especially in relation to the possible failure of protection works. However additionally, the policy documents and position papers of Denmark, Australia, South Australian and Victoria reflect this trend to quantify who is responsible to adapt to climate change, with an emphasis on the individual rather than governments.
- Governments have introduced legislation or policy that requires those who benefit from adaptation responses such as protection works, to contribute financially to their installation and maintenance. While presently this power does not seem to have been used significantly, governments seem to positioning themselves so that they can reduce their financial liability by passing on adaptation costs if necessary.

- All governments reviewed have responded to position scientific advice as independent of government. All governments used the IPCC predictions in relation to sea level rise as the basis for their own policy responses. Most jurisdictions reviewed also have made their scientific advisory panels independent from government and are providing funds so that improved vulnerability or impact assessments can be undertaken in the coastal zone. This separation effectively reduces government responsibility to 'have regard' to the best available science, not to get the science right.

In Australia, all state jurisdictions have legal frameworks and policy with which to effectively defend against claims in relation to rising sea levels, albeit with some variation in degree of effectiveness. NSW, Victoria, QLD, and South Australia have more developed legal frameworks and policy, whereas the other jurisdictions require some improvement. It seems that all jurisdictions should consider adopting similar legislation as Section 773, of Local Government Act (NSW) 1993 to afford them the greatest protection. Finally, Councils are much less likely to be liable for damages relating to actions of the sea unless:

- the Council has acted contrary to scientific advice;
- the Council has not taken into account potential sea level rise in decision making;
- the Council has installed protection works and failed to maintain or upgrade them; and
- the Council fails to warn its constituents of the risks associated with potential sea level rise.

In relation to administrative appeals, Councils face a greater obstacle as it is likely that decisions of the Council will continue to be challenged.

5.6 Review Limitations

While the project scope indicated that there exists a spectrum of policy to deal with climate change risks to existing coastal settlements, a review of the literature did not bear this out. Adaptation options relating to sea level rise are often explained but there is no stand-alone policy about how and when they should be applied. The recent report, *Coastal Climate Change Risk – Legal and Policy Responses in Australia* (Commonwealth of Australia (2011) p. 9*)* concurs with this assessment within the Australian context:

> *'Noticeable is the general lack of policies addressing the issue of how to deal with the impact of CCC [coastal climate change] risks to existing developments. There are some policies that acknowledge in a general sense and provide, for example, that a hierarchy of adaptation responses are available to decision makers'.*

There are a number of possible reasons for this limited development:

1. While the Intergovernmental Panel on Climate Change (IPCC) has had adaptation in its publications for well over a decade, the early response to climate change national level has been to deal with mitigation. The focus on adaptation has really only gained momentum in the last few years (Commonwealth of Australia (2011) p. 6).
2. Adaptation is highly specific locally and each location contains numerous variables: land tenure, insurance cover, topography and geology of the land, bathymetry of the sea floor, tidal patterns and wind directions, financial capabilities and priorities of the community.
3. The climate change adaptation policy that was identified tended to be embedded in more general policy. Relevant policy has also developed over long periods of time. For example, the State of NSW of Australia has produced numerous policies over the last twenty years dealing with actions of the sea, but strengthened its legal position in relation to protection structures by adopting legislation in 2011. In summary, adaptation policy is often embedded in other general policy and is accumulative over time.
4. In relation to ascertaining who is liable and who has responsibility for dealing with climate change impacts in the coastal zone, generally governments around the world do not admit or discuss their liability, but they move to reduce it. This tendency makes some of this report necessarily interpretive and it must be viewed in this light.

5. Finally, while one of the briefs of this review was to ‘examine the policy options identified and quantify the legal and financial implications of each’, it is acknowledged here that this report relies on the legal expertise of others. Primarily, the recent report by Baker McKenzie (Baker and McKenzie 2011), *Local Council Risk of Liability in the Face of Climate Change - Resolving Uncertainties* is used as the framework through which the matters of liability were reviewed.

5.7 The Key Problems that Policy Needs to Address

To identify a constructive way forward to assist Councils in their role as decision makers in cases of existing developments threatened by sea level rise, the above review of policy was used to develop a decision map. The intention was to provide a logical series of decision steps and data collection that are applicable in a range of situations, that lead to a useful data set and that form critical input into the decision process. To do this it was first necessary to define the key problems that are facing Councils in respect of coastal climate change issues. Once these problems are identified, then the decision map can assist in defining solutions. The solutions in turn may be classified and organised and rendered capable of costing using valuation and insurance data for specific situations. Different solutions or packages of solutions may then be modelled and costed to provide information that Councils may use to set policy or make specific case related decisions. It is acknowledged at the outset that cost may not be the only criterion on which decisions are made, but if available can feed into a rational decision making process.

The fundamental problems identified for Councils addressing climate change threats to the coastal zone are physical, legal, political and financial. Each of these is briefly considered below.

5.7.1 Physical problems

The physical impacts of climate change on the coastal strip are described in details in Chapter 9 and can be summarised as either inundation or erosion. Inundation may occur as a result of either gradual sea level rise over time or as a periodic flood as a result of a storm event. Inundation can both damage or destroy Council owned infrastructure and private property, increase maintenance costs, reduce performance, result in repair costs and possibly render homes uninhabitable and infrastructure unusable. Erosion can occur gradually in response to mean sea level rise or more dramatically as a result of a storm event with high wave energy. Beach and cliff erosion will threaten property and infrastructure along the foreshore and as with flood may damage or destroy property and infrastructure. In addition, both flood and erosion may result in the loss of the land itself to the sea when the mean sea level gets high enough or extreme storms wash away cliffs and beaches.

5.7.2 Legal problems

The scope and boundaries of local Council action are often enshrined in either federal or state legislation that will have a strong influence on the nature of Councils’ response to particular problems. Often, in the case of coastal problems, legislation may involve the consideration of liability that might result either from taking certain actions or refraining from taking action. Examples would be the potential legal liability that a Council might acquire if it did not seek to defend a settlement threatened by flooding or the potential legal liability that the Council might face if it did seek to defend and then defences were breached. The potential financial cost to Council of liability might be an important consideration in any decision on such actions. It follows therefore that in any decision making situation, a clear understanding of potential liability is a vital prerequisite.

5.7.3 Political problems

While the physical forces and changes described above are likely to be inevitable, progressive and in some cases, unable to be accommodated or defended against, many landowners and members of the public will take the view (however unreasonably) that government should act in their defence. If government decides not to act, such decisions may be challenged or have repercussions for politicians. In the worst case it may mean Councillors will lose votes at subsequent elections. Therefore, in some instances, Councils may decide to act in defence of landowners, communities and infrastructure, despite evidence that such action is futile. It is also likely that Councils may choose to act to defend to buy time and put off difficult decisions about permanent retreat until some future date.

5.7.4 Financial problems

Because of these physical, legal and political problems, Councils are likely to face increased demand for financial expenditure. These costs may involve increased maintenance for items such as cracked footpaths and roads caused by cliff erosion, expenditure on coastal defence works such as levees and drains, or financial support for threatened property owners. Understanding the volume and frequency of such demands is central to this research. Financial expenditure is likely to vary depending on all of the above, the extremity, scale and speed of the physical problems, the viewpoint taken on liability and the strength of political concern about community views. An additional consideration relates to indirect impacts and specific policy imperatives. For example, a Council may decide that maintaining beach access is crucial in future. The physical erosion and sea level rise that will occur may necessitate alternative arrangements be made to maintain such access such as the purchase of additional land or development of land management agreements with private landowners. All of these options may require additional funds.

As a result of the review and analysis of adaptation options and legal responsibility the following steps to include in a decision support tool were identified:

- establish nature of physical threat;
- establish type and ownership of threatened asset(s);
- establish Council's legal and financial liability;
- define alternative solutions to the problem (it is important to consider the timing of actions as well);
- cost the different solutions;
- determine if any solutions will be dictated or ruled out by politics; and
- determine preferred policy.

Each one of these steps will most likely consist of a series of decisions or stages. The following chapters examine the context of decision making in the coastal zone and the development of a decision map as one of the project outputs.

6 DECISION PATHWAYS AND THE DECISION MAP

6.1 Principals in Decision Mapping

6.1.1 Decision mapping: approach and methods

Decision mapping has been adopted in this project as a primary technique, to analyse the decision environment faced by local Councils in framing adaptive policy and management responses to climate change. Decision mapping is a formal analytic instrument that combines the systematics of decision analysis with the visual display methods of flowcharting and business process mapping.

Flowcharting emerged first in military and business environments in the 1940's and 1950's as data flowcharting, and was brought to a sophisticated level of theory and practice in the 1970's (Gane and Sarson 1979). Gane and Sarson's work provided a foundation for the discipline of process mapping, a technique central to the continuous improvement and quality strategies in modern management practice (Damelio 2011).

The principal purposes of decision mapping are:

1. to develop a graphical presentation of states, actions, and outcomes relevant to the decision problem;
2. to resolve the complexity of the decision environment into the simpler parts of which it is constituted;
3. to identify all the individual elements relevant to the decision outcome, and formally define the scope and limits of the decision environment;
4. to identify structure and functional relationships between the identified elements, including sub-systems of elements and relationships, and to sequence elements, actions and emergent outcomes;
5. to identify subsidiary decision points in the sequence, and subsidiary parallel action structures ('swimlanes') that emerge from these decision points;
6. to identify external inputs into the decision framework required to inform internal decision points;
7. to develop the alternative set defined above, with its relevant input factors and relationships;
8. to construct an action framework as a business process map that identifies a logical sequence of actions and outcomes which, working through subsidiary systems and decision points, assembles the information required by the decision maker as input to the subsequent stages in the decision making process (financial model, decision table) and leads to a final decision;
9. to identify elements or variables in the decision framework which are most subject to uncertainty as input to a systematic analysis of uncertainty for outcomes;
10. to identify points in the decision analysis sequence where subjective judgement and subjective factors are material; and
11. to identify the set of stakeholders - including community, political, governmental, business or community - most influenced by or most contributing to the decision, and the nature of their interests in the decision outcome, and to display the nature of their relationships to elements and structures of the decision framework.

The informal logics underpinning the decision map are as follows (Heim and Kratzer 1998, Partee et al. 1990):

> *Sets*: the identification of elements relevant to the decision; the allocation of elements to category sets under denotational rules; the development of a hierarchy of sets; and the relationship of sets of elements constructed under the rules to each other, to larger sets in the hierarchy, and to the decision framework as a whole.

Relations: specification of the functional, structural or temporal relations between pairs of elements, viewed as processes, assembled as sequences.

Binary logic: Yes/No decision points in relational sequences.

Software support for decision mapping is now widely available, and includes Microsoft Visio, which was developed to support Gane-Sarson methodologies, and is the graphical platform for the decision mapping that was used in this project.

6.1.2 The decision mapping approach in context

Standard risk assessment and risk management frameworks applied in the Local Government context have so FAR been largely qualitative, with some general ratings and rankings on likelihood and frequency estimates. For example, one local UK authority that has taken a lead on climate change adaptation is the City of London (Bara et. al. 2010). Since the early 1990s, the City has been developing a practical risk management framework, in consultation with its major stakeholders. Key risks identified are flooding, water resources, heat and air pollution, and ground conditions. Adaptation options are then categorized under modified risk management rules (p. iii):

- 'No-regrets' measures deliver benefits that exceed their costs, whatever the extent of climate change;
- Low-regrets' measures are low cost, and have potentially large benefits under climate change;
- 'Win-win' measures contribute to climate adaptation and also deliver other benefits; and
- 'Flexible' measures are useful for dealing with uncertainties in the extent of longer-term climate change.

An informed, qualitative risk rating method is employed (p. 19):

> *The risk rating method involves considering the two components of risk: likelihood of hazard; and magnitude of consequence (impact). The likelihood assessment relates to the probability of the hazard occurring over the lifetime of the particular asset or service in question. The magnitude is based on a qualitative assessment of the consequence of the hazard, by considering four categories of consequence: health, social, economic, environment.*

A simple risk rating matrix is then used to prioritise the risk as very high, high, medium or low. Policy, practical action, and research options are then developed for each of the major risk areas.

Other UK agencies have followed a similar path. The Department for Environment, Food and Rural Affairs (DEFRA 2009; 2011) has established a framework of risk assessment (by frequency and impact, risk management options, and aggregated risk reduction. The Environment Agency has implemented a parallel process in its Strategic Environmental Assessment (Environment Agency 2008; 2011 a, b).

In Australia, the Municipal Association of Victoria's stocktake of Local Government climate change adaptation planning (Municipal Association of Victoria 2011) identified a decision process that consisted of risk assessment (impacts and likelihood ratings), actions on high priority risks, and benefit-cost assessments by risk-management rules.

In contrast, the approach of the current project is both analytic and quantitative. The decision mapping technique allows for a rigorous, detailed analysis of the challenges, or problems, presented to local management by climate change, of the risk and uncertainty associated with the variables that characterise it, and of the options open to Local Government in the management of risk. The decision mapping analysis process generates quantitative input into the financial model. With this data and analysis in hand, the final decision can be made by Local Government, using risk management rules, Multi-Criteria Analysis or another multi-dimensional decision framework.

6.2 The Project Decision Map

6.2.1 Introduction

While there is significant evidence to suggest that sea levels will rise over the next 100 years, the scientific predictions of 'how much' and 'how soon' are not certain. On the other hand, the literature review has revealed how difficult it can be for Councils to make decisions in the face of political and financial liability. These uncertainties make it difficult for Councils to decide how and when to act in relation to existing assets in the coastal zone. The purpose of the Decision Map below is to set out a systematic process whereby a Council might proceed to collect data, assess liability, and finally to evaluate options for dealing with potential impacts from sea level rise. The Decision Map does not provide an answer to the problems of inundation or coastal erosion as a result of climate change, but progressively refines the definition of the problem and provides quantifiable data in the form of financial costs that can be used to inform decision making.

The Decision Map was the product of a lengthy iterative process. Initially it was designed by the project team as a flowchart tool to describe the stepwise progression of defining the hazards of coastal climate change impacts and the collation of necessary data. The tool was then tested from a theoretical perspective by a wider technical panel and referred to representatives from the case study Councils for further revision. Further revisions were then undertaken using data from one of the case study sites and the tool further refined into a Decision Map to represent a clear and efficient decision process. One of the key rules applied to the Decision Map was that data should not need to be collected until it was very clear that it was necessary to the subsequent step. A key learning from this process was that understanding legal liability for damage or loss is central to the process, with several subsequent steps relying on a good understanding of this stage in the process.

The Decision Map has six stages:

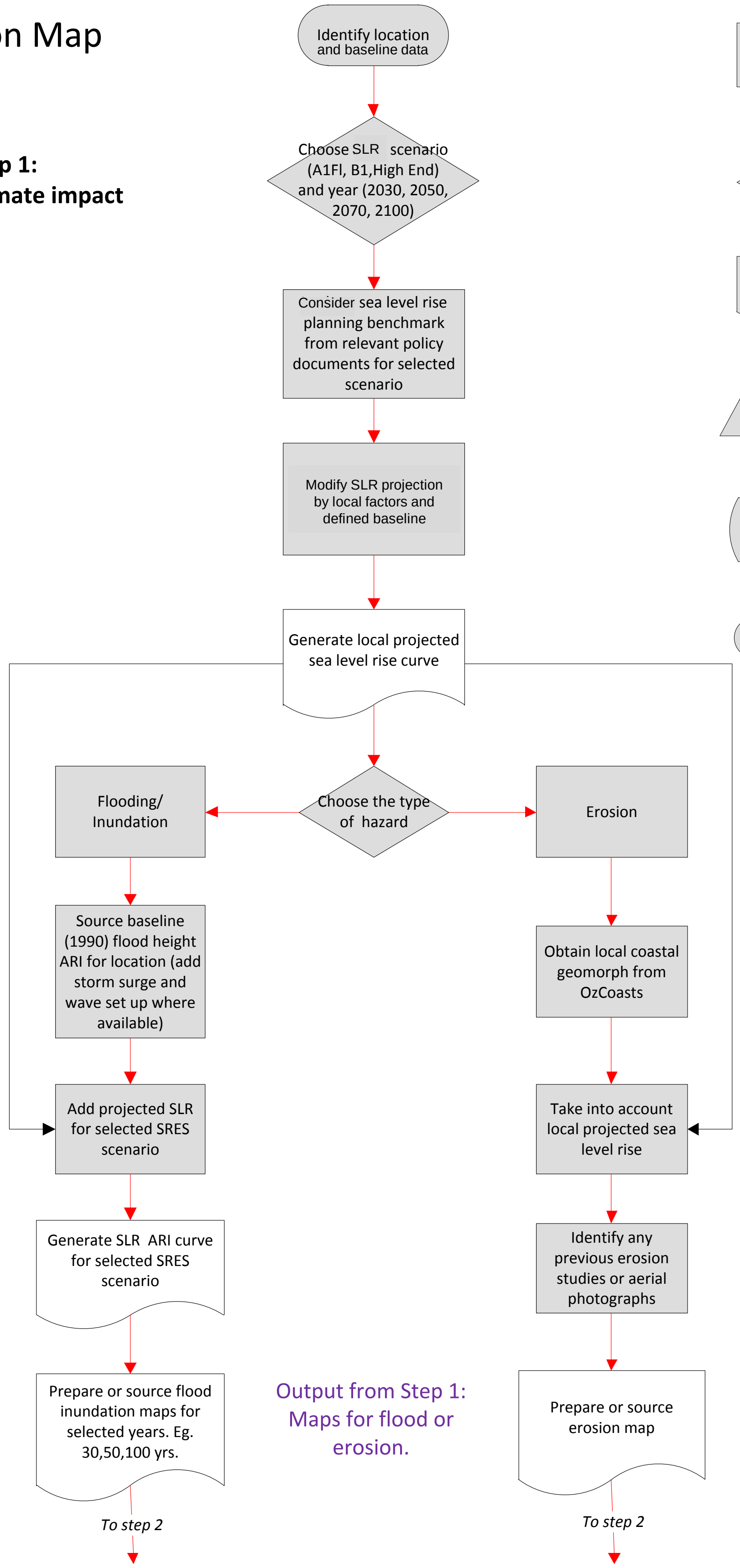
1. analyse the climate impact;
2. analyse existing protection structures and strategies;
3. establish the profile of assets at risk;
4. determine Council liability;
5. determine monetary value of assets at risk; and
6. analyse actions.

Each of these stages is outlined in the Decision Map that follows and described in detail in the remainder of the chapter.

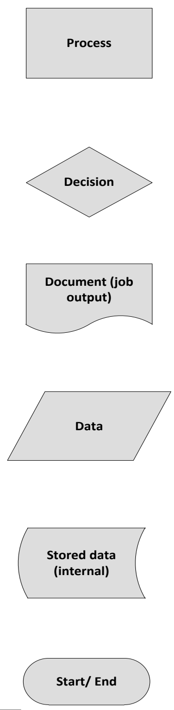
Coastal Adaptation
Decision Pathways

Decision Map

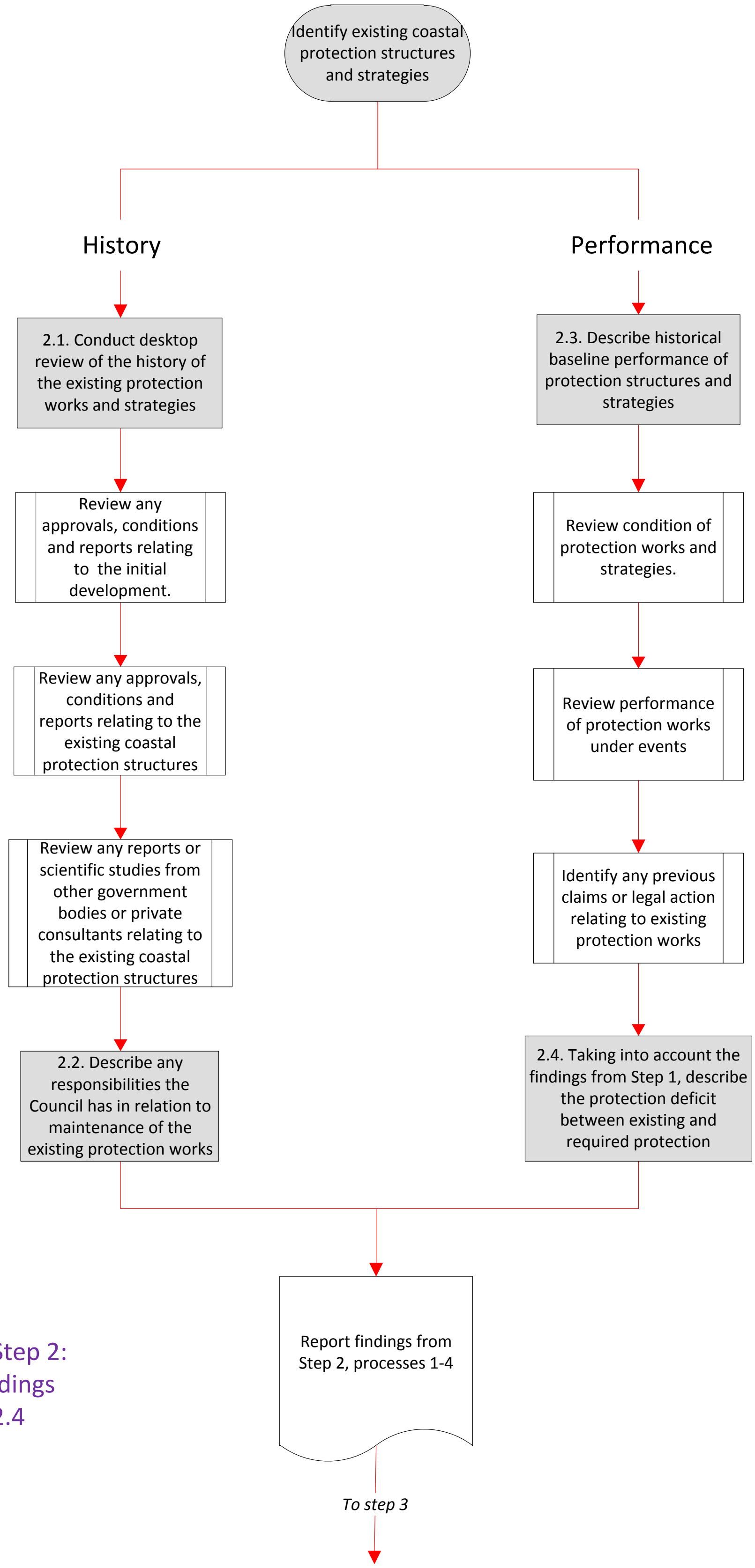
Step 1:
Analyse climate impact



Flowchart Shapes Key

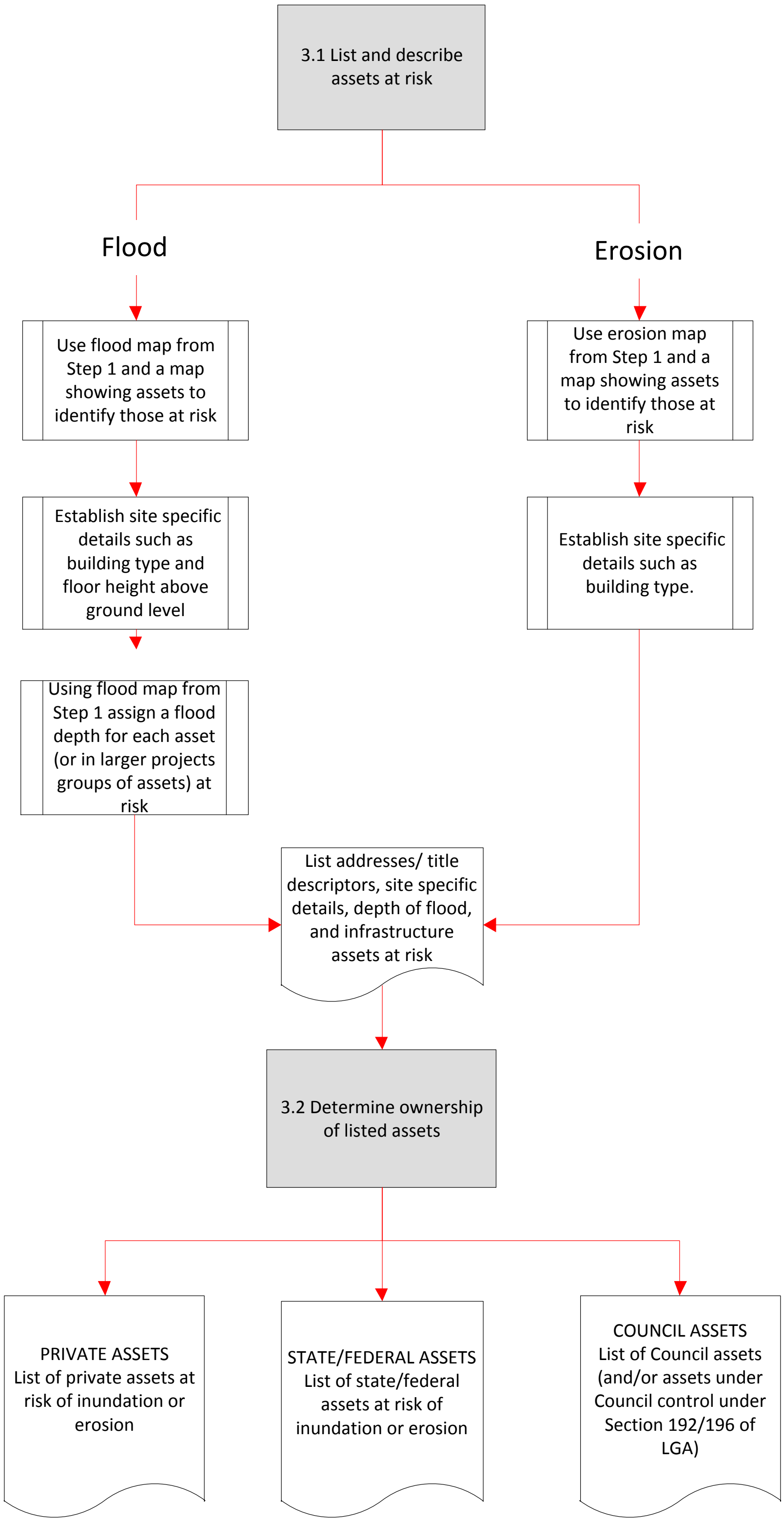


Step 2: Analyse existing protection structures and strategies



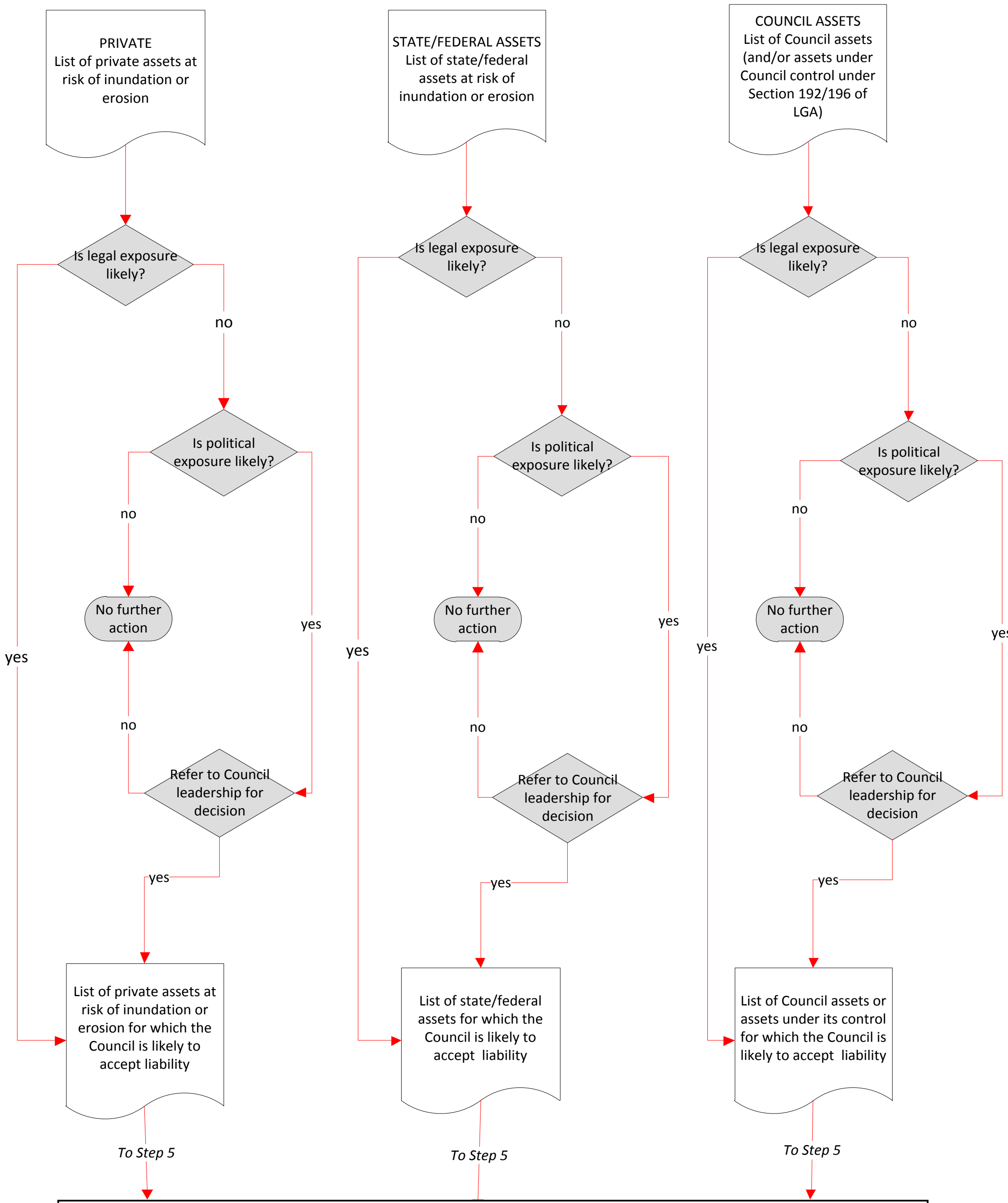
Output from Step 2: Report of findings from 2.1-2.4

Step 3: Establish profile of assets at risk



Output from Step 3: List of assets that includes location descriptors, ownership, and where appropriate, site specific details such as building type.

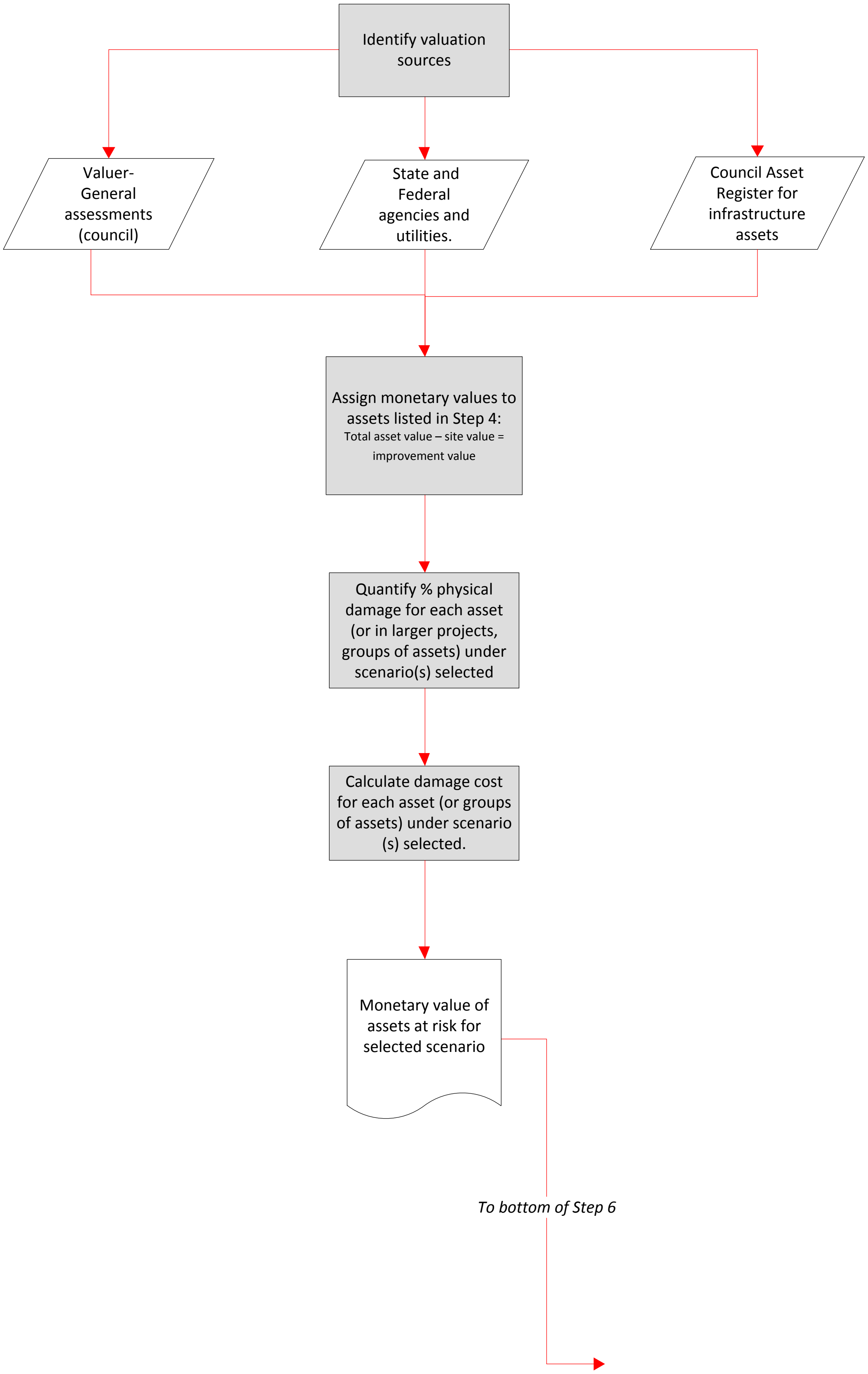
4. Determine Council Liability



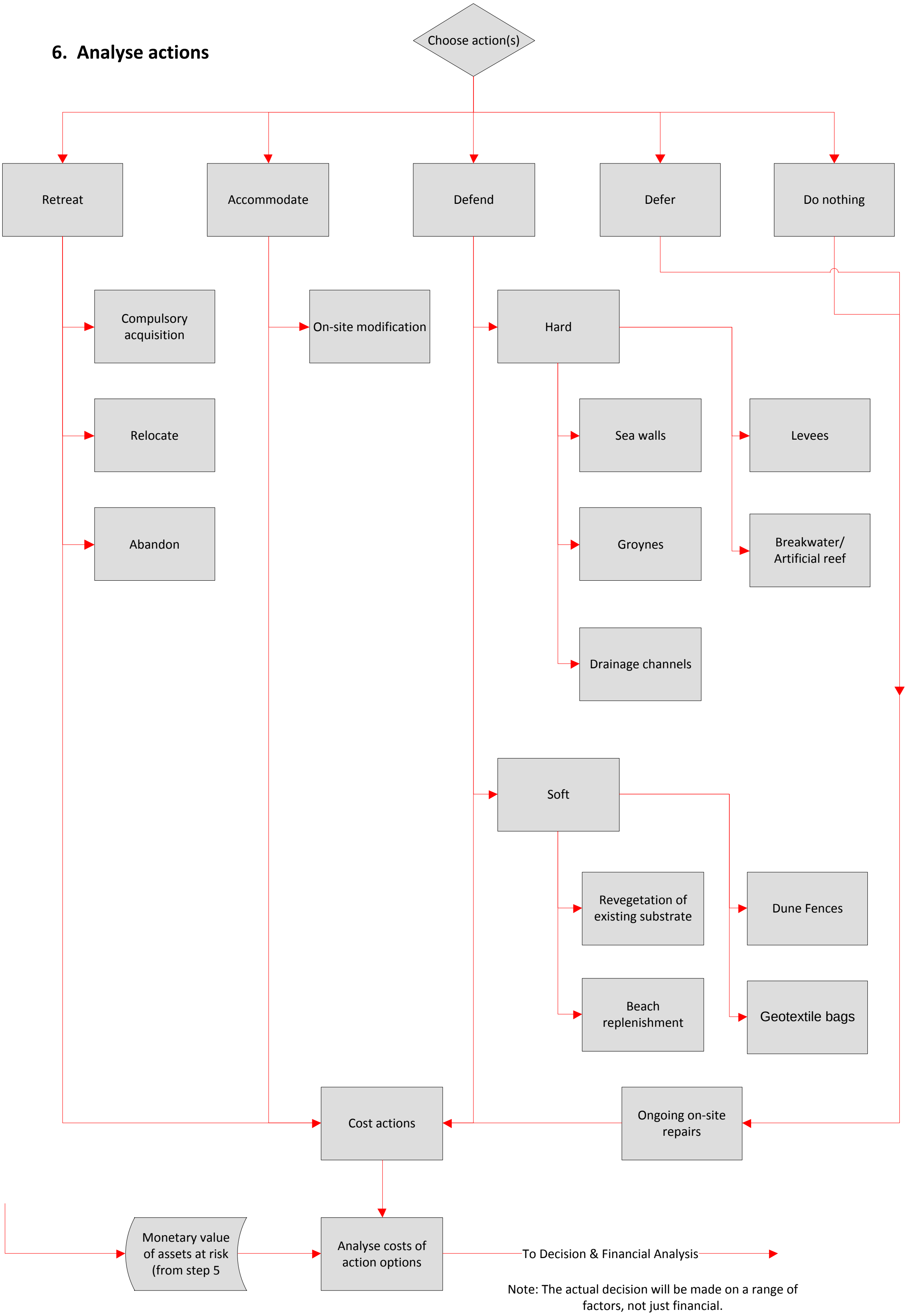
Check point: There may be two conclusions drawn at Step 4 that may bring the process to a close. The first may be that the council liability may be minimal and the cost of any action is not justified. Conversely, the liability of the council may be deemed to be major but the cost of action is out of reach. In either case, the Council has a duty of care to warn its constituents. These warnings may be generic warnings about the impacts of climate change, specific warnings targeted to locations under threat, or the institution of emergency action procedures.

Outputs from Step 4: A list of assets for which Council is likely to accept liability. This may be supported by a range of other outputs, including legal opinions, results from consultation with public, directives from council leadership.

5. Determine monetary value of assets at risk



6. Analyse actions



6.3 Step 1 – Analyse Climate Impacts

The two primary coastal hazards associated with climate change, and examined within the scope of this study, are inundation (flooding) and coastal erosion.

6.3.1 Inundation / Flood

Coastal inundation occurs as a result of a number of factors that together result in a total local sea water level that exceeds the natural or artificial defences. Factors include the slow topographic changes in the coastal land itself as a result of either uplift or subsidence, changes in water height as a result of tides and storms measured as the probability of a particular water height occurring (or the average recurrence interval (ARI) of a particular water height), wave run-up and wave set-up as a result of wind and topographic effects and sea level rise as a result of anthropogenic climate changes. In this project we have considered each of these components so as to be able to calculate the probability of periodic high water events and the resultant flood. Contributions from freshwater are not considered in this study but may, in the event of excessive rainfall or stream flows, provide additional water to a sea water flood event.

To be accurate enough to determine if a particular site on the coast is inundated (and hence determine potential damage costs), each of the contributors to total water level needs to be measured relative to the land (or elevation zero) for the location that is to be assessed. In addition, the elevation of the site and the height of the floor of buildings also need to be known for the calculation of damages. Unfortunately, these data are not always available for the identified site or at a vertical resolution fine enough to accurately quantify these measures and so estimates will need to be made. Complications arise as a result of the different baselines used for each measurement - both in time, because the sea levels have been and will continue to rise, and in the measurement of the vertical due to changes in the land and techniques for determining elevation and the Australian Height Datum (AHD). For these reasons the first step in analysing the climate components is to identify the location and define the baseline, both height (for example Geocentric Datum of Australia (GDA) AHD) and time (e.g. 1990 when the sea level rise projections start), to then ensure that all measures remain relative to the baselines for the calculations of total water height.

Once the site and baselines have been defined, the necessary measurements for each contributor to total high water level will need to be made (or estimated) for the site as many of the factors are locally specific. Added to the baseline measurements is a sea level rise between the baseline year and a defined future year. For example, sea level rise can be determined by either consulting a sea level rise projection (A1FI for the year 2100 = 0.79 metres) or by selecting a sea level rise height based on policy or other parameters (South Australia = 1 metre by 2100).

Once the baseline measurements are defined and the sea level rise projection selected, then inundation maps will need to be generated to show those areas that will be flooded. In most cases the inundation maps generated will be ‘bathtub’ or ‘bucket fill’ maps that project a total water height across the landscape - and should include the locally specific contributors to total water height and selected sea level rise projections. The maps do not take into account changes in water depth as a result hydraulic processes such as constrictions to water flow, natural or artificial protections that prevent water from entering a low lying area until breached, or other complex processes such as interactions with freshwater flow or erosion. For these reasons, local topography and other influences need to be understood before those areas shown as inundated on the map can be confirmed to be at risk of inundation. In addition, the resolution of maps is sometimes low and so there are errors associated with calculating exact areas of inundation in response to sea level rises at intervals less than 0.2 metres in most locations and as much as 0.5 or 1 metre in others (Figure 20 and Figure 21 - maps of coastal vertical resolution around Australia).

Once the flood maps have been developed and verified, then the damage costs resulting from flood events of varying depth at the site can be determined - a process described in more detail in the following Decision Map steps.

6.3.2 Erosion

Erosion is more difficult to quantify than flood and is dependent on numerous local influences including bathymetry and topography, geomorphology of the coastline, longshore drift and the availability of sediment for beach recharge among other things. In addition, although coastal erosion often results in response to an extreme storm surge event, models for predicting erosion are based on changes in mean sea level and so only provide long-term projections of coastline recession rather than 'real time' estimates. In addition, some sections of the coast are already eroding as a result of the observed sea level rise over the past century and from geological processes in play for thousands of years. So, as for inundation and flooding, the first step in analysing the climate components of erosion is to define the location and the baseline data and year against which to compare calculations of future sea level rise and erosion.

Models for predicting coastal erosion (e.g. the Brunn rule) are as yet simplistic equations for estimating the interaction of the complex coastal processes described above. Currently they are driven primarily by changes in mean sea level and other topographic and bathymetric parameters and do not consider extreme events, the average recurrence interval of high water events, wave run up or wave set up are not generally considered in the determination of erosion recession rates. The Smartline database as part of the OzCoasts project described in Section 4.2 has assessed the geomorphology of the Australian coast with the aim of providing guidance on likely stability of the shore but estimates for erosion particular sites will still need to be made at the local level to provide useful estimates. As for flood events, a map depicting the recession line of the erosive edge will need to be prepared to identify those properties at risk from erosion and can be generated either on the basis of erosion modelling or the continuation of observed erosion rates.

In South Australia, the Coastal Protection Branch of the DENR is able to provide the necessary measurements for locations in the state. Flood inundation maps are available for some locations. Further details on each of the contributors to inundation and erosion including a schematic that shows the relationship between then and calculations for determining threshold events is given in the modelling section of the report (Chapter 7).

6.4 Step 2 – Analyse Existing Protection Structures and Strategies

6.4.1 The rationale

There are two main reasons for analysing existing protection works and strategies:

1. An analysis of existing protection works and strategies will provide the Council worker with a historical context early in the assessment process. The original development application and conditions of approval for the implementation of the works will provide information on the science that was used, the options considered, the rationale for the adopted approach, and the engineering specifications used in the construction of the works. Additionally, any conditions of approval relating to the ongoing maintenance of the protection works will be more easily identified. A review of subsequent Council records and correspondence will inform whether the protection works have been breached or repaired, or whether the Council has fulfilled its maintenance obligations over time.
2. The policy review found a potential for increased liability for Councils where protection works have been implemented. The UK government has recognised this factor and has ordered a review of all protection structures with the express purpose of divesting itself of as much liability as possible. In the Byron Shire Council v Vaughan; Vaughan v Byron Shire Council (No 2) NSW [2009] legal case, the court found that the Council had failed to maintain the protection works in accordance with the conditions of approval it had granted itself. Therefore, to review the circumstances of the implementation and historical performance of the existing protection works, and whether any maintenance obligations have been fulfilled will begin to create an early picture of Council liability.

6.4.2 The process

The process involves two main investigative areas that can be completed in any order. One area to investigate is the original Development Application for the settlement and/or for the protection works and strategies. This initial investigation will lead to other reports such as scientific reports, engineering reports, and correspondence between the Council, other agencies and the developer. Additionally, any conditions of approval, such as who was to be responsible for the ongoing maintenance of the protection works, will be identified as part of this step.

The second main area to investigate is how the works have performed over time. A visual inspection of the protection works is recommended and a photo record established of any suspected deficiencies. A review of Council minutes and general records will reveal whether there have been any reports commissioned that relate to the section of coast under review, or whether there have been any incidents where breaches of the protection works have occurred.

If it is ascertained that the Council had a responsibility to maintain the protection works, a check should be made to ensure that these have been carried out properly.

To date, litigation in relation to existing development has been very limited, but this may not be the case in the future. Therefore, a review of any court cases or claims made against the Council in relation to actions of the sea is advised.

Finally, taking into account the data from Step 1, describe the protection deficit between the existing and required protection.

While the collection of the data above may be achieved at the Council level, a suitably qualified professional may be required to make and assessment of the protection works.

The output from Step 2 should include a report or reports detailing:

- a summary of the circumstances in which the original protection works were constructed;
- a description of any obligations the Council had to maintain the works and whether these have been met over time;
- a list of any incidents where the protection works were breached or where claims for compensation have been made against the Council that relate to the existing protection works; and
- a description of the protection deficit that takes into account the data from Step 1 and describes where the protection works are likely to fall short of what will be required with rising sea levels and increased inundation and erosion events.

It is recommended the Steps 3-5 then be completed before any time and expense is allocated to finding remedies for any perceived deficiencies.

6.5 Step 3 – Establish Profile of Assets at Risk

6.5.1 The rationale

The purpose of this stage of the Decision Map is to identify all the assets whether in public or private ownership that may be at risk from sea level rise and to characterise these. Two factors are important at this stage. First to identify the level of risk or damage to specific assets or asset groups (an example of an asset would be a group of houses), and second to identify the ownership of these assets.

6.5.2 The Process

Identify the level of risk or damage to specific assets

The process to identify the profile of assets at risk from inundation and erosion vary slightly and are explained here separately. Despite the differences, a spread sheet was found to be the best way of recording the relevant data

Inundation

When assessing a flood scenario, the flood map(s) from Step 1 are used to identify all assets that will be affected by the greatest depth of flood in the chosen flood scenario. A cadastral map can be used to identify and record allotments upon which various assets are situated. Public assets such as roads and footpaths should be recorded separately. The various flood lines on the flood map from Step 1 will indicate the depth of flood. Use the flood line that represents the greatest depth of flood and record the depth of flood of each asset. Use a topographical map to cross check the depth of flood. It is important to note, that even with the flood at its greatest height, the depth of flood at specific sites will vary, depending on their elevation above sea level. Record the depth of flood for each asset in a spread sheet such as that illustrated below (Table 5).

A site visit will probably be necessary to determine site specific characteristics that are not able to be determined from mapped records. These factors may be critical in determining the extent to which land and buildings are flooded, and therefore the extent of the damage. For example, a site inspection may reveal that the bench under a building has been elevated, or the building is of light weight construction and is situated on poles or stumps. A simple observation of how many steps are required to enter the building will give a guide to the height of the floor above natural ground. Other examples where site specific characteristics may need to be taken into account is in multi storey buildings where flood damage may be contained to the bottom storey. These site specific adjustments should be entered into the spread sheet (Table 5). Surfaced and unsurfaced roads are likely to suffer different degrees of damage from flooding, and so these differences, which may not be apparent from maps, should also be recorded.

Once the data is collected it should be possible to assign a flood depth for each asset (house, road, infrastructure item). With small area studies (say less than 200 dwellings) it should be possible to record each property's details. With larger areas, it may be necessary to aggregate data on properties (e.g. most dwellings in a particular flood depth zone are lightweight construction and raised on (0.5 metres piles).

Table 5: Example spread sheet output from Step 3 for a flooding scenario.

Property Address			Construction Type	Notes (if any)	Sea Flood Depth	Site specific Factors	Total Sea Flood Depth
Str. no.	Lot no.	Street Name	V; LWC; TR; PH; BR*.		Depth from flood map using ARI 100 year flood (mm)	above/below natural ground (mm)	Modified by site specific factors (mm)
1		The Esplanade	BR	Elevated bench	1000	600	400
3		The Esplanade	LWC	On 400mm stumps	800	400	400
5		The Esplanade	PH	Pole house.	1200	2500	-1300

Erosion

Using the erosion map(s) from Step 1 identify all assets that will be affected by erosion for each increase in mean sea level. As with inundation scenarios, a cadastral map will be useful in identifying and recording allotments upon which various assets are situated. Public assets such as roads and footpaths should be recorded separately.

Identify the ownership of specific assets

The final stage in Step 3 is to assign ownership of the assets identified. Ownership should be grouped in three categories - private assets, state/ federal assets and Council owned assets. Records of assets should be capable of being separated by ownership for subsequent analysis.
A spread sheet (as set out in Table 5) that includes property details (either singly or grouped), construction type, details of finished floor levels and flood details taken from the Step 1 maps is an appropriate output from this step. It is recommended that a separate sheet is developed for each ownership category.

6.6 Step 4 – Determine Council Liability

While the issue of liability has been touched on in Step 2, in relation to existing protection works Step 4 deals specifically with who is liable for the assets at risk.

The Rationale

Liability to Councils comes under two broad categories. The first is legal liability. A Council that accepts legal liability for an asset may face claims for future damage to that asset from its owners. If liability has not been clearly established such claims may result in legal action where the Council may have to spend time and money to defend itself in court, and then pay damages if it loses the case.

The second liability is political liability. The policy review found that governments can come under significant pressure to install protection works and other measures, regardless of whether they are legally obligated to protect assets belonging to others or not. The Byron Bay case study demonstrated the amount of pressure the Council found itself in the media spotlight on a national stage. Nevertheless, the policy review noted a strong trend for Governments at a National and State level (in Australia) is to shift liability on to individual asset owners.

Baker and McKenzie (2011) provide both an insight into the range of actions where a Council may be exposed and the limitations of exposure. For example, the responsibility of Council may be limited to simply warning its constituents of a potential risk.

Additionally, the Council needs to evaluate the legal consequences of taking a course of action as the implementation of new protection works may incur a new range of liabilities.

In summary, it makes logical sense to first ascertain what legal liability exists before ascertaining whether there is any political liability. This finding will at least enable the Council to act from a position of strength if it can be determined that legal liability is unlikely in the given scenario.

The process

At the outset it needs to be recognised that the determination of Council liability is normally a specialist legal task. Therefore, the Council worker responsible for overseeing this step is likely to act as a facilitator rather than decision maker and the process is likely to be more fluid than exact.

There are three classes of assets as identified at Step 3:

- privately owned assets;
- assets owned by other governments or government agencies; and
- assets owned by Council (or under control of Council).

In relation to the first two classes, it is necessary to ascertain whether there is any legal liability. This matter should be referred to the legal department of the Council or to external legal personnel where there is no internal advice available. Once a legal opinion has been obtained, the matter should be referred to the Council leadership if there is the potential for legal liability, or if it is likely that political liability may eventuate.

In relation to assets owned by Council, or under the control of Council, the Council will have a responsibility to protect its financial investment. The matter should be referred to the asset manager within the Council and as some of these assets will be insured, the matter should be referred to those that manage the Council's insurance cover as well.

At the conclusion of this step, the Council should have ascertained if it is liable for assets owned by others should flooding or erosion eventuate or whether it is just responsible for its own assets.

Once liability is clear, the Council may decide to cease the process at the end of this stage either because the risk is deemed to be minor or because the threat and potential liability may be so large that it is judged beyond the Council's control to mitigate the risk. Whatever the level of risk, the Council has a responsibility to warn its constituents and such a warning will assist the Council in limiting its liability (Baker and McKenzie 2011). In situations where new development is allowed in areas at risk from inundation, conditions of approval may ensure that emergency action plans are prepared by the resident. While the Council does this out of concern for the safety of its constituents, it is also the ultimate 'warning' to the resident that they are putting themselves at some risk and almost eliminates Council liability. Equally, implementing emergency action plans in existing development deemed at risk from actions of the sea will also act as a significant warning to residents. This strategy would be similar to those implemented for developments in bush fire zones.

6.7 Step 5 – Determine Monetary Value of Assets at Risk

6.7.1 The rationale

The purpose of this stage of the Decision Map is to determine a dollar value for all of the assets that have been identified as at risk to flood or erosion and for which the Council considers it has some responsibility or liability (Step 4). All assets previously considered, for which Council does not accept liability, can be excluded from consideration in this step.

6.7.2 The Process

Various sources of data are potentially useful. Central to the process will be the Councils' own asset register of Council owned property and infrastructure. The State Valuer General's list which records rateable values is also likely to be a useful data source especially for residential properties and land. State and or federally owned assets, such as major roads, airfields and waste water treatment plants may require approaches to the relevant agencies to ascertain appropriate values. Where large sites or areas with significant numbers of assets or properties are under scrutiny, a grouping of assets by value may be necessary. In the case of Valuer General's property data, usually both the capital value (the total value of the land and any structures) and the site (or land) value is available. The site value subtracted from the capital value gives the improvement value (i.e. the value of the buildings or structures on the site). Improvement value needs to be calculated in each case because periodic flooding is likely to affect only this aspect since it has no permanent effect on site value. However, erosion is likely to affect the capital values as it can potentially destroy both land and buildings.

Assessing the value of loss or damage in monetary terms depends on the nature of the problem (flooding or erosion), the sea level rise estimate, depth of flood and the nature of the affected asset. In erosion cases loss of land may occur separately from loss of buildings, with varying financial implications but in most erosion cases total loss of land and assets will be the eventual outcome. Damage curves are normally applied by insurance companies to assess flood damage to buildings. The extent of damage is normally expressed as percentage of total building value and depends on flooding depth (Middelmann-Fernanades 2009) (Figure 26).

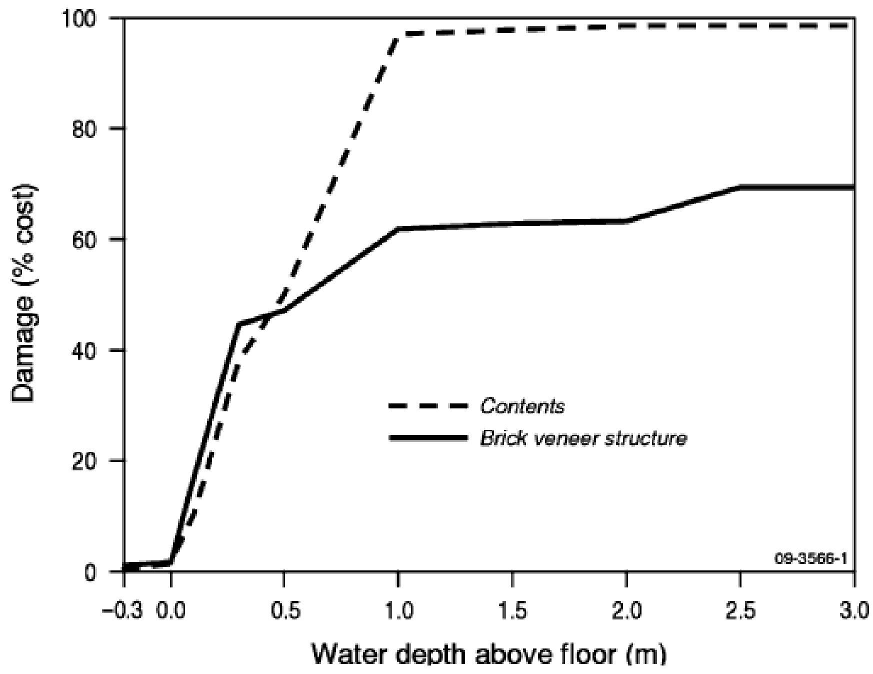


Figure 26: Stage-damage structure and contents functions for single-storey residential buildings (Source: Dale, unpublished).

A damage curve like Figure 26 above can be used to derive estimates of the cost of damage to buildings at different flood depths. However, various types of infrastructure assets such as roads, pipelines, fences and outdoor structures will need to be assessed separately and some damage estimates made before costs can be quantified. Roads and some other infrastructure items may suffer minimal damage from flooding, but could be seriously affected by erosion. There may also be a difference between damage levels inflicted on sealed and unsealed roads from flooding. These localised and asset specific aspects need to be determined before values are input to a financial assessment tool. Councils may hold data on damage estimates or may need to refer to professional advice from engineers or insurers in particular cases. The final stage in Step 5 is to total all the monetary values and input these to a financial assessment tool. In this project, the data were entered to the financial model developed. Table 6 below provides an example of a flood scenario and calculations of damage in relation to flood depth. This example provides a typical output from Step 5.

Table 6: Presentation of data to estimate flood damage to a building.

l Sea Flood Depth	Flood depth above FFL (in five scenarios)					Value of assets (land and improvements - land = value of improvements)			Value of assets under threat (in five scenarios)				
fied by site ific factors (mm)	Depth at 1.00m SLR flood scenario	Depth at 0.80m SLR flood scenario	Depth at 0.60m SLR flood scenario	Depth at 0.40m SLR flood scenario	Depth at 0.20m SLR flood scenario	Land and improvements	Land value only	Value of improvements	Damage $ at 1.00m SLR flood scenario	Damage $ at 0.80m SLR flood scenario	Damage $ at 0.60m SLR flood scenario	Damage $ at 0.40m SLR flood scenario	Damage $ at 0.20m SLR flood scenario
400	400	200	0	0	0	$350,000	$190,000	$160,000	$72,000	$64,000	0	0	0
400	400	200	0	0	0	$280,000	$175,000	$105,000	$47,250	$42,000	0	0	0
-1300	0	0	0	0	0			$0	0	0	0	0	0

6.8 Step 6 – Analyse Actions

6.8.1 The rationale

Step 6, the final step in the Decision Map, is designed to present and analyse the range of alternative actions as explained in the theory (Section 6.1 above). It is designed to be a clear and useful set of choices which can inform policy outcomes. By tabulating and making explicit the requirements of different actions, dollar values may be attached and a comparison of these may be used to arrive at an appropriate policy pathway. It should be noted at this point that because of the inclusion of uncertainty and complexity, compounded by the need to consider the standpoints of multiple stakeholders and objectives, the financial cost of these alternative actions may not prove to be the only or the most important variable in reaching an agreed policy direction. For example, the preservation of a sandy beach because of its social value may eliminate other options that in pure monetary terms are more cost effective.

6.8.2 The process

The Decision Map sets out five parallel pathways or 'swimlanes' that may be taken to respond to the rising sea level threat to existing coastal developments. These options have been derived from the literature review and represent an exhaustive set of alternatives grouped as retreat, accommodate, defend, defer or do nothing. As such they cover the full spectrum of possible actions. Each option is then broken down into subsidiary actions or decisions. For example, the choice of a defend strategy requires subsidiary choices regarding the nature of hard or soft defence mechanisms and within these, further technical choices such as using beach nourishment or revegetation within a soft option pathway. Councils should follow each action choice in turn and ascribe relevant cost and value data from steps 1 to 5 for each alternative. So for example, using a retreat option the relative costs of compulsory acquisition, relocation or abandonment should be recorded. These costs should include the capital value of private properties, the cost to Council of abandoning infrastructure (in some instances, such as a waste water treatment plant, it would need to be relocated elsewhere) and any income forgone by such action (e.g. loss of rateable income to Council). In every case it should be noted that Council liability has already been determined in Step 4, so there should be no debate necessary in Step 6 about which costs to include. All recorded costs should be ones that Council considers it has a legal or political duty to bear. When complete, Step 6 provides outputs that can be used in two ways. Firstly, it allows Council to view a tabulated breakdown and comparison of the relative cost of all five potential actions pathways. Secondly, for this project the step provides input into the financial modelling tool, which can further analyse these alternatives by assessing the risks attached to each action.

7 DEVELOPMENT OF THE FINANCIAL MODEL

7.1 Real Option Analysis

The term "Real Options" can be traced to Myers (1977), who first identified investments in real assets as mere options. A real option is a permit with different value at different time periods to undertake some business decision, typically an option to make a capital investment. For example, an opportunity to invest in the expansion of a firm's factory is a real option. In contrast to financial options a real option is not tradable - e.g. the factory owner cannot sell the right to extend his factory to another party, only he can make this decision. The terminology "real option" is relatively new, whereas business operators have been making capital investment decisions for centuries. However, the description of such opportunities as real options has occurred at the same time as thinking about such decisions in new and more analytically based ways.

Real options analysis has become a key management tool for many of today’s businesses. It is an accurate method for estimating the value of corporate investments and it can be effectively used in situations where management has flexibility in large capital budget decisions with high uncertainty.

Business conditions are fraught with uncertainty and risks. These uncertainties hold with them valuable information. When uncertainty becomes resolved through the passage of time, actions, and events, managers can make the appropriate midcourse corrections through a change in business decisions and strategies. Real options incorporate this learning process (Mun 2006, p16).

In contrast, the traditional discounted cash flow analysis assumes a static investment decision, and assumes that strategic decisions are made initially with no recourse to choose other pathways or options in the future.

Simulation is any analytical method that is meant to imitate a real life system, especially when other analyses are too mathematically complex or too difficult to reproduce. One type of spread sheet simulation is Monte Carlo simulation, an analysis that randomly generates values for uncertain variables over and over to simulate a real life model. Monte Carlo simulation is an important tool for valuing real options due to their complexity nature.

In a recent study, Linquiti and Vonortas (2011) use a Monte Carlo simulation model to test the strategy for two coastal cities in developing counties and find that, under certain circumstances, a real option strategy has the potential to reduce the costs of adapting to climate change.

Climate change has been hotly debated for many years, in part due to the high uncertainty associated with future projections over the longer time frames. Coastal Councils are facing two major challenges as a result of climate change. One is inundation, which is driven by storm surge and sea level rise, and the other is erosion, driven by mean sea level rise. Both forces are likely to lead to significant, even disastrous, asset damage along the coastal zone. With limited resources Councils need tools to identify the most cost effective options to reduce potential damage into the future. Given the level of high uncertainty in sea level rise and storm surge, it was considered by the team that a real options approach would provide the best approach with which to model future climate change scenarios and risk mitigating responses.

7.2 Model Flow Chart - Flood Model

The inundation event is driven by total water height as a result of local factors including storm surge events and sea level rise. We calculate costs associated with the following five strategies:

1. **Do nothing:** maintain the status quo and no further protection action is taken;
2. **Inflexible:** make the protection height decision once for the next 90 years;
3. **Sense and respond:** make the protection height decision every year. If inundated in the past year, then increase the protection height by a defined amount, e.g. 0.5 metres the next year;
4. **Predict and respond**: make the protection height decision once every 10 years based on available data. If inundated during the 10 year period, then increase protection height by the maximum flood height (at least 0.5 metres); and
5. **Retreat:** Councils buy out the properties to avoid any future damage.

Note that the retreat strategy does not have any uncertainty as we assume that the asset values will be constant in real terms over the time. Thus, retreat now is always preferred to retreat later. However, the upfront retreat costs are not necessary the same as the Valuer General's identified value for each site. Other factors such as disruption in people's life, market price fluctuations and legal costs may mean significant variation from the Valuer General values. Also, to encourage residents to retreat, it is possible that the Council would have to pay an additional monetary incentive to get people to move.

In addition to the above strategies, there is the option to accommodate flood events. With the accommodate strategy, we assume that the buildings and other assets are modified to avoid / reduce the flood risk. One example of possible modifications is to raise the house floor level by certain amount. As modification costs are too difficult to estimate for the simulation, we decided to exclude the accommodate strategy from evaluation and provide instead a single flat cost to accommodate the whole study site as was done for retreat.

In sum, the simulation model will focus on the first four strategies for financial valuation while the remaining two will be provided as estimates in real terms for retreating or accommodating the entire settlement at risk. The overall approach is illustrated by the flow chart in Figure 27 on the following page.

Note that the initial year in the modelling of the case study locations was taken as 2010. This is due to lack of financial data for years prior to 2010. Given that the available climate forecasts extend to the year 2100, and we wanted to model the worst case scenario as the example, the end of the century was selected as the terminal year for our modelling. Thus the modelling period is 90 years.

The selection of discount rate is based on the following considerations:

- Councils differ from commercial firms in having low financial risk. Thus, the discount rate should be close to the risk free rate. This is often measured in Australia by the long-term government bond yield;
- Over the period from 1971 to 2008, the average rate of return on the 10-year government bond is 9.2% while the average inflation rate during the same period is 6.2% based on the data from Reserve Bank of Australia). Thus, the average real rate of return over the period is about 3%;
- The current interest rates (around 2010) in Australia are low compared to historical interest rates; and
- We evaluate the climate change impacts over a longer period of 90 years.

We thus arrive at a discount rate of 2.85% which is slightly lower than the average real rate of return on the 10 year government bonds over the period from 1971 to 2008. Of course, the discount rate for different Councils can be slightly different and it can vary over time for the same Council. Thus, the discount rate can never be precise and can be a contentious issue. As the discount rate is a variable in the model that can be changed, a sensitivity analysis can be carried out with respect to the discount rate if necessary. However, in the context of this report, the results from the case studies do not appear to make it necessary.

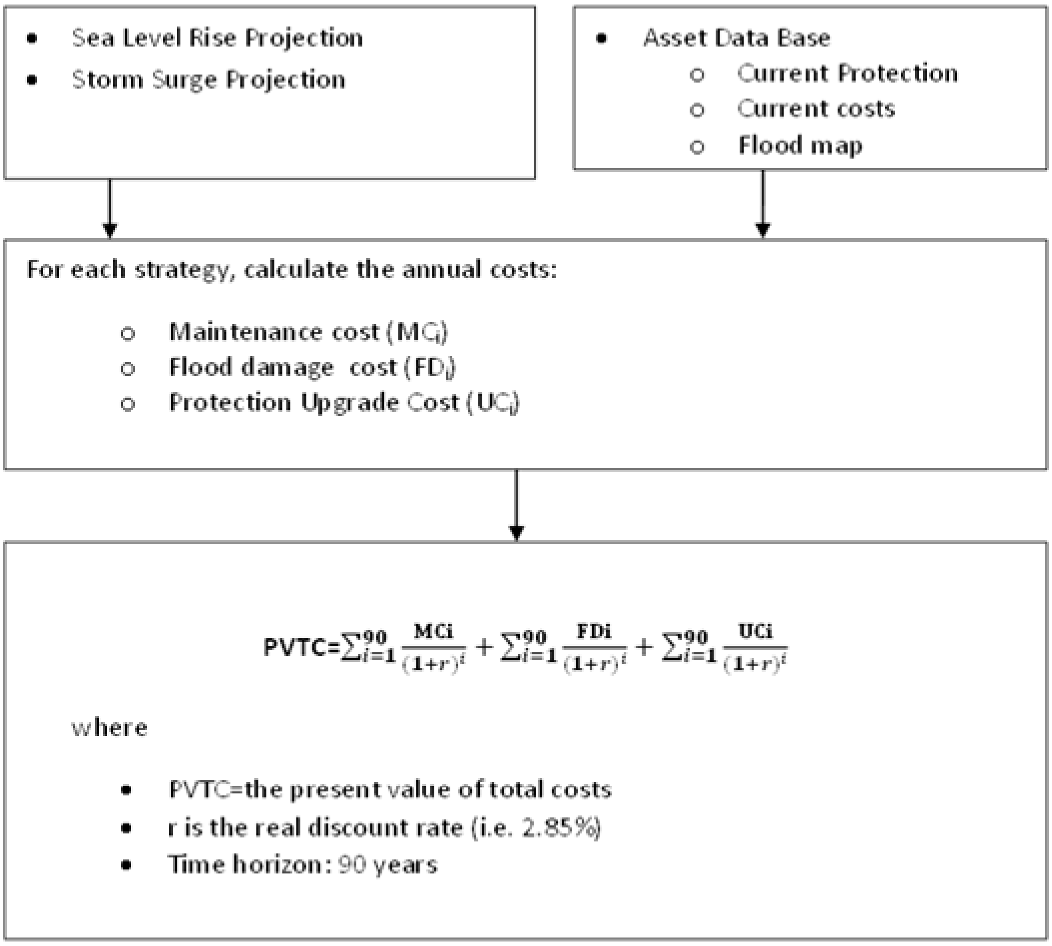


Figure 27: Flow chart of processes and calculations embedded in the real options Monte Carlo simulation inundation model developed.

7.3 Flood Calculations in the Model

To model the height of a sea flood event at a particular location on the coast there are a number of contributors to total water height that must be taken into account. In the development of the financial model these factors were grouped into three types:

- Local effects include adjustments for the local mean sea level relative to the Australian average mean sea level for a particular site, the average recurrence interval of high water events, and local terrestrial subsidence or uplift.
- Sea level rise effects include observed local sea level rise to 1990 and projected rates of sea level rise between 1990 and 2100.
- Wave effects take into account wave set up and wave runup.

So as to determine a flood height relative to a particular point on the land measurements of sea level and land elevation are made relative to the Australian Height Datum (AHD). AHD zero is defined as the averaged mean sea level for 30 reference tidal gauge stations around the Australian coastline over the 1966 to 1968 period. AHD zero is also the zero height datum for terrestrial elevation used by surveyors up until recently and on most maps (AHD zero = terrestrial elevation zero).

> '*On 5 May 1971, Geoscience Australia, on behalf of the National Mapping Council of Australia, carried out a simultaneous adjustment of 97 230 kilometres of two-way levelling. Mean sea level for 1966-1968 was assigned a value of 0.000m on the Australian Height Datum (AHD) at 30 tide gauges around the coast of the Australian continent'* (Geosciences Australia Website 2012).

AHD is also considered the same as the average Australian Mean Sea Level (MSL), the height of the water between lowest and highest level over the period 1966 to 1968. Because of the inaccuracies associated with measuring mean sea level, surveyors and the National Tidal Centre are currently changing to the new Geocentric Datum of Australia (GDA) measurement system that uses global navigation satellite systems technology to measure the height of the sea and land relative to the ellipsoid height (a measure from the centre of the earth). In the process, the height of all Australian tide gauges have been measured relative to the GDA and adjustments between AHD and the GDA measure made. The adjustment measurements will be available from Geosciences Australia.

For a particular location on the coast, the Local MSL at the time the AHD was defined may have been marginally higher or lower than the Australian MSL. The Local MSL at any point on the coastline can be calculated relative to the Australian MSL as defined by AHD by adding or subtracting the difference between the two as an adjustment.

Added to the Local MSL at any particular location is the height of the water for a range of naturally occurring water level events as a result of tidal and storm influences. The Average Recurrence Interval (ARI) is the average period of time for which a water height of a particular level will occur and are locally specific. Water heights are expressed as an ARI curve relative to AHD and usually over a 100 year period. For example, ARI 100 is the highest measured water level over a 100 year period and would be expected to occur at a frequency of once every 100 years. These are values taken from the curve by the model randomly and simulate the natural variability of storm flood events and a distribution of total water heights (refer to Section 4.1.1 Climate Change Impacts for a full explanation of ARI curves and example graphs).

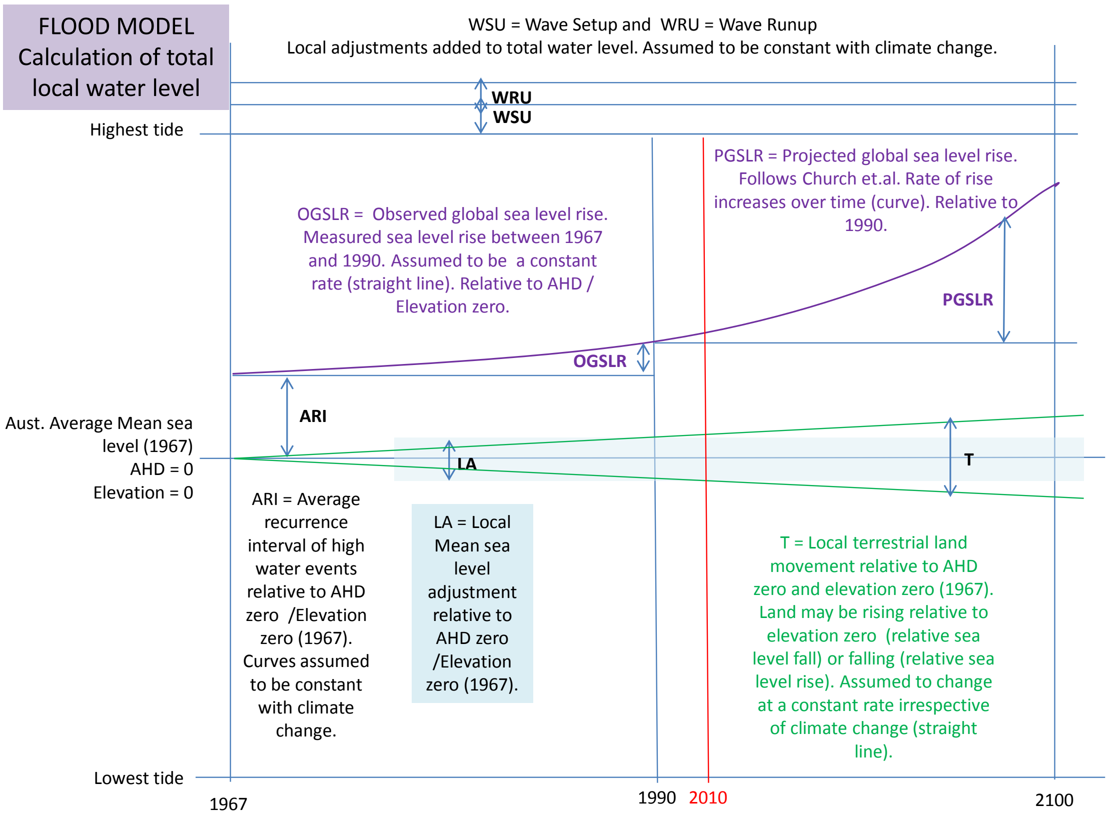
The third local effects component to consider is movement of the land. Terrestrial elevation changes (T) are the result of uplift where the land is rising relative to AHD or subsidence where the land is falling relative to AHD. In the model T is defined as the change in the land relative to AHD and elevation zero between 1967 and the year modelled. This change in terrestrial elevation is assumed to be a constant trend over time irrespective of climate change for the period 1966/68 to the year modelled.

The second group of factors refer to anthropogenic sea level rise. Observed Global Sea Level Rise (OGSLR) is the observed global sea level rise between 1968/68 when AHD and elevation were set to zero and 1990 when the global sea level rise projections start.

Projected Global Sea Level Rise (PGSLR) is the projected increase in global mean sea level relative to the 1990 level for future scenario years (determined by the model using sea level rise projection curves provided to the project by Church et. al. 2012). The projected local sea level rise is assumed to be the same as the global sea level rise (*pers. comm. Murray Townsend, Coast Protection Group, Department of Environment and Natural Resources, South Australia, Feb 2012*).

For some locations Local Relative Sea Level Rise (LRSLR) has been measured by the National Tidal Centre Sea Australian Baseline Sea Level Monitoring Project and is the observed sea level rise at a specific location relative to 1990 when the project started. This value takes into account two factors, global sea level rise and local terrestrial changes in the height of the land (e.g. terrestrial uplift or subsidence).

The final factors to consider are associated with waves - Wave Run Up and Wave Set Up (WRU and WSU). These measures are locally specific increases to total local water level to include the height of swell and wave heights. All of these factors are shown in Figure 28 relative to time along the X axis. The variables and equations used in the model are also defined. The year 2010 is when the model calculations start for our example outputs.



Calculation of total water level at year x = L+W+G

Where L is the local sea level calculations:

L = (ARI ± L ± Tx)

ARI = the local average recurrence interval of high water events (assumed constant relative to AHD).
LA = the local mean sea level adjustment relative to AHD (constant for each location – includes adjustment to the Geocentric Datum of Australia from Geosciences Australia where necessary).
T = the local terrestrial rebound or subsidence relative to AHD / Elevation zero (assumed to be at a constant rate for x years since 1967).

Where W is the wave components of the water level:

W = (WSU + WRU)

WSU = Wave set up (assumed constant at each location and with climate change).
WRU = Wave run up (assumed constant at each location and with climate change).

Where G is the global sea level rise:
G = (OGSLR + PGSLR)

OGSLR = Observed global sea level rise between 1967 when AHD and elevation were set to zero and 1990.
PGSLR = Projected sea level rise from 1990 to year x according to the Church et.al. curves.

Note: All values are relative to elevation zero / AHD zero / Australian average mean sea level 1967.

Figure 28: Graphical model and equations showing the components of total water height included in the simulation model to calculate the probability and cost of an inundation event.

The calculated total water height as modelled is then compared to the natural elevation at the site or base of any flood defence and the height of the flood defence system itself (in metres above

AHD and assumed to be a constant height along its length). If the modelled water height exceeds the natural elevation or flood defence height then a flood occurs. For each flood event, corresponding damages are calculated - a process described in Section 6.7.

7.4 Financial Calculations in the Flood Model

The flood model has two Excel ® worksheets. One is the *Input & Output* page (shown in six screen grab figures following) where flexible user input are inserted into the blue cells. The second worksheet is the *Flood Valuation* worksheet, in which the present value of the total costs for each strategy is calculated (not shown here).

The Local Effects section of the input screen (Figure 29) captures two data inputs relating to the the local mean sea level at the geographical point of interest and one for the impact of extreme events. The first is the difference between the local mean sea level and the the 1967 AHD against which all Australian sea levels and terrestrial elevations are measured. The second is the rate of uplift or subsidence at the site relative to AHD in metres per year. The figures are used to calculate how the local mean sea level may have changed relative to the AHD between 1967 when the height datum was calculated and 1990 when the sea level rise projections as a result of climate change begin. The rate is also used for future scenario calculations of total flood water height. The third input is the ARI flood heights at the location relative to the AHD. These figures are used to calculate the probability distribution curve of total water flood height at the site. ARI data are not used in the erosion model where erosion is driven by mean sea level only.

Local Effects					
Local 1967 Mean Sea Level adjustment relative to AHD (LA). Local MSL lower than AHD is a negative value, Local MSL higher than AHD is a positive value. This adjustment may be included in the ARI curves and should include corrections to the GDA if necessary.		**0**	m		
Terrestrial rebound / subsidence (m per year). Uplift is a negative value, subsidence is a positive value due to the relative effect on water height at the site. Calculated as an increase or decrease between 1967 when AHD and elevation were set to zero and the terminal year.		**0.002**	m per year		
Sea Flood ARI Table relative to AHD in 1967. Includes Storm surge and astronomic effects and probably local mean sea level adjustment. Check if ARI tables have been adjusted to AHD levels post 1967 and so have taken into account local mean sea level adjustments (including observed sea level rise) and terrestrial rebound/subsidence.	**ARI**	**AHD**	**AEP**		**Cum Dis.**
	1	**1.60**	0.632		0.37
	2	**1.79**	0.393		0.61
	5	**1.96**	0.181		0.82
	10	**2.07**	0.095		0.90
	20	**2.19**	0.049		0.95
NOT USED IN EROSION CALCULATIONS	50	**2.39**	0.020		0.98
	100	**2.60**	0.010		0.99

Figure 29: Flood simulation model input screen showing inputs for the local effects component of the calculation of flood height for the inundation model.

The Sea Level Rise Effects section of the input screen (Figure 30) collects data for two parameters in the model. The first is the observed local sea level rise rate in metres per year. This figure is used to calculate the total observed sea level rise at the site between 1986 when the AHD was calculated and 2010 when the model starts. The second is the terminal years for the calculation of projected sea level rise as per the Church et. al. (2012) curves.

Sea Level Rise Effects		
Observed average local SLR rate (m per year) - positive trend. This value exclues changes relative to terrestrial movement. The total observed local sea level rise will be calculated for years 1967 to 2010 when the model starts.	0.004	m per year
Terminal year (2100) for the calculation of Projected Global Sea level rise as per the Church et. al. curves. Sea level rise is calculated from 2010 to year 2100	2100	

Figure 30: Flood simulation model input screen showing inputs for the sea level rise effects component of the calculation of flood height for the inundation model.

The Wave Effects section of the input screen (Figure 31) collects data for two parameters – local wave set up and local wave runup. Both paramters are used to calcualte total water flood height. The Flood Protection section of the input screen identifies the natural elevation of the site in metres above AHD and the height in metres and value of any existing flood protections.

Wave Effects		
Local wave setup	0.1	m
Local wave runup	0	m
Flood Protection		
Natural Site Elevation (meters above AHD)	2.1	m
Current Artificial Flood Protection Height	0.5	m
Current Artificial Flood Protection Replacement Costs	$ 12,540,000	estimate

Figure 31: Flood simulation model input screen showing inputs for the wave effects component of the calculation of flood height for the inundation model and the existing flood protection height.

The Protection Composition and Costs section of the input screen (Figure 32) allow for the input of costs assoicated with constructing and maintaining a range of different flood protection works.

Protection type	Existing	Incremental	Costs of upgrade per linear meter per unit height	Maintenance cost p.a.
Revegetation	0%	0%	17.5	20%
Erosion matting	0%	0%	35	20%
Sand drift fencing	0%	0%	60	10%
Sand replenishment/revegetation	0%	0%	1200	30%
Clay Levee	100%	100%	3800	5%
Clay core plus Rock Armour	0%	0%	6530	2%
Rock Seawall (Rip-rap)	0%	0%	2730	2%
Concrete	0%	0%	10230	2%
Groyne	0%	0%	8400	2%
Accommodate (e.g. raising floor height)	0%	0%		
Total	100%	100%		
	% of the total shore length sum can be >1		unit height=0.5m	
Protection Height	0.5	1	1.5	2
Average Costs of upgrade per linear meter per unit height	4028.0	4332.0	4750.0	5244.0
Average maintenance costs (% of replacement value)	5.0%			

Figure 32: Flood simulation model input screen showing inputs for the calculation of protection height and cost options that may be put in place to prevent inundation.

The Asset Values section of the input screen (Figure 33) allows for the input of the value of assets (buildings, infrastructure and total improvements) that will be damaged for local MSL rises of 0 to 1 metre at 20 cm intervals. This screen as does others provides references to the decision map where the data for this stage of the analysis is gathered.

Local Sea Level Rise relative to 1990 (m)	Total damage cost to buildings (see Decision Map Step 5)	Total damage costs to infrastructure (see Decision Map Step 5)	Total Improvements value (Buildings + infrastructure)	Total Capital Asset Value (in 000s, including capital assets & sites value, Decision MapStep 5)
0	$ -	$ -	$ -	
0.2	$ 764,400.00	$ 80,000.00	$ 844,400.00	
0.4	$ 1,401,150.00	$ 80,000.00	$ 1,481,150.00	
0.6	$ 2,282,750.00	$ 80,000.00	$ 2,362,750.00	
0.8	$ 3,325,750.00	$ 80,000.00	$ 3,405,750.00	
1	$ 4,386,300.00	$ 80,000.00	$ 4,466,300.00	$ 17,300,000.00

Figure 33: Flood simulation model input screen showing inputs for the calculation of asset values that may be damaged in the event of inundation.

The final four inputs to the model are captured in the Other Model Parameters section of the input screen (Figure 34). They are the current year of the analysis, the terminal year for the analysis, the discount rate applied, the minimum protection height increase that would be implemented for the Sense and Respond and Predict and Respond strategies of protection and the total protection height increase for a one off Inflexible strategy of protection.

Current year	2010
Terminal year	2100
Discount rate	2.85%
Minimum Protection Height Increase	0.5
Protection Height Increase for inflexbile strategy	0.8

Figure 34: Flood simulation model input screen showing inputs for the calculation of simulation years, discount rates and protection heights.

The key assumptions for the flood model are as follows:

- all cost figures are in real terms;
- the initial year is 2010 and the time frame is up to 90 years (2100);
- all sea level heights are relative to AHD;
- the composition of protection works over time is assumed to remain the same;
- damage costs are obtained from the flood map;
- storm surge is a key factor and is taken into account;
- multi-flood events in a single year are not considered;
- revegetation costs are included in capital expenditure; and
- where current protection exists operating (as maintenance) costs apply.

7.5 Model Flow Chart - Erosion Model

The erosion event is driven by local MSL rise. We calculated the costs associated with the following four strategies:

1. **Do nothing:** maintain the status quo and no further protection action is taken;
2. **Inflexible:** make the protection height decision once for the next 90 years;
3. **Sense & respond:** make the protection height decision every year;
   If erosion nearly occurred in the past year, then increase the protection height by an amount, e.g. 0.5 metres the next year; and
4. **Retreat:** Councils buy out the properties to avoid any future damage.

Note: that the Predict & Respond strategy is not considered, as if an erosion event occurred it would be too late in hindsight to remediate the damage associated with the loss of land as well as infrastructure and buildings. Thus, we assume that erosion is not managed retrospectively on the basis of 10 year evaluations as a periodic flood event might. Instead, the decision to protect against erosion is made each year to see whether enforcement is necessary.

The overall approach is illustrated by the flow chart in Figure 35 below.

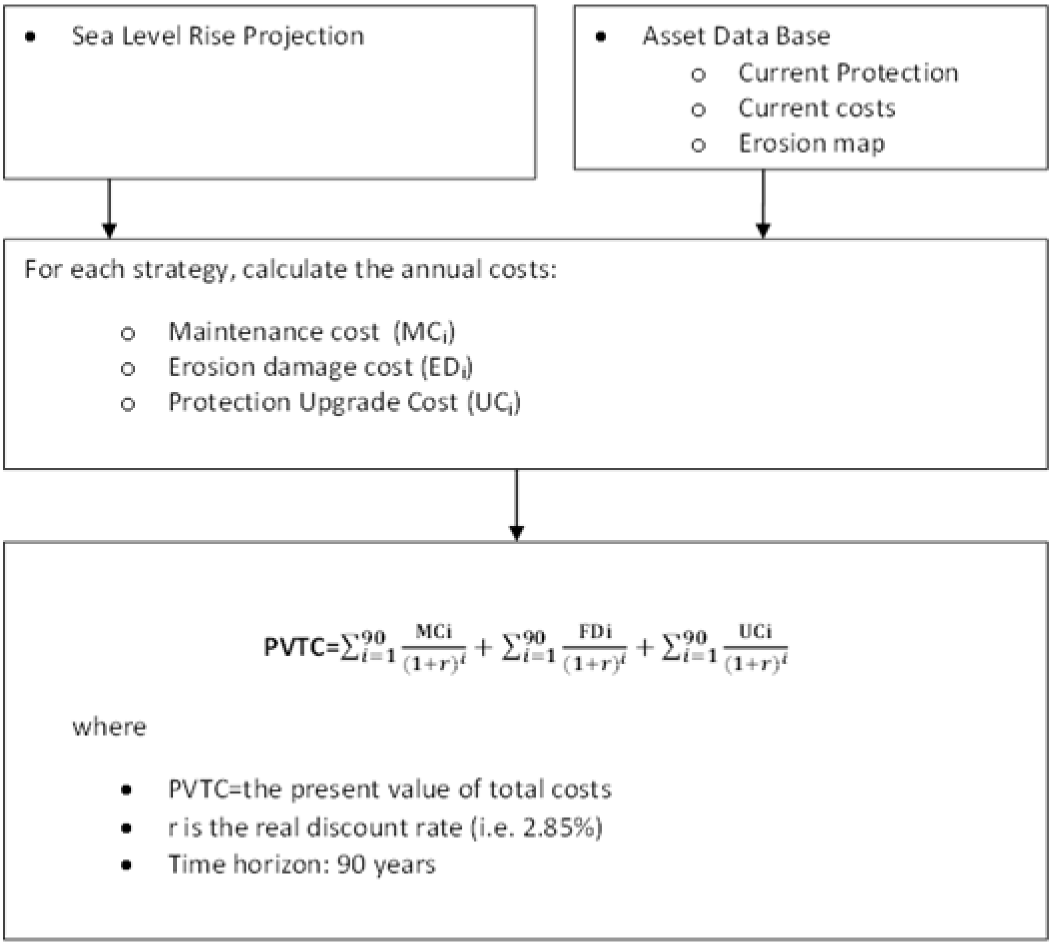
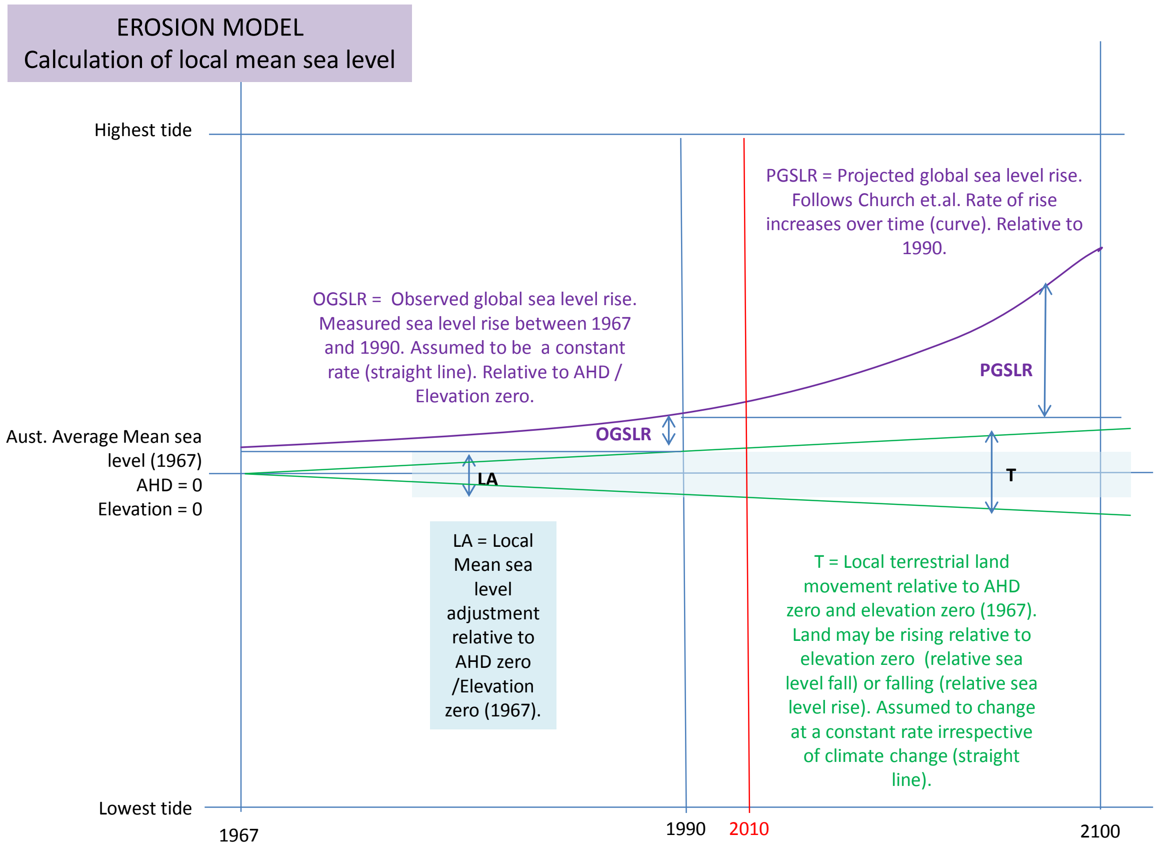


Figure 35: Flow chart of processes and calculations embedded in the real options Monte Carlo simulation erosion model developed.

The current year, terminal year and discount rate are similarly selected as for the flood model.

7.6 Erosion Calculations in the Model

Erosion is driven by changes in local mean sea level and projections of future coastal recession as a result of erosion use this parameter only and not total high water level (see Section 4.2 for a complete description of erosion processes and the models). Local mean sea level in the model is calculated as shown in Figure 36 as a function of local effects and sea level rise. ARI curves and wave effects are not relevant. In the model when the mean sea level increased above the AHD adjusted mean sea level then erosion was assumed to occur.



Calculation of local mean sea level at year x = L+G

Where L is the local sea level calculations:

L = (LA $\pm$ Tx)

LA = the local mean sea level adjustment relative to AHD (constant for each location – includes adjustment to the Geocentric Datum of Australia from Geosciences Australia where necessary).
T = the local terrestrial rebound or subsidence relative to AHD / Elevation zero (assumed to be at a constant rate for x years since 1967).

Where G is the global sea level rise:
G = (OGSLR + PGSLRx)

OGSLR = Observed global sea level rise between 1967 when AHD and elevation were set to zero and 1990.
PGSLRx = Projected sea level rise from 1990 to year x according to the Church et.al. curves.

Note: All values are relative to elevation zero / AHD zero / Australian average mean sea level and 1967.

Figure 36: Graphical model and equations showing the components of mean sea level included in the simulation model to calculate the probability and cost of an erosion event.

Erosion rates are usually drawn on a map as a series of coastal recession lines (lines to which the erosive edge will move to) and are determined by calculating the recession rate via observation or estimation using an erosion model. Existing rates of erosion are included in the maps to take into account sea level rise prior to 1966/68 in locations where the profile of the beach was not stable at that point. Erosion calculations are in most cases limited to sandy beaches.

7.7 Financial Calculations in the Erosion Model

The erosion model has two worksheets. One is the *Input & Output* page and as for the flood model it allows flexible user input information as illustrated in the snapshot below. The second is the *Erosion Valuation* worksheet, in which the present value of the total costs for each strategy is calculated (not shown here).

As for the flood model input page, the Local Effects section (Figure 37) captures data inputs relating to the the local mean sea level at the geographical point of interest - the difference between the local mean sea level and the the 1967 AHD and the rate of uplift or subsidence at the site relative to AHD in metres per year. ARI flood heights for the location are not needed for the erosion model.

Local Effects		
Local 1967 Mean Sea Level adjustment relative to AHD (LA). Local MSL lower than AHD is a negative value, Local MSL higher than AHD is a positive value. This adjustment may be included in the ARI curves and should include corrections to the GDA if necessary.	0	m
Terrestrial rebound / subsidence (m per year). Uplift is a negative value, subsidence is a positive value due to the relative effect on water height at the site. Calculated as an increase or decrease between 1967 when AHD and elevation were set to zero and the terminal year.	0.002	m per year

Figure 37: Erosion simulation model input screen showing inputs for the local effects component of the calculation of erosion water height for the erosion model.

As for the flood model, the Sea Level Rise Effects section of the input screen (Figure 38) collects data observed local sea level rise rate and the terminal years for the calculation of projected sea level rise as per the Church et. al. (2012) curves.

Sea Level Rise Effects		
Observed average local SLR rate (m per year) - positive trend. This value exclues changes relative to terrestrial movement. The total observed local sea level rise will be calculated for years 1967 to 2010 when the model starts.	0.004	m per year
Terminal year (2100) for the calculation of Projected Global Sea level rise as per the Church et. al. curves. Sea level rise is calculated from 2010 to year 2100	2100	

Figure 38: Erosion simulation model input screen showing inputs for the sea level rise effects component of the calculation of flood height for the inundation model.

The Erosion Protection section of the input screen identifies height and value of any existing erosion protection measures (Figure 39).

Erosion Protection			
Current Artificial Erosion Protection Height		0.48	assuming site elevation=4.5
Current Artificial Erosion Protection replacement costs	$	6,097,393	estimate

Figure 39: Erosion simulation model input screen showing inputs for existing erosion protection height.

As for the flood simulation model, the Erosion Protection Composition and Costs section of the input screen (Figure 40) allow for the input of costs assoicated with constructing and maintaining a range of different erosion protection works.

Protection type	Existing	Incremental	Costs of upgrade per linear meter per unit height	Maintenance cost p.a.
Revegetation	0%	0%	17.5	20%
Erosion matting	0%	0%	35	20%
Sand drift fencing	0%	0%	60	10%
Sand replenishment/revegetation	0%	0%	1200	30%
Clay Levee	100%	100%	3800	5%
Clay core plus Rock Armour	0%	0%	6530	2%
Rock Seawall (Rip-rap)	0%	0%	2730	2%
Concrete	0%	0%	10230	2%
Groyne	0%	0%	8400	2%
Accommodate (e.g. raising floor height)	0%	0%		
Total	100%	100%		
	% of the total shore length sum can be >1		unit height=0.5m	
Protection Height	0.5	1	1.5	2
Average Costs of upgrade per linear meter per unit height	4028.0	4332.0	4750.0	5244.0
Average maintenance costs (% of replacement value)	5.0%			

Figure 40: Erosion simulation model input screen showing inputs for the calculation of protection height and cost options that may be put in place to prevent erosion.

The Asset Values section of the input screen (Figure 41) for the erosion model allows for the input of the value of assets (total capital asset value) that will be damaged by erosion in response to a local mean sea level heights of 0 to 1 metre at 20 cm intervals. Total asset value is used as the value of the land is also assumed to be lost in the event of an erosion event, unlike for episodic flood where the land was assumed to remain undamaged. The screen also provides references to the decision map where the data for this stage of the analysis is gathered.

Local Sea Level Rise relative to 1990(m)	Erosion Map Total Capital Asset Value (in 000s, including capital assets & sites value, Decision MapStep 5)
0	$ -
0.2	$1,303,700.00
0.4	$2,607,400.00
0.6	$3,911,100.00
0.8	$5,214,800.00
1	$6,518,500.00

Figure 41: Erosion simulation model input screen showing inputs for the calculation of asset values that may be damaged in the event of erosion.

The final four inputs to the erosion model are as for the flood model (Figure 42) - the current year of the analysis, the terminal year for the analysis, the discount rate applied, the minimum protection height increase that would be implemented for the Sense and Respond and Predict and Respond strategies of protection and the total protection height increase for a one off Inflexible strategy of protection.

Current year	**2010**
Terminal year	**2100**
Discount rate	**2.85%**
Minimum Protection Height Increase	**0.5**
Protection Height Increase for inflexbile strategy	**0.8**

Figure 42: Erosion simulation model input screen showing inputs for the calculation simulation years, discount rates and protection height increases.

The key assumptions for the erosion model are as follows:

- all cost figures are in real terms;
- the initial year is 2010 and the time-frame is up to 90 years (2100);
- all sea level heights are relative to AHD;
- the composition of protection works over time is assumed to remain the same;
- erosion is driven by Local Mean Sea Level (LMSL);
- erosion occurs when the LMSL is greater than the protection height;
- the erosion model is valid for the beach erosion only;
- the model does not apply to cliff erosion, which is not considered;
- damage costs are obtained from recession lines on an erosion map; and
- where current protection exists operating (as maintenance) costs apply.

7.8 Protection Calculations in the Financial Model

The financial model allows the flexibility of considering most available flood and erosion protection options. The ones currently included in the model are:

- Revegetation;
- Erosion matting;
- Sand drift fencing;
- Sand replenishment/revegetation;
- Clay Levee;
- Clay core plus Rock Armour;
- Rock Seawall (Rip-rap);
- Concrete;
- Groyne; and
- Accommodate (e.g. raising floor height).

The costs associated with the flood or erosion protection considered in the financial model are the protection upgrade costs and the maintenance costs. The maintenance costs are calculated as a percentage of the replacement costs of the existing protection facility. The average rate of maintenance is estimated based on the current composition of protection types and assumes that the composition of protection types remains fixed. The total percentage of protection types may exceed 100% (for example in the event of sand replenishment and revegetation along the same stretch of beach).

However, the calculation for the protection upgrade costs is more complex. It depends on the existing height of the protection infrastructure (assumed to be a constant height along its length). Thus, height / area costs factors were introduced and estimated by engineers for each protection type. Together with the proportion composition of each type, we can calculate an "Average Costs of upgrade per linear meter per unit height" which is then used in the financial calculations.

The protection length is assumed to be a function of the sea level rise for both flood and erosion modelling. This information is included in the protection length versus sea level rise tables in the model. The protection upgrade is contingent on the occurrence of flood / erosion events. A minimum protection height increase (0.5 metres) deemed to be economically sensible is assumed.

7.9 Damage Calculations in the Financial Model

The complexity and difficulties of flood modelling in Australia are well recognised:

> *With the average annual cost of floods estimated at $377 million, floods are Australia's most expensive natural hazard. As a result, considerable expenditure is made by government and industry to define flood areas in an effort to reduce the impacts of floods. This work typically involves the creation of reports describing the methodology used, data sources and results of hydrological and hydraulic modelling and damage assessments. While numerous reports are developed each year, there was no centralised record of what studies had been undertaken in Australia at a state / territory or national level until the development of the Australian Flood Studies Database in 2004. In 2009, Geoscience Australia reviewed the Australian Floods Studies Database via an online questionnaire.* (Middelmann-Fernandes 2010).

The issue of estimating flood damage is extremely complex as damage varies as result of a range of factors such as flood depth, water velocity, water quality, silt content and duration of flood, etc. Dale et. al. (2004) report on the application in Australia of 'Black's Curves', otherwise known as stage damage curves, seek to evaluate the damage risk in respect of the flood depth and water velocity required to shift a house from its foundations. The work from the 1970s was originally carried out in the USA and subsequently has been widely cited worldwide. It relates mainly to riverine flooding where water velocities may be substantial. However, with periodic inundation from the sea we might assume that velocity is low and duration is short, so the most important variable is likely to be depth (*pers. comm Jon Kellett, Associate Professor School of Natural and Built Environments, University South Australia. April 2012*).

Stage damage curves are generally employed to assess the total cost of damage to both structure and contents when depth is taken as the only or most critical factor influencing damage (Middelmann-Fernandes 2010). According to this article for a standard single storey brick veneer construction dwelling damage costs to the structure rises steeply from 0 to 45% as flood depth increases from 0.0 metres to 0.3 metres. A 0.3 metres flood is likely to cause damage to the structure costed at 45% of value, at a depth of 1 metre the cost increases to 60% of structure value and 100% of contents. Damage costs to structure increase slightly to about 70% of value for depths above 1 metre. Damage to contents commences at over 0.0 metres and rises steeply to 95% at 1 metre flood depth (Figure 43 below).

It should be noted that the damage percentages given in the chart are crude estimates as a result of the range of factors mentioned above that might affect the amount of total damage compared to 100% damage when the whole structure is washed off its footings. The percentages do not take into account any remedial measures that might be taken such as the removal of contents or stacking contents on tables to raise them above flood level.

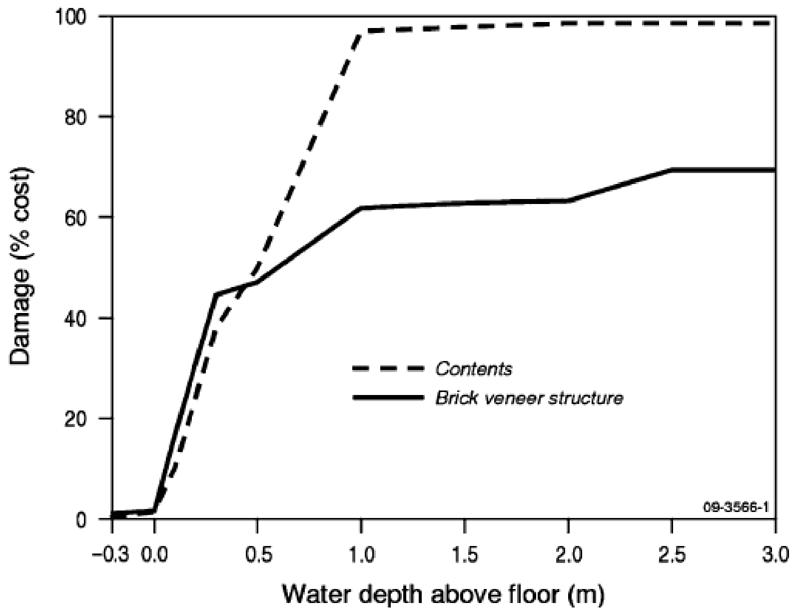


Figure 43: Stage damage structure and contents functions for single –story residential buildings (Source: Dale unpublished).

The curves were used to define the cost of damage in response to an inundation event resulting from sea level rise of 0.2, 0.4, 0.6, 0.8 and 1 metre as read off the inundation maps and entered into the model as total asset damage costs for buildings and other infrastructure (roads, storm water, etc). The value of the land was not included in the damage assessment as it is assumed that periodic flood events will not reduce the land value. Damage is calculated each time the flood occurs as it is assumed that flood damage is reparable and the sum of each damage added to provide a total at the end of the simulation.

For erosion, damage costs were assumed to be equal to the value of the land that has eroded and the total value of any assets upon the land. For erosion then, damage occurs only once as it is assumed that the land and damaged buildings are not able to be repaired.

The damage calculations in the model are, then, based on the flood map and erosion map information, and are reflected in the "Asset Value vs. SLR" tables for flood and erosion, respectively. In the model, whenever a flood (erosion) event occurs in a year, the sea level rise of that year is used to search for the corresponding flood damage costs from the "Asset Value vs. SLR" table. The Asset Value versus SLR tables were calculated for both the Thompson Beach and the Christie Beach using the approach described here.

An advantage of the approach is that we can base our study on the most recent flood and erosion study by experts, but also means that the results are highly dependent on the accuracy of the flood map and erosion map.

7.10 Calculation of Total Costs for Each Option

In calculating the total costs of each flood protection strategy, we proceed in the financial model as follows:

- simulate the water level derived from the ARI curve;
- calculate the total water level based on the above simulated figure and other adjustments including sea level rise as per the Church et.al. (2012) curves, local effects and wave setup etc;
- calculate flood depth which is defined as the total water level minus the sum of natural site elevation and protection height;

- determine if an inundation occurs for each year (it does only if the flood depth >0);
- calculate the flood damage costs if a flood occurs;
- determine if a protection upgrade is needed, if so, calculate the upgrade cost;
- calculate the maintenance costs; and then
- sum the total PV of future costs.

The above procedure is done for each of the relevant protection strategies (do nothing, inflexible, sense and respond, predict and respond, accommodate). The simulation gives us a distribution of the present value of the total costs.

In calculating total costs of each erosion protection strategy, we proceed in the financial model as follows:

- simulate the annual sea level rise based on the projections by Church et al (2012);
- calculate the local SLR based on the above simulated figure and local effects;
- calculate erosion depth which is defined as the difference between local SLR and the artificial protection height;
- determine if an erosion occurs for each year (it does only if the erosion depth >0);
- calculate the erosion damage costs if erosion occurs;
- determine if a protection upgrade is needed, if so, calculate the upgrade cost;
- calculate the maintenance costs; and then
- sum the total PV of future costs.

The above procedure is done for each protection strategy. The simulation gives us a distribution of the present value of the total costs.

In each case the assumptions for flood and erosion calculations apply and the composition of protection options remains fixed, and damage costs are input as per the flood and erosion map assessments determined in Step 5 of the Decision Map process.

8 CASE STUDY TRIAL AREAS

Two case study Council areas in South Australia were selected as pilot areas to collaborate with the project team in the development and testing of the decision support framework, tools and models - the District Council of Mallala and City of Onkaparinga (Figure 44). The District Council of Mallala north of Adelaide is a low population, rural Council while City of Onkaparinga to the south of Adelaide is a large, metropolitan city municipality.

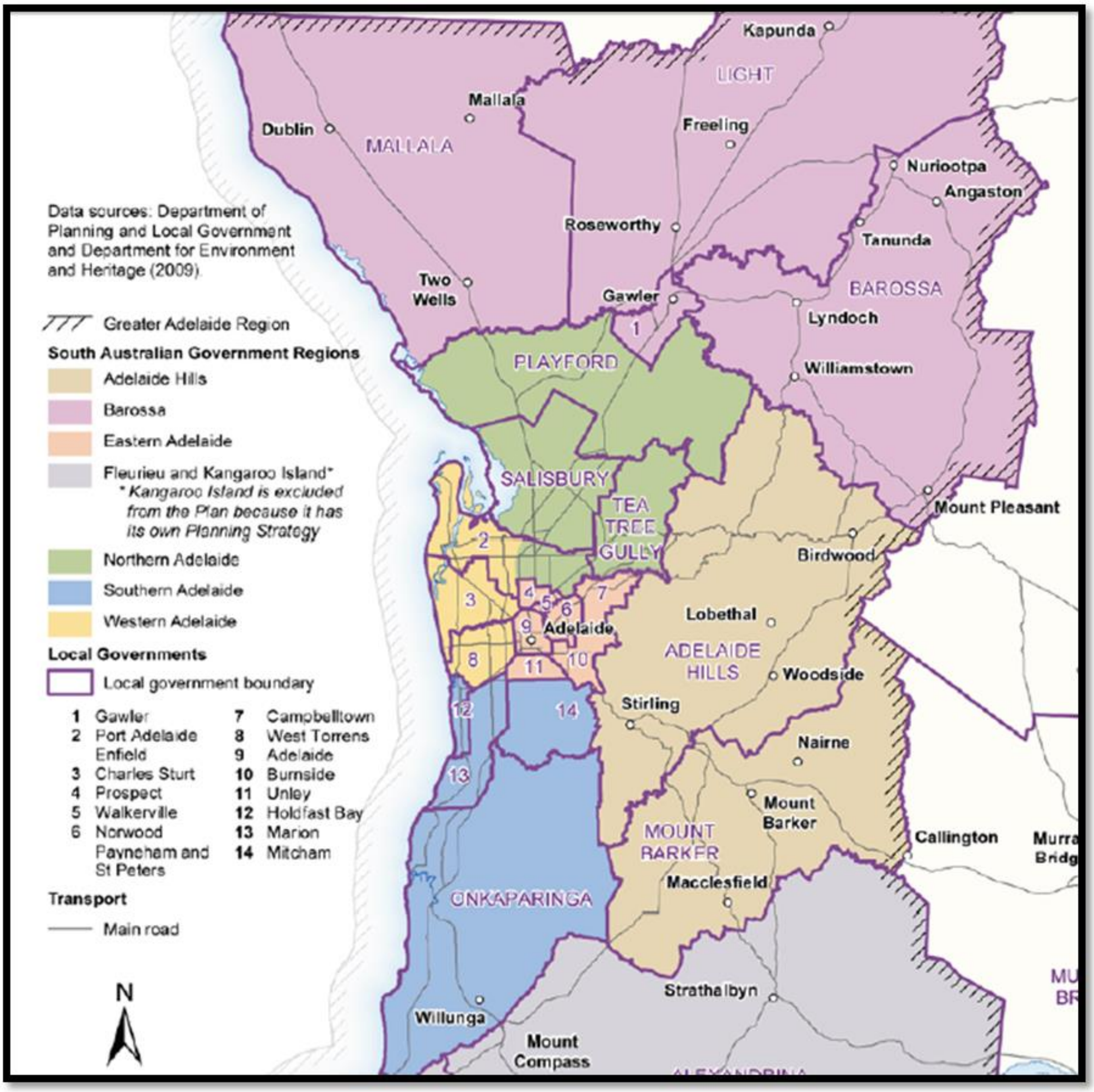


Figure 44: Local Government Areas (LGAs) of South Australia showing the location of the two case study Council areas: District Council of Mallala to the north and City of Onkaparinga to the south of Adelaide City Council (Source: South Australian Government 2010).

The two Councils were chosen as case study areas for a number of reasons. Mallala is located at the extreme northern end of the Adelaide metropolitan region and Onkaparinga the extreme southern end and display quite different topographical characteristics. Mallala is flat and low lying with substantial evidence of tidal flooding for significant distances inland even at the present time. Onkaparinga has rolling coastal topography with substantial cliffs and sandy beaches that are subject to continued erosion. Mallala's coastal zone is comparatively sparsely populated with small relatively low value settlements and little public infrastructure. Onkaparinga has substantial population resident in the coastal zone along with very significant public assets such as recreation facilities, waste water treatment and a recently constructed desalination plant. Lastly, Onkaparinga has invested heavily in research studies to inform policy development whereas Mallala has been constrained by lack of resources and consequently has much less information at hand to develop policy (Table 7).

Table 7: Overview of characteristics of City of Onkaparinga and District Council of Mallala.

	Mallala	Onkaparinga
Location	55 km north of CBD	32 km south of CBD
Planning designation	Barossa	Southern Adelaide
Population	8,500 (Approx.)	164,800 (Approx.)
Council Area	926 km^2	518 km^2
Coastline length	35 km	31.2 km
Climate Change Policy	No Specific Policy	Climate Change Strategy 2008-2013
Coastal controls in Development Plan (DP)	Coast Protection Board policies implemented in DP.	Coast Protection Board policies implemented in DP.

8.1 District Council of Mallala

8.1.1 Overview of the study area

The District Council of Mallala is situated about a fifty minute drive north of Adelaide City and covers an area of 926 km^2. The Council extends north along the coast and includes extensive tidal flats along the edge of the Gulf of St. Vincent. The coastal characteristics of the District Council of Mallala include low lying dune ridges, samphire, saltmarsh and mangrove habitat and has low levels of recreational use. The interior of the Council area is essentially a flood plain that is dissected by the Gawler and Light Rivers. The predominantly rural Council has three main townships (Mallala, Two Wells and Dublin). Port Parham and Webb Beach settlements are situated to the north-west of Dublin and are small holiday/recreation settlements on the coast laid out upon an historic grid pattern with relatively large allotments, a significant number of which are vacant.

The Council has a total population of 8,500 residents (ABS 2008). The population of the district is ageing but also growing at 3.7% per annum as retirees move to the area. There are coastal settlements at Middle Beach, Webb Beach, Thompson Beach and Parnham. Projections of population growth suggest an increase to 15,650 by 2021 (6% per annum growth) based on an increase in the number of commuters from Adelaide moving to the area. The study site of Thompson Beach is directly west of Dublin and the settlement was established in the early 1990's. It is still in the early stages of development with the potential to contain many dwellings (District Council of Mallala Development Plan 2012, p. 139).

8.1.2 The natural environment

The coastline faces the Gulf of St. Vincent and consists mainly of low lying intertidal and supratidal wetlands, dune vegetation, offshore sea grass beds and naturally occurring salt lakes (Draft Samphire Coast Conservation Strategy (2003). The section of coast is known as the 'Samphire Coast' is a low energy, tidal shoreline with sedimentary deposition occurring along its' length and is colonised by extensive mangrove forests and samphire flats. Land use includes tourism, recreational fishing, crabbing, boating and swimming, shell grit mining, salt harvesting, open grazing and some cropping. The draft Samphire Coast Conservation Strategy (2003) notes the near pristine condition along much of the coast, high diversity of plant species and importance of the habitat to migratory and local shorebirds and waders. The near shore ecosystems are also an important habitat for fish, prawn and crab nurseries and support the Gulf St. Vincent commercial and recreational fisheries. The goals for the natural and built environment within the Strategic Plan state 'A natural environment that is protected, valued and enhanced and a built environment that meets current and future community needs' and includes as two of its key outcomes 'enhanced flood management and responsiveness to climate change'.

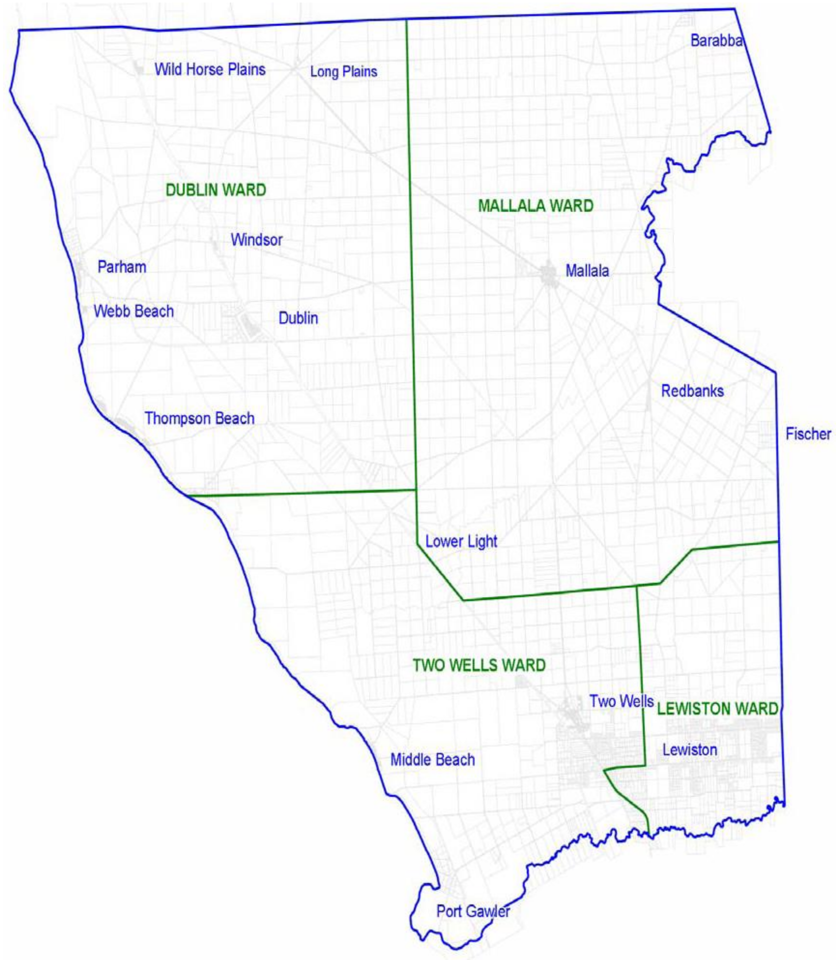


Figure 45: The District Council of Mallala (Source: DC of Mallala website).

8.1.3 Thompsons Beach

The settlement of Thompson Beach sits within a coastal landform of 'wide low tide mud flats, high tide narrow, steep, mixed sand shell grit beaches, low dunes/ beach ridges, at times narrow, backed by saltmarsh with chenier ridges usually below two metres in height that are frequent, discontinuous and varied in pattern' (Caton et.al. 2009). Two small creeks dissect the dunes to the south of Thompson Beach and allow tidal flow to the southern part of the saltmarsh (Figure 46). The area is subject to storm surge and inundation.

Figure 46: Looking east over Thompson Beach settlement, District Council of Mallala (Source: Caton et.al. 2009, Vol. 2).

8.1.4 Mallala Council Climate Change Policy

While the Council does not have a designated climate change policy or any policy that deals with sea level rise in particular, it has formed a Coastal Management Advisory Committee. In addition, the DC of Mallala Strategic Plan notes that the Council intends to 'investigate and plan for climate change at the local level' within the next few years (Mallala Strategic Plan 2011, p. 19). All local Councils are members of the LGA and so have access to the LGA MLS Climate Change Adaptation Risk Assessment project carried out in 2009. Subsequent to reviewing the Coastal Management Advisory Committee (CMAC) minutes, Clarke and Simpson (2010, p. 192) concluded that the committee 'shows clear evidence of engaging with the most up-to-date debate and predictions about the implications of climate change and sea level rise on its coastal zone'.

The Draft Samphire Coast Conservation Strategy (2003) lists as key objectives the sealing of roads to the coastal settlements of Middle Beach and Parnham with bitumen, provision of camping facilities at Thompsons Beach redevelopment of boat launching and parking facilities at Middle Beach, dredging and stabilization of Salt Creek and sand replenishment of Middle Beach Lagoon. Most of the coastal works to date in the Council area have been in relation to the quantification and monitoring of coastal fauna and flora, preservation of high conservation areas by limiting vehicle access to the beach and dunes, and reduction of feral animals and weeds, construction of coastal walks, management of reserves, revegetation of dunes and identification of threats to the sustainable conservation of coastal ecosystems. Anecdotal evidence indicates that there has been significant landward migration of mangroves in the area already (Caton et.al. 2009).

The Metro Adelaide and Northern Coastal Action Plan (Caton et.al. 2009) provided a conservation assessment and coastal action plan for the Adelaide coastline that included the District Council of Mallala.

The objectives of the Plan pertaining to climate change were:

- 'To monitor change in plant species and sediment accumulation at established Department of Environment and Heritage (DEH) survey lines adjacent to Barker Inlet to clarify the effects of climate change in the distribution of plant species within the region.
- To adjust now to climate change impacts on coastal habitats; and to avoid decisions now which compromise future adaptation.'

The plan included as climate change actions:

> ‘8.9. (i) To identify established survey lines adjacent to Barker Inlet to record vegetation changes and sediment accumulation changes over time (NRM and DEH CPB).
> 8.9. (ii) To facilitate a review throughout the region of areas suitable as buffer zones for saltmarsh retreat, together with tidal flows and potential tidal flows in those areas. The review is to include development plan provisions for buffer zones regionally.
> 8.9. (iii) To establish setback buffer areas on the Council Development Plans in order that development now does not compromise adaptation to sea level rise in the future.’

Issues specific to the District Council of Mallala coastline included:

- ‘Ongoing and accelerating sea level rise may displace supratidal samphire species and threaten neighbouring farmland (depending on sediment accumulation); and
- Incremental loss of Samphire (*Tecticornia flabelliformis*) habitat through damage, drainage changes, and changes in flooding frequency.’

A sea flood risk mapping project undertaken by the CPB of South Australia for selected coastal settlements on the Yorke Peninsula and north-east Gulf St. Vincent included Parham / Webb Beach and Thompson Beach in the District Council of Mallala area. The simple flood risk model shows the risk of inundation for each settlement in response to a 100 year ARI with an additional sea level rise of 0.3 metres and 1 metre above 1990 levels. Levels also included an allowance for storm surge, wave run up and wave set up of 2.6 metres AHD, 0.0 metres and 0.1 metres respectively. The projected flood area for Thompson Beach for each of the two sea level rise scenarios is shown in Figure 47.

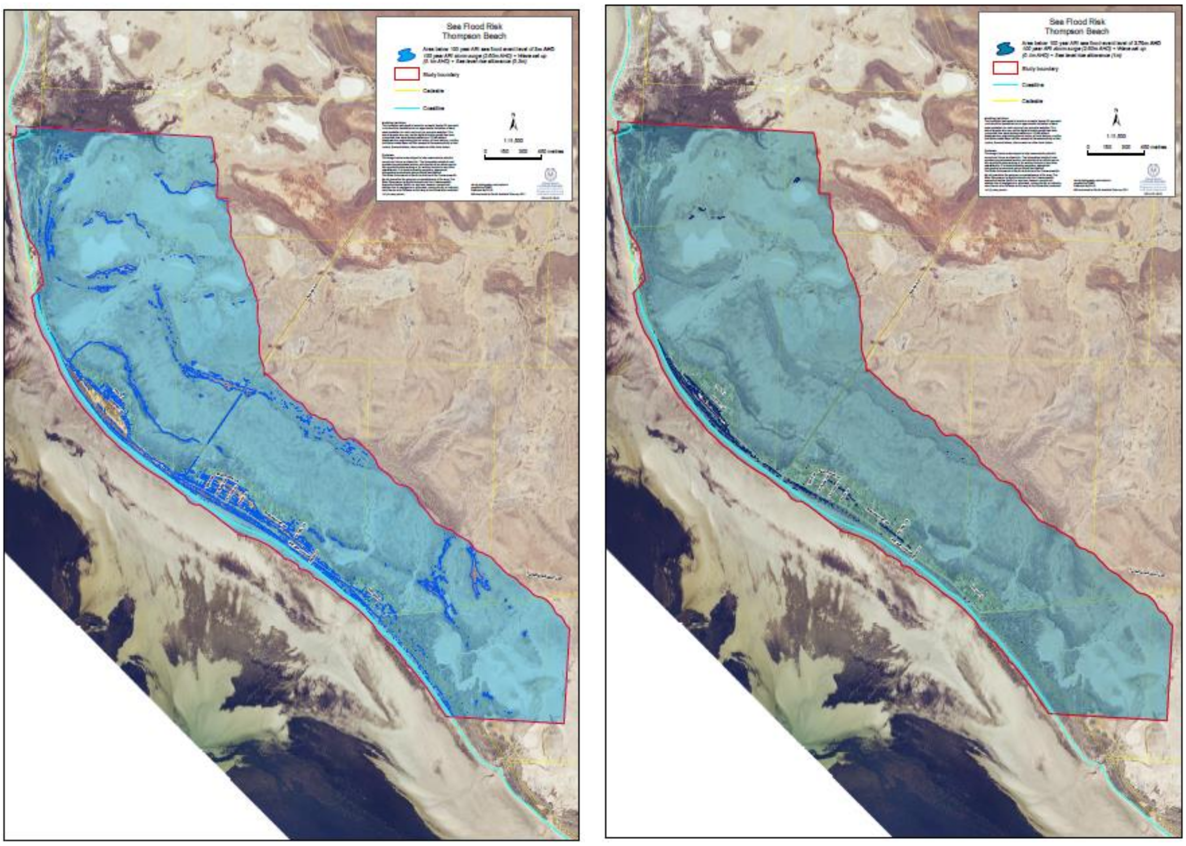


Figure 47: 100 year ARI flood areas including a (Left) 0.3 metres and (Right) 1 metre sea level rise for Thompson Beach. Blue areas are projected to be subject to inundation (Guy 2011).

Coastal erosion along the Mallala foreshore has not been modelled at a local scale. However, data generated by the project provides medium resolution projections for the area.

The District Council of Mallala Development Plan, which sets the framework for future development, incorporates objectives and principles of development control to deal with coastal planning issues and since 1993, all new development would have been referred to CPB for 'regard'. In addition to the controls described, the development plan includes the following controls that reflect the unique characteristics of the coast in the District Council of Mallala area:

- Development control 285 states land should not be divided unless a layout can be achieved whereby roads and development sites are at least 0.3 metres above the standard sea-flood risk level, unless the land is or can be protected in accordance with development control 288.
- Development control 292 states where there is an inadequate erosion buffer to protect development from long term erosion, the development should not occur unless: the Council has committed itself to erosion protection measures; a legally binding agreement is included on the freehold certificate(s) of title(s) that protection measures will not be built and that any building will be transportable and will be removed when threatened by erosion or storm surge flooding; or a legally binding agreement is included on the freehold certificate(s) of title(s) that protection that comply with the principle of development control 288 will be built by the land owner(s) when required.
- Development control 303 states that existing development which is contrary to the objectives for coastal areas should not be redeveloped unless the redevelopment significantly rectifies the unsatisfactory aspects (Government of South Australia 2012).

8.1.5 Specific Coastal Issues for District Council of Mallala

The following specific coastal inundation issues are identified from a review of the minutes of DC of Mallala and its associated subcommittees:

Thompson Beach

In 2010, the District Council of Mallala twice applied for funding to the Natural Disaster Resilience Program to undertake 'high priority remedial works to the Thompson Beach levee banks in for $50,000, with another $50,000 sought from the CPB and a commitment from DC of Mallala of a further 50,000 (DC of Mallala 27th September 2010). The funding for the project is likely to be successful although the DC of Mallala has deferred the application until financial year 2012/2013 (DC of Mallala 26th March 2012). CMAC acknowledged that the 'new level' was 3.8 metres this figure referring to the 1 in 100 year ARI flood taking into account sea level rise and wave set up. CMAC noted that levee system at the south end of Thompson Beach has suffered from coastal erosion and priority will be given to this end of the beach. The proposed levee bank will be built of clay and at a height of 5.8 metres (CMAC 6th October 2010).

The minutes of DC of Mallala and its associated committees reveal that the following reports and studies have been undertaken in relation to the potential inundation to the coastal settlements:

- CMAC indicated that risk assessments were due to be undertaken at Webb, Parham and Thompsons Beaches (CMAC 6th October 2010).
- Natural Disaster Resilience Program – Sea Level Rise Coastal townships Adaptation Options for the DC of Mallala dated 13th September 2010 (DC of Mallala 27th September 2010).
- Natural Disaster Resilience Program – Thompson Beach Levee Banks dated 13th September (DC of Mallala 27th September).
- CMAC indicated that a study Coastal Settlements Sea Level Rise Coastal Adaptation Options would be undertaken at end 2010 or early 2011 where options of 'protection, adaptation and planned retreat' would be evaluated for Parham, Webb Beach, Thompson Beach and Middle Beach (CMAC 1st December 2010).

The Strategic Infrastructure and Planning Committee (SIPC) received a briefing on 11th April 2011 but resolved that the information received 'by way of discussion and associated documents remain confidential and not available for public inspection until the matter is considered by the Council'.

8.2 City of Onkaparinga

8.2.1 Overview of the study area

The City of Onkaparinga area lies south of Adelaide City and extends from the coast to the Adelaide Hills over an area of 518 km^2 (Figure 48). The 31 km is characterised by steep sandstone cliffs, beaches, dunes and the Onkaparinga Estuary (Clarke and Simpson 2010, p. 84, 186). Onkaparinga is fortunate in that while it has a higher population than District Council of Mallala, its coastal topography will mean that it will not require extensive protection against flooding in settled areas such as on the Adelaide Metropolitan beaches (Caton 2007, p. 6).

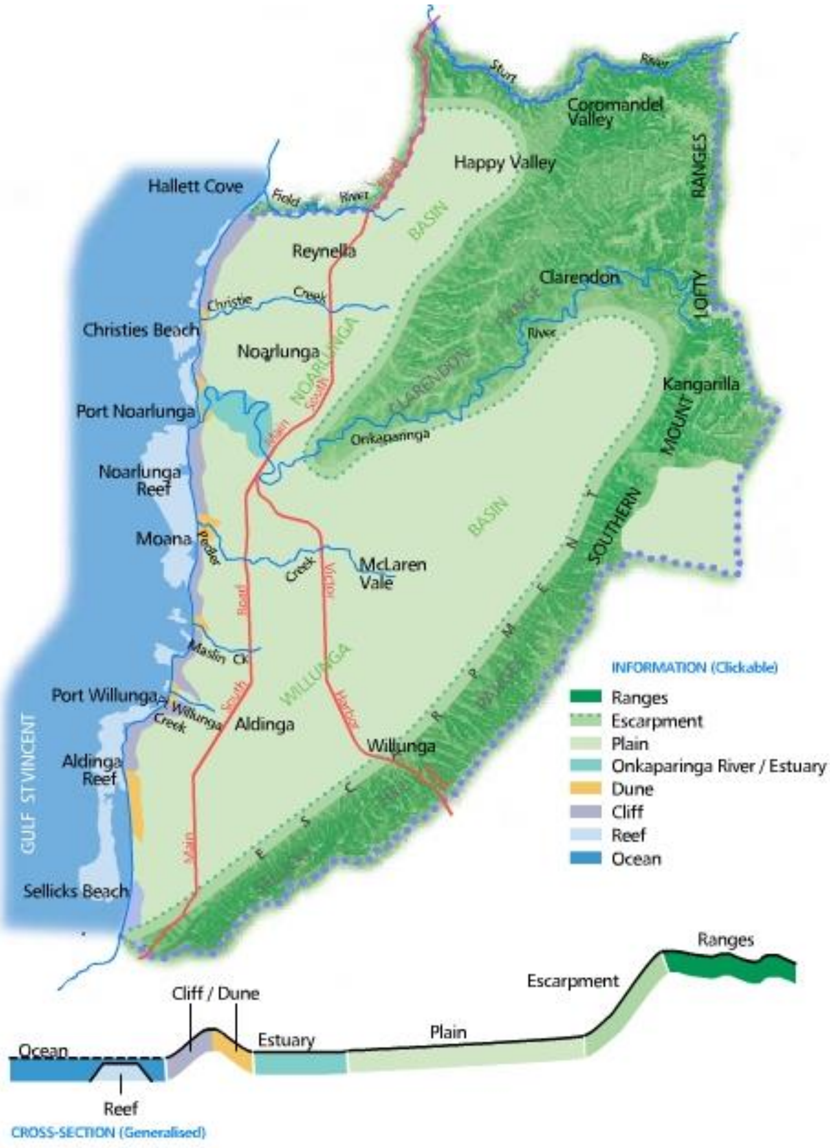


Figure 48: Major landforms of the City of Onkaparinga (Source: City of Onkaparinga web site 2012).

8.2.2 Climate change impact analysis

The Metro Adelaide and Northern Coastal Action Plan (MANCAP) (Caton et.al. 2009) also provided a conservation assessment and coastal action plan for the City of Onkaparinga coastline as for the District Council of Mallala area.

In 2007 City of Onkaparinga commissioned Brian Caton to assess the impact of climate change on its coast. In this assessment, the coast of the City of Onkaparinga was divided into 12 short sections and each of these sections was reviewed in the following framework (Caton 2007, p.11):

- Description – Land forms and biota, Principal uses and values;
- Impact – Sea level rise, increasing aridity, run-off regime change, and changes to gulf waters; and
- Suggested Adaptations – protection, planning, monitoring.

The Caton report identified Christies Beach as the location on the Onkaparinga Coast that would require the most immediate attention in relation to the effect of rising sea levels.

8.2.3 Christies Beach review 2009

Christies Beach review undertaken by Coastal Engineering Solutions (2009) undertook a review of historical shoreline changes, described the tide, sediment, wave and sediment transport regimes, described the existing conditions along the Christies Beach foreshore (Figure 49) and modelled the likely impacts of sea level rise.

> *'From the breakwater and low headland at O'Sullivan Beach, the beach runs south to the steep headland at Witton Bluff… Christies Beach is a relatively flat, fine grained, mineral sand beach… backed by a low 3-4m bluff….The beach is divided into 2 embayments with a small foreland at the surf club (see photograph below). The foreland appears to be caused by the protection from wave energy offered by Horseshoe Reef, some 300 metres offshore' (p. 15).*

Figure 49: Surf and Yacht club at Christies Beach (Source: Photo Figure 17: from Caton 2007 p. 15).

The principal uses of the beach are for recreation and associated urban foreshore facilities including esplanade, showers, surf club, yacht club and coastal suburbs. Considerable investment has already been made in protection works at Witton Bluff to secure the esplanade against erosion and cliff recession (p. 16).

Original low cliffs along the foreshore eroded away and so a sea wall has been constructed along sections of the foreshore. The seawalls extend from Christies Beach to Witton Bluff. From Dale street south to Witton Bluff the walls are engineered, constructed to a satisfactory standard and in good condition. The remainder are constructed of dumped rock, are of poor construction and not considered sufficient to withstand severe storm surge events in the current climate. The "O'Sullivans Beach Boat Ramp harbour, constructed in the late 1970's, has created an enhanced headland at the northern end of Christies Beach and resulted in the accretion of the beach and dunes between Christie Creek and the harbour." In addition, a groyne constructed to the northern side of the Yacht Club ramp has successfully retained sand at the toe of the ramp. "The dune system between Christie Creek and O'Sullivans Beach Boat Ramp harbour has a general crest level of +8 metres AHD or higher and will protect the Sewerage Treatment Plant against the 100 year return period storm event for present day sea levels."

Climate change impacts

The highest tides currently cover most of Christies Beach as FAR as the toe of the rock armoured bluff. Climate change scenarios for the study included 0.17, 0.32, 1 and 1.4 metres sea level rise. A storm surge of 1.4 metres was applied to all scenarios and represented the largest recorded storm surge for the area. Sea level rise, storm surge tides and wave run-up levels for each section of the foreshore are given below in Table 8.

Table 8: Sea level rise, storm surge and wave run-up heights used in the calculation of coastal climate change impacts for Christies Beach (Source: Coastal Engineering Solutions 2009).

Sea Level Rise (metres)	Storm Tide Sea Level to AHD (metres)	Wave Run-up Level metres (AHD)
2030 with 0.17 metres	2.37	5.55
2050 with 0.32 metres	2.52	5.7
2100 with 1.0 metres	3.2	6.7
2100 with 1.4 metres	3.6	7.2

Table 6.2: Water and wave run-up levels for climate change sea level rise scenarios from Beach Road to the foreshore beneath Dale Street and beyond

Sea Level Rise (metres)	Storm Tide Sea Level to AHD (metres)	Wave Run-up Level metres (AHD)
2030 with 0.17 metres	2.37	4.2
2050 with 0.32 metres	2.52	4.5
2100 with 1.0 metres	3.2	5.7
2100 with 1.4 metres	3.6	6.4

Table 6.4: Water and wave run-up levels for climate change sea level rise scenarios Beach Road to Ramp at Yacht and Surf Life Saving clubs.

Calculations of combined sea level rise, storm surge allowance and wave run-up were given and describe likely impacts for each scenario tested. Wave heights and wave run-up at Witton Bluff seawalls will increase by about 15% by 2100. This change would result in overtopping and damage to the seawalls. Impacts can be reduced by adding more armour rock and raising the level of the seawall. Non-engineered seawalls will need to be reconstructed to an engineered standard to withstand 2100 sea levels and wave conditions. The geotextile sand bag groyne may need to be raised to maintain sand at the toe of the yacht club ramp.

Estimates of longshore transport rates to the north were made using the Bruun Rule and the Beach Slope method and indicate a likely increase in beach erosion with sea level rise that would reduce beach widths.

Table 9: Sea level rise and beach recession rates used to calculated coastal climate change impacts on Christies Beach between Christies Beach and O'Sullivans Beach Boat Ramp (Source: Coastal Engineering Solutions 2009).

Sea Level Rise (metres)	Beach Recession by Per Bruun (metres)	Beach Recession Calculated from Beach Slope
2030 with 0.17 metres	3	5
2050 with 0.32 metres	6	9
2100 with 1.0 metres	20	30
2100 with 1.4 metres	27	42

Table 6.6: Beach recession estimates between Christie Creek and O'Sullivans Beach Boat Ramp.

Without retaining structures the rate of sand loss from the beach system was estimated at 20,000 cubic metres per year by 2100. Even without storms, sea level rise will result in a loss of beach width of about 5 metres by 2030 and 30 to 40 metres by 2100. Beach nourishment to maintain recreational beaches and protect the STW is unlikely to be sustainable unless the sand is contained by headland structures or groynes such as a larger headland at O'Sullivans Beach Boat ramp harbour, a training wall at Christie Creek or by extending the headland at the Yacht Club seaward. The volume of sand replenishment needed in the northern section of the Beach to protect the STW was estimated at 100 m^3 per linear metre.

In relation to possible increasing aridity and changed run-off regime, the report suggests that infrequent but more intense rainstorms may well be significant in increasing gully erosion on the cliffs at Witton Bluff and the report noted that the Council's long term cliff stability plan identifies the Witton Bluff for immediate remedial action because of the undercutting at the cliff base on the South side and gullying on the cliff face (p. 16).

In relation to gulf waters change, the report states that some changes may occur to the ocean habitat because of the deepening of the sea water but also that by 2070 rises of sea level would reduce the effectiveness of Horseshoe Reef protection of the small foreland on which the surf and yacht clubs are situated.

The study then focussed on the review of existing coastal protection and analysis of the capacity of it to withstand 2100 sea level rise and erosion. An analysis of flooding or erosion impacts to the infrastructure behind the coastal protection was not undertaken. With recommended mitigation actions, the existing sea walls and dunes are likely to protect the infrastructure behind them from both flooding and erosion out to the year 2100.

Suggested Adaptations

Caton (2007 p. 17) suggested that a storm surge has the potential to damage infrastructure in the current time, and that sea level rise will only exacerbate this risk. A preliminary examination of the rock wall might indicate that parts of it are not satisfactorily fitted together by contemporary standards. The report suggests that this wall will need assessment in relation to adequacy of standard as well as adequacy of height in relation to protection against storm surges. The report also suggested that sea level rise will increase erosion to the small foreland occupied by the surf and yacht clubs and this will require protection in the future, although the timing is deemed to be uncertain. In the medium to long term the dune at Christies STP will also need hard protection.

It is predicted that sea level rise will leave very little to no recreational beach at Christies Beach by 2030 and the report recognises that the 'response to this is significant in economic and social terms for the region' (Caton 2007, p. 17). Some possible ways of responding to this risk are sand nourishment and hard protection as in the Adelaide Metropolitan Beaches since 1973, or sand nourishment along with the construction of an offshore breakwater.

In relation to planning, the report states that no new development should occur west of the esplanade.

In relation to monitoring, the report notes that beach and near-shore sand levels have been monitored by the CPB since 1980. This long term record of beach change provides the opportunity for Onkaparinga Council to identify trends of change in the future along with the trends in sea level rise recorded locally at the Port Stanvac tide gauge (p. 18).

8.2.4 Christies Beach Long-term Concept Design

The Concept Design by Coastal Engineering Solutions (2011) focussed on coastal erosion along the Christies Beach foreshore and included the management and maintenance of existing coastal protections and recommendations for the nourishment of the beach front and upgrade of the seawalls. The report includes a review of the initial study and detailed estimates of recession rates and costs for each of the recommended options for hard and soft protection. Planned retreat of infrastructure was not considered a viable option. Flooding was not quantified or considered.

The current capacity of existing coastal protection was assed and likely impacts of climate change quantified. Failure to put in place the recommended actions was described. South of the Surf Lifesaving Club, beach and cliff erosion as a result of existing storm surge events is likely to put at risk the existing seawall, esplanade roadway and pedestrian footpath as a result of undermining of the foreshore. For the 2050 and 2100 climate change scenarios, failure to upgrade the protection wall will result in overtopping and undermining of the structure and erosion of the foreshore was estimated at 8 metres and 15 metres respectively.

Between Christies Beach Surf Life Saving Club and Christies Creek, the existing beach and wall provide better protection and are considered adequate for current day erosion events. However, the depth of the sea wall foundations are unknown and if they were to fail would again put the footpath and Esplanade roadway at risk. For the 2050 and 2100 climate change scenarios, failure of the protection wall would result in failure of the structure foreshore recession of 8 metres and 13 metres respectively, assuming its current construction has a founding of 1 metre or less.

The dunes to the north of Christy Creek are considered substantial enough to resist current day erosion events without damage to infrastructure behind them. Storm surge events to 2050 are expected to be confined to the primary dune but projections to 2100 suggest that dune erosion of 6 to 8 metres may threaten infrastructure in the STW.

Figure 50: Christies Beach locality and infrastructure (Source: City of Onkaparinga 2012).

8.3 Policy Analysis of Each Case Study Council

The two Councils are at very different stages of development with regard to the formal development of climate change policy and climate change adaptation strategies. DC of Mallala is in the early stages of policy development (Clarke and Simpson 2010, p. 192) while Onkaparinga has produced its own climate change adaptation strategy (City of Onkaparinga 2008). Despite this, the development plans of both Councils have had consistent planning controls in relation to the assessment of development in the coastal zone because of the role that the CPB has played in the State of South Australia since 1972. These controls became more significant after the adoption of the 1993 Planning Act (South Australia) that required all development in the coastal zone to be referred to the CPB for 'direction' or 'regard' under Section 37 of the Act. The following table illustrates the uniformity of coastal policies that have been used in the assessment of new development under the influence of CPB policy.

Table 10: Comparison of sea level rise policy in Mallala and Onkaparinga Development Plans.

Objective or Development PDC	City of Onkaparinga Development Plan	District Council of Mallala Development Plan
Council Wide		
Development to be located and designed that can be reasonably protected against tidal and/or stormwater flooding and probably sea level rise.	Objective 5 (p.17)	Objective 58 (p.51)
Development that can accommodate anticipated changes in sea level due to natural subsidence and probable climate change during first 100 years of development.	Objective 6 (p.17)	Objective 73 (p. 33)
Development which will not require public expenditure on protection of the development of the environment.	Objective 7 (p.17)	Objective 74 (p. 33)
Development not located in environmentally sensitive coastal features such as sand dunes, cliff tops, wetlands, or important native vegetation.	Control 3 (p.18)	Control 259 (p.71)
Development should not be undertaken where it will create or aggravate coastal erosion, or where it will require coast protection works which cause or aggravate coastal erosion.	Control 4 (p.18)	Control 261 (p.71)
Development should not preclude the natural geomorphological and ecological adjustment to changing climate, sea level or other conditions (e.g. the landward migration of wetlands, dune drift).	Control 8 (p. 18)	Control 268 (p. 72)
Hazard Minimisation	**City of Onkaparinga**	**District Council of Mallala**
Development should be protected against the standard sea-flood risk level which is defined as the 1 in 100 year average return interval flood extreme sea level (tide, stormwater, wave effects combined) plus an allowance for land subsidence for 50 years.	Control 18 (p. 19)	Control 284 (p. 75)
Commercial, industrial, or residential development and associated roads and parking should be protected from sea level rise by ensuring that the following levels are maintained above the standard sea-flood risk level:	Control 19 (p. 19): (a) site levels are at least 0.3 metres above; (b) building floor levels are at least 0.55 metres above; (c) the development could be protected against a further sea level rise of 0.7 metres	Control 286 (p. 75): (a) building floor-levels are at least 0.25 metres above and 0.55 metres above the standard sea-flood risk level), unless the development is or can be protected in accordance with control 288.
Buildings to be sited over tidal water or which are not capable of being raised or protected by flood measures in future, should have a floor level of at least 1.25 metres above the standard sea-flood risk level.	Control 20 (p. 19)	Control 287 (p.75)
Development that requires, now or in the future, protection measures against coastal erosion, sea or storm water flooding, sand drift etc. should only be undertaken if all of the following apply: (a) the measures will not have an adverse effect on coastal processes, public access, and amenity. (b) the measures will not require community resources. (c) the risk of failure of the protection measures is acceptable relative to the potential hazard resulting from their failure. (d) binding agreements are in place to cover future construction, operation, maintenance and management of the protection measures.	Control 21 (p. 19)	Control 288 (p.75)

Table 11 continued: Comparison of sea level rise policy in Mallala and Onkaparinga Development Plans.

Erosion buffers	**Onkaparinga Council Development Plan**	**District Council of Mallala Development Plan**
Development should be set back a sufficient distance to provide an erosion buffer which will allow for at least 100 years of coastal retreat for small scale developments or 200 years of coastal retreat for large scale developments unless: (a) appropriate private coastal protection measures to protect the development and the public reserve are incorporated or (b) the Council is committed to protecting the public reserve and development from anticipated coastal erosion.	Control 22 (p. 20)	Control 289 (p.76)
The width of an erosion buffer should be based on: (a) the susceptibility of the coast to erosion; (b) local coastal processes; (c) the effect of severe storm events; (d) the effect of a 0.3 metres sea level over the next 50 years on coastal processes and storms; and (e) the availability of practical measures to protect the development from erosion caused by a further sea level rise of 0.7 metres per 50 years thereafter.	Control 23 (p. 20)	Control 291 (p.76)
Development should not occur where essential services cannot be economically provided and maintained having regard to flood risk and sea Ievel rise, or where emergency vehicle access would be prevented by a 1 in 100 year average return interval flood event, adjusted for 100 years of sea Ievel rise.	Control 24 (p. 20)	Control 293 (p.76)
Maintenance of public access	Controls (p. 18-19)	Controls (p. 74,75)

In addition to the development controls noted above, City of Onkaparinga has developed Climate Change Strategy 2008 - 2013 as an initiative of its Community Plan 2028. The state objectives of the strategy are:

- Adaptation - to ensure the City of Onkaparinga is prepared and resilient to climate change;
- Reduction - to reduce greenhouse emissions; and
- Leadership - to provide community leadership in responding to climate change (p 14).

The main emphasis of the Onkaparinga strategy is on the mitigation of climate change impacts through strategies to reduce greenhouse gas emissions, as well as green building initiatives, and the development of renewable energy. Onkaparinga Council has also established and continues to use the services of a science panel to provide up to date and accurate scientific information (p. 7, 19) and has undertaken a comprehensive risk assessment of the impacts of climate change on the operations of Council. The assessment includes an assessment of flood mapping and coastal protection measures to manage the identified impacts of rising sea levels (p. 15).

Thus, with respect to planning policy, both Councils conform to the basic criteria set out by the state government but City of Onkaparinga appears to be a leader in the development of its consideration of climate change issues and has developed understanding and policy well beyond the criteria demanded by state government guidance.

9 TRIAL RESULTS

This chapter describes the results from work with the two case study Councils following the process outlined in the Decision Map and using the financial model to determine likely costs associated with the options identified in each case.

9.1 District Council of Mallala

The location selected for the Decision Map and financial modelling trial for District Council of Mallala was Thompson Beach.

As described in the previous chapter, the settlement of Thompsons Beach is located north of the Adelaide northern suburbs on low lying salt marshes that border the Gulf of St Vincent. The subdivision was granted development consent in the mid 1980's and has gradually expanded to around 140 dwellings. A total of 246 allotments were included in the original subdivision application but many sites remain undeveloped. The settlement is linear and extends north to south for approximately 3 km along the Esplanade, an unsealed road that separates the dwellings from the beach front. Several streets lie behind the Esplanade, most of which have been sporadically developed with housing (Figure 51). The majority of houses are holiday homes while a smaller number are occupied permanently. A variety of construction methods are evident in the properties on site. Half (50%) are portable wooden constructions on stump foundations, about a third (38%) are wood or weatherboard construction and sit on stump or concrete slab foundations. A small number of brick veneer dwellings (5%), located on concrete slabs are evident and a further 6% of dwellings are set on poles at least 2.5 metres above ground level. There is a small amount of Council owned infrastructure including some picnic tables, shade structures and toilet facilities and two 30,000 gallon concrete water storage tanks. The major Council infrastructure is Ruskin Road a sealed road that links Thompsons Beach with the major arterial A1 highway at Dublin 8 km to the east. Ruskin Road is elevated on an artificial levee for much of its length.

Thompsons Beach foreshore and settlement are in a flat and low-lying landscape. The shoreline consists of extensive mud flats with sporadic mangroves. At low water the sea recedes to over a kilometre from the high water mark. A narrow line of low dunes borders the land, which is elevated for much of its length not more than approximately two metres above AHD. Behind the dunes extensive areas of salt marsh that periodically floods already. Much of the settlement of Thompsons Beach is located on land that is no more than four metres AHD.

9.1.1 Decision map analysis

Step 1: Climate –Impact Analysis

For both sites, sea level rise projected under a worst case SRES scenario (IPCC A1FI) with rapid ice melt (Church 2011) was selected to the end of the century (2100). Projected median sea level rise for the selected scenario is 819 mm (Church 2011).

The local sea level rise planning benchmark set by the South Australian CPB is 30 cm by 2050 and one meter above current AHD by 2100. Since this coastline is protected from the open ocean by the Gulf of St Vincent there is little evidence of coastal erosion from wave action. However, parts of the settlement flood already under a 1 in 100 year storm surge event and sea level rise is expected to increase both the flood height and lead to more frequent inundation of property and infrastructure. Wave setup and wave run up in the area is minimal and measured by the Coastal Protection Branch of the DENR at 0.1 metres. The bathtub modelling exercise undertaken by DENR as described in Section 4.1 was expanded to provide flood contours on the topographic map at 0.2 metres increments to 1 metre sea level rise including a 1:100 year ARI storm surge event of 2.6 metres AHD (Figure 51). Changes in the land elevation were quantified for the financial model.

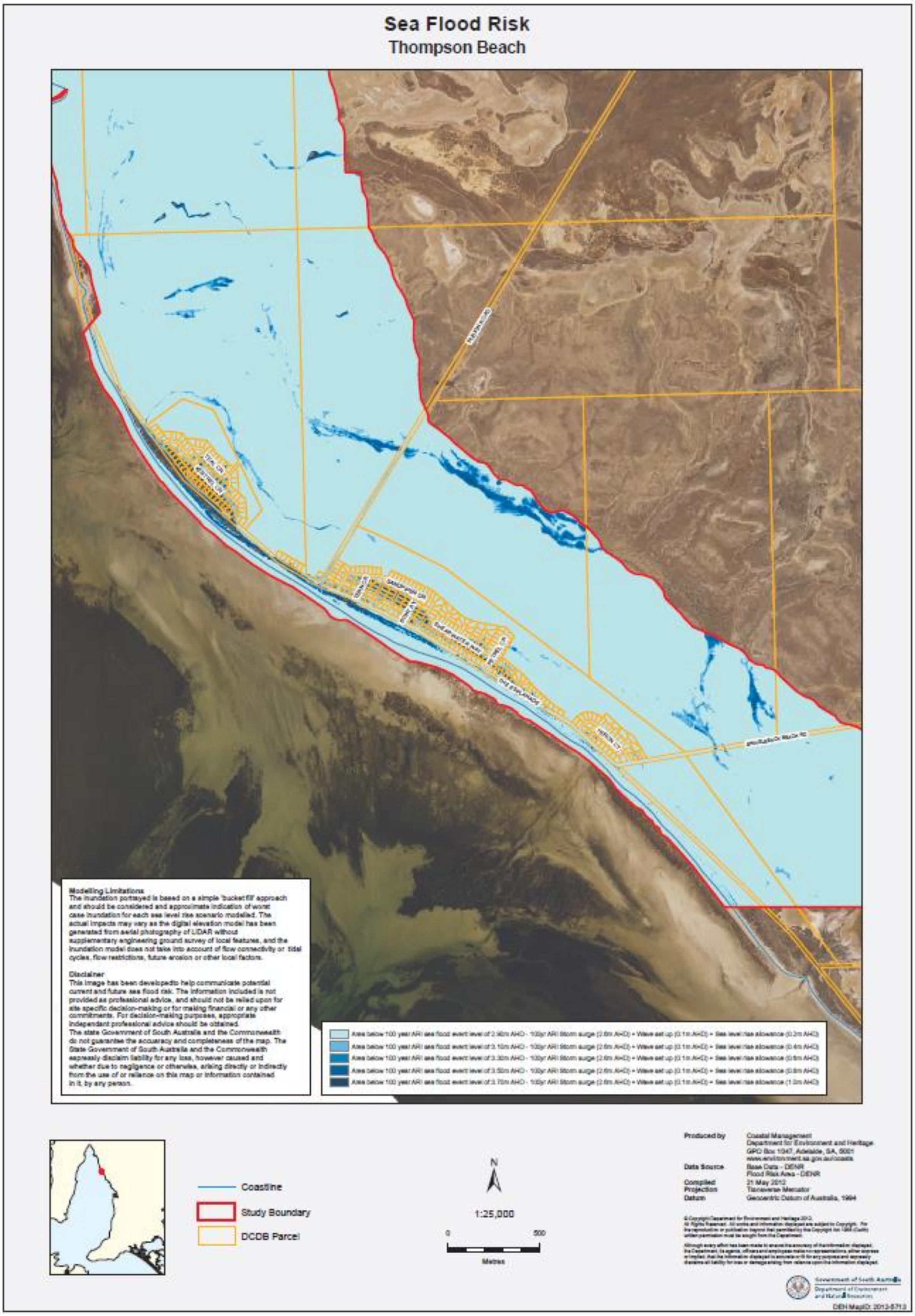


Figure 51: Thompsons Beach bathtub modelling showing flooding for a 1:100 year ARI flood event (2.6 metres AHD) including wave setup and run up of 0.1 metres and sea level rise of 0.2, 0.4, 0.6, 0.8 and 1 metre above 1990 levels (Source: South Australia Coast Protection Board, DENR).

Step 2: Analyse Existing Protection Structures and Strategies

Since its development in the late 1980's, Thompsons Beach has been protected by a levee bank that runs parallel to the coast in front of the Esplanade and to the back behind the settlement to protect it from tidal encroachment from the rear on the northern and southern flanks. Much of Ruskin Road is also raised on a levee, which further protects the settlement on its northern flank. Figure 52 below shows the sand core, shell grit covered levee structure.

Figure 52: Thompsons Beach levee (left) construction plans (Source: Coast Protection Board, DENR) and (right) photo of the Levee from the water seaward side (Photo: Jon Kellett).

The original subdivision consent required that the levee be constructed as the site was noted by both the CPB and the South Australian Planning Commission as vulnerable to tidal inundation. An Environmental Impact Statement (EIS) prepared by the developer in 1985 estimated the 1 in 100 ARI to be 2.7 metres and the 1 in 1000 ARI to be 2.8 metres AHD and noted that 155 of the 246 allotments proposed would be inundated to some extent. For this reason a minimum floor height of 2.8 metres AHD was recommended. The CPB noted that the extreme water level could be higher and recommended floor and building site levels of 3 metres and 3.2 metres as an absolute minimum. The CPB further criticised the EIS for not including any sea level rise protection measures and recommended a levee bank of at least 3.2 metres AHD be constructed. As a result, the levee was constructed as part of a condition which stated that "*flood protection measures be provided where appropriate in accordance with proper engineering practice to the reasonable satisfaction of Council, CPB and other relevant authorities, such measures being maintained at all times by the persons making use of the land*" (Comment on Condition 2 Council meeting 31st January 1990).

On its seaward side the levee was specified to reach a crest height of 3.4 metres AHD and appears to have been constructed as such. Much of the levee, now thirty years since construction, is well vegetated by native ground cover plants. The current condition of the levee is poor and in numerous sections its total height dips below 3.0 metres AHD. The levee also contains several breaks where vehicles access ways have been created and it is not long enough to prevent water moving around the southern end and into the community. In its current state the levee may not constitute an adequate defence against a severe storm surge, so even without consideration of sea level rise the settlement may be inadequately protected by its existing defence. It is unclear whether the Council is legally responsible for the levee's construction or upkeep. Certain documents specify that the levee should be provided by the developer and maintained by the users of the land but the Council is currently of the view that the repair of the levee may be its own responsibility. Experience elsewhere in Australia suggests that, should the Council go ahead and carry out such repairs, it could become liable for the protection of the settlement regardless of its previous liability. It is a critical step in the Decision Map process that Council collates all available documentation on the subdivision consent and levee and takes a legal opinion on its liability in respect of the settlement as a whole.

Stage 3: Establish Profile of Assets at Risk.

Analysis of the flood map projection data alongside cadastral and Council property asset data suggests that a range of assets are currently at risk. The levee itself is vulnerable to damage should a significant storm surge occur and it would likely be damaged by the inflow and outflow of tidal waters. The information on file does not provide a definitive view on the ownership of the levee. Most of the roads within the development including the Esplanade and parts of Ruskin Road are likely to be inundated by a combination of sea level rise and storm surge. Most of these roads are unsealed and therefore likely to suffer damage from tidal inundation. The Council lists all roads on its asset register.

Many of the private properties are vulnerable to inundation depending on the height of the storm surge, sea level rise and their site elevation and floor height. A detailed survey of all private properties revealed that a range of different floor heights are evident. Around 90% of the dwellings are on stumps 0.4 metres to 2.5 metres in height (above ground level) and so afford a degree of protection from flooding. For probably half of these dwellings it is also possible that the house could be raised further to take them above flood height at a reasonable cost. Many of the lightweight construction dwellings (38%) of total are either elevated on stumps or could be easily raised. However, a small number of this type of dwelling are built at ground level on concrete rafts and could not be raised. There is a very small number of brick veneer construction houses (5% of total) built on concrete slabs. Some dwellings of various types of construction have been built on raised earth pads to elevate their floor levels (Figure 53).

Figure 53: Example of Thompsons Beach dwellings raised above ground level (Photos: Jon Kellett).

An assessment of vulnerability to flood requires site specific consideration of the details of all dwellings. A site visit yielded information on the construction details of each dwelling. In addition, finished floor level elevations were estimated from observation and recorded in a spreadsheet so that they could be later assessed against potential flood levels and damage assessments made.

Over half of the dwellings in the community were assessed to be flooded for a 1-in-100 year ARI storm surge with a 1 metre rise in sea level. Applying the Decision Map approach at Thompsons Beach emphasised the importance of a detailed understanding of the site conditions as it illustrates that factors such as finished floor levels and form of construction might have significant implications for both flood and financial risk. Communities such as Thompsons Beach can be relatively easily assessed on a building by building basis. However, larger, more complex townships may require the classification of different building types by a risk factor, which would normally involve using the inundation maps to identify zones of risk that could then be analysed by building type or value.

Stage 4: Determine Council Liability

The Council takes full responsibility for the roads and other sundry assets which it owns at Thompsons Beach. Flooding would likely produce temporary loss of service while roads were inundated and may continue following the flood while damage is assessed and repaired. Engineer's advice would be required to predict the likely level of damage to inundated unsealed roads, particularly if the water flow rate were to be rapid. However, the central question at Thompsons Beach concerns liability for private property. The subdivision was granted consent by Council contrary to the advice of the CPB and the state planning agency at the time (South Australian Planning Commission). Several reasons for refusal were cited including that the proposal was contrary to the objectives of the development plan then in force and because of the unsuitability of the land for residential development as a result of risk of inundation from the sea. The levee bank was only put in place at the insistence of CPB. While there is evidence that all subsequent developers who erected property within the subdivision were informed of the potential flood risk, including the potential long-term effects of sea level rise, it could be argued that the grant of subdivision consent by Council, in the face of clear advice to the contrary, is sufficient to bestow liability on Council for subsequent flood damage. A detailed legal examination of the extensive documentary history on this case is required to arrive at a definitive judgement on where liability might rest. For the purposes of this exercise therefore we model two scenarios, one where the Council is not liable for damage to private property and a second where it is liable.

Stage 5: Determine monetary value of assets at risk

At this point in the Decision Map process we seek to identify the potential financial loss when flood scenarios out to the year 2100 are modelled. Many of the dwellings are of lightweight timber or weatherboard construction and are likely to be obsolete by the end of the century and therefore could be argued to represent little value at that time. Nevertheless, for the purposes of this example we have taken the current Valuer General's Improvement value as the best indicator of value and potential loss regardless of when that loss or damage might occur. Flood depth will vary for different properties dependant on their elevation so a detailed study is required to arrive at a damage cost using stage damage curves.

In total we estimate that 100 properties representing a total value of $15.7 million are at risk of inundation from a 1:100 ARI storm surge event and 1 metre of sea level rise. The number of properties at risk increases incrementally as the sea level rise increases over time. The cost of damage is dependent on flood depth and was calculated using proportional damage costs from damage curves as described in Section 6.7 of this report (Middelmann-Fernandes 2010). For example, the damage estimate for a 0.6 metres sea level rise is $2.28 million while for a 1.0 meter rise it is $4.4 million (Table 12).

Table 12: Summary of capital and building values at risk of inundation at Thompsons Beach for 0.2 metres incremental sea level rise projections.

Capital value	Building value	1 metre SLR	0.8 metres SLR	0.6 metres SLR	0.4 metres SLR	0.2 metres SLR
$15,709,000	$8,807,000	$4,386,300	$3,325,750	$2,282,750	$1,401,150	$764,400

In addition, roads and other infrastructure to the value of $1.6 million are at risk as is the levee itself. Estimates of damage to roads and other infrastructure were made. Most of the Council owned infrastructure would probably exhibit minimal damage in a flood. For these items engineer advice suggested that 5% of total value was a realistic estimate for the damage bill, although this cost would vary depending on the nature of the assets, their state of repair and flood height.

Assuming that the Council is not liable for private properties, then the monetary value of assets for which the Council has responsibility totals $1.6 million with a potential damage cost to this infrastructure for each flood event of $80,000.

For the scenario where the Council is considered liable for private property damage then the value of asset damage for which the Council has responsibility could amount to $4.5 million for a single maximum ARI flood event with a 1 metre sea level rise.

Stage 6: Actions analysis.

The values above were used as input to the financial model. A no private liability scenario was modelled first followed by a scenario where the Council is liable for private property losses as well. Each action option is taken in turn.

No liability for private losses scenario

Retreat

No compulsory acquisition is necessary as all private landowners would be seen as responsible for their own decision making. Should a retreat policy be decided upon then the issue would likely become highly politicised as landowners resist Council policy. A retreat decision would imply that Council would no longer maintain infrastructure such as roads, so the financial cost to Council would be minor but the political cost could be high. As dwellings are gradually abandoned Council will suffer a loss of rateable revenue.

Accommodate

Under this scenario Council has no costs in respect of private property but needs to consider the costs of repairing and modifying roads and other Council owned infrastructure to reduce damage from repeated flooding. Council would also need to offer advice to residents about appropriate flood strategies. This advice process implies some small financial costs to Council.

Defend

Under the no liability scenario Council would not choose to reinforce or raise the levee since this could trigger liability for future flood damage to private property. Council may choose to inform residents that they have the right to defend themselves at their own cost. Appropriate strategies to achieve this would need to be examined. In all probability the main approach would be to consolidate the levee but at the residents' rather than the Council's expense.

Defer

All of the above actions could be deferred pending further assessment of risk. This approach has the advantage of avoiding costs to all parties provided a flood does not occur and repairing damage only when it does. Either of the previous options would then be implemented at a point in time when it was most cost effective to do so as estimated by the financial model.

Do Nothing

This option is similar to the previous, but assumes that the Council does not implement any changes between 2010 and 2100 and instead just pays for the ongoing repairs of infrastructure that it is responsible for including roads when the flooding occurs.

Council liability for private losses scenario

Retreat

Under this scenario Council would cover the cost of abandoning all property and infrastructure at Thompsons Beach. This option could involve relocation or compulsory acquisition of private property and would amount to the total rateable value of all properties in the subdivision ($15.7million). It would also reduce to zero Council income from rates for all the affected properties.

Accommodate

Accommodating the enhanced flood risk could involve Council advising residents to consider elevating their properties. In many cases this is technically possible because of the form of construction, but would be costly for Council. Using Rawlinsons (2010) cost data estimates as a guide, raising a single dwelling to 2.4 metres would typically cost in the order $6,000, so raising 150 dwellings at Thompsons beach so they were protected from a sea level rise flood event of 1 metres would cost Council approximately $900,000. Other options include changing the use and design of lower floors in two storey dwellings by removing soft furnishings and tiling floors to reduce damage costs from flooding.

Defend

This option would require Council to fund the repair and maintenance of the levee and decide whether to extend the height of it now to the full 2100 sea level and storm surge flood height or raise the height of the levee incrementally either on a regular 10 year basis (predict and respond) or in response to storm surge events (sense and respond) as well as accept the damage costs of flooding should it occur. The costs associated with the defend option may be offset by insurance dependent on the insurer's view on the effectiveness of the levee and the degree of risk involved.

Defer

All of the above actions could be deferred pending further assessment of risk and an assessment of the most cost effective time for implementation. This approach involves paying for damages to both Council and privately owned assets in response to each flood event until actions to retreat, accommodate or defend are made.

Do Nothing

Doing nothing under the acceptance of liability scenario would mean that the Council covers the costs of damages for both Council and privately owned assets every time there is a flood between 2010 and 2100.

For both scenarios (liable and not liable) and all options to respond, it would appear prudent to prevent further development in the township to reduce future costs, a decision that would require a rezoning of the sub division. However, this option is not part of the scope of the study and so is not examined further.

9.1.2 Financial modelling simulation results: Flood model

Minor adjustments to take into account subsidence at the site and changes in mean sea level relative to AHD for Mallala were entered into the model. The driving factor in flood events is total water height which includes *storm surge*. Based on a study on Port Adelaide Enfield (2002), and adjusted for local conditions according to input from the Coastal Protection Branch of the DENR, the following ARI table was used for Thompson Beach (Table 13).

Table 13: Average recurrence interval water heights for Thompsons Beach, District Council of Mallala.

ARI	Water Level Derived from ARI Curve (metres)
1	1.60
2	1.79
5	1.96
10	2.07
20	2.19
50	2.39
100	2.60

The ARI table generates the following cumulative distribution for *Water Level Derived from ARI Curve*, which is used in the simulation for each year:

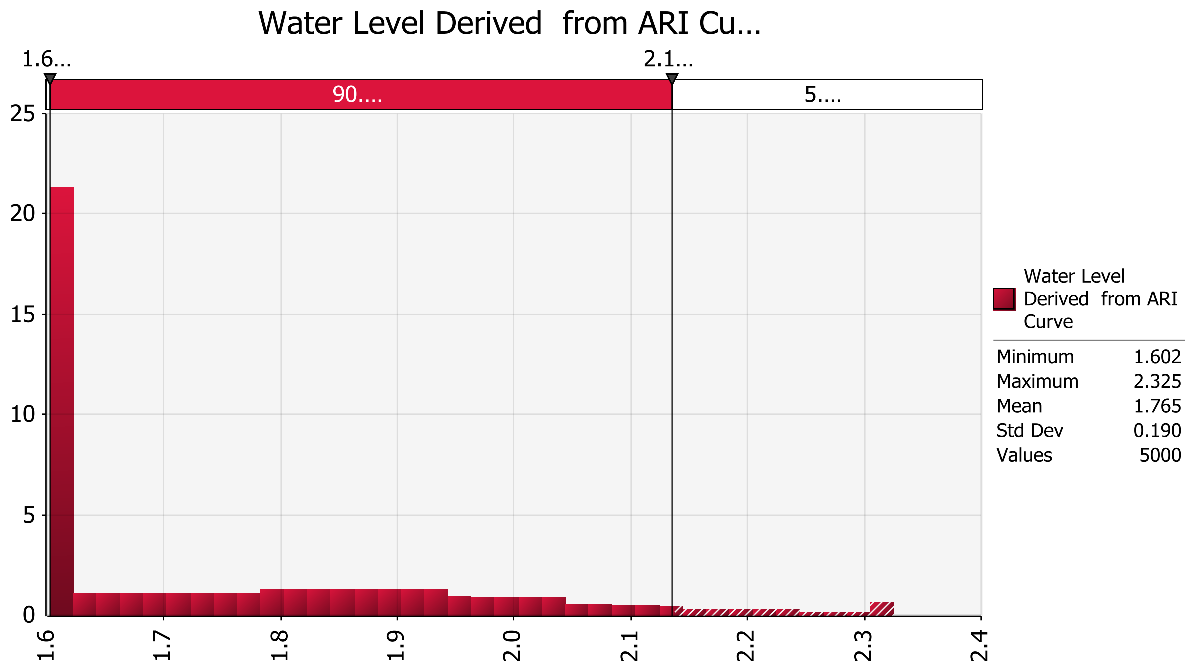


Figure 54: Water levels derived from the Thompsons Beach ARI curve data used in the model for the simulation of costs for various adaptation response options.

The *sea level rise* is a relatively smaller factor compared to the storm surge. For our simulation we used the A1FI projected sea level rise curve by Church et. al. (2012) that includes rapid ice melt (Figure 63).

Data for the existing length and height of the protection levee, and damage for every 0.2 metres of sea level rise were also entered into the model.

Based on the data for Thomson Beach, we ran the simulation model with 10,000 iterations. The following graphs (Figure 55 to Figure 58) show the model simulations outputs for costs of the four principle flood defence strategies. Numerical results for Minimum, Maximum and Mean are displayed in the table in the right hand column, along with the Standard Deviation and the number of iterations. The charts also show 90% value ranges.

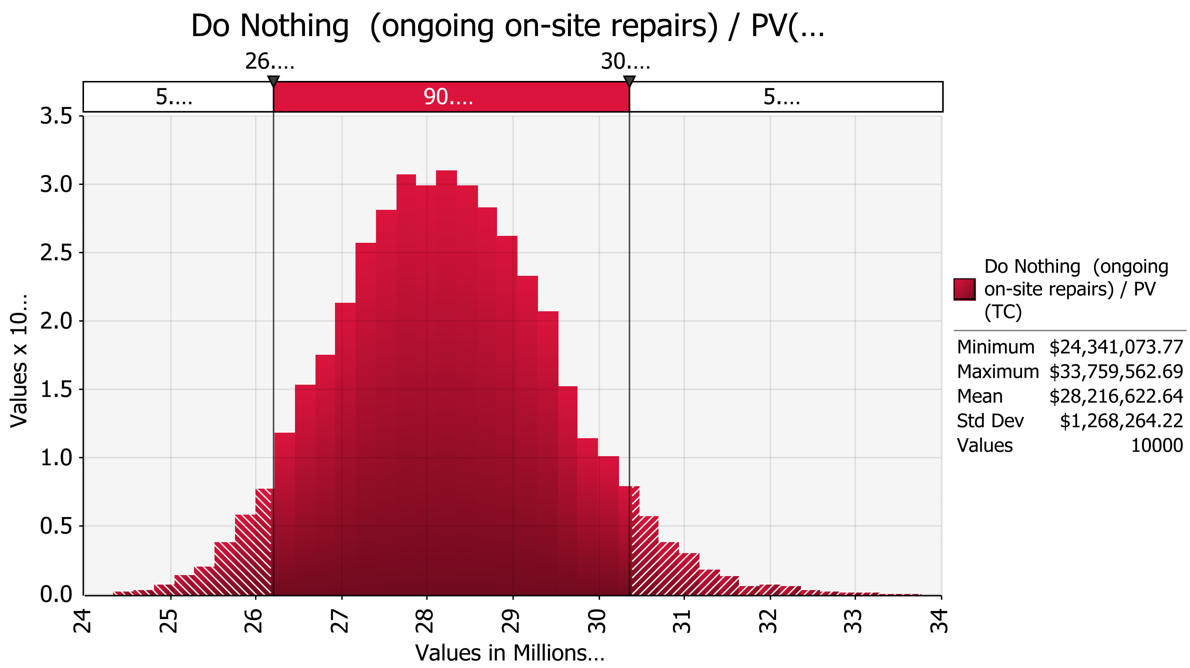


Figure 55: Financial model simulated costs for the "Do Nothing" option at Thompsons Beach, District Council of Mallala, South Australia.

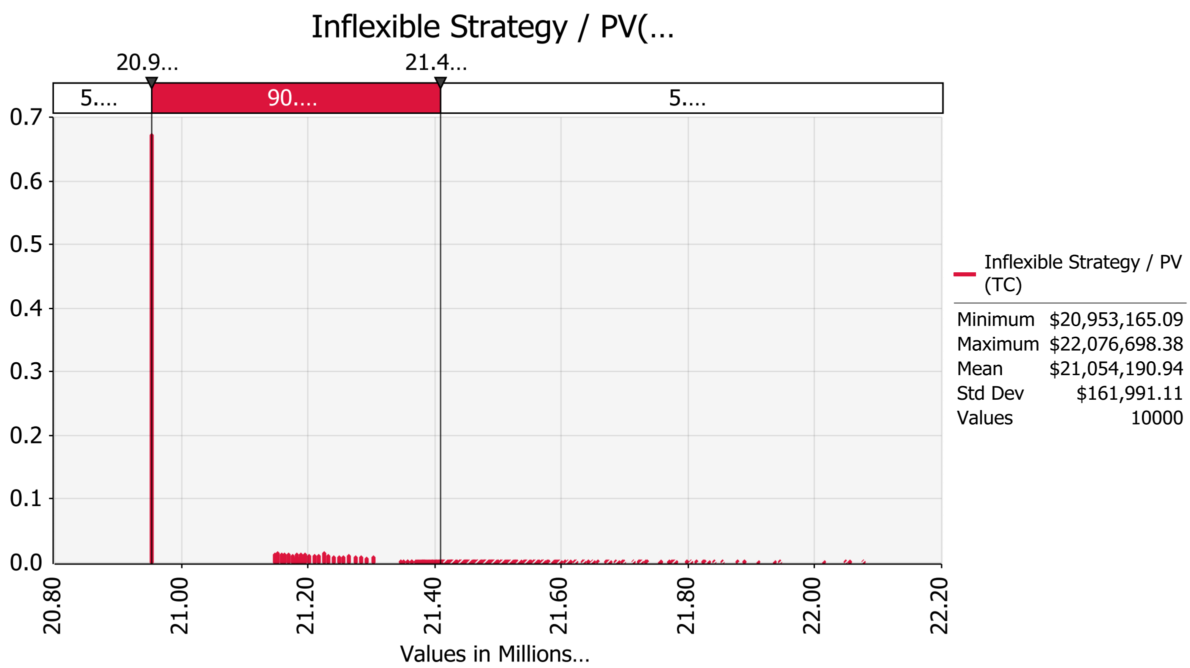


Figure 56: Financial model simulated costs for the "Inflexible" option at Thompsons Beach, District Council of Mallala, South Australia.

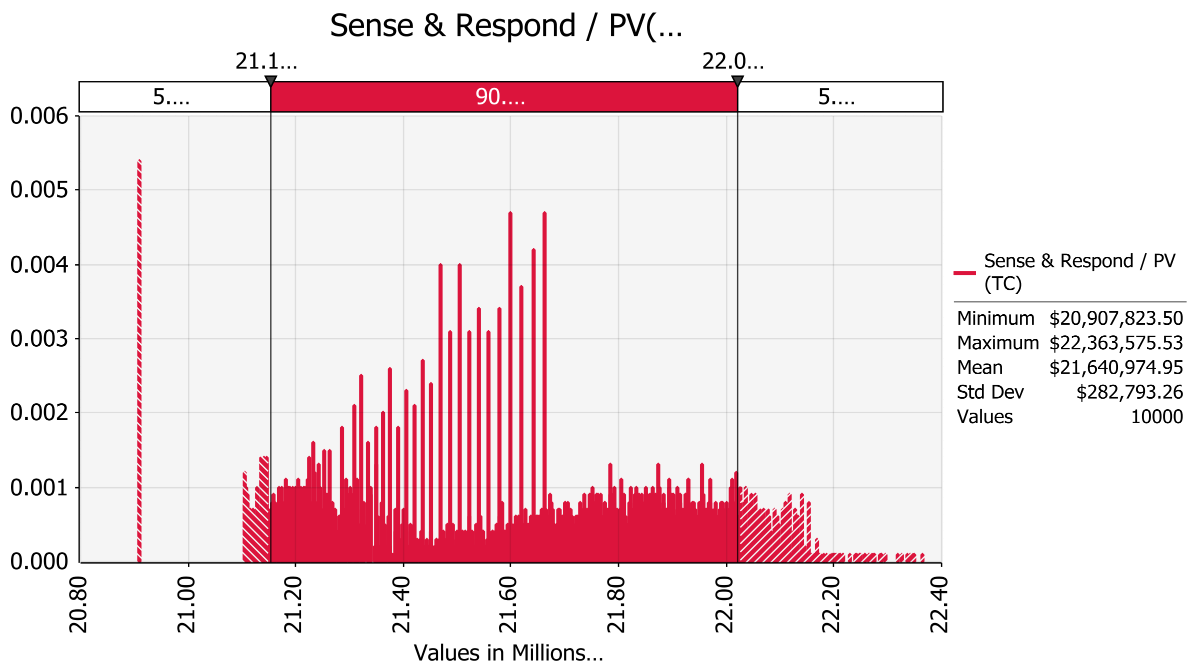


Figure 57: Financial model simulated costs for the "Sense and Respond" option at Thompsons Beach, District Council of Mallala, South Australia.

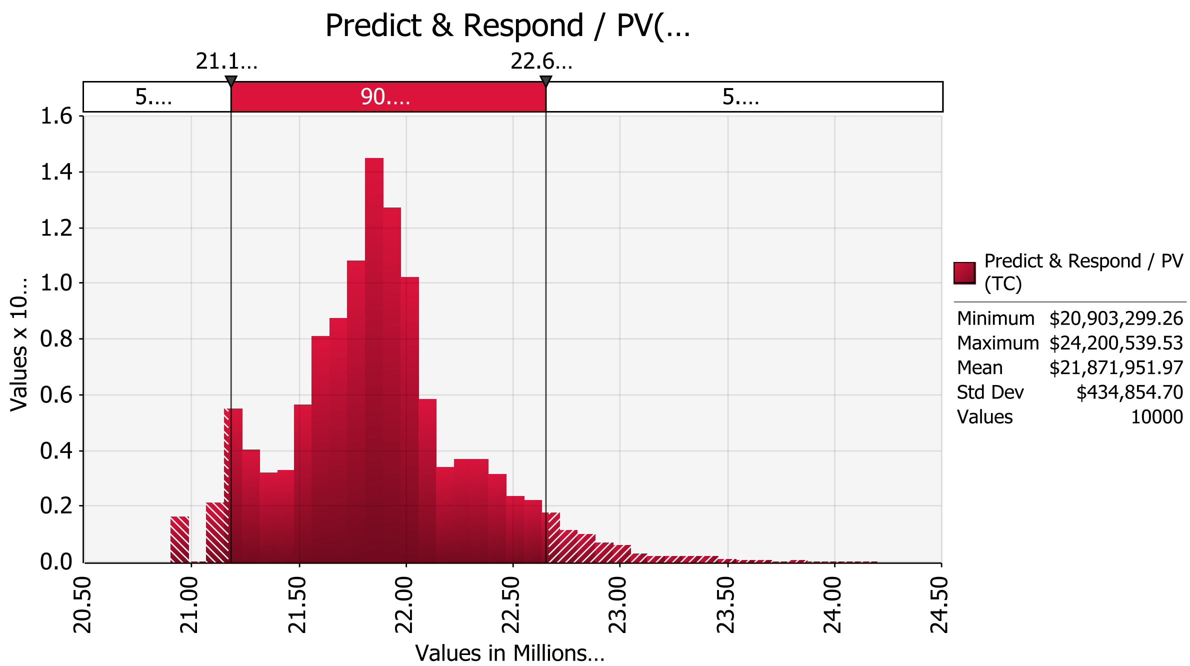


Figure 58: Financial model simulated costs for the "Predict and Respond" option at Thompsons Beach, District Council of Mallala, South Australia.

9.1.3 Discussion of results for District Council of Mallala

The Thompsons Beach case study is, at first sight, a simple scenario but the application of the Decision Map process identified some major concerns for District Council of Mallala, the resolution of which could have significant cost implications. As such the Decision Map approach proved useful in identifying key decision points and their likely implications. The liability issue is central to the resultant costing of different strategies. It is clear that legal advice on the liability situation is critical to determining the appropriate policy direction for Thompsons Beach. The fact that the whole settlement was developed against the advice from state government and the Coastal Protection Branch suggests that Council may well carry a residual liability for any flood damage to private housing which makes up most of the value of the development. However, this conclusion needs to be tested against existing South Australian legislation. The existence of the levee and its continued upkeep is also pertinent to this case. Equally, the accuracy of the hydrographic modelling of potential flood scenarios at Thompsons Beach is critical to the determination of likely costs and so appropriate policy. The existing "bathtub' modelling is useful but probably insufficient to allow an accurate estimate of the cost of flood damage. This is because the bathtub approach is indicative but not designed to accurately model the extent or depth of floods in different scenarios. Combined with a lack of detailed information about finished floor levels there is a degree of estimation as to which properties would be flooded and to what depth. Hence the cost of flood damage can be estimated but the actual values that are produced by the model should be treated with caution. Secondly, the damage costs assume still water and so do not take into account water velocity as the storm tide rises or recedes. High water velocity can significantly increase damage costs as houses may be washed off their foundations and effectively destroyed in some instances. The assumption made in the above analysis is that this will not happen, but engineering advice would need to be sought to validate this opinion.

The critical decision for District Council of Mallala, which results from the analysis, is clearly whether to repair the levee. Managed retreat may be a valid strategy if Council is not held liable for protection of the private properties, but this would then most likely trigger political opposition, so the final decision would rest on more than financial considerations. However, if the Council accepts liability for the existing properties then the financial assessment of the cost of different strategies becomes central to the choice of future direction. The case study demonstrates that reliable data about the finished floor levels, flood damage likelihood and costs of both levee repair and accommodating the community via the raising floor levels or sites would greatly assist in arriving at the best way forward.

The results from the model simulation suggest that, from a financial perspective alone, Do Nothing is the most expensive option (mean of $28,216,622). The other three options are all close with respect to means. However, the Standard Deviations suggest a possible cost ranking from highest to lowest of: Inflexible (mean of $21,054,190) > Sense and Respond (mean of $21,640,974) > Predict and Respond (mean of $21,871,951). These results should also be compared with the once off strategies of Retreat ($15.3 million) or Accommodate ($900,000). It should be noted here that all figures displayed here are on the basis of a trial simulation model only and are based on data that although as accurate as possible still contains significant margins of error and so should not be considered accurate enough to base policy decisions upon. In addition, as per the previous discussions, Council may not be liable to pay all or any of these costs.

9.2 City of Onkaparinga

The location selected for the decision framework and financial modelling trial in City of Onkaparinga was Christies Beach. As described in the previous chapter, the suburb of Christies Beach is located about 25 km south-south-west of Adelaide central business district and fronts the Gulf of St Vincent. It is served by Beach Road that links Christies Beach with Noarlunga Centre, a major urban service centre about 2.5 km to the east. From the breakwater and low headland at O'Sullivan Beach at the northern boundary of Christies Beach, the beach runs south to the steep headland at Witton Bluff. Christies Beach is a relatively flat, fine grained, mineral sand beach backed by a low 3 - 4 metres bluff. The beach is backed by a sloping coastal plain and is divided into two embayments with a small foreland occupied by The Christies Beach Surf Life Saving Club and Yacht Club. The foreland appears to be caused by the protection from wave energy offered by Horseshoe Reef, some 300 metres offshore (Caton 2007, p.15).

The community consists of suburban residential development that extends back from the Esplanade road that runs parallel with the shoreline. In total the suburb of Christies Beach contains 2,326 mainly detached dwellings 1.5 km north of the intersection of the Esplanade and

Beach Road and a 5.4 hectare waste water treatment plant located on the sea frontage. Principal uses of the beach are recreational and urban foreshore facilities include the Esplanade, showers, and sports clubs. Considerable investment has already been made in protection works at Witton Bluff to secure the Esplanade against erosion and cliff recession.

9.2.1 Decision map analysis

Step 1: Climate –Impact Analysis

In relation to sea level rise, the highest tides currently cover most of Christies Beach as FAR as the toe of the rock defences. The local sea level rise planning benchmark set by the South Australian CPB is 30 cm by 2050 and one meter above the current 1:100 ARI flood event by 2100. The study by Coastal Engineering Solutions (2009) reviewed in the previous chapter added a 1.4 metres storm surge (the largest recorded storm surge for the area) to a range of climate change scenarios. The Esplanade is located behind and atop a rock, armoured defence that ensures the road is 6 - 7 meters above AHD. Residential and other property is further elevated by approximately two to three metres and so there is no flooding risk either from the sea or from inland. However, there has been coastal erosion along the foreshore. Beach and near-shore sand levels have been monitored by the CPB since 1980 using Lidar transects, historic analysis of old photographs and by engaging the community on 'erosion watch'. By 2030 estimates indicate that sea level rise will lead to recession that leaves little beach and much of the rear of the beach will undergo increased storm erosion. The dunes at the northern end of the beach will suffer some erosion by 2030 and the earth embankment behind them may be exposed by storms by this time. Cliff toe erosion at the southern side of Witton Bluff will also be exacerbated by higher tidal levels (Caton 2007, p. 16). The small foreland on which the surf and yacht clubs are located are currently protected by the influence of Horseshoe reef. However, by 2070, further sea level rise would be likely to reduce the protective effect from erosion that the reef provides, and lead to a straightening of the plan form of the beach (Caton 2007, p.17). When damage may occur to the infrastructure on the foreland is uncertain, (and may be affected by any change in the spectrum of wave directions caused by climate change), but this area is especially under threat and will need further protection.

Step 2: Analyse Existing Protection Structures and Strategies

The Christies Beach review described in the previous chapter (Coastal Engineering Solutions 2009) reviewed historical shoreline changes, described the tide, sediment, wave and sediment transport regimes, described the existing conditions along the Christies Beach foreshore, including sea defences and modelled the likely impacts of sea level rise. An analysis of the proportion of each type of existing coastal protection was undertaken by City of Onkaparinga for this study for the northern end of Christies Beach (Figure 59) and the southern end (Figure 60). Original low cliffs along the foreshore eroded away and so a sea wall was constructed along sections of the foreshore. The seawalls extend from Witton Bluff to Christie Creek. Moving south to north from Witton Bluff to Beach Road the walls are engineered and generally, constructed to a satisfactory standard and in variable condition. The crest height of the wall is 5.5 - 6 metres AHD. Cliff toe erosion at the southern side of Witton Bluff is expected to be exacerbated by higher tide levels (Caton 2007).

Between Beach Road and the Surf Life Saving Club the sea walls are constructed of dumped rock, are of poor construction and not considered sufficient to withstand severe storm surge events in the current climate. Crest height is between 3.4 and 4.7 metres. North of the Surf Life Saving Club to Christie Creek the wall is not well engineered but generally is standing up to current conditions. The crest height is 5 to 5.3 metres. North of Christie Creek the coast protection consists of an earth embankment covered in sand dunes. The dune system between Christie Creek and O'Sullivans Beach Boat Ramp harbour has a general crest level of eight metres AHD or higher and will protect the waste water treatment plant against the 100 year return period storm event for present day sea levels (Coastal Engineering Solutions 2009). The O'Sullivans Beach Boat Ramp harbour constructed in the late 1970's has created an enhanced headland at the northern end of Christies Beach and resulted in the accretion of the beach and dunes between Christie Creek and the harbour. In addition, a groyne constructed to the northern side of the yacht club ramp has successfully retained sand at the toe of the ramp. Where storm drains are located within the cliff face or at the back of the beach, these may be damaged by storm waves, or by erosion processes affecting the cliffs.

Figure 59: Christies Beach northern end sea wall defences (Source: City of Onkaparinga 2012).

Figure 60: Christies Beach northern end sea wall defences (Source: City of Onkaparinga 2012).

Stage 3: Establish Profile of Assets at Risk.

Provided the existing defences remain effective it is unlikely that any residential properties, businesses or recreational facilities located in Christies Beach will be threatened by sea level rise before 2100 because of the existing sea wall defences. However the studies cited above suggest that the existing defences themselves are unlikely to be completely effective in the medium term (up to 2030). In particular, the existing rock wall south of the Surf Life Saving Club to Witton Bluff, apart from a short section between Dale Avenue and Witton Bluff, is considered vulnerable to damage from sea level rise. Caton (2007) also questions whether the dune system that currently protects the South Australia Water owned waste water treatment plant is sufficient protection in the long term (2100) and similarly whether the stability of sections of the Esplanade can be guaranteed should the rock wall on the seaward side be undermined. Potential for undermining is enhanced by beach sand removal, an activity that is already ongoing. Without retaining structures the rate of sand loss from the beach system was estimated at 20,000 cubic metres per year by 2100 (Coastal Engineering Solutions 2009) and result in little to no recreation beach at Christies Beach by 2030. Should the existing defences fail then potentially the waste water treatment plant, the Esplanade roadway and associated footpaths and the pedestrian footpath around Whitton Bluff will all become vulnerable to erosion. The Esplanade road contains significant storm water drainage infrastructure including a gross pollutant trap located beneath the road. Furthermore the Surf Life Saving Club, yacht club and Witton centre are all vulnerable to erosion should the defences prove ineffective in the medium to long term (Figure 61).

Figure 61: (Left) Existing rock defences at Whitton Bluff (Photos: Jon Kellett); (right) the foreshore developments at Christies Beach (Photo: Adam Gray).

Site visits to the beach as part of this study showed existing damage to foreshore infrastructure including car parks, stair access to the beach and fencing, and significant erosion along the coast (Figure 62).

Figure 62: (Left) Christies Beach access stairs showing current erosion damage; and (Right) erosion damage along the southern edge of the Christies Beach foreshore (Photos: Adam Gray).

Stage 4: Determine Council Liability

Currently the City of Onkaparinga takes responsibility for the sea defences that have been identified as at risk. Furthermore the Council has for some years actively managed the deposition of sand to replenish the beach and this is likely to be a necessary action into the future. Council owns significant assets along the foreshore including the Surf Life Saving Club and Witton Centre. As these are protected by the existing sea defences, liability for them is likely to be viewed as a Council responsibility. A large number of private dwellings set back from the beach are not at any foreseeable risk over the next 100 years, but their owners would also be likely to argue that since the coast is currently protected by hard defences that the Council would be liable for any damage to these properties as a result of storm surge should it occur. This liability would need to be checked by Council's legal advisors.

Stage 5: Determine monetary value of assets at risk

At this point we seek to identify the potential financial loss when future erosion scenarios are modelled. In the absence of remedial action the following are at risk (Table 14):

Table 14: Value of assets potentially at risk from future sea level rise driven erosion in the Christies Beach suburb of City of Onkaparinga.

Assets at risk from erosion	$
Waste water treatment plant	1,550,000
Telecoms tower	36,000
The Esplanade road and associated footpaths	727,750
Drainage infrastructure	477,750
Facilities e.g. SLSC, yacht club, Witton centre)	3,727,000
Rock wall sea defences	No value available
Christies beach (as result of sand displacement)	No value available

The current rock wall defence measures 740 metres in length and requires repair and replacement to ensure it is not eroded and overtopped. A total wall height of 6.7 metres AHD is recommended to cope with combined sea level rise of 1 metre, predicted storm surge and wave set up in 2100.

Without retaining structures, the rate of sand loss from the beach system was estimated at 20,000 cubic metres per year by 2100. Even without storms, sea level rise will result in a loss of beach width of about 5 metres by 2030 and 30 to 40 metres by 2100. Beach nourishment to maintain recreational beaches and protect the wastewater treatment plant is unlikely to be sustainable unless the sand is contained by headland structures or groynes such as a larger headland at O'Sullivans Beach Boat ramp harbour, a training wall at Christie Creek or by extending the headland at the yacht club seaward. The volume of sand replenishment needed in the northern section of the beach to protect the wastewater treatment plant is estimated at 100 m^3 per linear metre at a cost of $52,500 per year (Coastal Engineering Solutions 2009).

Stage 6: Actions analysis

The analysis above suggests that retreat is unlikely to be a viable option given the high values of the infrastructure and property along this stretch of coast. Should the existing defences fail then the assets identified in Table 14 above would be at threat from erosion damage. In the absence of new defences, erosion will likely threaten coastal infrastructure and private properties behind the Esplanade after 2100.

Retreat

A retreat option would avoid the cost of replacing or reinforcing the existing sea defences but would imply the gradual loss of the Surf Life Saving Club and yacht club, the waste water treatment plant and the gradual loss of service of the Esplanade road. The beach would also disappear in the medium term and reduce recreational opportunities and probably impact on local property values. Liability for private property damage would be a contentious issue and it is likely would become highly politicised as land-owners resisted Council policy. A retreat decision would imply that Council would no longer maintain infrastructure such as the Esplanade and Witton Bluff footpath. The financial cost to South Australia Water of damage to the waste water treatment plant would be significant as replacement plant would need to be constructed. Given the difficulties involved in finding an appropriately located, site large enough to accommodate the facility, the replacement the loss of this infrastructure asset would be measured in many millions of dollars, though it is difficult to precisely cost at this point. The facility represents an example of a coastal asset of strategic importance that should probably be protected at almost any cost. The financial cost to Council of a retreat option could be significant as recreational opportunities, local businesses and rateable values are all reduced under this scenario. A conservative estimate of the retreat option is a minimum loss of assets valued at $13.25 million.

Accommodate

The possibility of accommodating erosion damage is not considered possible as unlike in a flood event, the land itself is removed and so there is no capacity to modify existing structures to reduce damage.

Defend

The defend option would require the Council to strengthen or replace some 740 metres rock wall between the Surf Life Saving Club and Dale Avenue to a height of 6.7 metres. Beach replenishment would need to continue indefinitely and would be an ongoing cost to Council. An initial feasibility study followed by construction of headland structures or groynes such as a larger headland at O'Sullivans Beach Boat ramp harbour, a training wall at Christie Creek or by extending the headland at the yacht club seaward, may be necessary. At the least, an exisiting geotextile sand bag groyne may need to be raised to maintain sand at the toe of the yacht club ramp.

The Council have already carried out a feasibility study to defend the Beach and options considered included coastal protection works costing $5.4 million and various beach nourishment programs totalling $7 million up to 2100 (all $ values are 2011) (Coastal Engineering Solutions 2010).

Do Nothing

The do nothing option would mean Council fund only the cost of damages to the coastal infrastructure and Council owned assets for erosion into the future.

Delay

The delay option means that Council would pay only the cost of damages as a result of erosion until the most cost effective option or retreat or defend is implemented.

9.2.2 Financial modelling of options

Erosion is determined by the local mean sea level rise as the storm driven seawater events that cause flooding are not considered. Hence, in this case, sea level rise is treated as the key component of uncertainty.

Because the existing coastal defences are high enough to protect the infrastructure behind it from erosion over the coming century, costs as a result of model simulations outputs would represent maintenance to the existing beach and wall – figures already calculated by the assessments undertaken by the Council. So as to demonstrate the model capability, the current defences were assumed to be only 5 metres high and the infrastructure behind it at risk from erosion as a result of a sea level rise that could be expected by the end of the century. The results provided below are as a result hypothetical only.

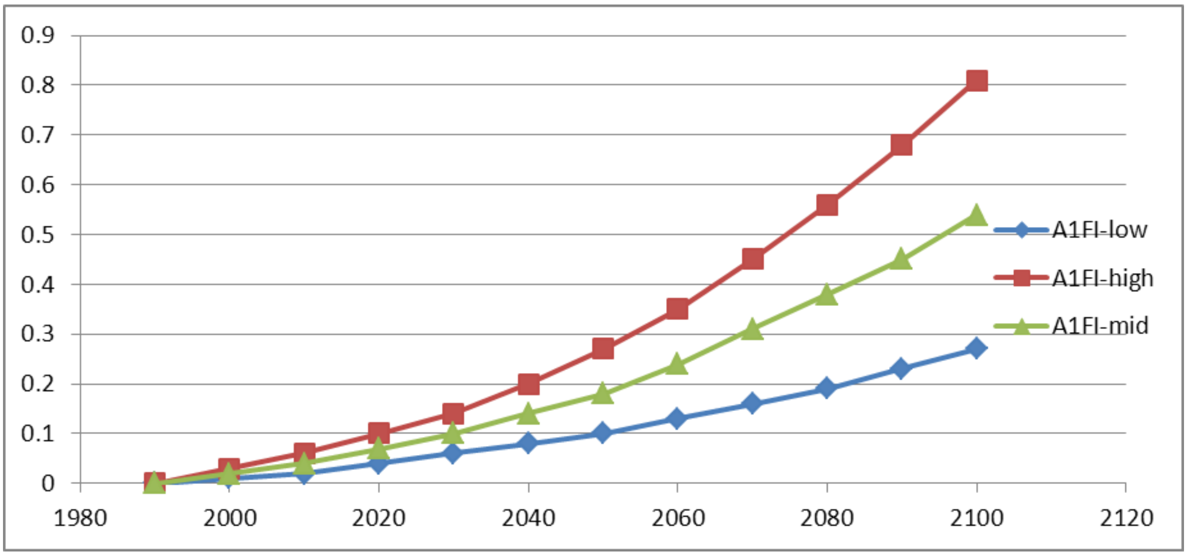


Figure 63: Sea level rise projections for the A1FI SRES scenario with rapid ice melt (Provided by Church et al 2012 unpublished).

The sea level rise for each year is simulated as a truncated normal distribution around the A1F1-mid value. For every year, the sea level change is confined to be nonnegative.

Based on the data for Christie Beach of the Onkaparinga Council, we ran the erosion model with 10000 iterations. The following are then the outputs of simulations for costs of the three principle erosion defence strategies. The illustrative output of costs for different protection strategies are shown in the graphs in Figure 64 to Figure 66. Numerical results for Minimum, Maximum and Mean are displayed in the table in the right hand column, along with the Standard Deviation and the number of iterations. The charts also show 90% value ranges.

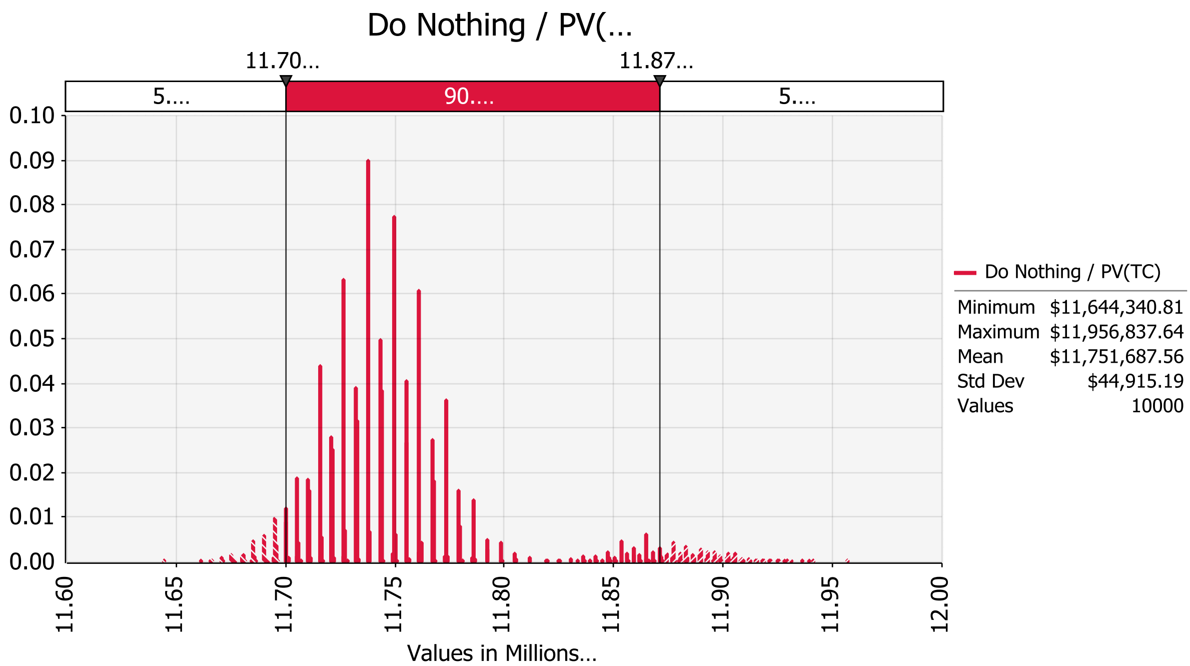


Figure 64: Financial model simulated costs for the "Do Nothing" option at Christies Beach, City of Onkaparinga, South Australia.

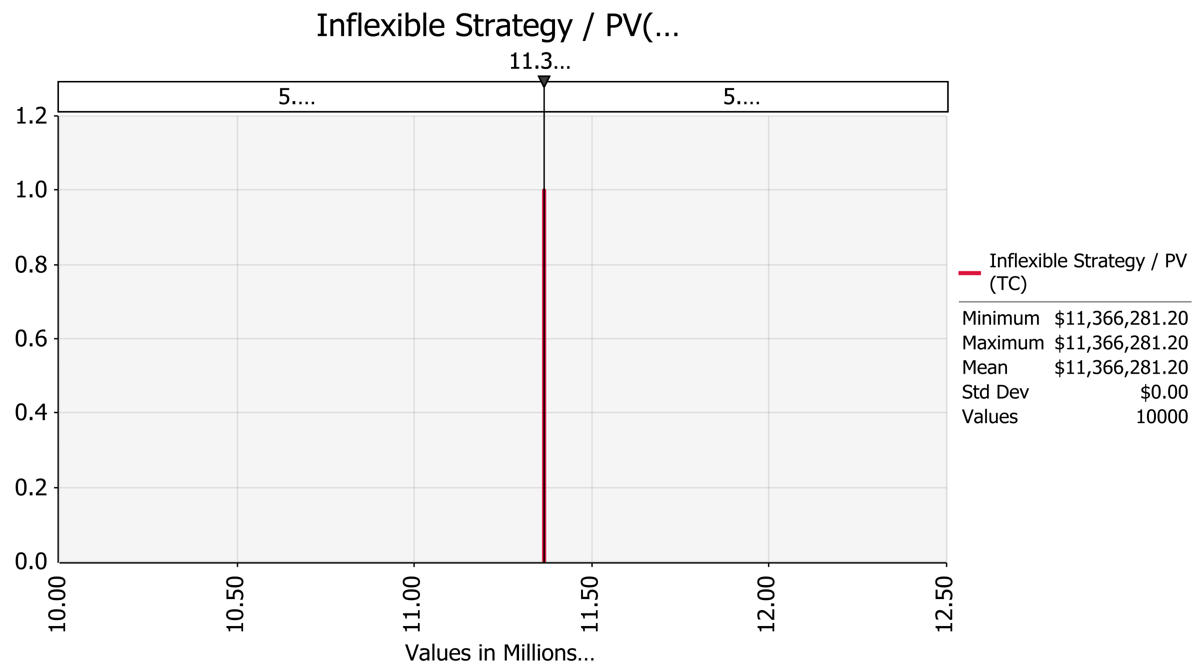


Figure 65: Financial model simulated costs for the "Inflexible" option at Christies Beach, City of Onkaparinga, South Australia.

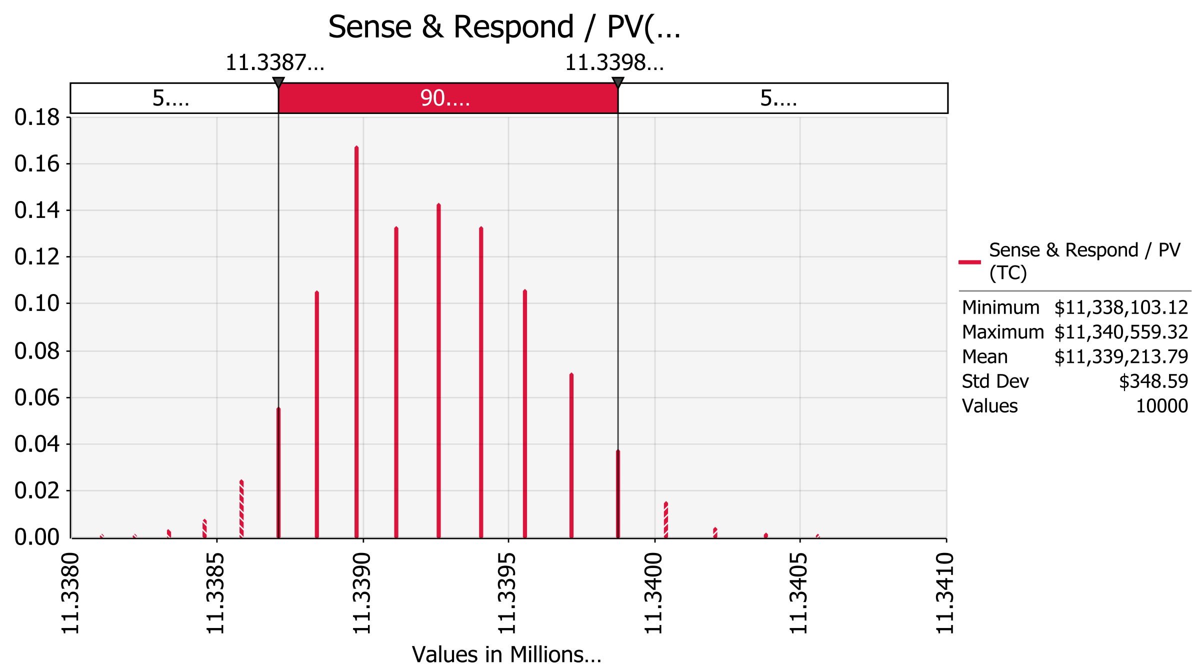


Figure 66: Financial model simulated costs for the "Sense and Respond" option at Christies Beach, City of Onkaparinga, South Australia).

9.2.3 Discussion of results for the City of Onkaparinga

The Christies Beach case study illustrates a number of critical factors. First of all the technical data required as inputs to the decision map are numerous. It is difficult to arrive at reliable estimates of potential damage to property without a detailed understanding of the existing coastal processes. The effect of the reef which deflects some of the energy from waves, the rate of beach sand loss, and a good understanding of the likely cliff base erosion potential are all vital prerequisites that feed into the Decision Map. The performance of existing sea defence structures such as the various sea walls needs to be understood. Forecasting how these processes might change as sea levels increase is also important. Specialist coastal engineering expertise and resources are needed as part of this process. Secondly the infrastructure that currently exists along this stretch of coast is varied. A clear inventory of assets and their current value and replacement costs form further vital inputs to the decision map. The engineering solutions that involve beach sand nourishment and numerous engineering works must be costed and their functional relationships over time analysed.

It is clear from the analysis that the value of the existing infrastructure and property (both public and private) outweighs the costs of protection to 2100. So defence is the most likely policy outcome over this time frame. Nevertheless, the protection costs are considerable and in the case of beach nourishment need to be projected over the long term (2100 and beyond). It makes sense therefore for Council to begin consideration now as to how those costs may be met and to ask whether the entire protection burden should fall on public resources. Local residents have reasonable expectations that the Council will continue to protect their properties from erosion so a case can be made for gradually shifting some of the financial burden of that protection on to the house and business owners who benefit. Coastal protection in a scenario of rising sea levels will remain an issue, its costs are significant, both the general public and private property owners benefit and the degree of threat is likely to increase over time. A local levy as part of the rating system or a charge levied on property transactions to help fund coastal protection works may be viable considerations.

The results from the financial model simulations assume that the height of the existing defences is lower than they actually are and so represent a hypothetical output only.

10 DISCUSSION AND FURTHER STEPS

They key aim of this project was to assess and quantify the likely impacts to Councils from coastal inundation and erosion as a result of climate change on existing assets and identify decision pathways for a range of adaptation options. More specifically we were to provide nationally transferrable deliverables in the form of:

- a review of the likely climate change impacts on the Australian coastal zone;
- a review of the identified policy options for addressing the impacts both in Australia and overseas;
- an easy to use decision map to guide decision makers through the steps associated with determining the likely costs and liabilities associated with climate change impacts on existing coastal assets; and
- a generic pilot financial model to evaluate the costs associated with identified policy and investment options in the coastal zone.

As evidenced by this report and the accompanying Excel ® CADSP Financial Simulation Model, these deliverables have been met. Part A of this report provides the review of climate change in Australia and the likely impacts for the coastal zone. Part B provides a detailed review of climate change adaptation policy both internationally at a federal level and here in Australia at a federal and state jurisdictional level. Part C of the report and accompanying Model provide the key outputs of the project including a review of decision making processes, the Decision Map and the pilot financial simulation model for quantifying the likely cost of impacts and various adaptation actions for both inundation and erosion on existing coastal assets. As a pilot study the project outputs provide a significant step in the development of useful tools and processes for addressing the impacts of coastal climate change on existing infrastructure. Development and testing of both the Decision Map and the Model with the two case study Councils and their real life situations and data constraints proved a valuable process and allowed for iterative improvements on both deliverables.

Councils around Australia should now be aware of the threat of sea level rise driven inundation and erosion to new development in the coastal zone and may already be dealing with the issues through planning and policy mechanisms. However, existing development, both public and private, poses a much more intractable problem and may have significant cost implications. Councils are therefore advised to extend their awareness of climate change driven impacts on their coastal zone and commence the collection of data for current high water events (including tidal and storm surge components) for their local areas as well as sea level rise projections. Modelling of likely local flood and erosion scenarios should be undertaken to provide a sound information base for the development of sea level rise strategies.

The Decision Map tool is recommended as a straightforward, logical, stepwise process that may be used to guide the collection and analysis of data and aid decision making. Several steps illustrated by the Decision Map require specialist inputs, for example from climatologists, lawyers and engineers. Data that is not currently readily available may be required to arrive at sound recommendations. Councils are urged to test the Decision Map by applying it to a manageable local case study to familiarise themselves with its operation and data requirements and to gain an improved understanding of both the nature of the sea level rise threat to existing coastal development and the potential for the generation of workable, cost effective policy outcomes. Once Council is satisfied that the Decision Map is an appropriate tool for its particular local circumstances and is familiar with its data requirements, then the approach can be rolled out more extensively and longer stretches of coastline may be assessed.

For this project we have developed a financial model for Councils to evaluate the main flood defence strategies. Based on the real data from the pilot Council, the model can provide useful insights to assist Councils in making the flood defence decision.

A preliminary model for evaluating erosion defence strategies has also been developed. It has also been tested with the data from a pilot Council and seems to provide useful results. However, caution needs be taken in interpreting these results, as it is based on a highly simplified understanding of the erosion mechanism, which is FAR more complicated than that for flood.

Any given coastal location threatened by future tidal inundation or erosion may be analysed using the methodology determined by this project. Once the Decision Map analysis for the site has been completed, if any liabilities are identified then these may be costed and alternative policy solutions tested using the financial modelling tool. Outputs of the process will likely be a range of costed future policy or action scenarios. However, it should be noted at this point that there are limitations in the outputs delivered by the Model (as described in the report in detail) and these need to be understood before outputs are considered. Limitations include the assumptions made in the Model itself, the errors associated with the measurement of vertical heights above the AHD and both inundation and erosion mapping processes. Having said that, the structure of the model and the calculations developed are sound and with further development and testing it is likely to prove a highly useful tool for the assessment of coastal impacts and adaptation options. Given the scope of this project, we are satisfied with the current pilot version of both models.

Regardless of the accuracy of quantitative financial analysis, Councils should beware of simply taking the least cost solution as the preferred option. The aim of the Decision Map and tool is to provide a logical and comprehensive approach to analysing specific coastal inundation and erosion problems. If comprehensive high quality data is used throughout then Councils should have confidence both in the scenarios modelled and the costs in each case. It is nevertheless important to recognise that the eventual resolution of complex coastal problems may depend on more than a simple evaluation of the dollar cost of different solutions.

The macro policy environment is of great importance. The review of literature in Part B of the report revealed a range of different approaches by national governments around the world. These approaches ranged from clear attempts to divest higher levels of government from any liabilities attaching to future coastal problems, to at the least an implicit assumption that national government will pick up the bill. Similarly, while some governments have attempted to clarify a managed retreat approach, in practice this has sometimes not played out as intended and some backtracking and subtle policy shifts have been required. Political pressure may prove a decisive factor in certain cases and the least cost option may not always prove the best because additional uncosted factors may prove important in the decision making process. For example, the ecological or recreational value of particular coastal areas or assets, that have intentionally not formed part of this study, may prove critical to the decision process but were beyond the scope of this study.

Given the multifaceted nature of the problem, we suggest that the monetary valuations that result from the approach set out above are important, but not the only factor that must be considered when arriving at a decision to act. A number of decision making frameworks are designed to handle such multi-dimensional problems. Some of the most widely used are:

1. Multi criteria analysis (MCA) is a decision making tool intended for complex problems where there may be conflict between different solutions. It is often used in situations where multiple interpretations and perspectives are apparent and where different professions or disciplines may be involved in problem definition and resolution and the problem is framed in multiple ways. There are various interpretations of MCA but typically a MCA will establish criteria against which a solution will be assessed and each alternative will be scored according to how well it meets each criteria. So, cost to the Council may be one criterion, but public safety, public acceptance, private costs and indirect impacts such as longshore drift or ecological change may represent examples of other concerns. The outcomes of the application of the approach described here may form one element in a MCA based decision process (DCLG 2009). Data and approaches developed in parallel studies under the Coastal Adaptation Pathways Project may be

valuable adjuncts to this report in the eventual resolution of complex climate induced coastal problems.

2. Structured decision rules are already widely used in Local Government decision-making related to climate change (Bara et al. 2010, DEFRA 2009, Environment Agency 2011). The main decision rules are as follows (Peterson 2009 p. 40-56, Goodwin and Wright 2004, ch.5):

a) *Maximin rule*: Maximise the minimal value obtainable with an act.
b) *Leximin rule*: If the worst outcomes are equal, choose an alternative such that the second worst outcome is certain to be as good as possible (if not unique, the third worst outcome, and so on). This addresses scale and range effects in the maximin rule.
c) *Maximax rule*: maximise the maximal value obtainable with an act.
d) *Optimism-pessimism rule*: consider both the best and worst possible outcome of each alternative, and then choose an alternative according to the decision-makers degree of optimism/pessimism (scored appropriately).
e) *Minimax regret rule*: choose an alternative under which the maximum regret value is as low as possible.
f) *Principle of insufficient reason*: if one has no reason to think that one state of the world is more probable than another, then all states should be assigned equal probability.

These rules operate under different trade-off assumptions, are used in different decision tasks, and are applied to values that are associated with actions, independently derived (as, for example, through the decision mapping and financial modelling methodology presented in this report).

3. Uncertainty and decision tree modelling: Where well-defined alternatives can be defined, valued and assigned well-founded probabilistic parameters (Level 2 uncertainty), standard decision tree methodologies can be applied (Moore and Thomas 1976). It must be noted that the variables related to climate change are predominantly of Levels 3 and 4 uncertainty, which are not readily amenable to decision tree analysis. However, there are currently a number of computing platforms that have been developed for modelling highly volatile systems, through influence diagrams, that allow for nested relationships, and the aggregation of probabilistic effects into a probability distribution around specific values, as output. The Excel-based software @RISK has been used in this project for the financial modelling, and can be extended in its application to multi-dimensional decision problems. An alternative is Analytica, which operates from a graphical interface, and was specifically developed to be applied to policy and management contexts (Morgan and Henrion 1990).

4. Deliberative methods: As has been noted above, the complex problems characteristic of policy decisions at the local planning level require consideration of both natural and human factors (Ostrom 1990). Typically analysts are much better at handling scientific data than human, subjective data. Deliberative methods in policy making have been developed to place the weight of decision making on the communities who are most affected by them. These have been generically described as follows (Layzer 2008, p.295):

Ideally, participants in a collaborative process jointly establish the rules of engagement, define the issues, design the collection and analysis of scientific data, help develop solutions, and aid in implementing decisions.

The deliberative methods approach not only allows for input of local knowledge and community attitudes and values into the decision-making process, but develops ownership of the outcomes (Gastil and Levine 2005). There are a range of such methods, including Citizen's Juries that have been used in the Australian Local Government context. All provide for the input of expert opinion and analysis. The Belongil Spit case study described in Part B could be interpreted as a somewhat unplanned and chaotic version of this approach. Lessons from that experience, taken in conjunction with the case studies outlined above, may provide some insight into how to approach complex, multifaceted problems such as are addressed in this report. In a deliberative methods framework, the role of the analysis undertaken in this project would be to provide rigorous empirical and analytic input into the policy analysis and deliberation phases (Focht and Trachtenberg 2005). Engagement with all stakeholders, transparency of information and comprehensive high quality data inputs are all suggested as critical to achievement of viable policy outcomes.

Feedback from the two case study Councils and the LGA on the project outputs were positive. From Adam Gray, Director – Environment, LGA, Adelaide:

“The management and inherent decision making in the coastal zone is of key concern to the Local Government sector nationally. The interaction between human settlements/ infrastructure and coastal processes has and always will be a complicated relationship to manage, with accelerated climate change and associated sea level rise adding another layer of complexity to this already challenging task. Local Government is at the front line of this management task and as such the Department of Climate Change and Energy Efficiency (DCCEE) Coastal Adaptation Decision Pathways program has been welcomed by Councils in South Australia.”

“The outcomes from LGA project have already proven valuable for the 2 South Australia pilot Councils and the LGA looks forward to engaging the wider Local Government audience in promoting this decision making tool. The LGA acknowledges the funding and support from DCCEE and the significant efforts of all parties involved in delivering this project, in particular Uni South Australia, the District Council of Mallala and City of Onkaparinga and the State Coastal Conservation Branch and Climate Change & Sustainability Division of DEWNR.”

Feedback from Andrew Thomas, Workgroup Coordinator, Water Resources and Asset Management, City of Onkaparinga:

“The CAP project provides new modelling software to assist Council in assessing options for coastal management, in response to environmental changes such as rising sea levels and ongoing coastal erosion. Decisions made by Councils in relation to these issues need to be informed by good science and based on methodologies which are transparent and replicable. The CAP software allows Council to undertake its own ‘in house’ scenario modelling, to help us understand the medium and long term financial implications of a range of coastal management options for a particular site. The Council will continue to seek independent specialist advice on appropriate coastal management issues, with the CAP software modelling complementing this advice.”

And from Charles Mansueto, Chief Executive Officer, District Council of Mallala:

“The District Council of Mallala appreciated its involvement as a pilot Council in the Coastal Adaptation Decision Support Pathways Project. Climate Change is a key challenge for Council and its community and such projects give Council a better understanding of the issues and potential tools to assess the impacts and improve decision making. Council will further evaluate the outcomes of the project in its decision making process.”

The positive responses to outputs from the pilot study suggest that further future research that builds on this work and the financial tool developed would be of use to all Councils Australia wide. Directions for further work as identified by the project team that would build upon the current project outputs include:

- application of the decision tools to a wider range of case studies - location, size, stakeholder profile;
- development of a Decision Map Powerpoint ® slide tool that steps users through the process and provides additional information and guidance on each step in a single stand-alone format;

- development of three shorter summaries of each part in the final report as guides for Councils wanting concise summaries of the work undertaken;
- systematic historical study of decision-making across Councils, decision-map tested against it;
- elaboration and analysis of non-financial factors of decision map: e.g. political factors - community, government;
- integration of decision pathways into multi-dimensional decision frameworks e.g. MCA, decision rules, decision trees and uncertainty analysis, deliberative methods;
- potential role of real options approach for financial analysis; and
- research into the role and capability of Local Government in this kind of modelling: relationship between local / agency / academic areas in developing sophisticated integrated models and decision-making frameworks.

11 GLOSSARY

ADAPTATION
Adaptations are actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected changes in climate conditions.

AR4
Fourth Assessment Report.

BOM
Bureau of Meteorology.

CHENIER DUNE
A discrete, elongated sand and/or shell bodies stranded on a coastal mudflat or marsh.

CLIMATE
Climate summarises the average, range and variability of weather elements, e.g. precipitation, wind speed, air temperature, humidity, and sunshine hours (solar radiation), observed over many years (typically > 30 years) at a location or across an area .

CLIMATE VARIABILITY
Climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. Examples of climate variability include extended droughts, floods, and conditions that result from periodic El Niño and La Niña events.

CLIMATE CHANGE (global warming)
Climate change refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer). Contemporary climate change refers to anthropogenically driven changes in the climate as a result of changes to the composition of the atmosphere via the addition of greenhouse gases.

CPRS
Carbon Pollution Reduction Scheme.

CSIRO
Commonwealth Scientific and Research Organisation.

DCCEE
Department of Climate Change and Energy Efficiency.

DEH
Department of Environment and Heritage.

DEM
Digital Elevation Model.

DROUGHT
Drought in general means acute water shortage. When dry conditions are not relieved by equally wet periods over a number of years, or when a shorter period of dry is exceptional, it is commonly called drought.

DWLBC
The Department of Water, Land and Biodiversity Conservation, South Australia.

ESTUARY
A partially enclosed coastal body of water that is either permanently, periodically, intermittently or occasionally open to the sea within which there is a measurable variation in salinity due to the mixture of seawater with water derived from on or under the land'. It also encompasses the ecosystem processes and associated biodiversity within estuaries and their adjacent habitats.

GCM
Global Climate model.

GIS
Geographic Information System.

INTERTIDAL FORESHORE
The coastal zone measuring from the lowest to the highest tide mark. The intertidal zone is subject to alternating periods of flooding and drying.

IPCC
Intergovernmental Panel on Climate Change.

LITTORAL
In coastal environments, the littoral zone extends from the high water mark, which is rarely inundated, to shoreline areas that are permanently submerged. It always includes the intertidal zone and is often used to mean the same as the intertidal zone. However, the meaning of "littoral zone" can extend well beyond the intertidal zone.

NEARSHORE
The area extending from the low water shoreline to the generally less than 10m depth or beyond the breaker zone.

RISK
Risk is the product of consequences and likelihood - what can happen, and what are the odds of it happening. Both of these factors are important in determining whether and how we address specific risks.

SUPRATIDAL
The shore area above the high tide level.

VULNERABILITY
Vulnerability to the impacts of climate change is a function of exposure to climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes. Vulnerability is typically described to be a function of three overlapping elements - exposure, sensitivity, and adaptive capacity. For example, agricultural vulnerability to climate change is described in terms of not only exposure to elevated temperatures, but also crop yield sensitivity to the elevated temperatures and the ability of farmers to adapt to the effects of that sensitivity, i.e. by planting more heat-resistant cultivars or by ceasing to plant their current crop altogether. Vulnerability is place based – region rather than country, and needs to match the scale of decision-making of the collaborating stakeholders.

WEATHER
Weather describes atmospheric conditions at a particular place in terms of air temperature, precipitation, wind speed, pressure, and humidity.

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APPENDIX 1 - REVIEW OF INTERNATIONAL COASTAL CLIMATE CHANGE POLICY

THE UNITED STATES OF AMERICA

INTRODUCTION

The United States of America (USA), is situated in the northern and western hemispheres, and is bordered by the countries of Canada to the north and Mexico to the south (Figure 1). To the east is the Atlantic Ocean, in the southeast the Caribbean Sea and Gulf of Mexico, and in the west the Pacific Ocean. Approximately 30 states are coastal, with 'more than ten thousand square miles of land... within two meters above the sea' (Titus 2011:9).

Figure 1: Map of the United States of America (Source: http://beaconedu.com.np/abroad-study/usa/fast-fact).

The United States of America is a constitutional republic, with three tiers of government that include the Federal Government, located in Washington D.C., the State governments of 50 states, and the Local Governments (See Table 1).

Table 1: System of governance in the United States.

Level 1	Federal Government comprising: Executive Branch (President and Vice President) Legislative Branch (House of Representatives and Senate) Judicial Branch (Supreme Court)
Level 2	State Government (States)
Level 3	Local Government

GENERAL ATTITUDES TOWARDS CLIMATE CHANGE

In 2009, the Obama Administration 'convened the Interagency Climate Change Adaptation Task Force (the 'Task Force'), co-chaired by the Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA)' (Council on Environmental Quality 2012). The role of this body was to help develop a report with recommendations for how the Federal Government can strengthen policies and programs to better prepare the Nation to adapt to the impacts of climate change.
In the October 2010 Interim Progress Report to the President (the 'Interim Report'), the Task Force recommended that 'Federal agencies develop and implement coordinated climate adaptation plans' (Council on Environmental Quality 2010). The Task Force also recommended that at a minimum, six elements should be included in the development of a national strategy. These included (Council on Environmental Quality 2010:4-6):

- *Science Inputs to Adaptation Decisions and Policy;*
- *Communications and Capacity-building;*
- *Coordination and Collaboration;*
- *Prioritization*(sic);
- *A Flexible Framework for Agencies;*
- *Evaluation.*

The CEQ and the Office of Management and Budget (OMB) have recently implemented the Federal Agency Climate Change Adaptation Planning: Implementing Instructions, (Implementing Instruction), or 'implementing instructions' and a supporting document, informing Federal agencies on 'how to integrate climate change adaptation into their planning, operations, policies and programs' as was recommended by the Task Force's 2010 Progress Report to the President (Interagency Climate Change Adaptation Task Force 2011a).

In October 2011, the Task Force released the completed 2011 Interagency Climate Change Adaptation Task Force Progress Report (the 'Progress Report') outlining the 'Federal Government's progress in expanding and strengthening the Nation's capacity to better understand, prepare for, and respond to extreme events and other climate change impacts' (Council on Environmental Quality 2012). As of January 2011, 'eleven states had completed adaptation plans, four had plans in progress, and eight had recommended developing adaptation plans in their State Climate Action Plans' (Interagency Climate Change Adaptation Task Force 2011a:3-4). However, the Federal Government is yet to ratify a national adaptation strategy.

Other programs available for the State and Local Governments in relation to climate change include:

- National Global Change Research Program (USGCRP) to coordinate Federal research activities and make research and information accessible;
- National Climate Service (NOAA) to provide weather data, forecasts and warnings;
- Adaptation Science and Information Program (NOAA/USGS) to provide science, information and technical assistance to assess and address impacts to natural resources;
- Drinking Water Utilities Research (EPA, Commerce, DOE, Interior) to fund research on the impacts to drinking water utilities to assist utilities in adaptation efforts.
  (Adapted from Arroyo 2009)

SCIENCE

The United States admits it is taking a 'leading role in addressing climate change', and is heavily involved in both domestic and international climate change programs and affairs (U.S Department of State 2011a). For example, the nation is a 'strong supporter' of the activities of the U.N. Framework Convention on Climate Change (UNFCCC) and Intergovernmental Panel on Climate Change (IPCC), as well as working with Australia, China, India, Japan and South Korea under the Asia Pacific Partnership on Clean Development and Climate (U.S Department of State

2011a).The 2011 Progress Report recognises that by the end of this century, global sea level is 'expected to rise 2 feet in a low emissions scenario or nearly 3.5 feet in a higher emissions scenario'. This finding supports the scientific data presented by the UNFCCC (Interagency Climate Change Adaptation Task Force 2011a:2). The report also recognises that climate change is caused by both human induced and natural causes. Furthermore, there is evidence of national concern relating to climate change in the US. In a 2011 survey of 396 mayors from all 50 states, it was found 'that over 30 percent (of these individuals' Local Governments) are already taking climate impacts into account within their capital planning and improvement programs' (Interagency Climate Change Adaptation Task Force 2011a:16).

RESPONSIBILITY

Responsibility for protection from, adaptation to and damage because of the effects of climate change appear to be contentious issues in the United States. This attitude is especially prevalent in relation to sea level rise, coastal erosion, storm surge on both public and private property and can relate to definitions of ownership. In the 2011 Progress Report, the Federal Government recognises that in general

> *'Climate change will challenge the missions, operations, and programs of Federal agencies. To ensure resilience and save taxpayer dollars in the long-run, the* ***Federal Government has a responsibility to reduce climate risks as part of ongoing agency planning****'* (Interagency Climate Change Adaptation Task Force 2011a:5 emphasis added).

The report continues that the Federal Government and its' Federal agencies play a significant role in 'managing our Nation's natural resources and infrastructure'. This role includes the management of roads, airports, national parks, fisheries, dams, levees, and military installations (Interagency Climate Change Adaptation Task Force 2011a:5). Furthermore, the Task Force found that the 'Federal Government has a critical obligation to carry out adaptation planning because climate change directly affects a wide range of Federal services, operations, programs, and assets (e.g., infrastructure, land, water resources), and clearly has broad national security implications' (Interagency Climate Change Adaptation Task Force 2011c). As part of this responsibility, relevant Departments are required to partner with and support local communities, indigenous tribes and States in managing and assessing climate risks. Responsibility also includes making readily available scientific data and methods to support these groups (Interagency Climate Change Adaptation Task Force 2011a:5).

Furthermore, as the United States, like Australia and the United Kingdom, is governed by common law, there are various rights that the public has to the shoreline. These rights can conflict with private investors/property owners who own land along these areas, and ultimately they impact upon the manner in which shorelines can be planned for, managed and protected (Titus 1998:1293. See also National Oceanic and Atmospheric Administration 2009). For example, legal issues have arisen in regards to States banning waterfront property owners from constructing permanent armouring (such as sea walls) along the shoreline. This policy can be viewed as 'unconstitutional taking of a common law property right' (Pace 2010).

In the United States, various mechanisms adopted by Local Governments, planners, insurance companies and other government and private agencies to adapt to sea level rise, such as 'buying back' or restricting development of coastal land, has been contested in the court of law. For example, in the States bordering the Gulf of Mexico (including Texas, Louisiana, Mississippi, Alabama and Florida), State and Local Government action that limits or impacts upon private coastal property rights has been seen to be in violation of the Fifth Amendment, or 'Taking Clause' of the US Constitution, as governments cannot 'take' private property. This is known as 'regulatory taking' and again leaves the various levels of government vulnerable to court action (Craig 2010).

In one of the best-known US cases concerning coastal policy and property acquisition, Lucas v. South Carolina Coastal Council (1992), the US Supreme Court noted that:

> *'No unconstitutional taking of private property occurs if the property owner's claimed rights were never part of that owner's title to begin with. As a result, certain "background principles" of state property law shield governmental action from taking liability, even if that action interferes with or prohibits a landowner's desired use of the property'* (Craig 2010:1*).*

Various programs, partnerships and mechanisms have been established between Federal, State and Local Governments and organisations in the US, to address legal issues that relate to sound coastal management, planning for sea level rise and regulatory taking. In 2009, a partnership between the EPA, Sea Grant, Northern Gulf Institute and the U.S. Geological Survey were awarded a research grant to analyse 'federal and state constitutional and statutory takings jurisprudence and theories to aid in the creation of innovative land use planning policies for adaptation to sea level rise' (Florida State University 2010).

INSURANCE

The Federal Emergency Management Agency's (FEMA) National Flood Insurance Program (NFIP) is a national program which offers flood insurance for homeowners, business owners and renters if their particular community is participating in the NFIP (FEMA 2012). Although not explicitly related to the impacts of climate change and primarily designed for floodplain (not coastal) areas, the NFIP is under investigation to better incorporate sea level rise, storm surge and associated phenomenon in to the program.

In 1991, FEMA released a document that investigated the impact of sea level rise on the NFIP, based on two 100-year scenarios – a one and a three foot increase in sea levels. The report noted that the then current flood insurance rating would not be affected by a one foot increase, while the impact of the three foot rise would not truly be witnessed until circa 2050. This, FEMA notes, would allow investigation into 'alternative approaches to the loss control and insurance mechanisms of the NFIP and to implement those changes that are both effective and based on sound scientific evidence' (Federal Emergency Management Agency 1991). More recently the US Climate Change Science Program has noted:

> *'Sea-level rise does not threaten the financial integrity of the National Flood Insurance Program. Incorporating sea-level rise into the program, however, could allow flood insurance rates to more closely reflect changing risk and enable participating Local Governments to more effectively manage coastal floodplains' (U.S. Climate Change Science Program 2006:141).*

PROPOSED RESPONSE TO PERCEIVED CLIMATE CHANGE IMPACTS (CCI)

Response Strategy

In their 2010 Interim Report, the Task Force created a set of guiding principles that 'governments, communities, the private sector, and others should consider when designing and implementing adaptation strategies'. These guidelines include:

- Adopting integrated approaches;
- Prioritising the most vulnerable (areas);
- Using the best available science;
- Building strong partnerships;
- Applying risk management methods and tools;
- Applying ecosystem based approaches;
- Maximising mutual benefits;
- Continuous evaluation of performance.
  (Adapted from Interagency Climate Change Adaptation Task Force 2011c:14):

Maryland is discussed below as an example of State level action which seeks to implement these guidelines.

Case Study: Maryland

In 2010, the Maryland Commission on Climate Change released a report detailing methods to address climate change impacts, such as sea level rise. Entitled the 'Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change: Building Societal, Economic and Ecological Resilience', this Phase II report is a companion document to the Phase I 'Strategy for Sea Level Rise and Coastal Storms' document released in 2008. Both of these documents form part of the State's extremely comprehensive Climate Change Action Plan.

Maryland is considered 'at the forefront of planning for climate change' in the United States. The state is also recognised for its' 'efforts to mitigate climate change', 'being a national leader in advancing ...scientific understanding' in the area, as well as 'advocating sound planning to avoid or minimize (sic) ...anticipated impacts' (Center for Environmental Science 2011). Several policy measures have been specifically adopted or suggested for adapting to climate change, and sea level rise. Some main points include:

Planning preparation
Planning preparation relates to several factors, including responsibility, awareness and innovation in planning for sea level rise. Firstly, Phase 1 stresses the need for Local and State Governments to have further access to the accurate anticipatory tools and information needed for preparing their communities for climate change. Tools include GIS mapping and modelling data and baseline studies (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008:25-26). There is an emphasis also on educating the public service and local community on capacity building (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008: 29). The report also recognises there is need for integrated planning mechanisms – not only between types of services (i.e. infrastructure and health services), but between Local and State Government agencies.

Insurance
Phase 1 recognised the economic impact that sea level rise would have, not only on natural resources, but properties and communities. The report advised the establishment of an 'independent Blue Ribbon Advisory Committee' that would 'advise the state of the risks that climate change pose(d) to the availability and affordability of insurance' (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008: 1). As a result of the Climate Change Action Plan, a Climate Change Insurance Advisory Committee was established, and a report released outlining various options for insurance for Marylanders in the face of increasing climate change impacts. Options included various State and Federal incentives, reducing the risk of hazards in development planning and building alliances with the private and public enterprise (Climate Change Insurance Advisory Committee 2010).

Furthermore, the 2008 report recommended the creation of a Maryland Sea-Level Rise Disclosure and Advisory Statement that owners of coastal properties built before 1978 would require when selling or leasing their properties. This statement, enforced under Federal and State law, would contain information relating (but not limited) to disclosure settlements, zoning maps and similar (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008:18). Further investigation reveals no new developments on this incentive.

Infrastructure
Maryland has substantial property located along its' shoreline, including private and public infrastructure. Scenario modelling shows major city areas, such as Annapolis, inundated and vulnerable to sea level rise in the future (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008:12). The report suggests a

variety of options available for vulnerable infrastructure including the development of local and state policies that involve the protection, retreat or abandonment of these assets. The report also places specific emphasis on the State Government to undertake any action with regards to infrastructure, although a comprehensive, integrated approach with the private sector and local/regional governments is recommended. Current State programs are investigating critical infrastructure and vulnerability (Maryland Commission on Climate Change, Adaptation and Response and Scientific and Technical Working Group 2008:12-13).

CANADA

INTRODUCTION

Canada is situated in the northern and western hemispheres, and is bordered to the south and west by the United States of America. Canada is surrounded by the Pacific Ocean to the west, the Atlantic Ocean to the east and the Arctic Ocean to the north (Figure 2).

Figure 2: Map of Canada, North America. (Source:-http://www.ezilon.com/maps/north-america/canada-road-maps.html).

Canada is a democratic constitutional monarchy, with three tiers of government. These include the Federal Government, the State Governments comprising ten provinces and three territories and the Local Governments (Table 2).

Table 2: Summary of the system of governance in Canada.

Level 1	Federal Government comprising: - Executive Branch (The Crown; Queen's Privy Council (including the Prime Minister) - Legislative Branch (Parliament- Senate and House of Commons) - Judicial Branch (Supreme Court)
Level 2	State Government (Provinces and Territories)
Level 3	Local Government (Municipalities)

GENERAL ATTITUDES TOWARDS CLIMATE CHANGE

The Government of Canada is taking an 'aggressive approach' to climate change, supporting an 'approach that achieves real environmental and economic benefits for all Canadians' (Government of Canada 2012a & b). In December 2007, the Federal Government announced an

$85.9 million investment into climate change adaptation (Government of Canada 2012c). The investment included approximately $35 million towards Natural Resources Canada, to develop regional adaptation programs and risk management tools such as analytical models and guidelines (Brooks et. al 2009).

Because of the varied geographic and economic conditions within Canada, issues of climate change importance differ greatly between regions. For example, the east coast is concerned about the 'impacts of sea level rise as well as commercial fisheries', whereas in the agricultural centre of Canada, there is concern for too little water (Lemmen 2004). Overall, there is an increasing emphasis upon local decision makers to be informed about the impacts and risks of climate change, as perceptions and levels of knowledge will affect both the timing and magnitude of actions undertaken (Lemmen 2004; Lemmen et. al. 2008).

Various documents and strategies have been prepared in relation to climate change adaptation in Canada. In 2004, a national adaptation framework was released by the Federal Government's Intergovernmental Climate Change Impacts and Adaptation Working Group. The intergovernmental framework sought to provide a basis for the means of co-operation between all tiers of government in relation to this climate change, as well as promoting research and the development of tools needed for the creation of detailed regional adaptation plans.

The Federal Sustainable Development Act (2009) was designed to 'provide the legal framework for developing and implementing a Federal Sustainable Development Strategy that will make environmental decision-making more transparent and accountable to Parliament' (Section 3). Furthermore, in 2009, the Government of Canada released the 'Climate Change Plan for Canada', which details the Government's intentions and priorities in tackling climate change (Government of Canada 2009).

A key national document that addresses climate adaptation and strategies for Canada is the scientific assessment report 'From Impacts to Adaptation: Canada in a Changing Climate' (2007). The report investigates the current and future impacts of, and vulnerabilities to climate change, as well as regional adaptation actions and programs taking place. It also recognises and identifies various policy issues, but deems any further action 'beyond the scope of this scientific assessment' (Lemmen et. al. 2008:5). Even so, findings from the report have provided the basis for current Federal Government climate change programs, such as the Regional Adaptation Collaborative Program, led by Natural Resources Canada (Natural Resources Canada 2011a). In 2010, a shorter updated version of the report was presented for public view.

Other tools/guidelines include:

- Bizikova L., T. Neale, and, I. Burton (2008) *Canadian communities' guidebook for adaptation to climate change. Including an approach to generate mitigation co-benefits in the context of sustainable development*. 1st ed. Vancouver: Environment Canada and University of British Columbia.
- ICLEI Canada, (2008) *Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation*, Canada: ICLEI - Local Governments for Sustainability.
- Mehdi, B., Mrena, C. & A. Douglas, (2006) *Adapting to Climate Change: An Introduction for Canadian Municipalities*, Canada: The Canadian Climate Impacts and Adaptation Research Network.

SCIENCE

The Federal Government acknowledges that climate change can be attributed to both natural and human induced impacts. 'From Impacts to Adaptation: Canada in a Changing Climate' (2007) notes that there is an expected '0.3 to 0.6 plus metres (increase in sea level) by 2100' (Black et. al 2010:5). The report also cites that coastal erosion, enhanced as a result of sea-level rise, decreased ice cover and storminess, as well as other non-climatic factors, will result in the 'accelerated erosion and degradation' of the dunes and coastline 'throughout the Gulf of St.

Lawrence, north-eastern Prince Edward Island and south-western, western and eastern Newfoundland' (Lemmen et. al 2008:9). The conclusions of the report are linked to the findings of the IPCC Report 4 (Lemmen et. al 2008:5).

RESPONSIBILITY

There is an expectation upon local decision makers in Canada to be well informed and understand climate change risks in developing effective adaptation strategies and policy. This expectation includes consideration of the precautionary principle in governing sustainable development (Sustainability Act, 2009). However, there is no specific legislation in Canada that specifically addresses obligations or responsibilities on climate change adaptation. Even though currently there is limited legal responsibility, ICLEI Canada (2008:14) notes that 'it may not be reasonable for infrastructure decision-makers (for example) to seriously dispute the significance of climate risks, but ignoring the risks may not guarantee immunity to legal liability (in the future)'.

ICLEI Canada makes specific mention of legal liability in regards to climate change, noting that:

> *'a growing number of legal professionals are looking at how failure to adapt to known and expected climate change realities may expose communities and governments to legal actions by individuals or others for property damage and personal injury. Beyond financial compensation, the implications of this heightened exposure to legal liability include investor risk aversion, decreased confidence in governments, and backlogs in infrastructure projects'* (ICLEI Canada 2008:14).

As with other nations dependent on common law such as Australia and the United States, there is a legal obligation for Canadian Local Governments to be compliant with common law principles of 'negligence, nuisance, strict liability and occupier's liability legislation' in relation to infrastructure. For example, a Local Government can be found 'negligent' if it 'demonstrated awareness of a particular climate risk, such as the risk that decreased lake levels will result in the failure of an above-ground water system and affect water quality, but did not address the risk'. Furthermore, for infrastructure practitioners, 'reliance on existing codes, standards and related instruments would likely prove an insufficient defense (sic) against negligence, particularly if it is known that the codes or standards were inadequate under changing environmental conditions' (ICLEI Canada 2008:14).

However, there is some personal responsibility on the owner for private developments in vulnerable coastal areas. For example, in New Brunswick, Nova Scotia, the Sustainable Planning Branch, part of the Department of Environment and Local Government, openly states in its Coastal Areas Protection Policy that:

> *'individuals should not transfer costs for private risk to the public purse or to others. In other words, there should be no compensation provided to people who choose to build in harm's way, and any development should not increase risk for others'* (The Sustainable Planning Branch 2002:7).

INSURANCE

There is recognition in Canada that climate change will have a 'profound impact' upon the insurance industry. For example, the cost of insuring homes and businesses in recent years has increased where there is research to support that any future damages, will be higher than the historical damage (Mehdi et. al 2006:25). Further evidence demonstrates that insurance premiums are increasing because of climate change impacts, including severe storms.

INFRASTRUCTURE

Recognising the importance of reliable, effective infrastructure under a changing climate, the Government of Canada has committed itself to working with province and municipalities to 'establish a ten-year infrastructure program that will accommodate long-term strategic initiatives essential to competitiveness and sustainable growth' (Government of Canada 2009:16). More specifically, the Canadian Council of Professional Engineers, in support of the Natural Resources Canada's Climate Change Impacts and Adaptation Division developed a document entitled the 'Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment Part 1' The document provides a detailed report on the impact of climate change on Canada's infrastructure (PIEVC 2009:4).

RESPONSE STRATEGY

Recognising the potential impacts of climate change in Canada, the Federal Government is advocating a proactive approach towards adaptation. The Government recognises that although spontaneous or autonomous adaptation has, and will continue to occur within Canada, there is also a need for 'effective planning, co-operation and co-ordination' to 'improve the success of adaptation', as well as to monitor the associated costs (Lemmen et. al 2008:429). For example, specific government divisions have been created to aid Federal, State and Local Governments and agencies to successfully adapt to climate change (Figure 3).

<table>
<tr><th colspan="7">ADAPTATION</th></tr>
<tr><th>Based on</th><th colspan="6">Type of adaptation</th></tr>
<tr><td>Intent
In relation to climatic stimulus</td><td colspan="3">Autonomous
(e.g. unmanaged natural systems)</td><td colspan="3">Planned
(e.g. public agencies)</td></tr>
<tr><td>Action</td><td colspan="2">Reactive
(post)
(From observed modification)</td><td colspan="2">Concurrent
(during)</td><td colspan="2">Anticipatory
(ante)
(Prior modification)</td></tr>
<tr><td>Temporal scope</td><td colspan="3">Short term
Adjustments, instantaneous, autonomous</td><td colspan="3">Long Term
Adaptation, cumulative, policy</td></tr>
<tr><td>Spatial scope</td><td colspan="3">Localized</td><td colspan="3">Widespread</td></tr>
</table>

Figure 3**: Different types of adaptation considered in Canada (Lemmen et. al 2008:428). The report notes that 'in most circumstances, anticipatory planned adaptations will incur lower long term costs and be more effective than reactive adaptations'.**

Natural Resources Canada's Climate Change Impacts and Adaptation Division was specifically designed to generate policy, knowledge and understanding of adaptation practices in Canada. Recognising that this knowledge and resilience to climate change is important, as well as complementary to adaptation, the Division currently encompasses two major activities:

The Regional Adaptation Collaboratives (RACs) Program
The $30 million, three-year Federal RACs program was designed to help Canadians (such as Local Governments, community groups and individuals), 'reduce the risks and maximize the opportunities posed by climate change' (Natural Resources Canada 2012b). Actions include helping local communities adapt to local climatic problems caused by climate change. Ultimately,

the goal of the program is to help local decision makers incorporate adaptive measures into policy, as well as encourage regional interaction and strategic development in the area. In total, six RACs have been implemented.

Tools for Adaptation

The Tools for Adaptation incentive includes 'guidelines, methods and approaches to help people incorporate information about a changing climate in decision-making' (Natural Resources Canada 2012c). The tools have been divided into two specific themes: Risk Management Tools and Adaptation Tools.

The risk management tools are based upon 'classic risk assessment approaches', while '*provid(ing) a step-wise approach to assessing the risks from climate change to a community, region, infrastructure or business'* (Natural Resources Canada 2012c). This activity includes the aforementioned 'Infrastructure Climate Risk Protocol', as well as the guide 'Adapting to Climate Change: A Risk Based Guide for Local Governments'. The risk based guide outlines a detailed methodology for adapting to climate change in Canada (Figure 4).

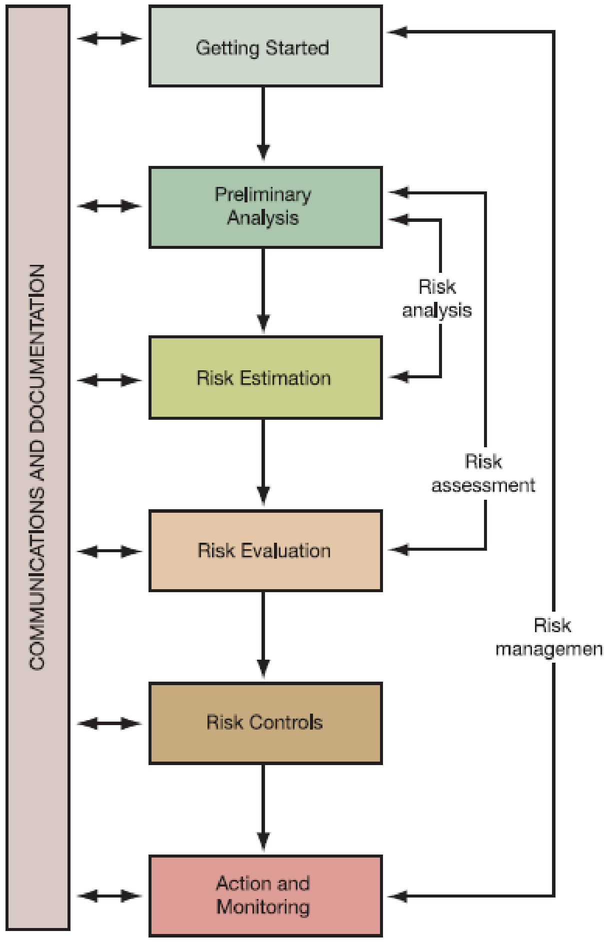


Figure 4: Steps in the risk management process (Black et. al 2010).

On a more local level, the 'Changing Climates: Changing Communities Guide' recommends 'five key mechanisms' that Local Governments can use in implementing climate change adaptation actions. These include (ICLEI 2008:14):

- Land use and urban planning;
- Licensing and regulation;
- Facilitation, advocacy and leadership;
- Community service delivery, community development and civic engagement; and

- Workforce development.

SUMMARY

Two fundamental ideals appear evident in the Canadian Government's stance on climate change. These are:

1. Canadians, both the general public as well as policy and decision makers, have both a right and a need to access current, relevant data on climate change.
2. A strong sustainable, intergovernmental approach to decision making is required.

These ideals are integrated into climate change legislation (such as the Sustainable Development Act 2009), policy and reports as well as to insurance and liability aspects. Methods and tools have been developed to help Local Governments consider, assess and manage risk and uncertainty in climate change policy and planning decisions, and include the Canadian Environmental Assessment Agency's (EAA) 'Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners'.

CASE STUDIES

Several Federal and/or State initiatives to adapt to climate change driven sea level rise are active within Canada. A brief overview of some of these initiatives follows.

Atlantic Canada's Atlantic Climate Adaptation Solutions Project

Under the Regional Adaptation Collaboratives (RACs) Program, the Atlantic Climate Adaptation Solutions Project has been working with a range of government and non-government agencies and departments to understand Atlantic Canada's vulnerability to climate change, as well as to 'enhance resilience' within the communities (Natural Resources 2012d). One theme of particular interest is the 'Community Planning for Flood and Coastal Areas' program, and includes:

- 'Assessing risk and vulnerability;
- Reviewing relevant policies and guidelines;
- Evaluating adaptation options; and
- Making recommendations where appropriate'.

Natural Resources Canada further notes that these activities will ultimately lead to recommendations in relation to improved current coastal management plans and shoreline protection/development mechanisms and other plans/policies related to reducing climate change related impacts (Natural Resources 2012d).

Halifax, Nova Scotia

Halifax, Nova Scotia, is Atlantic Canada's largest city, home to a large seaport and significant infrastructure (Natural Resources 2011e). Various projects have been implemented to both mitigate and adapt to the impacts of climate change, especially in relation to sea level rise and coastal erosion. In March 2004, the Local Government of the region, the Halifax Regional Municipality, released the ClimateSMART (Sustainable Mitigation and Adaptation Risk Toolkit), aimed at 'mainstreaming' climate change mitigation and adaptation principles into decision making, while also creating successful collaboration between Local, State and the Federal Government and private enterprise (Mehdi et. al 2006:18-19). Principal tasks of the Halifax ClimateSMART project included the following:

- Vulnerability assessments and sustainability analyses;
- Cost-benefit assessments;
- Emissions management and mitigation tool;
- Climate change risk management plan;

- An emissions management and adaptation methodology, including methodologies for each sector of the community; and
- Communications and outreach.

Halifax Regional Municipality has also worked with the CCIAD in Planning for sea level rise in Halifax Harbour. This work has included investigating scientific data and utilising climate scenario modelling to understand and plan for potential sea level rise and coastal storm surge impacts. In August, 2006, the Council adopted the Regional Municipal Planning Strategy, which considered these impacts, and regulated for future development accordingly. For example, recently approved under the Strategy is a requirement for development along the Halifax waterfront area to be a minimum of 2.5 metres above the 'ordinary high-water mark', a threshold that is able to be 'adjusted based on ongoing sea-level rise monitoring and analysis' (Natural Resources 2012e).

UNITED KINGDOM

INTRODUCTION

The United Kingdom (UK) includes England, Scotland, Wales, and Northern Island and is situated between the North Atlantic Ocean and the North Sea (Figure 5). The UK has a total land mass of 1680 km^2 and 12429 km of coastline, and in 2009 had a population of approximately 61.8 million in 2009 (Central Intelligence Agency, 2012).

Figure 5: Map of United Kingdom (Source: http://mappery.com/map-of/United-Kingdom-Physical-Map).

The UK is a parliamentary democracy within the framework of a constitutional monarchy. The UK has a unitary system of government, where power is held by central government although some powers were devolved to Scotland, Wales and Northern Ireland at the close of the last century. Across the country, Local Governmental bodies are organised into a mixture of one-tier and two-tier systems. In some parts of England town and parish Councils act as a third tier of Local Government (Table 3), although these have very limited statutory powers and resources (UK Government 2012).

Table 3: Administrative divisions of UK Government.

<table>
<tr><td>Level 1</td><td colspan="2">UK Parliament</td></tr>
<tr><td rowspan="3">Level 2</td><td colspan="2">Local Government</td></tr>
<tr><td>County:
Public services and infrastructure</td><td>Unitary authorities</td></tr>
<tr><td>District Councils – (Also called borough or city Councils):
Local services and planning</td><td>(In most large towns or in some small counties)</td></tr>
<tr><td>Level 3</td><td colspan="2">Town and Parish Councils</td></tr>
</table>

SCIENCE

The UK Government sees the main cause of the warming of the earth's surface and rising sea levels as related to the rise of the emission of greenhouse gases produced by human activity and is committed to doing its part in limiting global average warming to 2°C (UK Government, DEFRA 2012). The UK shows a high regard for the science of climate change and firmly adopts the findings of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007). In relation to sea level rise, the UK Government states that the associated risks to the UK from rising sea levels are 'high' and adopts a one metre sea level rise threshold based on the mid-range IPCC model in its policy.

However, the UK Government accepts that this level could be higher if emissions are not reduced, possibly several metres higher if 'tipping points' are reached where ice sheets melt faster than anticipated. In relation to the Thames Estuary 2100 Project, a 1.9 m sea level rise has been used as a basis for future defence upgrades. Those areas in the low lying parts of eastern and southern England are deemed to be the most at risk from erosion and flooding from increased storm surges.

RESPONSIBILITY AND LIABILITY

Following a change of central government in 2010 there has been a significant shift in policy towards a localisation of power and resources and a much stronger emphasis placed on individual responsibility and liability. The Flood and Water Management Act (2010) marks the beginning of this trend. The policy document, 'Understanding the risks, empowering the communities, building resilience' (DEFRA 2011, p. 35) gives the clearest view of contemporary UK policy:

> *'Flooding and coastal erosion cannot be entirely prevented and the relevant legislation is largely permissive. This means that there is no general right to be protected from flooding and coastal erosion, and no right to be protected to any particular standard where risk management action is taken.'*

Therefore it seems that the Government has moved to virtually eliminate its risk by legislation, and absolves itself from any responsibility even where it undertakes a risk management action. The wording and tone of this policy document reflect this legal stance throughout. For example:

> *'Localism is at the heart of the new strategy, recognising that there is a limit to what Government and national bodies can achieve alone (p. i)'*

> *'Communities and individuals in risk areas are advised that they should take responsibility for understanding the risks, and where appropriate, take steps to protect themselves and others.' (p. 26).*

Responsibilities of the Government are couched carefully to avoid any appearance of legal liability. For example, the responsibility of Environment Agency is to increase 'public awareness of the risk...and engaging with people at risk to encourage them to take action to manage the risks that they face and to make their properties more resilient.' (p. 14).

FINANCIAL RESOURCES

The UK approach of localisation is further evidenced by the Environment Agency approach to maintaining existing defence systems and describes four categories of defence system:

1. Assets for which there is an economic case for maintenance;
2. Assets that are required to protect internationally designated environments;
3. Assets that don't fit one and two but for which there is an apparent legal obligation; and
4. Assets that do not fit the above three.

The aim of Environment Agency is to continue maintaining categories one and two, to cease category three as soon as it can remove its apparent liability, and cease maintaining category four immediately. It appears likely that the last two categories may include defence systems that protect private interests (p. 38, 39).

The allocation of financial resources has also changed from one of centralisation (p. 14) to one where funding will need to be sourced from other places than the national government (p. 17). At the same time the Government states it will prioritise funds to protect those at risk that are least able to help themselves (p. 37) although it seems that everyone else will also need to contribute when they receive a benefit (p. 16). The wording with regard to funding is also careful in that it allocates funds to 'risk management strategies' but never to anything concrete such as 'infrastructure'.

INSURANCE

The UK is unique in that flood insurance is a standard feature of household and small business insurance policies. Flood cover is offered in accordance with a set of Statement of Principles between the Government and the insurance companies. The current 2008 agreement will expire in 2013. The basic concept of the agreement is that if the Government agrees to work toward managing the risks then the insurance companies will continue to cover for flood events. As early as 2004, the Association of British Insurers (2004) were calling for large upgrades in expenditure on flood defence systems, with the veiled threat that insurance cover could not be assured unless this was done.

Despite the expectation that the Statement of Principles will continue (p.26), a recent report by Oxera Agenda (Neils, G, (Ed), 2011) indicates that the current agreement is regarded by the industry and government as unsustainable, and therefore will not be renewed when it expires in 2013. As the Government moves to legislate to remove its liability, it is difficult to see how this arrangement could work into the future without amendment. Nevertheless, in the interim residents are encouraged to ensure 'they have adequate insurance' (DEFRA 2011 p. 26, 27).

ORGANISATION AND LEGISLATIVE FRAMEWORKS

The UK appears to have taken an intensive approach to the way it has organised itself to manage climate change impacts. The initial response of the UK was to concentrate on the mitigation of climate change by dealing with greenhouse gas emissions first. The Climate Change Act 2008 introduced a binding reduction target requiring the UK to reduce its emissions by at least 80% by 2050 against 1990 levels. The second legislative response was taken last year when the Flood and Water Management Act 2010 was passed. This piece of legislation defined roles and responsibilities for existing and new risk management authorities. The organisational structure under these legislative arrangements is shown in Figure 6.

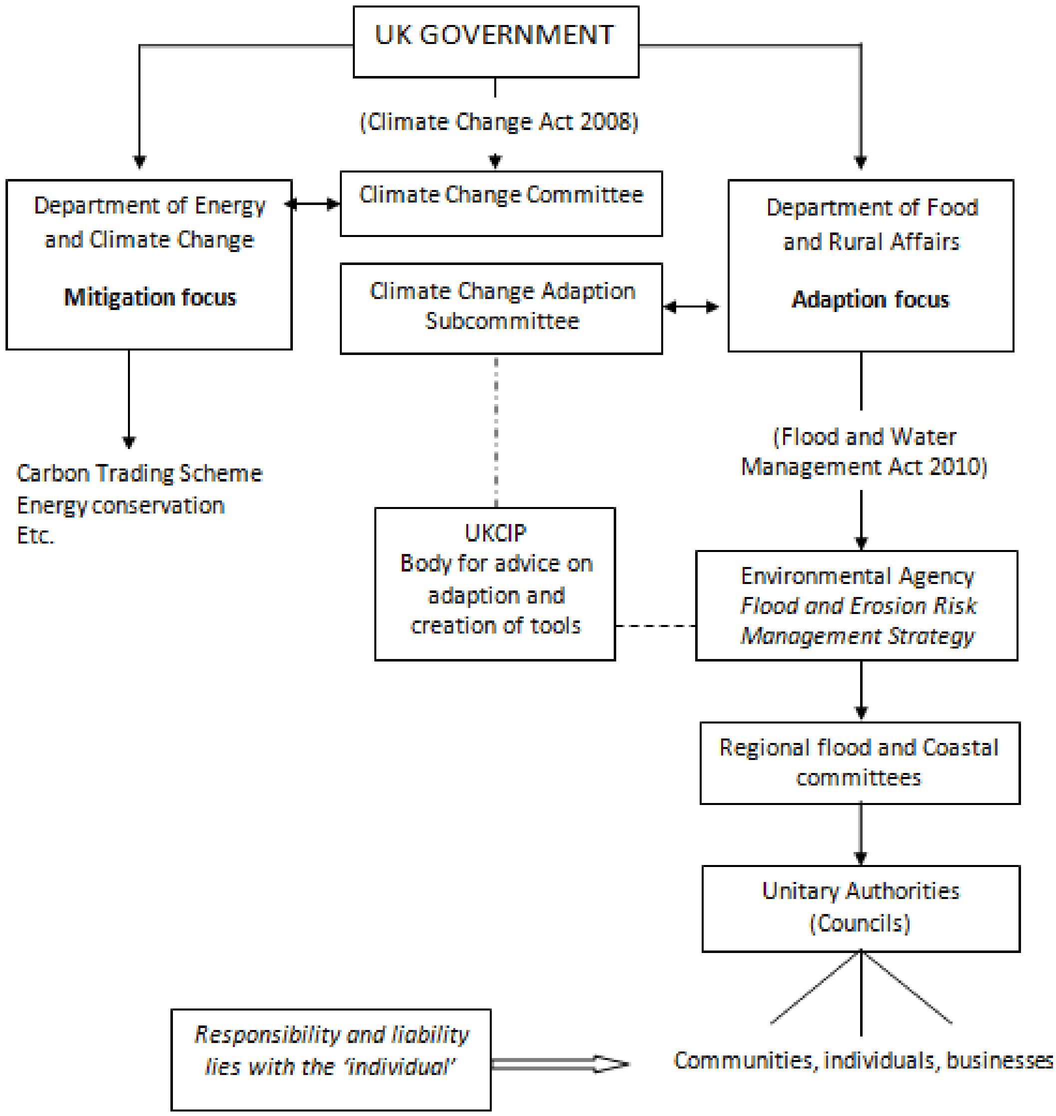


Figure 6: Summary of the organisational structure of UK Government to cater for climate change.

Broadly speaking with respect to climate change issues, the Department of Energy and Climate Change (DECC) deals with mitigation strategies such as carbon trading schemes and energy conservation measures while the Department of Food and Rural Affairs (DEFRA) deals with adaptation (although there seems to be some overlap). Under the Climate Change Act 2008, the Climate Change Committee and Subcommittee appear to act as a nexus between all strategies and report directly to the Cabinet of Government. The Flood and Water Management Act (2010) has only just had Stage Five of its implementation strategy rolled out (1st October, 2011). As noted above, the Act has effectively limited the Government's liability to rising sea levels and places the responsibility on the individual person, business or community. The United Kingdom Climate Impacts Program (UKCIP) program started in Oxford, is now the official advisory body on how to adapt to climate change impacts, and may be subsumed into the Environment Agency by the time of writing.

RESPONSE STRATEGY

The UK response has been organisationally and legislatively intensive and reflected a more top-down approach in the early stages of climate change adaptation policy. In relation to sea level rise and associated erosion and flooding potential, the government has recently legislated for a more standard risk management strategy. The legislation has effectively transferred the onus for adaptation to the individual, business and community level. The government has also moved from a centralised funding approach, and informs the communities that they will need to find alternative funding sources, as well as applying to central government for assistance. While the reason for stating that alternative funding sources are needed is so that the available government funds will go further, it is likely that this policy also reinforces the idea that the government is not liable. While stating that it is not responsible to fund adaption projects, the government does indicate that it will look after communities that can least afford to pay for their own projects (Environmental Agency 2011). In line with this limitation of liability is the commitment to provide a £6,000 coastal erosion assistance grant for homeowners who are at risk of losing their property to coastal erosion to contribute to the costs of demolishing the property and moving. The government acknowledges that the UK does not have a policy of compensating those at risk of losing their properties (UK Government 2010). Another indication of a move to limit liability is noted in the Department of Communities and Local Government (DCLG) announcement that it would put an end to central performance monitoring in March 2011 with the view to decentralising power (DEFRA 2011).

Over the last year the UK has transformed its original centralised response to climate change adaptation to a bottom-up standard risk management strategy. DEFRA (2011) has stated that 'adaption to climate change is a process. It needs to be built into our normal planning and risk management procedures' and the advice to local authorities is that they are 'free to decide how best to address these challenges' and that it is 'up to individuals, companies and groups to take responsibility for how climate change will affect them'.

As noted above, the Government carefully places itself as an organisation to give advice and to oversee the risk management process, not as the responsible entity for the maintenance or improvement of coastal defences. In line with this position, there is an emphasis on the provision of tools and advice from which others can devise their own adaption plans. A vast number of case study examples show how communities are acting to bring about climate change adaption changes.

ADAPTATION TOOLS

Shoreline Management Plans (SMP) were introduced in the mid-1990s to raise public awareness of changing coastlines and have now been adapted using new methods of risk management to also take into account sea level rise projections (UK Government 2010). These plans are also now included in the current legislation as mandatory tools to manage rising sea levels.

The UKCIP program begun at Oxford University, and now transferred under the auspices of Environment Agency was a forerunner in providing advice and generating tools. For example the UKCIP (2012) website has a Local Climate Impacts Profile tool that allows local authorities to assess their vulnerability to sea level rise. It also provides a number of other tools including:

> Adaptation Wizard take the user through a process of determining vulnerability to climate change, identification of key climate risks, and development of a climate change adaptation strategy. It is also a guide to all of UKCIP's information, tools and resources.
>
> AdOpt is a guide that explores the nature of adaptation in the context of climate risk.
>
> BACLIAT (Business Areas Climate Impacts Assessment Tool) helps users explore the implications of climate change for their business or sector.

CLARA (Climate Adaptation Resource for Advisors) is aimed at helping business advisors support small and medium enterprises (SMEs) understand and prepare for the impacts of climate change.

Costing the impacts of climate change is a methodology for calculating the costs of climate impacts and how to compare these to the costs of adaptation measures.

LCLIP (Local Climate Impacts Profile) is a resource that local authorities can compile so that they better understand their exposure to weather and climate.

Risk framework is a step-by-step decision-making framework to help users judge the significance of climate change risk compared to the other risks faced, so users can work out which adaptation measures are most appropriate.

SES (Socio-Economic Scenarios) enable users to explore what future worlds might look like and to consider how our vulnerability to climate change and adaptation responses might vary with different future worlds.

UKCP09 offers background and key findings for the latest future climate change information, UK Climate Projections. Headline messages from the previous climate change scenarios are also available.

AdaptME toolkit provides tools to help users evaluate current adaptation activities.

CASE STUDIES

There are a plethora of case studies on the UKCIP website (UKCIP 2012) and Environmental Agency website (Environmental Agency 2011) that reinforce the Government's message of a bottom-up approach. These studies emphasise what individuals are doing, rather than what the Government is doing.

In relation to strategies either to defend, or plan for retreat, the Government is largely silent. In its most recent policy (Environment Agency 2011) on adaption it acknowledges that:

- *Assets such as raised embankments, floodwalls and seawalls, culverts and drainage systems often work in combination with a risk management system and are likely to reduce flood impacts;*
- *Steps that can be taken to reduce the damage and disruption are to control inappropriate development, adapt buildings to minimise damage, move items out of the way of floodwaters;*
- *Other steps might mean transferring risk to other areas such as allowing land adjacent to populated areas to flood, or by sharing part of the risk with others by their agreement through shared insurance schemes, or tolerating a residual level of risk, recognising that flooding may cause some disruption.*

A review of the case study file indicates a general move away from using hard engineering defences systems and reflects the Government's intention to cease financially liability for maintaining defences wherever possible.

DENMARK

INTRODUCTION

Denmark is situated in north-central Europe and is ringed by bodies of water including the Baltic Sea, North Sea, Kattegat Bay, Kiel Bay and the Skaggerak Strait (Figure 7). The population of Denmark is 5,529,888 and 1,914,865 people live within the city and metropolitan area of Copenhagen. The country consists of the Jutland Peninsula and over 440 islands and has a total area of 42,434 km^2 of land and 660 km^2 of water and a total of 7,314 km of coastline (World Atlas 2012).

Figure 7: Map of Denmark left (Source: http://www.mir.com.my/rb/photography/companies/Leica/Leica-M6/M6-Royal_Wedding1995/index.htm) Map of Denmark right (Source: http://geomapiaa.blogspot.com.au/2009/06/map-of-denmark.html).

The government of Denmark is a democratic constitutional monarchy with two tiers of government: the State and a second level tier of five regions and 98 municipalities. The latter two are not subordinated to each other as they possess different tasks and responsibilities (Local Government Denmark 2009) (Table 4).

Table 4: Administrative divisions of the Government of Denmark.

Level 1	The state	
Level 2	Regions	Municipalities

SCIENCE

The Government report, 'Danish Strategy for Adaptation to a Changing Climate' (2008), affirms that 'climate change is a reality, and an *important* part of global warming is due to human activity' (emphasis added, p.6). The report indicates general acceptance of the science, data and projections of the IPCC and has included into policy a sea level rise threshold of between 0.45 m and 1.05 m by 2100. The assessment of the Policy Research Corporation (2008) is that Denmark is adopting a 'wait and see' approach to climate change with the view that 'changes in the climate are too uncertain to pro-actively invest in adaptation measures' (PRC 2008, p. 5).

RESPONSIBILITY

The report indicates that the Government places the responsibility for the protection or adaptation of assets under threat from the impacts of climate change on the individual owner, whether that owner is private or public (p.19, 20). According to the Policy Research Corporation, the overall principle of adaptation to coastal protection in Denmark is 'that the persons who profit bear the responsibility' although there is no indication where this principle is found within the literature (PRC. p. 3).

INSURANCE

In relation to insurance, Denmark has a public scheme of insurance that is collected by way of tax levies but this scheme does not provide 100% cover so individual asset owners also take out insurance cover (Hallegatte, S. et al. 2008). However, Denmark as yet has completed no systematic research into the insurance related impacts of climate change and the report noted that new financial insurance instruments will be needed to cover incidents relating to climate change.

RESPONSE STRATEGY

In accord with Denmark's 'wait and see' approach, the initial national strategy is limited to 10 years, while keeping the period to 2100 in constant view. The response to climate change in the strategy involves two main approaches. The first approach is 'autonomous adaptation', a term used over 30 times in the Government report, *Danish Strategy for Adaptation to a Changing Climate* (2008). This policy places the onus for climate change adaptation on the individual citizen or owner of the assets under threat to respond within the existing legislative and policy environment. "Planned adaptation' only follows after 'autonomous adaptation' where it becomes evident that existing legislation and policies are inadequate, or where the threat is of a magnitude that requires a national response.

Using the principle of 'autonomous adaptation' as a foundation, the Government defines a six step strategy:

1. Describe the challenges facing any particular sector;
2. Describe the autonomous adaptation measures already in place;
3. Allow this information flow to influence the need for any change of legislation or regulations for future autonomous adaptation and any required planned adaptation;
4. Describe examples of specific proposals for planned adaptation to be used as future strategies;
5. Operate targeted information campaigns to inform individuals of their risks and responsibilities;
6. Develop socio-economic analysis strategies and tools so as to more accurately quantify future actions.

Organisational Response

The Danish Government has proposed two primary government bodies to deal with its autonomous adaptation strategy. The first is the 'Coordination Forum for Climate Change Adaptation' whose primary role is to operate as a communication nexus between all state bodies and local municipalities. The forum has no decision making capability, and its role is left within individual ministry portfolios or at Local Government level. The second entity is the 'Coordination Unit for Research in Climate-change Adaptation' which operates under the Ministry of Climate and Energy.

To inform all stakeholders, the government has established the Information Centre for Climate Change Adaptation which provides data, maps, analyses, assessment tools for decision makers, and an interactive map of Denmark that includes a coastal planning tool that can be used to screen the physical conditions of Danish coasts on its web portal. Figure 8 below shows the organisational framework in which Denmark proposes to address climate change adaptation.

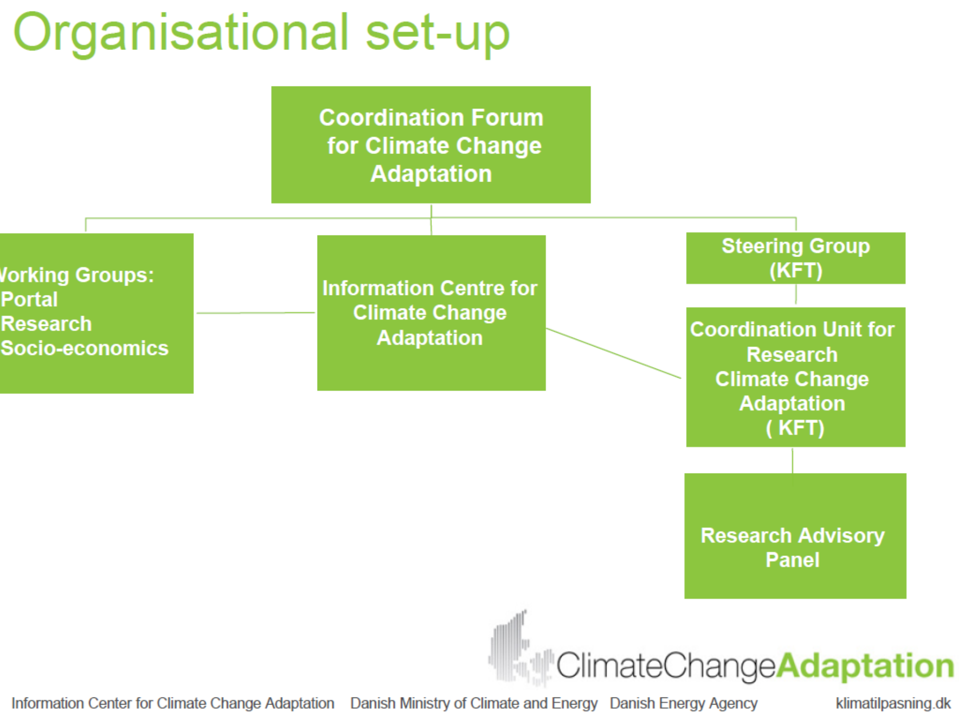


Figure 8: Danish organisation to cater for climate change adaptation (Source: www.klimatilpasning.dk)

CASE STUDIES

Copenhagen

Hallegatte *et. al*.(2008) completed the case study '*Assessing Climate Change Impacts, Sea Level rise and Storm Surge risk in Port Cities: A Case Study on Copenhagen'* which analysed the city's vulnerability to rising sea levels and associated increases in the level of storm surges. As indicated in the title, the report is mainly focussed on the assessment of potential risk from storm surges and concluded that 'Copenhagen is well protected and as a result the risk of economic impacts from coastal flooding is currently low'. The recommended approach was to evaluate and monitor existing dykes and sea walls and raise these if required.

Raising infrastructure at ports

While not just confined to the Copenhagen port, Danish municipalities are presently evaluating areas in their ports with the view to taking protective action against rising sea levels. Svenborg authorities are contemplating the design of future buildings with underground car parks that might act as a flood water collection location that could be emptied quickly after the event, or the installation of large dykes across the sound (Danish Government 2012).

Coastal planning screening tool

A coastal planning screening tool is in the process of development and puts data on high water events from the Danish Coastal Authority on an interactive map. The tool will enable asset owners to evaluate potential risks from future events in specific locations. It appears that the tool is only widely in use at Nyborg where asset owners can visit the municipality's website and choose their own storm-surge scenario. Once a location and storm surge level have been chosen, the system calculates which areas are at risk of flooding and the results are shown on a map (Danish Government 2012, www.klimatilpasning.dk/en-us/service/cases/).

Municipality Planning

The storm surge portal described above currently only gives one example of a municipality that has adopted a 'climate-adapted' municipal plan that incorporates all future construction works and land use designations and takes account of increased rainfall, rising sea levels and other predictable climate change impacts.

SUMMARY

Denmark has a long history of adapting to impacts from the sea and has used sea walls, dykes, and other protective measures over many decades. It seems likely that Denmark will continue to use a 'wait and see' monitoring approach to expected climate change impacts in coastal areas and adapt, or install, infrastructure in accordance with the main policy option of 'protection'. The Danish response is best described as 'bottom up' adaptation as it places the onus for adaptation on the entity that owns or is responsible for the asset. However, the Danish National Government is providing the environment for communication between different government departments and providing a coordinated approach to research and communication with the general population.

NEW ZEALAND

INTRODUCTION

New Zealand is situated to the south-east of Australia in the Pacific Ocean (Figure 9). The population of New Zealand is 4,173,460 and includes those who inhabit the North and South Islands as well as the numerous smaller islands. The country has a total land area of 268,680 km^2, a water area of 1,080 km^2 and a total of 15,134 km of coastline (World Atlas 2012).

Figure 9: Map of New Zealand and Oceania (Source: www.worldatlas.com).

New Zealand is a parliamentary democracy and constitutional monarchy and has only one chamber of the parliament called the House of Representatives. The second tier of governance in New Zealand, the Local Government is divided into 11 Regional Councils responsible for the environment and public transport and 67 City and District Councils responsible for other Local Government responsibilities (Table 5).

Table 5: Administrative divisions of Government of New Zealand.

Level 1	State
Level 2	Local Government
	Regional: (Environment and Transport)
	District and City (Other Local Government responsibilities)

SCIENCE

The Government report, ‘Preparing for Coastal Change’ (2009), admits that some climate changes are already occurring but maintains that until about 2050 sea levels will be relatively insensitive to climate change (p.4,5). The report concedes that the IPCC in its Fourth Assessment Report (2007) did not set a best estimate for predicted sea level rise but did report a modelled base range of 0.18 m to 0.59 m range by the mid-2090s and adds another 0.1 to 0.2 metres rise in relation to possible ice sheet meltdowns. *Preparing for Coastal Change* recommends that a sea-level rise threshold of 0.5 m relative to the 1980-1999 average be considered but ‘at the very least’ that 0.8 m sea level rise be taken into account for all planning and decision making. In summary, New Zealand is taking the data seriously but may best be described as 'tentative' in their approach rather than reactionary (Figure 10). Perhaps the New Zealand Government also believes that it has a 40 year window with which to react if the projections unfold as expected.

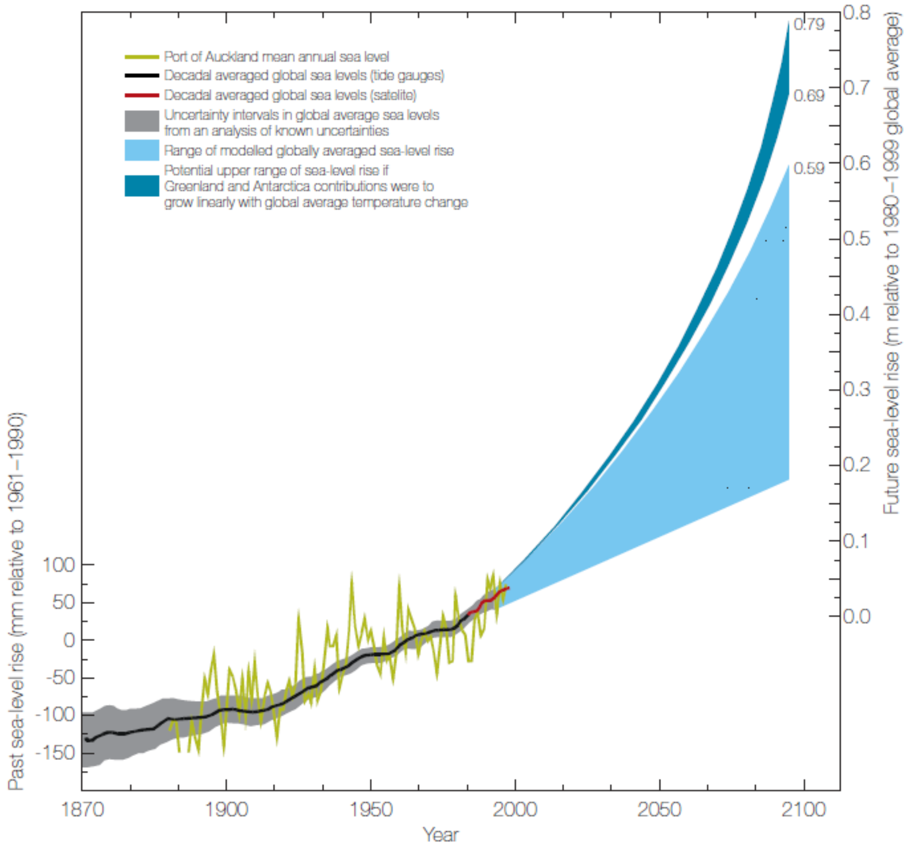


Figure 10: Observations of past sea level rise and projects of future mean sea-level rise to the mid-2090s (Source: New Zealand Government, 2009 p. 7).

THE LEGISLATIVE CONTEXT

The New Zealand regional and territorial authorities have the responsibility to avoid or manage coastal hazard risk (New Zealand Government, 2009) under two main Acts of Parliament: the Local Government Act (2002); and the Resource Management Act (1991). A further act, the Civil Defence Emergency Management Act (2002) focuses on the management of hazards and on the safety of people, property and infrastructure in an emergency (p.20). Under these acts is the New Zealand Coastal Policy Statement (2010) that requires local authorities to amend policy statements and plans and any authority considering planning consent must give consideration to relevant provisions in the statement.

RESPONSIBILITY AND LIABILITY

A review of New Zealand Government documents show a tendency for the Government to accept the major portion of the risks associated with rising sea levels. The legislative framework described above tends to put the onus of responsibility on the authorities to manage coastal climate change risks. In addition, the *Coastal Hazards and Climate Change: Guidance Manual* (2008, p.45) states that 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'. However, the report also suggests that in reality, financial risk may only occur when an area becomes uninhabitable (p.45). The New Zealand Government (2009, p.13) in the report, *Preparing for Coastal Change* 2009 noted that landowners on the Ohiwa Spit were compensated by the Government when their houses became unusable because of coastal inundation. With respect to managed retreat, the guidance manual states that 'purchase of property' or 'subsidies for relocation' are options. These statements may indicate some acceptance of responsibility by Government. In discussing insurance, it is acknowledged in the manual that increased insurance premiums are likely, but where insurance is refused altogether in a particular area, the result 'can result in extreme pressure on Councils to provide protection against the hazard' (New Zealand Government 2008, p. 77). On the other hand, the Government identifies that landowners need to be educated to the risks they face, but equivocates by stating that giving information to people does not influence people's decision making (New Zealand Government 2008, p. 64,65). A tentative conclusion here is that the Government seems to take a significant sense of responsibility in protecting its landowners and may see itself as financially liable in cases where areas become uninhabitable.

RESPONSE STRATEGY

The New Zealand strategy is one that subsumes potential climate change impacts into its existing framework (Figure). In other words, it places the potential for rising sea levels in exactly the same category as any other matters it deals with in coastal protection:

> *'Climate change will not introduce any new types of coastal hazards. Yet it will exacerbate existing coastal hazards by changing some of the hazard drivers' (Preparing for Coastal Change, 2009 p30).*

This perspective of the New Zealand Government is continued in the recently released *New Zealand Coastal Policy Statement* (2010) gazetted on 4th November 2010, the contents of which are to be incorporated into Local Council planning decisions. For example, of the seven objectives identified (p. 9,10) only one deals with climate change in any overt manner, and a review of that particular policy reveals the same policy trend - rising sea levels are considered as 'business as usual' in its operations, but monitoring of sea level rise is noted as necessary.

In broad terms, New Zealand's response is to use risk management practices based on the New Zealand Standard for Risk Management, AS/ZS4360ss when dealing with all threats, not just those related to climate change (p. 50).

> *'Climate change considerations are unlikely to drive or initiate Local Government action on their own. Rather, through the application of risk management procedures in assessing and prioritising possible responses to climate change effects, these considerations may modify an outcome' (Ministry for the Environment, 2012).*

Organisational Response

In keeping with its 'business as usual' response strategy, New Zealand has founded no new committees or statutory bodies to deal with the perceived threat of rising sea levels or any other climate change impacts. All climate change matters are dealt with by the Ministry for the Environment and the existing framework of government is used to bring about any adaption measures (Figure 11).

> *'To help New Zealand build its resilience and plan ahead, the government has formed partnerships with organisations such as Local Government, engineers, the insurance industry and the agricultural sector (Ministry for the Environment, 2012).*

However, it also appears from the literature that the local Council will be the primary body that will deal with any climate change impacts although the agenda will be set through the New Zealand Government by way of policy statements that have some statutory basis.

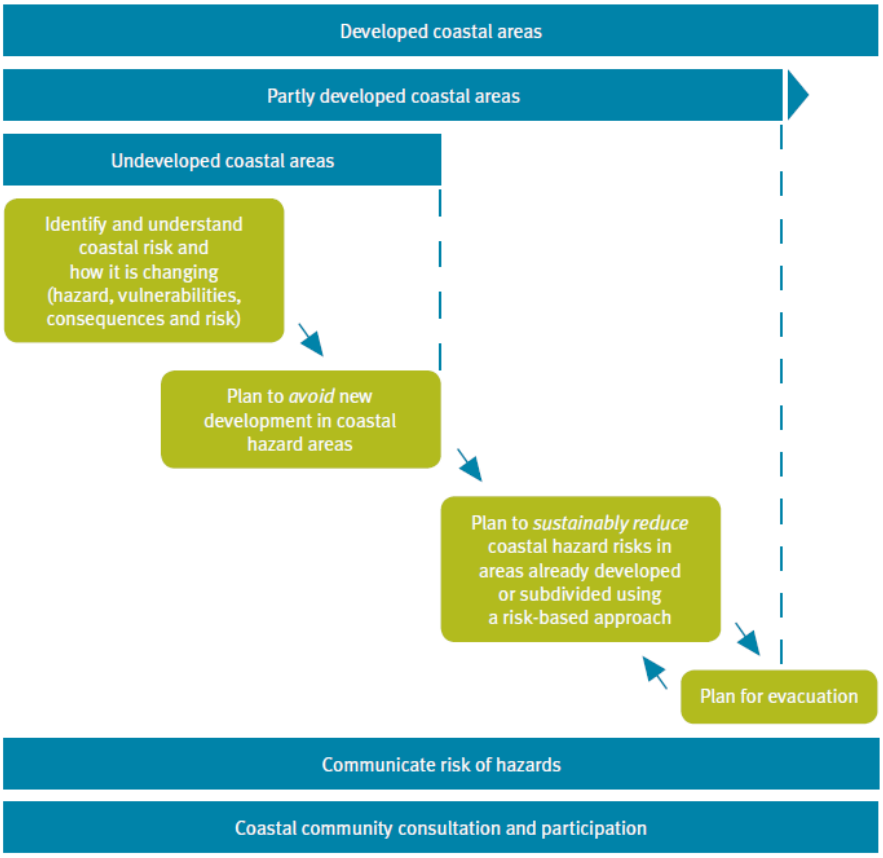


Figure 11: Basic hierarchy of principles relating to managing coastal hazard risk and the different levels of coastal development to which the principles apply (Source: New Zealand Government 2009, p. 22).

Specific Responses

New Zealand is responding to rising sea levels in two ways. The first relates to new developments and the second relates to existing development. Using the recently gazetted *New Zealand Coastal Policy Statement* (2010) the following adaptation responses are identified:

New development

As new development is not the main focus of this research, it is enough to note that the planning system of New Zealand is used to avoid coastal climate change risk by assessing proposals against established climate change data and making the necessary judgements. Where it seems that the decision is compromised, the intention is to use covenants on titles to warn future purchasers of any perceived risk (*Policy 25.NZ Coastal Policy Statement, 2010*):

> *'for proposed new development sites, regional and district planning controls can be used to ensure that new development is located beyond defined coastal hazard zones' (New Zealand Government, 2009, p. 24).*

Existing development

Policy 27 in the *New Zealand Coastal Policy Statement* (2010) deals exclusively with protecting significant existing development for coastal hazard risk (p. 24). The range of options for reducing coastal hazard risk in areas of significant existing development likely to be affected by coastal hazards includes:

1. promoting and identifying long-term sustainable risk reduction approaches including the relocation or removal of existing development at risk;

2. identifying the consequences of potential strategic options relative to the option of 'do nothing';
3. recognising that hard protection structures may be the only practical means to protect existing infrastructure of national or regional importance;
4. recognising and considering the environmental and social costs of permitting hard protection structures to protect private property and land; and
5. identifying and planning for transition mechanisms and time frames for moving to more sustainable approaches.

While the policy statement appears to place hard protection structures as an equal option to others, parts 2-4 of Policy 27 make it quite clear that these are to be only used as a last resort and usually only in places where it is deemed necessary to 'hold the line' for development already in place. Policy 26 confirms this priority in its recommendation of using 'natural defences' against coastal hazards (p. 24), including beaches, estuaries, wetlands, intertidal areas, coastal vegetation, dunes and barrier islands. The installation of esplanade reserves and strips are put forward as viable options for defence but deemed 'not a complete solution' (p. 29).

Hard engineering options such as seawalls, groynes and dykes are not considered to be preferred solutions due to their ineffectiveness over time and the possible financial burden of upkeep. There may also be a hint of the 'liability/ responsibility' question in this preference as well. Any hard engineering option that is installed by government may become the point where litigation begins if and when the sea traverses the structure in a large storm event.

Finally, where protection measures fail, managed retreat at various scales is detailed as follows (*Coastal Hazards and Climate Change: Guidance Manual,* 2008, p. 70):

- *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;*
- *financial instruments or assistance measures including the purchase of property, subsidies for relocation, taxation of risk or adverse effect, pre-paid community relocation fund, or transferable development rights;*
- *relocation of infrastructure out of hazard areas;*
- *insurance incentives or disincentives.*

Planned or managed retreat

'Managed retreat' is defined as any strategic decision to withdraw, relocate or abandon private or public assets that are at risk of being impacted by coastal hazards. At present, relocation of properties tends to occur on a case-by-case, occasional basis, and no Council has yet developed a district or region-wide strategic approach to reducing coastal hazard risk this way' (p. 67-70. *Coastal Hazards and Climate Change: Guidance Manual*, 2008). However, given the level of existing coastal development in the 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 installations. This option 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. Hard infrastructure impacts significantly on beaches and on natural character, amenity and public access values. 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 including the trigger levels that would require relocation. Despite Turbott's and Stewart's work, significant barriers remain before managed retreat becomes a more commonly applied mechanism of coastal climate change adaptation in New Zealand.

INSURANCE

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

This combination of factors 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.

CASE STUDIES

The New Zealand Government report, *Preparing for Coastal Change* (2009) details the following case studies:

- The Ohiwa Spit has a documented history of continual land loss and accretion since 1867. Some landowners were compensated in the 1970s by the Government and so may set a precedent for Government liability in relation to coastal threats (p. 13).
- Existing land use rights seems to be an obstacle in dealing with the prevention of unsuitable development or managing retreat. The *Canterbury Regional Coastal Plan* is one of the few plans that currently contain specific mechanisms to control existing use rights within the coastal hazard zones. The rules permit existing uses to continue but control the reconstruction or replacement of structures to take sea level rise into account. The plan also provides the scope to move existing unaltered development landward should the need arise.
- In line with the New Zealand view of avoiding hard engineering works, the Whakatane District has made all land protection works, whether private or public, non-complying. The reason behind the action was that New Zealand policy makers expect hard protection works on one property to exacerbate the problem on the next property. Additionally, New Zealand considers these options as expensive and likely non-productive over the 100 year time frame.

SUMMARY

The New Zealand response administratively is one that is best described as 'business as usual' in dealing with any threat from rising sea level. It is observed that climate change threats, while not discounted, are subsumed into existing structures and practices without the creation of extra statutory bodies or advisory committees. The main responsibility for dealing with climate change threats in relation to rising sea levels rests at the level of Local Government while the Federal Government takes a steering role through the use of policy statements that have a statutory basis in the Resource Management Act 1991.

It is likely that New Zealand believes it has a number of years to plan for the increases of sea levels in the latter part of this century. The country will use its planning system to prevent any risky developments in the future, it will use soft and natural defences that are congruent to the existing coast line, and where these don't work or are not available it will use 'managed retreat'.

Hard engineering structures will be used only as a last resort and only in areas where significant development is already in place.

APPENDIX 2 – REVIEW OF AUSTRALIAN COASTAL CLIMATE CHANGE POLICY

AUSTRALIAN FEDERAL GOVERNMENT

INTRODUCTION

Australia is the world's sixth largest country in area and is fringed by the Indian Ocean on the west and the Pacific Ocean on the east. The country has a total land mass of 7,682,300 km^2 and 25,760 km of coastline (Figure 1). The population of Australia in July 2011 was approximately 21.8 million, of whom 85% live in the coastal region (World Atlas 2012).

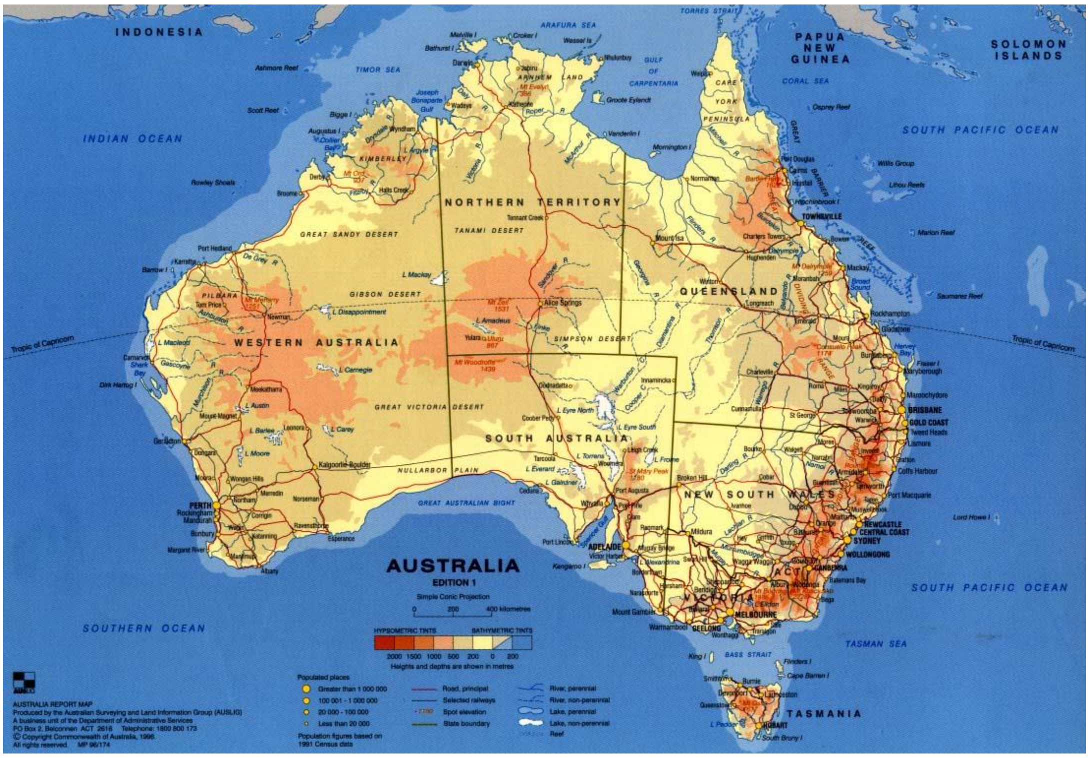


Figure 1: Map of Australia (Source: www.australia.gov.au).

The Commonwealth of Australia is a parliamentary democracy within a constitutional monarchy. There are three 'arms' of the Australian Government: the parliament or the legislature, the executive or administrative government, and the judiciary which is independent of the other two. Australia is a federation of six states (VIC, QLD, SA, WA, TAS and NSW) and each of these have their own three arms of government. There are the two territories that both have the right of self-government (ACT and NT). The six state parliaments are permitted to pass laws related to any matter that is not controlled by the Commonwealth under Section 51 of the Australian Constitution and any conflict between the two layers of government is resolved by deference to the Commonwealth. Local governments are established by State and Territory Governments to take responsibility for a number of community services. Table 1 shows the three levels of government in Australia.

Table 1: Administrative Divisions of the Government of Australia.

Level 1	Federal Government
Level 2	State Government
Level 3	Local Government (Councils)

SCIENCE

The Federal Government has a high regard for the science of climate change and states that there 'is clear evidence that our climate is changing, largely due to human activities' and relies on the IPCC *Fourth Assessment Report* (2007) to conclude that there is 'overwhelming evidence for human-made global warming'(Australian Government 2011a). The Australian Government recognised the *Fourth Assessment Report* prediction of a 0.79 metres average global sea level rise by 2100, but accepted that more recent analysis had found that sea level rise of up to a metres or more was plausible over the same time period and adopted a 1.1 metre rise by 2100 for its *First Pass National Assessment of Climate Change Risks to Australia's Coast* (Australian Government, 2009a). The Department of Climate Change website states that a rise as high as 1.5 metres cannot not be ruled out. The Australian Government position paper, *Adapting to Climate Change* (2010) states that due to the lag between greenhouse gas emission and the actual climate change effects, changes over the next 20-30 years are already 'locked in' and so concludes that the 'risks are serious and persuasive' (Australian Government 2010 p. 4). In relation to the coastal zone, the Department of Energy Efficiency and Climate Change website estimates that even with a 50 cm sea level rise, inundation events that previously occurred once every 100 years could happen several times a year. The Australian Federal Government indicates it is taking a long-term perspective to climate change as illustrated in Figure 2.

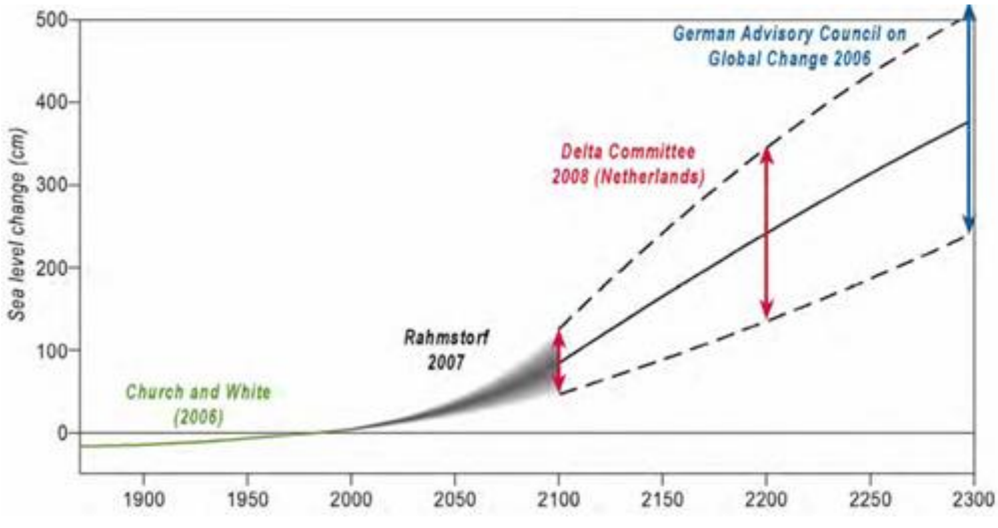


Figure 2: Recent estimates of future sea-level rise relative to the 1990s (Source: Australian Government 2009 p. 26).

LIABILITY

The Federal Government position paper, *Adapting to Climate Change in Australia* (Australian Government 2010) tends to place the responsibility on individuals, communities, and businesses to adapt to possible climate change impacts:

> *'Adaptation to the impact of climate change is, in large measure, about managing risks. Business and communities will need to assume responsibility as they do in managing other risks... Most of the assets and activities at risk from climate change are owned or*

managed by businesses and the community. It is therefore reasonable to expect that much of the national effort to adapt to the impacts of climate change will be actions taken by businesses and communities.' (p. 7).

However, at the end of the paper it intimates that when 'the magnitude of the risk to national wellbeing' is evident then a national response will be required. The Federal Government also states it will intervene where there is 'market failure', but the report gives no indication of what these failures might be (p. 8). The report, Climate Change Risks to Australia's Coasts (Australian Government 2009, pp. 138, 141), also points to the "moral hazard' whereby communities believe that the insurance industry or government will bail out or underwrite the costs to those who are threatened or damaged by a natural event rather than allow them to face the consequences of the risk they assumed when they purchased the property. The report calls for policy that clarifies the limits of public sector capacity and/or willingness to protect coastal properties so that there is an incentive for people to take into account their own risks.

Specifically in relation to infrastructure assets, the Natural Disaster Relief and Recovery Arrangements (NDRRA) provide for the Commonwealth and States to share in the costs of reconstruction of infrastructure following natural disasters. The funding is distributed to the States who generally then allocate it to Councils as required. Once a State's costs of disaster recovery and reconstruction in any one financial year have passed a certain threshold, Commonwealth funding becomes available, first as a 50% Commonwealth, 50% State contribution, and then at a ratio of 75:25 when a higher threshold is reached. Trigger points for Commonwealth intervention are determined in dollar value as a proportion of State revenue (Comrie 2011). For example, funding to NSW in 2010/2011 at the first threshold was available once expenditure exceeded $119.7 million whereas funding was available at the first threshold for Tasmania at $9.6 million in the same time period. Recent changes to the NDRRA now place a greater onus on states/territories to have insurance arrangements that minimise the financial impact to federal taxpayers and are discussed more fully below.

Generally, the Australian Government seems to have two positions in relation to responsibility and liability. On the one hand its tactfully worded position paper suggests that individuals and communities will be responsible to adapt to threats to sea level rise, which might reflect a 'bottom-up' approach to liability, but it also suggests State and Local Governments will also answer appeals for assistance. The Federal Government admits that it needs to qualify whether 'adaptation is a commonwealth responsibility or requires commonwealth leadership to deliver a nationally consistent adaptation outcome' (p. 11).

A recent review of government liability by Baker and McKenzie (2011), notes that the Federal Government:

- *has limited powers to legislate for local and regional climate change adaptation;*
- *is primarily responsible for setting high level national policy and assisting the State and Local Government responses through funding and research; and*
- *role will be to assist with the provision of information and financial resources through Council of Australian Governments.*

Baker and McKenzie suggest that while the Federal Government has a clear responsibility to legislate in regard to mitigation, it only has a shared responsibility for adaptation. The main legislative changes and implementation strategies need to be driven by the states.

In conclusion, it is likely in regard to the impacts of sea level rise that the Federal Government's direct financial liability is limited to taking care of its own assets. However, there is also likely to be political pressure and historical precedents that will act as an impetus to intervene where the impacts to assets owned by others are significant and sudden.

INSURANCE

Just as the Australian Government has a preference for using price signals on carbon as a market mechanism to change behaviour, it seems to have the same preference for price signals to influence people's behaviour in adaptation. The Australian Government Position Paper, *Adapting to Climate Change in Australia* states:

> *Insurance markets are commonly used to spread risks...the price of insurance can be an incentive for people to adopt or avoid particular behaviours. Insurance markets could be valuable in managing risks from climate change...by providing incentives for people to take actions that reduce exposure to climate change impacts. Government policy settings to maintain a strong and flexible economy will, in general, help to ensure that price signals are able to drive efficient behavioural responses (p. 8).*

The Garnaut *Climate Change Review* and associated submissions, completed in March 2011 explains this concept more fully (Garnaut 2010; Institute of Actuaries, 2011 p. 15,16). In relation to general insurance, the review states that there is a trend for insurance companies to now price the risks at the individual address level, based on information from flood map data and similar resources. This trend means that risks will be increasingly less subsidised across regions and premiums will increase for areas deemed as high risk. Those who choose to live or carry out business activities in high risk areas will face greater insurance costs. Furthermore, insurers may exit certain areas of the market where they believe the risk and costs are excessive.

The 2009 report *Climate Change Risk to Australia's Coast*, highlights that at present insurers generally exclude 'storm surge', 'action of the sea', and 'erosion and subsidence' from their policies. The report also notes that the insurance industry is recommending that people with low lying land pay into a fund that can be drawn upon when compensation is required (Australian Government, 2009a, p.144). However, this recommendation may only refer to land as an asset class that is not presently covered by any insurance policies.

In the aftermath of the wide spread flooding in Queensland, New South Wales and Victoria in the summer of 2010-2011, many home owners found that the insurance policies they held to protect against flood did not actually cover their losses. Consumers called for clarification as to precisely what was covered by insurance policies, to what extent these policies provided cover for flood, and what cover for flood meant (Hobson T, Crichton A & McConnell M, 2012). On 5th April 2011 the Federal Government released a consultation paper, *Reforming flood insurance: clearing the waters* (Australian Government the Treasury, 2011a) that called for a standard definition for 'flood' to be employed by the insurance industry, and for the compulsory distribution to consumers of a 'Key Facts Sheet' to provide easy to understand policy information. The Federal Government also commissioned the Natural Disaster Insurance Review that was completed in September 2011 as an 'inquiry into flood insurance and related matters' (The Australian Government the Treasury, 2011b). After a further consultation period, in April 2012 the Australian Government amended the Insurance Contracts Act 1984 with one of the changes to allow for the following definition of flood to be included in the Insurance Contracts Regulations 1985 in the future:

> *Flood means the covering of normally dry land by water that has escaped or been released from the normal confines of:*
> *A. any lake, or any river, creek or other natural watercourse, whether or not altered or modified; or*
> *B. any reservoir, canal, or dam.*

Taking into account this definition, and that Regulations 10 and 14 in the Insurance Contracts Regulations 1985 prescribe 'flood' and 'action of the sea' as different events in an insurance context, the immediate relevance of these changes to this research is limited. Chapter 10 of the

National Disaster Insurance Review does address disasters other than flood, such as cyclones and tsunamis but in relation to coastal risks relating to climate change states:

> *Other coastal inundation relates to events such as king tides and rising sea levels. Cover for these types of events is generally not available in the current market. They are different from other weather events such as floods and cyclones because they appear more likely to be associated with possible climate change.*

And concludes,

> *In any event, the Review Panel is not proposing that any changes be made by the insurance industry at this time in relation to coastal inundation (The Australian Government the Treasury, 2011, p. 82)*

While the direct application of the recent action by the Federal Government to the risks associated with climate change in coastal regions is limited, some of the recommendations may be indicative of how insurance arrangements may be implemented to cater for those risks in the future. The Federal Government is recommending the following proposals to deal with the risk proposed by flood (The Australian Government the Treasury, 2011, p.3, 4, 13):

- that an agency sponsored by the Commonwealth Government be created to manage the national coordination of flood risk management and to operate a system of premium discounts and a flood risk reinsurance facility, supported by a funding guarantee from the Commonwealth;
- that all home insurance, home contents and home unit insurance policies make flood insurance available but that it also not be compulsory;
- that a system of premium discounts be introduced in order that most purchasers of home insurance, home contents and home unit insurance policies in areas subject to flood risk be eligible for discounts against the full cost of flood insurance;
- the Commonwealth Government guarantee the payment of claims by ensuring that, whenever a funding shortfall occurs in the reinsurance facility through claims exceeding the funds held in the facility, the Commonwealth would meet the shortfall and the Commonwealth would seek reimbursement of a portion of the shortfall from the State or Territory government in whose jurisdiction the flood occurred; and
- that the proposed national agency would coordinate flood mapping across the country, introduce national guidelines for flood risk mapping, act as a repository of flood risk information, and monitor the effectiveness of flood mitigation.

However, the report also recognises the need to make insurance affordable enough so that consumers do take up the necessary insurance with the need to change behaviour so that new development is not encouraged in high risk areas. The Federal Government recognises that unless consumers take up insurance then it is likely to bear the cost of damage itself through political pressure and precedents set in previous disasters. The following principles underpin the design of a system of premium discounts (The Australian Government the Treasury, 2011, p. 10, 12):

- premiums should rise with the level of flood risk;
- those whose homes do not face a flood risk should not pay a flood premium;
- there should be no cross subsidisation of premiums between policyholders;
- there should be some limitations on discounts to high-value homes;
- the discounts be assessed by reference to an ‘affordability threshold’ for flood premiums;
- only existing homes would be eligible for discounts;
- discounts would be phased out gradually over time; and
- that homes at high and extreme risk of flood be provided with discounts initially and that they be assessed regularly for mitigation work already undertaken and the potential for further mitigation.

The Federal Government may institute similar arrangements should the risks associated with sea level rise escalate. With a system of reinsurance and Government guarantees the Federal

Government would be able to spread its political exposure to large damage bills while ensuring that consumer behaviour did change over time due to the higher premiums paid by those who choose to live in higher risk areas, but not so high that insurance was unaffordable. Over time residents in high risk areas would also need to show that they were attempting to mitigate the risk of damage to their properties for the insurance discounting to continue. A limit on insurance discounting to those owning high end valued properties would ensure that tax payer monies were not spent on those who have the capacity to look after themselves, and that the cost of insurance for those who wished to establish new residences in high risk areas would likely be unaffordable for the vast majority of consumers.

Finally, these conclusions are speculative as the above proposals have yet to be implemented to cover flood risk and it is not yet known how the insurance sector will respond to these arrangements in practice.

ORGANISATIONAL, LEGISLATIVE AND POLICY FRAMEWORKS

Baker and McKenzie's opinion that legislative changes and implementation strategies will be largely driven by the States seems accurate in that the Federal Government has introduced no new legislation to address climate change adaptation. Thus the Commonwealth *Environment Protection and Biodiversity Conservation Act,* (1999) remains the umbrella legislation to deal with climate change adaptation at the Federal level, whereas the current policy of the Federal Government is best observed in the Australian Government Position Paper, *Adapting to Climate Change in Australia* (Australian Government 2010a).

The Department of Climate Change established in 2007 was superseded by the Department of Climate Change and Energy Efficiency on 8th March 2010 and is the lead climate change agency in Australia. In April 2007 the Council of Australian Governments (COAG) agreed to the *National Climate Change Adaptation Framework* that defines a range of cooperative actions between all Australian governments to begin to address climate adaptation options. The Australian Centre for Climate Change Adaptation (now called the *Climate Change Adaptation Program*) was a recommendation of the 'Adaptation Framework' and was founded in May, 2011. The National Climate Change Adaptation Research Facility was established in November 2007 at Griffith University's Gold Coast Campus to have a key role in:

- developing National Adaptation Research Plans;
- synthesising existing and emerging national and international research on climate change impacts and adaptation;
- undertaking research to establish national climate change priorities; and
- establishing and maintaining adaptation research networks that assist researchers focus on national climate change priorities.

The Coasts and Climate Change Council was established in late 2009 to: provide advice to the Australian Government on the implications of coastal climate change for decision makers; engage with communities and stakeholders; and raise awareness of coastal climate change adaptation issues (Australian Government 2011b).

The National Sea Change Taskforce although not a Federal Government initiative was established in 2004 as a national body to represent the interests of coastal Councils and now has 68 member Councils from around Australia. The Taskforce is developing a revised Coastal Policy Framework as an advocacy campaign to be conducted in the lead up to the next Federal election in 2013. A review of the draft of the revised policy framework indicates that this organisation sees its role as initiating policy and action relating to coastal matters in general, but including the challenges of climate change to be coordinated across the three tiers of government (National Sea Change Taskforce 2011).

FEDERAL GOVERNMENT ADAPTATION RESPONSE

Underlying the Federal Government's climate change policy are the three general pillars reported on the Department of Climate Change website (Australian Government, 2011c):

- Mitigation –to reduce Australia's greenhouse gas emissions;
- Adaptation – to adapt to the climate change that cannot be avoided;
- Global solution – to help shape a collective international response.

The Federal Government has focussed on the first of these over the last few years and endorses price signals in a market economy as the key strategy to bring about greenhouse gas emissions reductions. The introduction of a price on carbon, and the investment of billions of dollars in clean energy sources are expected to facilitate emissions reductions.

The Federal Government's role in climate change adaptation

Confirming the opinion of Baker and McKenzie (2011) that the States will take the main role in adapting to climate change impacts the Federal Government's position paper states that its role will be to:

- *Maintain a strong and flexible economy and a safety net. One way in which the government intends to maintain a strong and flexible economy is to ensure that price signals, such as through insurance markets, will drive efficient decision making. In relation to a safety net, the government intends to assist those who do not have the resources to adapt on their own to climate change impacts;*
- *Lead national reform. The Federal Government acknowledges that while adaptation decisions will be mostly localised and driven by the State Governments, it has a role to maintain national consistency in relation to standards (such as building codes for example);*
- *Taking responsibility for its own assets and programs. The Australian Government, as an owner of assets including ports, defence facilities, and airports, will manage its own risks in relation to climate change impacts. It also manages a number of programs such as emergency management and national security, and will factor climate change risks into these areas as a matter of normal course; and*
- *Provide information to individuals and businesses. To fulfil this objective, the Australian Government adopted a National Climate Change Science Framework chaired by the Chief Scientist of Australia in May 2009.*

A guiding principle given in the position paper is that 'adaptation considerations and responses will be embedded within existing policy and institutional frameworks rather than creating new ones. The reason given for this principle is because, in most instances, climate change is likely to exacerbate existing risks and therefore can be dealt with most efficiently through existing institutions and frameworks' (Australian Government 2010a, p. 5).

Federal Government Adaptation Initiatives

The Climate Change Adaptation Program (formerly Australian Centre for Climate Change Adaptation) was funded with $126 million and is presently undertaking or has already completed the following programs (Australian Government 2011d):

- a 'first pass' assessment of Australia's coastline to ascertain the extent of the risk to coastal ecosystems, infrastructure and settlements. High resolution mapping is now available and shows the areas on the Australian coast that are most susceptible to sea level rise and storm surge. Display scenarios have been developed for low (0.5 metres), medium (0.8 metres) and high (1.1 metre) sea level rises for the decade around 2100, and include a state by state analysis (Australian Government 2009a & 2011d);
- the Local Adaptation Pathways Program will ascertain how local communities might best adapt to climate change threats (the current study is funded under this program);

- the National Climate Change Adaptation Research Facility is based at Griffith University and is a collaboration of seven other Universities and has a large catalogue of tools and resources on its website; and
- the Integrated Assessment of Human Settlements Program considers five case study areas from around the country.

In addition to the information on the Department of Climate Change and Energy Efficiency) website, the following are key Federal Government reports or studies that deal with adapting to climate change impacts in coastal areas:

- Parliament of Commonwealth of Australia (2009), *Managing our coastal zone in a changing climate*, House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts, Canberra.
- Department of Climate Change and Energy Efficiency (2009), *Climate Change Risks to Australia's Coast, A First Pass National Assessment*.
- Department of Climate Change and Energy Efficiency (2010), *Developing a National Coastal Adaptation Agenda,* A report on the national climate change forum held in Adelaide 18 and 19 February 2010.
- National Climate Change Adaptation Research Facility (2010), *National Climate Change Adaptation Research Plan – Settlements and Infrastructure.*
- Department of Climate Change and Energy Efficiency (2011), *Climate Change Risks to Coastal Buildings and Infrastructure.*

Adaptation Options

A review of the reports listed above reveals that while adaptation options are often enunciated there is no national policy developed to support those options. Despite this lack of supporting policy, three adaptation descriptions have become main stream: protect, accommodate, and planned retreat. Table 2 from the Australian Government (2009a, p. 152) report, *Climate Change Risks to Australian Coasts* represents the most detailed review to date of the adaptation options available.

Some of the key concerns from the National Coastal Adaptation Agenda (Australian Government, 2010b) held in Adelaide in February, 2010 were:

- the issue of legal liability was of particular concern to Local Governments. It was noted that because there is uncertainty as to whether Local Government carries a legal responsibility for defensive expenditure, there are potential obstacles to effective coastal adaptation (p.2,15,16);
- information is required on the comparative costs and benefits of adaptation options and at what timeframe a particular adaptation option becomes cost-effective (p 24);
- there was a uniform call for a risk guidance framework that would be consistent across all three levels of government. Such a framework would provide an overarching risk methodology to support effective coastal adaptation decision making (p. 22);
- the participants agreed that climate change risks need to be incorporated into guidance for planning and development, building codes and standards, and that the current diversity of sea level rise bench marks between state jurisdictions was confusing (p. 38);
- participants recommended that access to an authoritative body that can provide the most up to date science, collate large data sets together and integrate and synthesise the information would provide more certainty to decision makers (p. 29);
- it was recognised that there was a need for accessible and comparable multi-use data sets, such as high resolution digital elevation models and bathymetry, to build capacity for local and regional risk assessments (p. 29); and
- participants also saw the need for data bases that record assets at risk in coastal areas so that risk management can be followed over time.

Table 2: Adaptation options to future sea level rise (Source: Australian Government, 2009a p. 152)

Planned retreat

Planned or managed retreat involves a decision to withdraw, relocate or abandon assets that are at high risk of being affected by climate change hazards in the coastal zone. In the longer term, planned retreat often provides the most cost-effective approach to managing risks to medium to high-value assets exposed to inundation or erosion risk.

Planned retreat, which can occur on a range of scales, can involve increased setback provisions, relocation of structures within properties, and rezoning of land (for example, to constrain ribbon development in high risk areas or to provide for horizontal migration of wetlands). It can include buyouts of properties.

At present there have been few experiences with planned retreat to deal with climate change, with the exception of Byron Bay. Lessons can also be learned from property relocations caused by the construction of new dams. In some areas, early community consultation suggests that there could be opposition to the early adoption of planned retreat. Options for implementing planned retreat would probably include a mix of regional planning, constraints on property title, financial instruments and insurance incentives.

Costs	Benefits
• Lost value of land, infrastructure, and social, economic and environmental values • Potential compensation costs for loss of land or infrastructure • Management costs associated with retreat plan (for example, removal of septic tanks as houses retreat)	• Increased public safety • Significantly lower ongoing maintenance costs than for protection measures • Reduced need for costly adaptation measures in future, should risks increase • Potentially allows for greater space for ecosystems to horizontally adapt

Protection

Protection of the shoreline typically involves the construction of seawalls or other defences to maintain coastal assets in their current location. It includes the repeated nourishment of beaches with sand and engineering works, such as tide gates, to constrain flooding.

Many protection works will have a decadal life, as they will be constructed to a particular standard that will be exceeded over time with climate change. As indicated in Chapter 2, the effectiveness of beach nourishment will decrease over time as beaches switch from being stable to eroding.

Areas where ongoing coastal protection is a long-term option include highly developed urban areas with a long history of protection, and areas where there is a need to preserve irreplaceable cultural, Indigenous and heritage values.

The public will often call for protection when private property is threatened by coastal erosion. However, the use of protective structures can also lead to a false sense of security and encourage greater development in areas behind protective structures, than for similar locations that do not have protective barriers. Protection should only be considered as a long-term option as part of a wider management plan for the area.

Costs	Benefits
• Construction and ongoing maintenance costs could be high • Expectations that area will continue to be protected can limit the flexibility of retreat options in the future • Costs are likely to be much higher if structures fail, because their construction encourages development in protected areas compared with similar but unprotected areas • Impacts on areas upstream or downstream of protective works include loss of coastal and marine habitats	• Avoided damages or loss of land and structures • Continued public access to beaches and other recreational areas • Improved public safety

Accommodation

Accommodation includes a range of usually minor works to allow continued or extended use of at-risk areas. Measures include elevated floor requirements, increased setback requirements, and preparation of emergency evacuation plans.

Accommodation measures are often cost-effective in a transitional strategy. They are suitable for areas with modest to higher value assets where exposure to climate change risk is low to medium. An example is The Honeysuckles, Ninety Mile Beach, Victoria where new residents are required to provide a response plan to climate change, identifying how structures would deal with possible flooding and storms for the next 60 years, and a caveat is included on the property title to warn future owners of risk. While accommodation strategies may also generate a false sense of security, they do start to signal restricted access or development requirements and begin a difficult task of managing private ownership development expectations.

Costs	Benefits
• Marginal additional construction costs • Costs from loss or damage that may occur if measures not adequate • Possible reduction in investment values	• Continued use of land and infrastructure • Generally less impact on surrounding environment than protection measures • Generally cheaper than protective measures • Increased public safety • Promotes risk management

In developing adaptation options the conference recognised:

> *'There are three common approaches to managing the built environment in the coastal zone: protect, accommodate and retreat. However, each approach requires complex analysis and trade-offs of specific local social, environmental and economic factors. A better understanding of the social costs and benefits of each approach, and of optimal timing, is required for effective adaptive investment and risk management….Effective adaptation responses will build upon risk or vulnerability assessment. Local government representatives at the Forum reiterated the need for support and guiding principles in the development of adaptation strategies... Decisions about whether to protect, retreat, accommodate or abandon will need to be worked through with communities' (p. 24).*

SUMMARY

The Australian Federal Government will take an oversight and facilitation role in the process of adapting to climate change due to its position within the Australian government system. It is continuing to create a scientific framework with the aim of assisting State and Local Governments in their decision making. The Federal Government has identified use of the insurance market as the preferred policy to change people's behaviour over time about their preferences for where they live. Furthermore, recent changes to the Natural Disaster Relief and Recovery Arrangements (NDRRA) that provides funding to replace damaged infrastructure will place the onus on states/territories to have insurance arrangements that reduce the financial exposure to taxpayers. While the Federal Government's role is oversight and facilitation, it will influence adaptation outcomes by what programs and initiatives it chooses to fund. The direct liability of the Federal Government would seem to be limited to taking care of its own assets. However, the Federal Government has also indicated that it will provide a strong safety net, and it is likely to be susceptible to political pressure to provide financial assistance in the circumstances where damage is widespread.

GENERAL AUSTRALIAN LEGAL FRAMEWORK

One of the aims of this study is to investigate perceived liability relating to climate change impacts in the coastal zone. This section is a summary of the recent report by law firm Baker and McKenzie (2011), *Local Council Risk of Liability in the Face of Climate Change - Resolving Uncertainties*, and is intended to provide a general framework of understanding rather than to be read as legal advice. With this intention in mind, the summary encompasses a wider review than just that relating to dealing with climate change liabilities to existing assets.

Legal actions against Councils

Councils are established by statute usually by a Local Government Act, and a range of powers are conferred on Councils by a range of Acts. Local Government responsibilities usually relate to:

- land use planning and development;
- land and infrastructure management;
- public health;
- community facilities;
- emergency planning; and
- finance.

Baker and McKenzie (2011) state that Councils may potentially be held liable in negligence or nuisance for decisions, acts, and omissions that relate to the exercise of these powers and functions. Each of these powers and functions exist independently of climate change but climate change creates legal uncertainty as there is no specific law that regulates it and it is not clear where it fits into the legal framework that currently governs Councils (p. 21).

Baker and McKenzie give a summary of the type of legal actions that have already been brought against Councils (p.3):

- *claims by private property owners to challenge the refusal of development approval in the coastal zone by Councils on the basis of the anticipated risks of flooding and erosion or because planned retreat strategies had not been fully considered;*
- *claims by third parties against decisions to approve development where it was argued that the Council did not take into account potential climate change impacts;*
- *challenges to the adoption of planning scheme amendments that sought to impose standards to guide development in the coastal zone;*
- *proceedings where a Council sought to prevent a private landowner constructing coastal protection works; and*
- *proceedings initiated by a private landowner seeking to compel a Council to construct coastal protection works.*

Tort based claims

The report notes that there are two classes of tort based claims (those that claim a breach of duty other than under contract) that might be brought against a Council: negligence and nuisance. Baker and McKenzie (2011) then divide the potential climate change related actions into five different types of claim:

- *claim for approving development when the risk of harm was foreseeable;*
- *claim for failure to include protective standards in planning schemes. For example, failing to create minimum standards regarding height above sea level for new development and for buildings to be capable of withstanding extreme weather;*
- *claim for failure to maintain or build infrastructure or conduct coastal mitigation works. For example, failure to upgrade stormwater systems and roads and to build mitigation works such as sea walls;*
- *claim for compensation for failure to provide information. For example, information regarding flooding and coastal hazards on property information certificates; and*
- *claim for compensation for providing incorrect information.*

Elements of Negligence Actions

Negligence is a failure to exercise care or skill. An action of negligence 'will not succeed if the defendant can establish a defence' (p.27). Assuming the Council is the defendant the elements are:

- the defendant owed the plaintiff a duty of care;
- the defendant breached that duty of care;
- the plaintiff suffered loss or damage as a result of the breach of duty; and
- the loss or damage is not too remote.

Duty of Care

In common law, a Council that is under no statutory obligation does not generally owe a common law duty of care. 'Therefore at common law, there are only limited circumstances in which a Council is liable for failure to exercise a statutory function' (p. 28). Each State and Territory (apart from SA and NT) has legislation to further limit the liability of statutory and public authorities that also includes Councils (p. 28).

Breach of duty

A plaintiff must show that a reasonable person in the defendant's position, would take certain reasonable precautions against a reasonably foreseeable risk of injury. In determining this a court will consider the following factors:

- the likelihood of the risk occurring;
- the magnitude of the risk and the seriousness of the potential harm;
- the difficulty, expense and inconvenience of taking the precautions; and
- the social utility of the defendant's conduct.

Causation
The plaintiff must prove that the defendant's negligence cause or materially contributed to the injury or damage suffered by the plaintiff.

Remoteness of damage
The damage must be of a kind that a reasonable person (with the defendant's knowledge and experience) should have foreseen.

Elements of Nuisance Actions
In common law there are two types of nuisance tort claims: private and public. Private nuisance is an interference with an individual's rights in relation to the use of the land that may occur by material damage to land or property upon which the interference occurred. In some cases a person may be liable in private nuisance even if the damage results from natural causes, if the defendant knew of the cause but did nothing to prevent it. The following elements must be proven (p. 28, 29):

- the defendant is vested with management and control of the premises or asset;
- as a result of interference, material damage is caused to the property;
- the interference arose as a result of the defendant's actions or inactions; and
- the defendant had knowledge of the risk of harm.

Public nuisance is an interference with the rights of the public at large and must be deemed as substantial and unreasonable. Activities that cause unreasonable interference to another person's land for which a Local Government may be liable include landslides, bushfires, flooding and coastal erosion. However, a Local Government will only be liable if it was in control (either as the landowner or the principal manager) of the premises, or the resources from which the nuisance emanated.

Defences against tort claims
In common law, the defence of 'voluntary assumption of risk' provides that there will be no liability of the defendant if it can be established that the plaintiff was fully aware of the risk, comprehended the risk, and accepted the whole risk. The concept of 'risk' has been strengthened by statute in Australia to include that the defendant is not liable for the occurrence of an obvious risk, i.e. one that is obvious to a reasonable person in the plaintiff's position (p. 29). A further statutory defence is that a defendant's liability for the 'materialisation of an inherent risk' (one that cannot be avoided by the exercise of reasonable care and skill) is limited only to a failure to warn of the risk. A contract between the plaintiff and the defendant may exempt the defendant from liability in negligence where there is a clear statement that liability for negligence is excluded. Where there is no contract, a disclaimer may give the plaintiff sufficient knowledge of the risk to satisfy the defence of voluntary assumption of risk or to constitute reasonable warning (p. 30).

It is Baker and McKenzie's view that NSW has the best defence among Australian states for dealing with claims in both negligence and nuisance. Where acts or omissions that caused the plaintiff loss or damage were done honestly or in good faith in the performance of statutory functions, Section 733 of *Local Government Act*, 1993 (NSW) 'exempts Councils from liability arising in respect of advice given, acts or omission in relation to flooding, its nature and extent, provided that it was done in good faith. This legislative clause provides protection for a local Council provided it can be shown that it acted with an honest intention and without deliberately misleading a resident. If this can be demonstrated, the Council will be not held liable.' (p. 30, 31).

The questions to determine whether a Council is liable under an action of negligence are:

- Was a duty of care owed?
- If so, what was the standard involved in the duty of care?
- Did the harm or loss occur as a result of a failure to adopt the standard of care?

The relevant questions to ask to determine whether a Council may be liable under an action of nuisance are:

- Is the Council vested with the management and control of the premises or resources?
- Did the interference result in material injury to property or reasonable enjoyment of it?
- Did the interference arise as a result of the Council's actions or inactions?

Possible tort related claims

Baker and McKenzie (2011) list and explain the following tort claim types (1-4) that might be brought against a Council:

1. *claim for approving development when the risk of harm was foreseeable;*
2. *claim for failure to include protective standards in planning schemes;*
3. *claim for compensation for failing to provide information; and*
4. *claim for compensation for providing incorrect information.*

Of the types of claims listed above, number (3) and (4) may be more likely to relate to existing infrastructure and buildings.

(3) Claim for compensation for failing to provide information.

If a Council does not take steps to mitigate a potential risk, it may have a duty to inform its residents of the potential risk, for example, advice regarding flooding and coastal hazards. If it fails to do so and the resident suffers damage the Council could be liable in negligence. Where the risk is inherent (one that cannot be avoided even with the exercise of due care and skill), the liability of a Council for the materialisation of an inherent risk is limited to the failure to inform the plaintiff of the risk. In jurisdictions where there has been statutory reform, a Council is not liable for failure to warn of a risk unless the plaintiff has enquired about the risk from the Council or the Council is required by law to warn the plaintiff of the risk (p. 41). It is Baker and McKenzie's view that given the protections surrounding Councils it would be difficult to establish that they are liable for failure to warn or inform of the risk of climate change. If Councils have a duty to warn of a risk, the required response would depend on the magnitude and immanence of the risk. The extent to which the Council goes to provide information needs to be considered in this context and the answer will differ depending on the nature of the risk and the surrounding circumstances. Baker and McKenzie advise that the best defence for States/Councils is to enact exemption provisions similar to Section 733 of the Local Government Act (1993) NSW.

(4) Claim for compensation for providing incorrect information.

A claim for providing incorrect information is more likely to be brought than a claim for failure to provide information because it is likely to be easier for a resident to prove that the information provided was misleading. Baker and McKenzie (2011) note that Councils in NSW would not be liable in a claim for providing incorrect information under Section 733 (3) (f5) of the Local Government Act (1993) NSW.

Possible administrative actions

Administrative law seeks to safeguard people who are affected by government decisions by allowing those who are adversely affected to challenge. Examples of administrative decisions open to challenge are decisions to compulsively acquire land, to impose a condition on a licence, or to grant or reject planning permits (p.43).While administrative actions would normally relate to new development, mitigating climate change risks along the coast may include the need for Councils to implement actions that are considered development (e.g. sea walls, filling, cutting of land etc.). Baker and McKenzie (2011) state that the climate change related legal actions most commonly relate to the administrative review of planning decisions (p. 45). Administrative law seeks to provide safe-guards to people who are affected by government decisions, by allowing people adversely affected by those decisions to appeal them (p. 43). A person's right to challenge a government decision arises under common law and statute law and may include:

- merits review under the original empowering legislation that involves the new decision maker standing in the place of the original decision maker to either confirm, alter, or change the decision; and
- judicial review by a court under the relevant empowering legislation is a challenge to the lawfulness of a decision and does not consider the merits of the case. Examples of

grounds for judicial review include: no jurisdiction, error of law, relevant and irrelevant considerations (p. 44,45).

Baker and McKenzie (2011) explain many types of administrative appeals but only the administrative appeals relating to planning permits made by Councils are included here.

A right to merits review is normally available for all planning approval decisions made by Councils. Based on the cases brought to date, the Courts are taking a precautionary approach to considering climate change impacts (See Taip v East Gippsland SC [2010] VCAT 1222 (28th July 2010).

It is the opinion of Baker and McKenzie (2011) that successfully arguing a judicial review case is more difficult and it is envisaged that the ability for people to successfully bring a case for judicial review will decrease as climate change knowledge is further embedded into legislation and procedures (See Minister for Planning v Walker [2008] NSWCA 224 & Aldous v Greater Taree City Council [2009] NSWLEC 17).

In summary, in situations where the statutory obligations placed on Councils to consider climate change are not clearly expressed, or the information that Councils are required to consider is not clearly specified, merits or judicial review is more likely to be pursued.

> *'At present, many climate change risks are detailed in policies and strategies that are not legally binding documents. Councils are increasingly taking this information into account to avoid negligence claims associated with climate change risks' (p.51).*
>
> *'Councils retain significant discretion as long as the correct processes are followed. The extent of the duty imposed on any decision maker to take into account climate change impacts will almost always be a question on the facts of the case. Provided that the guidance materials relied upon, and the decision making is proportionate and reasonable, the decision is unlikely to be regarded as unlawful under judicial review' (51).*

Mitigating risks of claim under administrative review

'Councils will be able to mitigate the risk of judicial review through balanced clear decision making on the best available evidence' (p 52). The ability to mitigate the risk of merits review related to climate change considerations is more difficult. Baker and McKenzie expect that many landholders would bring an application for merits review if their application was rejected or conditions relating to temporary use or planned retreat are imposed upon the decision. Conversely, community groups may use merits review processes as a means to test policy and bring public awareness to climate change issues. Another option for Local Governments to limit the risk of merits review is by the use of Ministerial call in powers by which the Minister responsible for Planning in state jurisdictions decides the merits of a development application directly instead of a Council. In this case the Council may be liable for increased costs in dealing with these actions.

Recommendations for planning permit decisions

Baker and McKenzie (2011) recommend that Councils take into consideration the following when making planning decisions:

- *develop clear and certain criteria for making coastal climate change decisions based on best available evidence;*
- *assign a role to a centralised body to collect and disseminate scientific information and where appropriate advise Councils to assess impacts and risks. This information should be kept as current as possible;*
- *ensure property owners have access to information such as flood mapping and other data;*
- *ensure public consultation procedures are appropriate; and*

- *use time-based consents and place covenants on title or issue temporary development permits. For example, in Victoria a development permit can include a condition that the use must cease and the development be removed at a particular time if for example coastal erosion approaches a particular threshold, or a proposal may be permitted for a specified time (p54).*

Other claims

Baker and McKenzie (2011) list several other types of claims that may relate to climate change related liability for Councils:

1. claims related to failure to provide services (p. 59);
2. statutory compensation claims (p. 61);
3. compulsory acquisition claims (p. 63); and
4. claims regarding title boundaries: erosion and accretion (p. 58).

Claims related to failure to provide services

The report notes the longstanding dispute between Vaughan and Byron Shire Council (p.60) that concerned the provision of coastal protection works in Byron Shire. The Council had granted itself consent for the construction of a geobag erosion control wall on the coastline of private beachfront property. The private owners brought an action alleging breach of the development consent following a storm that caused erosion of the beach including about 10 metres of private property. Held: the terms of the consent obliged the Council to monitor, maintain, and repair the beach stabilisation works they had erected. The Council was ordered to restore the interim protection wall to its height and shape before the storm event. In addition the court found that the private owners had the option of bringing action in negligence or nuisance in the Supreme Court to seek damages for the loss of their property (p. 60).

Statutory Compensation Claims

Baker and McKenzie (2011) state that 'planning almost always involves some form of interference with a landowner's property rights. If certain land uses are prohibited or development restricted, a diminution in the land value may result. However, planning decisions only attract compensation in a limited number of circumstances' (p. 61). One example is compensation for a failure to grant a planning permit although it is generally accepted that there is no compensation payable unless the land is required for a public purpose. Another example is a compensation claim for a planning scheme amendment. If a planning scheme is amended so that it restricts development on coastal land, land owners may seek compensation 'because their property rights have been taken away' (p. 62). However, Baker and McKenzie take the view that in most states such arguments are unlikely to succeed unless land has been reserved for public use or compulsorily acquired. Queensland is the only state with a wide 'ranging injurious affection provision for general planning scheme amendments' (p. 62). Landowners who seek to argue that re-zoning land in a manner that severely restricts the development of that is a 'de-facto reservation for public purposes' will find that this argument has already been rejected (Meyden v MMBW [1980] VR 255, Equity Trustees Executors and Agency Co Ltd v MMBW [1994] 1 VR 534).

Compulsory Acquisitions Claims.

Compulsory acquisition powers are found at all three levels of government. As the coast recedes in response to sea level rise, Councils may be required to bring land adjacent to the coast into public ownership to ensure that there is public access to the coast, to conduct coastal protection work, or to ensure that significant coastal landscapes are preserved (p. 63). A more extreme situation might be the need to compulsorily acquire large amounts of land to relocate entire communities further inland, although the report states that this is more likely to be a State based activity than a Council one.

Claims regarding title boundaries: erosion and accretion
The common law doctrine of accretion and erosion applies when such erosion and/or accretion between land and water alters gradually and imperceptibly. In the absence of evidence to the contrary on title, if freehold land has a boundary to the coast or to a river, accretion into the water extends the boundary of the freehold land, and erosion of the freehold land by the water diminishes the boundary of that land and extends the area of the body of water (which is Crown land) p. 65.

If coastal erosion occurs due to sea level change in a gradual manner, property boundaries may shift to extend land in Crown ownership and decrease the size of the private property. This factor may have major implications for property owners whose land abuts the coast line. Conversely, if a straight-line boundary can be proven, Councils may lose access to coastal land. It is important to note that there is no statutory right for compensation for loss of land through natural process. One of the requirements for this doctrine to come into effect is that the change is gradual and arguably does not apply if the change occurs due to a sudden event such as a storm. In the case of sudden erosion events that are accelerated by climate change, Councils may face an increasing loss of land, and public access to land, and may need to use powers of compulsory acquisition to retain access to the coast. Baker and McKenzie suggest that:

> *'Councils may wish to consider advocating that States amend, through legislation, the common law doctrine such that erosion events caused by sudden events (such as large storm surges) result in the boundary of land moving and reverting to the Crown. Similarly, the doctrine of accretion can also be amended by Statute. Such amendments will ensure public access and ownership and may prevent large compulsory acquisition claims.' (p. 66).*

Summary by Baker and McKenzie

In each State and Territory (with the exception of NT and SA where there is a weaker defence at common law) there is legislation that can limit the liability of Councils in civil litigation (p. 4). In determining whether a Council is exercising its functions reasonably, the circumstances must be balanced against other legitimate functions of the Council. In all jurisdictions (with the exception of SA and NT that rely on less well developed principles at common law) the following limitations apply to the liability of Councils (p. 21):

- financial and other resources available to the Council limit the functions required to be exercised by it;
- the general allocation of resources by the Council is not open to challenge;
- a reference must be made to the broad range of the Council's activities in deciding the functions it must exercise; and
- Council may rely on evidence of its compliance with general procedures and relevant standards as evidence of the proper exercise of its functions.

Key risks that Councils face in relation to sea level rise (p. 22):

- flooding of coastal properties resulting in damages or loss of land and assets and/or changes to property boundaries;
- storm water runoff and flooding;
- infrastructure instability or buildings not built to withstand the impacts of increased flooding, winds and temperature; and
- climate change related impacts on public open spaces.

Climate change related impacts will affect both public and private buildings and land. Adaptation strategies and responses need to address both actions that can be undertaken by a Council and the provision of information to private property owners so they can handle their own adaptation and risk management.

> '*The potential resource burden for Councils is significant and will need to be managed and planned for. Where impacts are unavoidable or are not avoided due to costs, insurance may or may not be available to transfer or share the risk.' (p. 22).*

In conclusion, the Executive Summary of the report states:

- *Councils must ensure they keep up to date with general climate change science and information related to mitigation and adaptation strategies, especially where information relates to their specific local area. The courts will take into account the latest science but will also judge a case on what science was available at the time of the original decision.*
- *Clear criteria for decision making should be developed to increase public confidence that decisions are made on the basis of the best available scientific evidence. Baker and McKenzie suggest an expanded role for a centralised advisory body.*
- *Increase public consultation on decision making to improve transparency and limit administrative review, taking into account available resources and costs.*
- *Ensure property owners have access to information such as flood mapping and data that will inform them of climate change related risks. Communicate potential risks so that property owners adjust their expectations.*
- *The fundamental means of avoiding liability for Councils is to exercise reasonable care when making decisions. At the very least, development in highly sensitive areas should be minimised.*
- *Council staff need to be educated about climate change impacts and the potential risks that Local Governments face.*

AUSTRALIAN STATES/ TERRITORIES AND LOCAL GOVERNMENTS

INTRODUCTION

Generally Australian States take a similar position to the Federal Government in regard to the importance and reliability of climate change science. In relation to predicted sea level rise, the States have adopted different benchmarks but usually note the Federal Governments assumption of 1.1 metre by 2100. The differing threshold levels for sea level rise for each State are summarised in Table 3 below. To date, all states have had an emphasis on dealing with mitigation rather than adaptation responses.

Table 3: Comparison of predicted sea level rise between Australian States.

State	By 2050	By 2100
NSW	0.4 metres	0.9 metres
VIC	Not given	Not less than 0.8 metres
QLD	Not given	0.8 metres
SA	0.3 metres	1 metre
WA	Not given	0.38 metres to 0.90 metres
TAS	Not given	Not given

Baker and McKenzie (2011) state that the Commonwealth constitution gives the States and Territories primary responsibility for the management of land, natural resources and environmental protection. The assignment of this responsibility means that legislative change to implement adaptation strategies will be driven by the States. Councils are established by statute, and a range of powers, functions and responsibilities are conferred on Councils by various Acts such as Local Government Acts, Environmental Acts, and Planning Acts (p.20). Consequently Councils often find themselves at the forefront of responding to the impacts of climate change (p. 1). State Governments appear to take a similar position to the Federal Government by providing a general framework and support for adaptation to occur while recognising that it has additional responsibility to manage changes to planning schemes and maintain emergency services, utilities and coasts.

As demonstrated in the section below, the way the State Governments have managed this responsibility in relation to coastal climate change risks so far is by enacting legislation to provide a legal framework in which change is to take place, but in relation to adaptation, the context for change is within the existing land use planning system. As such there are no specific coastal climate change provisions, and risks are dealt with predominantly in non-binding state wide policy documents. Gibbs and Hill (2011, p. 14) note that changes to decision making is brought about by the incorporation of these policies through the land use planning system by:

- being implemented into planning policies and strategies directly;
- being matters that are considered when planning schemes are drafted or updated;
- being matters that are required to be taken into account; and
- being matters that form part of the conditions of approval for a development application.

Gibbs and Hill (2011, p. 43, 44) also state that in ‘relation to existing settlements, policy tends to be vague’ and recognise that three strategies are used to deal with increased coastal climate change risks. The first strategy is to reduce the intensity of existing coastal settlements through the rezoning of high risk areas, but don’t give any examples of where this has been undertaken in

Australia to date. The second strategy is to undertake coastal protection works, and the third strategy is to plan emergency responses. Gibbs and Hill (2011, p.43) recognise that the first strategy could take decades to bring about any real change in land use in hazard zones because of the existing use rights that exist in all jurisdictions in Australia and within the states of Queensland, Tasmania and Western Australia. Provisions also exist for 'injurious affection' where property values are diminished because of planning decisions made by government.

Generally, Councils in all states and territories have appropriate levels of public liability insurance as well as insurance for real property, plant and equipment. However, with the exception of a few assets, infrastructure assets are largely uninsured despite that fact that infrastructure is by far the largest class of assets by dollar value for most Councils (Comrie 2011, p.i). As noted above, the Commonwealth Government provides financial assistance to states and territories that suffer loss of infrastructure due to natural disasters. State and Territory Governments then allocate these funds to local Councils. Recommendations of the Review of Local Government Natural Disaster Insurance Issues (Comrie 2011) include that infrastructure insurance in mutual pools and in the private market should be sought. Additionally, the level of financial support made available by the Commonwealth and States and Territories should not diminish if Local Governments broaden their insurance cover to include infrastructure assets. At present, funds are allocated after insurance payouts have been taken into account and so there is little incentive for Councils to pay high insurance premiums to cover infrastructure if less funds would then be received from the Commonwealth in the event of a natural disaster. It is recognised here that these Commonwealth funds are only available in the event of a natural disaster as defined by the Commonwealth and only available once expenditure on reconstruction has exceeded certain annual thresholds. It follows that these funds would not be available for infrastructure under threat by gradual erosion for example, but rather for extreme events.

The following section reviews the climate change adaptation responses in three states: New South Wales, Victoria and South Australia. The report by Jan McDonald (2010) *Climate change adaptation in South East Queensland Human Settlements: Issues and context* provides a comprehensive overview of the adaptation response in Queensland up until March 2010. References are made to other States where applicable. It was noted in the introduction to this policy review that adaptation policy is often embedded in other general policy and its effect is cumulative over time. Therefore, the approach in this section is to 'drill down', firstly through any legislation that relates to dealing with climate change risks, and then through the various State policy documents that have been produced over time.

NEW SOUTH WALES

With recent amendment to the *Coastal Protection Act*, 1979 and the subsequent issue of management guides in 2010, it is likely that NSW has the most advanced legislation and policy frameworks in Australia to address the likely coastal impacts of climate change. However, a complete picture of the NSW response is only achieved through a review of all policy developments that have evolved over the last few decades.

Legislative framework

Generally, management of coastal areas falls to Local Government authorities under the *Local Government Act*, 1993. Specifically, coastal management in NSW is undertaken under the following legislation and policy frameworks. *Local Government Act NSW* 1993 Section 733 which states:

> *'A Council does not incur any liability in respect of:*
> *- Any advice furnished in good faith by the Council relating to the likelihood of any land being flooded or the nature or extent of any such flooding; or*
> *- Anything done or omitted to be done in good faith by the Council in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.'*

Section 733, (4) and (5) of *The Local Government Act* 1993 also defines 'acting in good faith' as where a Council has substantially acted in accordance with the principles contained in the relevant manual. Baker and McKenzie (2011) state that this clause provides Councils with the most effective defence against most claims that can be brought against a Council in relation to their climate change related decision making. Where a Council can demonstrate that it has acted 'in good faith', it is free from liability in the courts.

It is noteworthy that the first item on draft Coastal Sustainability Charter and Policy Framework for Coastal Australia is to:

> *'Promote the adoption in all jurisdictions of legislation to give similar effect to that provided by Section 733 of the NSW Local Government Act, which affords protection from legal liability for local Councils where they provide advice or make a decision in good faith relating to coastal planning and the impact of climate change' (National Sea Change Taskforce, 2011, p.3).*

It would seem likely that all States will move to reduce their liability from climate change impacts related to sea level rise by adopting similar legislation to NSW in the near future.

The Coastal Protection Act 1979 (NSW).

The *Coastal Protection and Other Legislation Amendment Act* 2010 (NSW) includes further exemptions of liability for Councils that include:

- the preparation of a coastal zone management plans that set out matters such as: protection of the beach environment and amenity; what emergency actions are permitted; how Councils will ensure continued public access to the coast; the impacts of climate change and coastal hazards; and arrangements relating to long term protection works;
- acts of omissions regarding beach erosion or shoreline recession on Crown land or land owned and controlled by the Council;
- the failure to upgrade flood mitigation works or coastal management works in response to projected or actual impacts of climate change; and
- the failure to remove or enforce the removal of illegal or unauthorised structures on Crown land or land controlled by the Council which results in beach erosion.

In relation to emergency coastal protection works, landowners within twelve coastal erosion hotspots whose homes are at imminent risk from coastal erosion will now be able to place sandbags or sand on beaches to protect their homes for up to twelve months. The works may only be placed once for each landowner and they must obtain a certificate to do so.

In relation to long-term coastal protection works, landowners will be allowed to build long-term coastal protection works to protect their properties provided that the consent authority (either the Council or the newly formed Coastal Panel) is satisfied that the works will not unreasonably limit public access to the coast and that the authority is satisfied the satisfactory arrangements have been made to maintain the works. Councils will have the power to levy an annual charge on landowners for the works where there is a need for them to manage off site impacts of the works. Future owners will also be liable for the charge (Smith 2010, p.3).

These amendments would seem to deal directly with the legal issues raised in the Byron Bay case of Vaughan versus Byron Shire (see case study below) so that in the future government will not be held liable for any future defence works. Additionally, these amendments deal with the anger and possible litigation from owners who were denied the right to defend their properties under the Byron Shire policy of 'planned retreat', and at the same time, the government has shifted the onus to the property owners both in terms of who is liable as well as for the cost of installation and maintenance of defences.

Environment Planning and Assessment Act 1979 NSW (EP&A)
State Environment Planning Policies Number 71 – Coastal Protection (SEPP 71) applies to land generally defined as one kilometres inland of the high water mark of the sea and around lakes and estuaries, and three nautical miles seaward.

The *Principal Local Environmental Plan* was introduced in 2007 to standardise all Local Environmental Plans across the state. Clause 5.5 of this instrument prevents the granting of development consent on land that is in the NSW Coastal Zone unless consideration has been given to the effect of coastal processes, hazards, and impacts including sea level rise on the proposed development.

Changes have been proposed to the issuing of planning certificates under S149 of the EP&A Act whereby planning certificates will be required to include information about coastal erosion hazard policies that restrict development, thus enabling potential purchasers to be more informed about possible climate change risks.

Policy frameworks

NSW Coastline Management Manual (NSW Government 1990)
The NSW Government website (http://www.environment.nsw.gov.au/coasts/coastalmgtdocs.htm) states that the *Coastline Management Manual* is presently under review but it is still quoted in later policy documents including the *Coastal Risk Management Guide* (2010).

NSW Coastal Policy 1997
The *NSW Coastal Policy* (1997) is the principal policy to guide the state government and local Councils responsible for coastal protection and management in NSW. New initiatives in this policy included prohibiting new sandmining ventures, prohibiting new canal estate developments, and protecting public access to the beaches.

NSW Floodplain Development Manual 2005
The *Floodplain Development Manual* (2005) policy promotes the use of a merit approach that balances social, economic, environmental and flood risk parameters to determine whether a particular use of the flood plain is appropriate. In other words, the policy establishes that all applications will be included on merit rather than establishing 'no development zones' in areas that are already zoned for development. The policy would also seem to reduce the possibility of land owners litigating for loss of development potential or land value in the event a Council declares a flood prone area unable to be developed. Under the policy the onus is on the applicant to demonstrate how it will deal with the threat of flood.

The *Floodplain Development Manual* also notes that Councils are primarily responsible to manage flood risks and that the NSW Government will provide specialist technical assistance, financial assistance for works to reduce the potential for flood damage, provision of emergency management, and protection of Councils for damages from their issued advice or granted approvals on floodplains providing that such action was taken in accordance with the principles and guidelines in this manual (an example of Section 733 in practice).

NSW Sea Level Rise Policy Statement 2009
The *Sea Level Rise Policy Statement* (2009) adopts a sea level rise of 40 cm by 2050 and 90 cm by 2100 but acknowledges the IPCC's predictions in 2007 that sea levels could rise higher than these benchmarks. The objective of the policy is for the State Government to support local Councils and the community by:

1. promoting an adaptive risk-based approach to managing the impacts of sea level rise;
2. providing guidance to local Councils to support their sea level rise adaptation planning;
3. encouraging appropriate development on land projected to be at risk from sea level rise;

4. continuing to provide emergency management support to coastal communities during times of floods and storms; and
5. continuing to provide up to date information to the public about sea level rise and its impacts.

Statements that relate directly to existing development are:

> *'The Government will also continue to provide guidance and assistance to local Councils on reducing the risks to private and public property from coastal hazards. The risks from coastal hazards are significant and are expected to increase with sea level rise.' (p. 4).*
> *'When allocating funding assistance to local Councils for coastal protection works, the Government will give priority to public safety and protecting valuable publicly owned assets, and then to private land'.*

The criteria the Government will use to allocate any funds to local Councils to protect or voluntarily purchase private property will be:

- magnitude of current and future hazards;
- cost-effectiveness of management actions;
- contribution of the project;
- financial contribution to the project's cost from the Council; and benefitting landowners, taking into account genuine hardship for affected coastal residents;
- effectiveness of the proposed arrangements for maintaining any proposed works; and
- ability of the project to accommodate sea level rise.

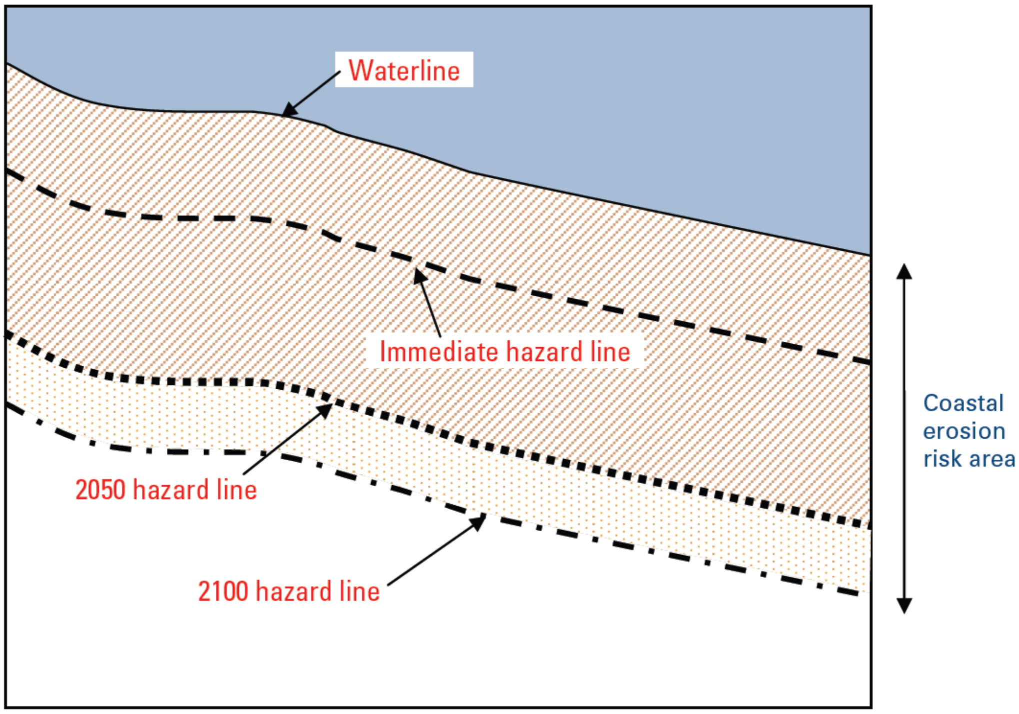
Where assistance is provided to reduce the impacts of coastal hazards the Government does not assume any responsibility for these hazards. Specifically in relation to (5) above, one reason the State Government states that access to current and credible information on sea level rise is important is to assist the insurance industry to price risks from sea level rise in their policies (p 6).

NSW Coastal Planning Guideline: Adapting to sea level rise (2010).
The *Adapting to Sea Level Rise* guideline (2010) was prepared to provide guidance on how sea level rise is to be considered in land use planning and development assessments in coastal NSW. The aim of the guide is to promote ecologically sustainable development and to promote a precautionary approach to land use planning and development assessment in the light of potential sea level rise impacts. The guide adopts a risk-based approach to planning and development and states that it is to be read in conjunction with policies listed above. A review of the guideline reveals that its main focus is in relation to planning and assessment regimes for future development within the framework of the following six principles:

Principle 1 – Assess and evaluate coastal risks.
Principle 2 – Advise the public of coastal risks.
Principle 3 – Avoid intensifying land use in coastal risk areas.
Principle 4 – Consider options to reduce land use intensity where feasible.
Principle 5 – Minimise the exposure of development to coastal risks.
Principle 6 – Implement appropriate management responses and adaptation strategies.

However, Principle 2 (which relates to making information available to the public) suggests that not only should coastal risks be included on Section 149 certificates that are issued at the time a property is purchased, but the broader community should be informed on issues relating to coastal risk. Ways that this information transfer may occur include brochures and maps either in print media or on the internet. Under Principle 3 and 4, Councils may now adopt sea level rise investigation areas to inform their strategic planning on an interim basis. The Council can use the sea level rise planning bench marks as a basis for declaring these areas (p.5). This practice seems to be a way for a Council to forewarn land owners that an area is under investigation but not yet named as a hazard area. This mechanism is also a way to defer the zoning of land until appropriate investigations are concluded (p.5).

Figure 3 shows the type of assessments that will determine sea level rise investigation areas and possible eventual hazard area nomination.



Nb: Coastal erosion risk areas are identified in studies undertaken in accordance with the *Coastline Management Manual* complemented by the *Coastal Risk Management Guide*. The latter shows how the sea level rise planning benchmarks should be included in the modelling of the 2050 and 2100 hazard lines.

Figure 3: Coastal erosion risk areas (Source: NSW Coastline Planning Guideline - Adapting to Sea Level Rise 2010, p.6).

In relation to the effects of protection works on land use capability, the guideline notes that 'comprehensive works by the local planning authority or by individual landholders are permitted as long as they do not adversely affect coastal processes or the environment' (p. 8). The guide states that soft engineering options such as beach nourishment or re-establishing barrier dune systems are preferred to hard engineering. Structural works can include seawalls, revetments, gabion walls, artificial reefs and groynes as well as temporary solutions such as sand bags. However, these works need to be consistent with an approved management plan so as to prevent shifting the problem elsewhere. While in the past any work on public land has been done by public authorities, private landowners may now apply to construct protection works on their own land or on public land to protect their properties (p. 9).

Principle 4 encourages the reduction of land use intensity in coastal risk areas where feasible (p. 9). In addition to coastal risk, when Councils consider reducing land use intensity the following factors should be considered:

- land tenure – public or private;
- current land uses and existing rights;
- the availability of mitigation options (not explained);
- existing constraints such as bushfire, flood risk, slope stability etc;
- other planning constraints such as distance to community services, utilities; and
- the potential for requiring land acquisition.

Rather than prohibiting infill or redevelopment, Council can consider measures that would enable ongoing occupation of the land until such time as coastal risks threaten life and property. An example of such a measure may include the use of time and/or trigger limited development consent conditions (p. 10). A trigger point could be the distance to which an erosion escarpment comes to a lot boundary. This distance could be a uniform measurement for all Councils. In existing areas the Councils and/or landowners could consider the use of long-term coastal protection works as well. Chapter four of the guide lays out how development assessments are to be undertaken in coastal areas. Figure 4 provides a simple example of how assessments might be made.

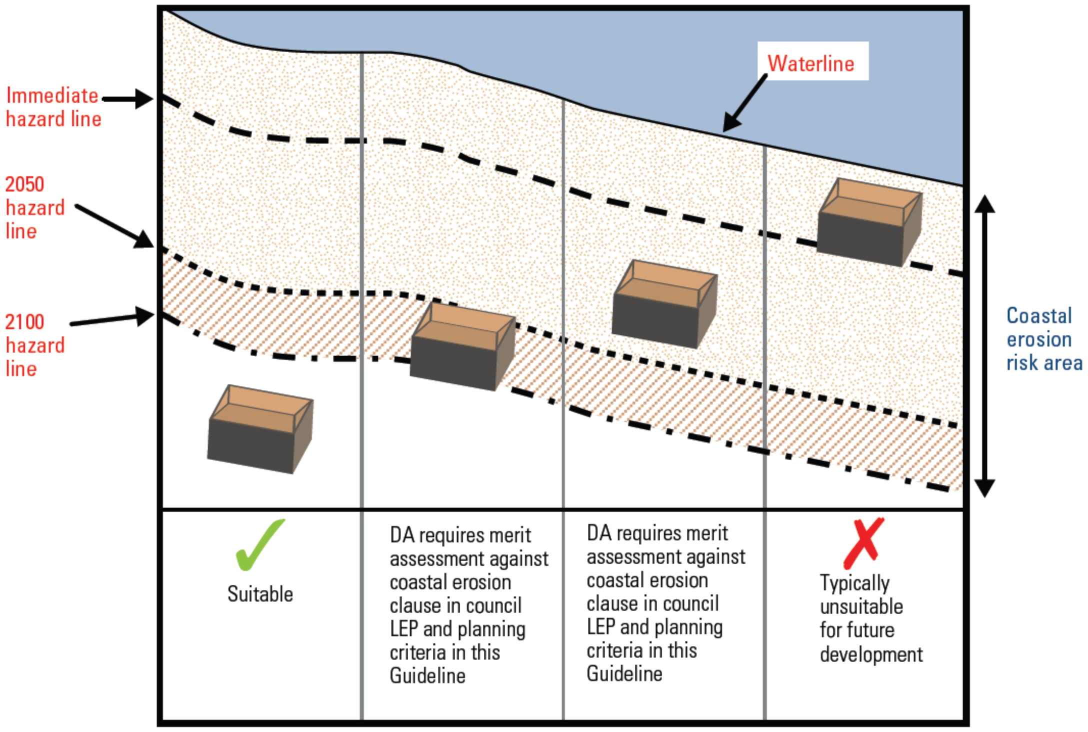


Figure 4: Coastal consideration in DA assessment (Source: NSW Coastline Planning Guideline- Adapting to Sea Level Rise 2010, p. 18).

NSW Coastal Risk Management Guide 2010

The *Coastal Risk Management Guide* (2010) guide is to be read in conjunction with the *Coastline Management Guide* (1990). The two key risks identified in the guide are coastal inundation and landward recession of sandy shorelines. The risk to established development is the threat to foundation systems and gravity drainage systems in close proximity to the shoreline. The policy describes coastal hazard assessments and identifies hazard limits such as hazard lines or hazard areas but notes that ‘in most instances dunal systems along the open coastline are sufficiently elevated that episodic threat from oceanic inundation due to wave run-up and overtopping of coastal dunes or barriers is negligible’ (p. 2, 3). The areas deemed to be most at risk are the lower lying estuarine foreshores where erosion will be exacerbated because of the interaction with catchment flooding. The main focus of the guide is in the application of sea level rise to planning benchmarks rather than dealing with any existing infrastructure or buildings. Figure 5 and Figure 6 illustrate the types of methodologies used to ascertain hazard areas.

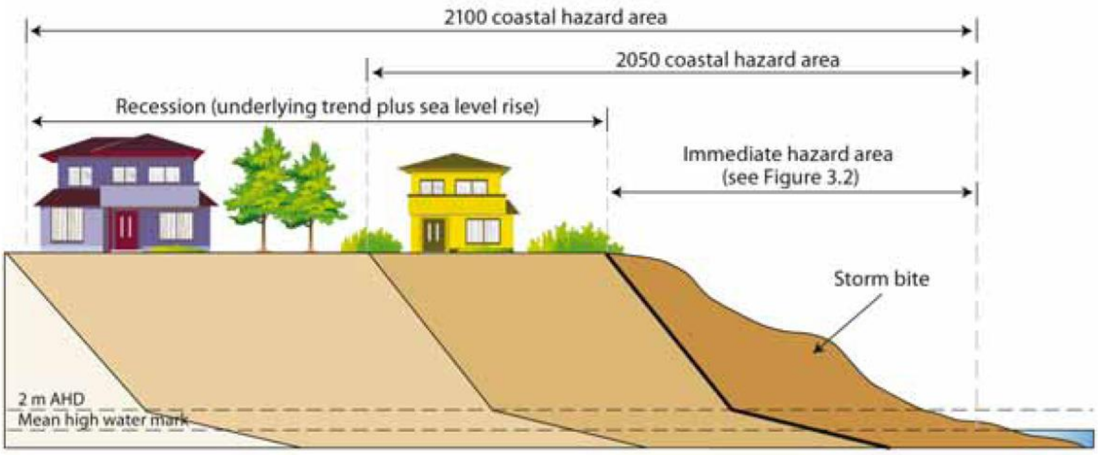


Figure 5: Idealised schematic of a dune profile depicting the high hazard area, 2050 coastal hazard area and 2100 coastal hard area (Source: NSW Coastal Risk Management Guide 2010).

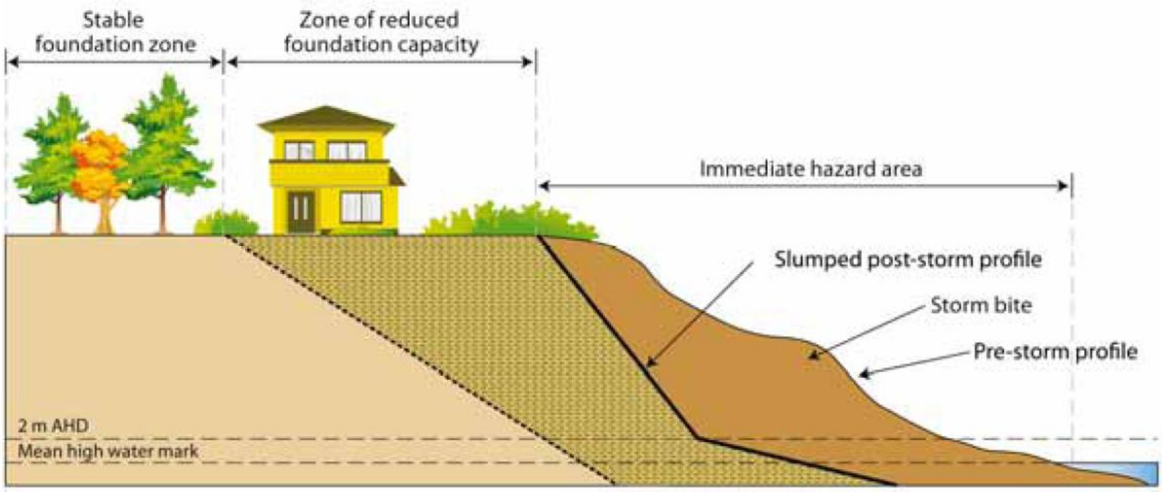


Figure 6: Idealised schematic of a dune profile depicting the immediate hazard area and associated zone of reduced foundation capacity (Source: NSW Coastal Risk Management Guide 2010).

When making an evaluation in NSW of the likely recession of a sandy shore line, the Bruun Rule is to be employed. Recession is the product of the sea level rise (over the planning timeframe of interest) multiplied by the inverse of the active profile slope and is illustrated in Figure 7.

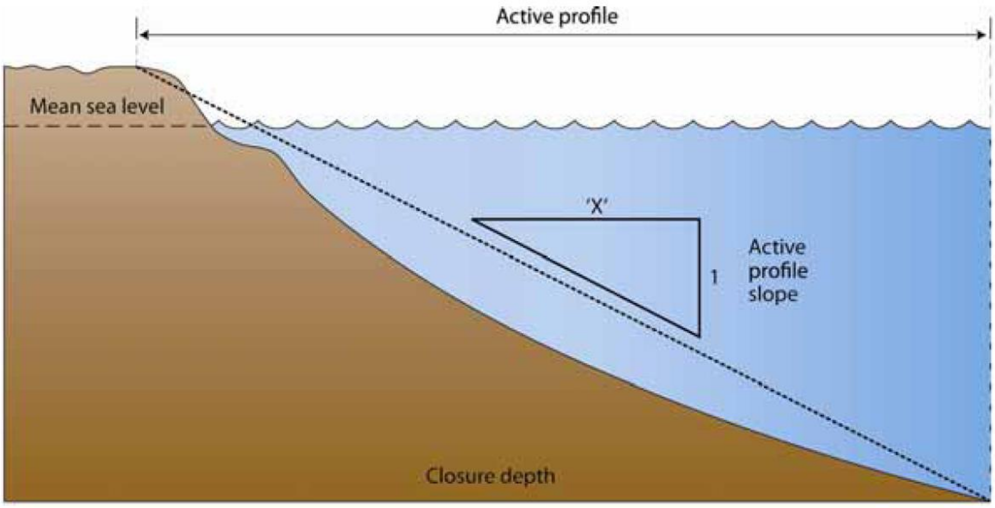


Figure 7: Idealised schematic of the active profile for consideration in Bruun Rule applications (Source: NSW Coastal Risk Management Guide 2010).

Flood Risk Management Guide 2010

The *Flood Risk Management Guide* (2010) should be considered in addition to the Coastal Risk Management Guide (2010) as it takes into account general flooding and deals more specifically with water ways and general inland flooding caused by sea water coming into estuaries or flooding compounded by water from river flooding.

New South Wales Summary and conclusions

At the time of writing, NSW has acted to address the coastal risks from climate more fully than the other Australian States. The main emphasis has been on planned adaptation for new development. This review concludes that the NSW Government is not recommending an approach that refuses development outright (including new subdivisions) but rather that the proponents have to demonstrate how they will mitigate the risk of climate change impacts. This strategy may reduce the problem of litigation and also reduce future liability. A Council may decide to approve a development but will place information on property information certificates that warn any future purchasers of the risks, or may include trigger points, such as erosion boundaries that require dwellings to be moved.

In respect of existing development, the NSW Government has also acted legislatively to allow landowners to defend their own properties in an emergency, but formal approval will need to be obtained where longer-term protection works are required. Development applications for coastal defences will need to demonstrate that the protective actions proposed will not transfer coastal erosion and impacts of sea level rise to other places along the coast. Additionally, the Government has also legislated that it is not liable for the failure of those protection works or a failure to remove them, should they fail.

The NSW Government has made it clear that it will not be allocating financial assistance to the most wealthy of its constituents but also reserves the right to expend money where the impacts are the greatest. Even in these situations it appears that NSW will request a contribution from private and other government land owners for the installation and maintenance of any protection works.

With regard to coastal climate change related liability, NSW state policy is strong apart from a couple of areas:

- where Government has already erected coastal defences (such as in Byron Bay), these defences may need to be protected into the future; and
- where Councils in more recent applications have not taken climate change impacts into account. However, according to Baker and McKenzie (2011) in most jurisdictions, 'a claim

must be brought within six years of the cause of action accruing, that is, the decision, action or inaction of the Local Government which is the subject of the claim and any action is based on the knowledge of a reasonable person in the position at the Council at the time the decision is made'.

The following from *National Coastal Adaptation Agenda* (Australian Government 2010b) reflects the NSW legislative position well:

> *Cr David James (Pittwater Council) described the NSW position as when a property is diminished or removed by a natural process, such as by the ocean, that it is at the property owner's risk. No less than 'if you were built on the side of a hill, and there is a landslide, and that property finished up unusable and at the bottom of a valley, that would be your risk.'*
>
> *Also requiring consideration is the issue of individuals' role in defending their own private property. Professor Bruce Thom and Mr Mark Conlon (NSW Department of Environment, Climate Change and Water) outlined the NSW approach, where private property owners have the right to protect their property but 'must ensure in perpetuity, that the beach is maintained in front of their property. Secondly that it has no consequential offsite effects on adjoining property' (Professor Bruce Thom AM). Mr Conlon elaborated 'we came to the resolution that people do have that right, but it shouldn't erode the common good. And the balance between those two things is going to be critical for us in the coastal zone….'*

VICTORIA

Introduction

The Victorian Government takes a similar position to the Federal Government in regard to climate change adaptation. The following statements from Victorian Green and White Papers are illustrative:

> *'Commonwealth, State and Local Government should facilitate this response by ensuring that private markets (insurance, for example) and regulatory structures (such as water markets) are effective. The best way to adapt to a changing climate may vary greatly for different individuals in different locations and different types of communities. Depending on the circumstances some individuals will be happy to ignore the risks or delay decisions while others will be keen 'lock in' high levels of protection today' (Victorian Government, 2009).*
>
> *'The Government has a clear role in providing accurate and accessible information to individuals, businesses and communities, and providing the right market, regulatory and institutional arrangements to enable private adaptation to occur' (Victorian Government, 2010).*

Legislative Environments

Victorian Climate Change Act 2010

Subsequent to the above papers, the Victorian *Climate Change Act* (2010) came into operation on 1 July 2011. While the Act also deals with climate change mitigation, Section 6 deals with adaptation:

> *(g) Managing risks to Victoria's infrastructure, built environment and communities through good planning and emergency response systems;*
> *(h) Working in partnership with Victorians to provide the knowledge and information needed to respond effectively to climate change;*

(i) Helping to ensure vulnerable communities are not further disadvantaged as a result of climate change.

The Act describes a number of principles to be integrated into policy. Principle 9 requires that climate change considerations be integrated within the decision making processes of Government. Principle 10 requires that the principle of risk management be employed in the decision making process but also that a decision should not rely on a lack of full scientific certainty as a reason to delay appropriate responses that may prevent serious loss or damage as a result of climate change. Other principles seek to provide intergenerational equity (Principle 12) and community engagement (Principle 13). Specifically related to adaptation the relevant Minister must prepare a Climate Change Adaptation Plan (Section 16) that sets out a risk assessment of the potential impacts of climate change on regions in Victoria.

Environment Protection Act (Vic) 1970

Amendments to the Environment Protection Act (1970) empowered the relevant Minister to form an Advisory Panel with up to eight members from a diverse range of expertise that report to the Minister and Sustainability Victoria to advise the Minister and the Premier on climate change matters. This panel is now established and is called the Coastal Climate Change Advisory Committee.

Commenting on the original Bill, some have criticised the absence of more detailed adaptation planning information and suggested that a commitment to prepare a plan with strategic responses, that then has to be implemented in unspecified ways with unspecified funding, may not be helpful to Councils. Others noted that the Bill was more 'statement than law' and that the Government of Victoria only needs to 'endeavour to ensure' that its climate change policy has regard to the objectives where relevant, and that decision makers are required to 'consider' climate change in a range of decision making situations (Guild 2010). While admitting to speculation, it may be that the purpose of the legislation is to provide a simple mechanism that will limit the possibility for future litigation. The legislative requirement is for climate change impacts to be taken into consideration in decision making and that this decision making take place in a risk assessment environment. Where Councils and others fulfil this requirement, it is likely that courts will rule in favour of these irrespective of whether the evaluation and/or application of the science proved to be correct.

Policy Environments

Victorian Coastal Strategy 2008.

The *Coastal Strategy* (2008) was established under the *Coastal Management Act*, 1995 and aims to provide a comprehensive integrated management framework for the coast, 96% of which is in public ownership (p.8). The strategy adopts a sea level rise threshold of not less than 0.8 metres by 2100 to be applied for planning and risk management purposes (p.13). The report suggests some of the potential climate change impacts through erosion will include loss of beaches, loss of crown land, infrastructure threat or damage, loss of or threat to private property and damage to infrastructure...energy, water, roads, jetties, and buildings (p. 14).

The strategy notes that the challenge for coastal planners and managers now lies in preparing to adapt to climate change risks and impacts and identifies three approaches:

- Protect (protection of beaches, dunes and infrastructure, land use and development);
- Accommodate (planning and building policies and provisions, redesign and rebuild); and
- Retreat (relocation of infrastructure, land use and development).

These three options together with emergency disaster and management must be considered for all vulnerable areas along the coast (p. 37, 38). Decisions are to be precautionary, meaning that they should plan for future circumstances even if full scientific certainty is not possible.

The strategy states that any new development that may be at risk from future sea level rise will not be protected by the expenditure of public funds. This statement may or may not indicate a propensity to expend public money defending existing development. The strategy identifies coastal protection works such as groynes and seawalls but neither discourages or encourages their use apart from stating that flow on effects need to be considered in addition to whether these defences will be adequate over the long term (p. 49). The strategy requires that the maintenance of piers and jetties, seawalls, groynes and other coastal protection infrastructure should continue to be funded (p. 63).

The overall strategy could be described as risk management integrated into planning schemes to avoid new development in inappropriate places (Figure 8). However, the strategy signals that it aims to develop a long-term approach to planning and managing buildings and infrastructure and that it is seeking to assess impacts on existing development and prioritise future actions (p. 61). The strategy also seeks to build community awareness of the risks associated with climate change (p. 43), and determines to develop a planning research program that ascertains existing land tenure and the predicted impacts of climate change on built environments (p. 61).

Figure 8: Victorian climate change decision making process (Source: Victorian Coastal Strategy 2008).

General Practice Note December 2008

The *General Practice Note* (2008) identifies two main coastal hazards: coastal inundation and erosion. Coastal inundation includes the flooding of land by ocean waters or river catchments. Long-term erosion refers to a trend over years while short-term erosion occurs over a short period as would occur as a result of extreme weather events (p. 1). In short-term erosion, sand is normally naturally replenished after the storm event from the sea floor. The practice note suggests that climate change will not introduce new types of coastal hazards but is likely to increase the frequency, intensity, and extent of existing hazards.

The practice note reiterates the importance of avoiding new development in vulnerable areas and also deals with assessing applications for planning permits within existing areas that are within, or adjacent to, low lying areas subject to coastal hazards such as the replacement of a house, or a proposal for a vacant allotment and suggests the following strategies (p. 4):

- with minor building work it is suggested that no change to existing assessment strategies is required;
- where a house is to be constructed then further information could be sought from the proponent such as a vulnerability assessment to demonstrate how they have taken into account coastal hazards including design responses and setbacks for example; and
- where a more substantial development is proposed a coastal hazard vulnerability assessment may be required to determine potential exposure with coastal engineering, design or setback responses necessary to demonstrate that the assessed risk can be effectively and sustainably managed (p. 5).

Adaptation programs and research projects

Future Coasts Program (2010)
The *Future Coasts Program* (2012) is led by the VIC Department of Sustainability and Environment and provides a comprehensive vulnerability assessment of the risk of climate change to the Victorian coast (p.37). Digital elevation models (DEM) have been prepared to provide high resolution three dimensional representations of the land and sea floor and can be accessed by decision makers (Figure 9).

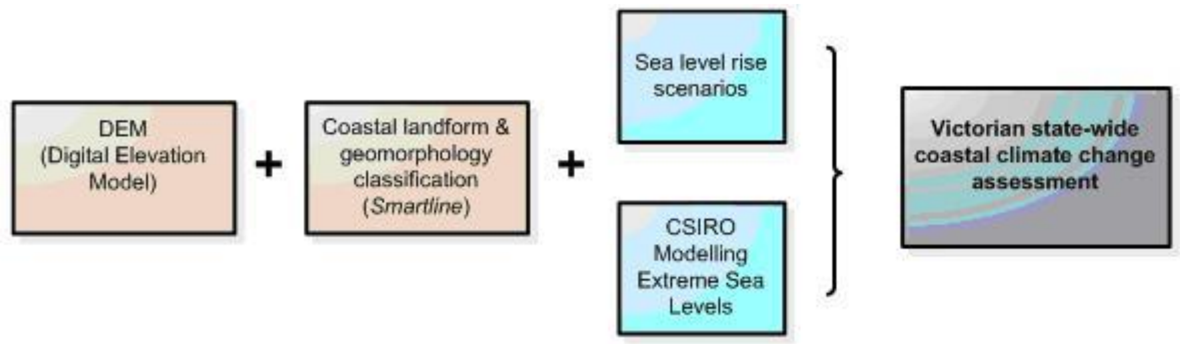


Figure 9: Components of the Victorian state-wide coastal climate change assessment (Source: http://www.climatechange.vic.gov.au/adapting-to-climate-change/future-coasts/what-is-being-done).

At the time of writing, the Future Coasts program is preparing a Victorian Coastal Hazard Guide due for release at the end of 2011, but not yet released[1]. The guide aims to:

- provide information on coastal hazards and the effects of climate change on these hazards;
- provide a risk-based approach for incorporating coastal hazards into the decision making processes associated with managing coastal areas; and
- promote the use of adaptive management and no-regrets response options to improve adaptive capacity.

The guide will not have a particular focus on any one decision making system (e.g. the land use planning system), rather it will provide 'best practice' information in a user friendly language that could be applied by a range of users. The guide will set out 'what to consider' rather than 'how to consider' coastal hazards in decision making processes.

Victorian Centre for Climate Change Adaptation Research
The Victorian Centre for Climate Change Adaptation Research (VCCCAR) was established in 2009 to assist government and other relevant agencies make climate change related adaptation

[1] http://www.climatechange.vic.gov.au/adapting-to-climate-change/future-coasts/resources-and-publications

decisions by undertaking climate change adaptation research. The University of Melbourne currently manages VCCCAR on behalf of four partner universities: Melbourne, Latrobe, Monash and RMIT. Significant resources exist on the website that relate to how to conceptualise adaptation responses. The site suggests (VCCCAR 2012):

> *'Research to support adaptation therefore needs new, integrative modes of inquiry that marry social and biophysical knowledge and multiple sources of evidence. Different models or analyses can be used to explore consequences of assumptions, while case studies can be used to test hypotheses. It involves strong participatory interaction, systems thinking, consideration of uncertainty and risk, and new thinking to support the institutional changes required to address climate change challenges.'*

The site hosts several working papers on different approaches to adaptation and one on costing climate change impacts. The recommended approach to climate change adaptation by VCCCAR is best described as a risk management approach using scenario based strategies to improve climate change adaptation decision making (Biggs et. al. 2011). The centre has produced a guidebook, *Scenarios for Climate Adaptation - guidebook for practitioners* (VCCCAR 2011).

Research: Municipal Association of Victoria
In 2011, the Municipal Association of Victoria (MAV) produced the report *Stocktake of Current Victorian Local Government Climate Change Adaptation Planning* (2011) that reviewed and analysed best practice adaptation processes both in Australia, the UK, New York City and California. The review also included a study for the City of Toronto that in turn had analysed six cities considered to be leaders in climate change risk assessment.

The report demonstrated that strategic risk management underpinned by an impact assessment was the predominant approach. The Sydney City Councils were the exception and had undertaken a vulnerability assessment that integrated indicators of exposure, sensitivity and adaptive capacity for a range of impacts to form an overall map of net vulnerability.

The review of state, national and international documents identified four principles that were used to assess climate change adaptation plans:

- climate change adaptation planning should reflect good practice strategic planning;
- the planning process should include techniques to deal with uncertainty;
- risk identification and assessment should consider a breadth of information about a community or organisation; and
- climate risk and adaptation planning should be embedded as much as possible into Council's existing frameworks and business plans (p. 23).

The report concluded that there was a clear preference in the state, national and international documents and organisations for using a risk management decision-making framework (and within a strategic planning framework p. 25). The benefits of this approach were identified as a capacity to deal with uncertainty and a familiarity amongst many Council staff with the process.
There was no clear preference for the methodology of the assessment to underpin the risk management process, with both impacts-based and vulnerability-based assessment methods identified as having relative merits and drawbacks. The report suggests that key elements of both could be combined for use in a risk management process.

Victoria specific legal issues

Baker and McKenzie (2011) identified the following issues specific to Victoria:

- generally Victoria's legislative and policy approaches are less well developed than NSW or Tasmania for enabling Councils to manage coastal climate change risks (p18);
- in Victoria the ability to take emergency works appears limited and consideration may be given to clarifying provision under the *Coastal Management Act*, 1995 (VIC) and

Environment and Planning Act, 1987 (VIC) to allow Councils or persons to undertake emergency works without obtaining ministerial approval (p. 60); and
- *Victorian Coastal Strategy*, 2008 is now embedded into the Victorian planning system across three sections of the Victorian Planning Provisions.

Victoria has introduced time based consents where a permit can include a condition that the use must cease and that the development be removed at a particular time, for example in the following circumstances:
- a proposal should be permitted only until a specific event occurs, for example until certain erosion events occur; and
- a proposal may be permitted for a specified period either because it is only intended to operate for this period or because the responsible authority wishes to review the operation of the proposal after a fixed period of time.

A key deficiency in the Victorian policy environment is that there is no universal permit trigger for all developments near the coast. If a development or use is permitted 'as of right' no permit is required and in such situations Councils have no control over the development even if climate change impacts are foreseeable. The development of a 'climate change risk overlay' may be considered by Councils as one means of overcoming this issue (p. 72).

In Victoria the *Environment and Planning Act*, 1987 (VIC) creates the capacity for Councils to enter into 'Section 173 Agreements' that can be registered on the title (p. 54). These agreements between the owner and the Council allow for any climate change related factors to be carried forward in perpetuity to new owners. For example, a development that was required to implement protection works as a condition of approval may have maintenance issues relating to those works enshrined in an ongoing manner with subsequent owners.

Victorian Summary and conclusions

Similar to NSW, Victoria's initial adaptation focus has been on planned adaption for new development. In relation to liability the State Government of Victoria takes a similar position to NSW and puts the responsibility of adaptation to climate change on the individual. However, apart from stating that it will not spend any public money defending new developments in coastal impact zones, the government gives no indication as to how it will prioritise finances in relation to existing developments. However, it is Baker and McKenzie's view that Victoria is 'less developed' legislatively to deal with liability issues.

At first review, it is difficult to see how the recent *Climate Change Bill* (VIC) 2010 deals specifically with the threat of climate change on existing development in the coastal zone apart from the fact that decision makers must have regard to climate change science. However, while the following summary is speculative, perhaps the Victorian Government has opted for a simple three pronged approach:
1. decision makers must have regard to climate change science in all its decision making (*Victorian Climate Change Act* 2010);
2. the Victorian Government has put emphasis on developing adaptation methodologies through VCCAR, although these methodologies are to be encapsulated within normal risk management approaches (*Victorian Climate Change Act* 2010); and
3. it is likely that Victoria is encouraging the use of vulnerability assessments utilising the tools and hazard guides it is currently developing. These tools used in conjunction with the high resolution DEM and Bathymetric modelling from *Future Coasts* provide a comprehensive approach to adaptation.

In summary, decision makers who use a normative risk management approach, and take climate change science into account in decision making may be afforded protection from liability under the *Victorian Climate Change Act,* 2010.

SOUTH AUSTRALIA

South Australia was the first state to implement sea level rise considerations when it enacted the *Coast Protection Act (*1972) and subsequently formed the Coast Protection Board. The South Australian Government has high regard for climate change science and has concentrated initially on mitigation efforts but recognises that mitigation and adaptation should be recognised as 'complementary and equally necessary approaches' (SA Government 2010, p. 9).

Legislative framework

Key legislation that governs how local Councils are to take into account climate change related impacts in coastal regions are *Coast Protection Act*, 1972 (SA), *Development Act*, 1993 (SA) and *Climate Change and Greenhouse Emissions Reduction Act,* 2007 (SA).

Coast Protection Act (SA) 1972

The *Coastal Protection Act (*1972) (SA) established the Coast Protection Board (CPB) as a body under control of the relevant Minister for the purpose of managing coastal areas of South Australia. The CPB has incorporated the services of engineers, planners and scientists with expertise in coastal bio-physical processes and associated planning issues (Caton and Huppatz 2010). The coast is defined in the Act to include one hundred metres above the mean high water mark to three nautical miles seaward of mean low water and includes all land within any estuary, inlet, creek, bay or lake subject to the ebb and flow of the tide. The CPB acts as an independent body to provide advice, conduct research, allocate funds and oversee coastal works. In reality most physical coastal works are conducted by local Councils, apart from the sand replenishment program on the metropolitan beaches which is under the CPB's direct control. In the 1970's and the 1980's the CPB worked on defining policy on coastal development but there was no requirement for Councils to incorporate these into the development approval process. The *Adelaide Coast Protection Strategy Review* (1984) highlighted the possibility of accelerated sea level rise due to 'green-house' warming as a result of increased carbon dioxide in the atmosphere. In this report, an extensive review of alternative protection options were identified and costed on an options basis using various discount rates (Coastal Protection Board 1984, p. 61-70).

Development Act (SA) 1993

The *Development Act* (1993) (SA) and subordinate regulations require local Council development plans to take into account sea level rise. Since 1994, Section 37 of *Development Act,* 1993 and associated *Development Regulations* 2008 (Regulation 24 and Schedule 8) stipulated that applications for development within a designated coastal zone are required to be referred to the CPB for 'direction' or 'regard' in the approval process. In practice, approximately 85% of applications are referred for 'regard'. In 2009, the advice of the CPB was followed in 85% of cases referred for 'regard'. Of the remaining 15% (23 decisions) that were not in accord with the advice of the Board, all applications related to dwellings or extensions to dwellings, and all were outside the Metropolitan area. Of these 23 decisions, 12 decisions related to 'conflict with the Board's coastal hazard policy on flooding, erosion and sand drift risks' (Caton and Huppatz 2010).

All coastal protection works must be referred for 'direction' meaning that the CPB has the authority to direct this aspect of development in coastal zones.

Climate Change and Greenhouse Emissions Reduction Act (SA) 2007.

While the main emphasis of the Climate Change and Greenhouse Emissions Reduction Act (SA) (2007) (the Act) relates to mitigating the effects of climate change, it also provides the legal framework for adaptation efforts in Section 11. The Act establishes the Premier's Climate Change Council with the primary function to provide independent advice to the Minister about matters associated with reducing greenhouse gas emissions and adapting to climate change. 'The legislation also commits the State Government to work with business and the community to develop and put in place strategies to reduce greenhouse emissions and adapt to climate change. Resulting initiatives include 'Climate Change Sector Agreements' and the 'Climate Change Adaptation Framework for South Australia' (SA Government 2012).

Policy Framework

Coast protection and new coastal development (1991) SA

The Coast Protection and New Coastal Development (1991) policy accepted that sea levels were rising by approximately 1.5 mm per year for most parts of the SA coast (while also acknowledging uplift or subsidence in some areas). The CPB also took into account the 1990 report by the IPCC and accepted that sea levels would rise more rapidly and thus adopted a sea level rise benchmark of 0.3 metres by 2050 and 1 metre rise to 2100. The following policies were adopted:

- for commercial or habitable buildings, floor levels should be no less than 0.25 metres above a height determined by adding 0.3 metres to the 100 year ARI water level;
- where protection measures exist or are to be provided as part of a development, 'building sites should be no lower than the design flood level taking into account the mitigating effect of the protection measures'. Floor levels should be 0.25 metres above this level. Development that depends on protection works would need to demonstrate that there is low risk of failure of these mechanisms and that they will be adequately maintained;
- major developments would need to consider the full range of possible climate change and sea level effects with the inference on the requirement to take into account longer time frames and higher sea level rises;
- development should not occur on sand dunes or close to soft erodible cliffs. One hundred year erosion rates are to be employed taking into account local coastal processes and assuming a sea level rise of 0.3 metres by year 2050. For major developments, 200 years of erosion recession should be considered along with sea level rise;
- development should not be located where it will create or aggravate coastal erosion or if it will require coast protection works that will cause or aggravate coastal erosion;
- the CPB will not oppose isolated single owner developments where it is satisfied that adequate arrangements have been made to ensure that any erosion or flooding damage to the development, provision of future protection works, or relocation or demolition of threatened structures will be the sole responsibility of the developer or future owners;
- the CPB will not oppose development behind existing protection works where the CPB's and the local Councils' intention is to maintain or upgrade these;
- the CPB will not oppose development where there is already a need for protection of existing development, where this is likely to be provided by local or state government. This would include development behind esplanade roads or other public property where these are likely to be protected in the future. Each of these cases is to be considered on its merits;
- developers of coastal land will be required to provide sufficient information to demonstrate that proposed developments will be safe from tidal inundation or coastal erosion. Where coastal protection measures are to be included an assessment of the beach and adjacent coastline must be included;
- the CPB will not protect private property nor provide Councils with funds for this purpose unless there is associated public benefit, there is simultaneous protection of public property, a large number of separately owned properties are at risk, or the erosion or flooding problem has been caused or aggravated by Government coastal works;
- the CPB will not fund protection of coastal property and installations owned by other Government agencies; and
- ongoing coast protection costs for private development, such as for sand management or maintenance of seawalls should be met out of funds generated by the development.

Coastal erosion, flooding and sea level rise standards and protection policy (1992) SA

The Coastal erosion, flooding and sea level rise standards and protection policy (1992) is essentially an explanation of the 1991 policy using both words and diagrams. The policy does add that development that could not reasonably be protected against sea level rise beyond 0.3 metres needs to be on higher land or set far enough back from the coast to be safe for a possible 1 metre rise by 2100 (Figure 10).

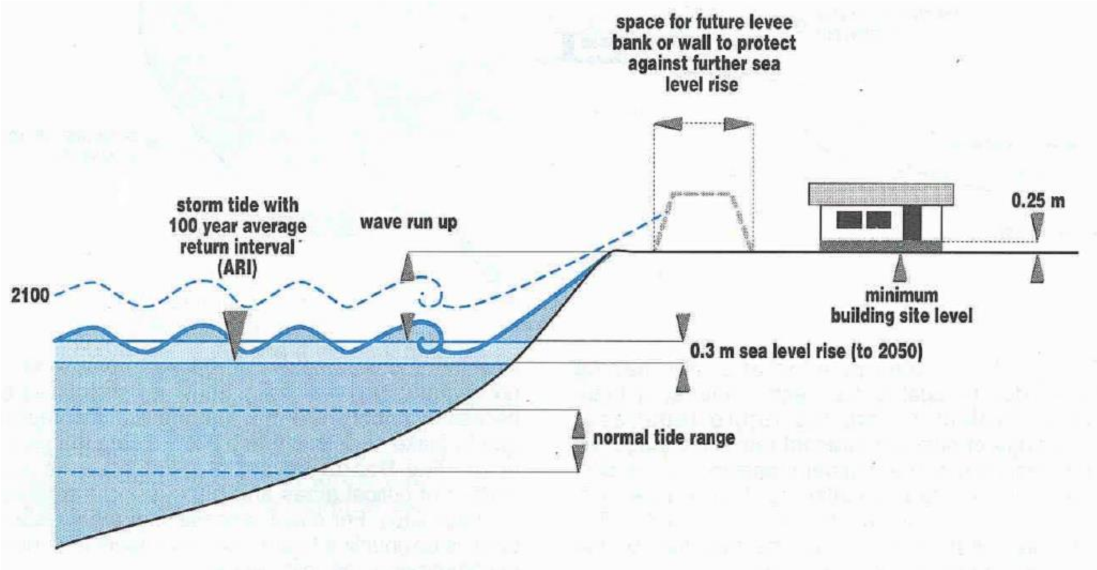


Figure 10: Minimum elevation for buildings set back from the water's edge (Source: Coastal erosion, flooding and sea level rise standards and protection policy 1992).

The policy also explains more extensively with how to deal with erosion of the coast as it relates to new development and the need to take into consideration different soil types (Figure 11).

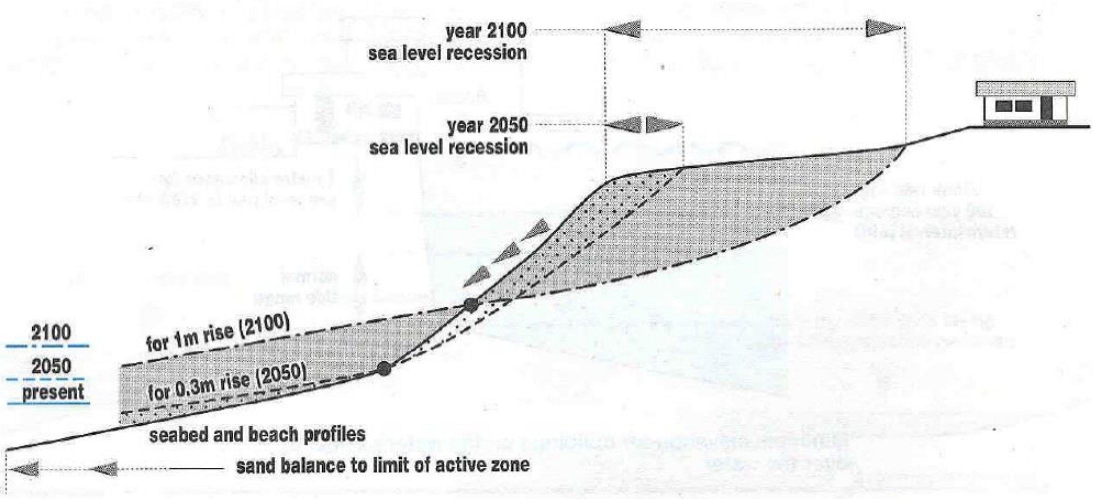


Figure 11: Recession due to sea level rise (Source: Coastal erosion, flooding and sea level rise standards and protection policy 1992).

Coast Protection Board Policy Document August 2002

The *Coast Protection Board Policy Document* (2002) builds on the South Australian policies described above but places more emphasis on the interrelationship between the use of land and the effects of that use on marine and coastal environments (p. 7).

In relation to new development

In relation to new development the CPB states it will provide an assessment of the hazard exposure, an evaluation of the strategies proposed to deal with those hazards, as well as an assessment of the broader impacts that the development may have on the coast (p. 8). The CPB states (p. 12-15) that it opposes:

- linear or scattered development;
- development in sand dunes, wetlands, coastal estuaries;
- land division that increases the number of allotments abutting the coast, except within already established developed areas, or in the event of new settlements, concentrated into nodes; and
- works that significantly affects coastal processes unless a binding management plan is in place.

The CPB also asserts that it will seek removal of unauthorised development, with particular mention of unauthorised coastal protection works (p. 16).

In relation to hazards (p. 17-21)

In relation to 'hazards' the CPB asserts that it has used the best available advice in resolving to use the IPCC median sea level predictions as part of its hazard policy since 1989 (p. 17) and declares that the CPB has developed policies and standards applying to new development that have been written into the Development Plan since the adoption of the Regional Coastal Areas Policies Amendment in 1994 (p. 18).

In relation to planning

The CPB set planning time frames at 50 years for minor development, 100 years for small development, and 200 years for new significant development such as new settlements and power stations (p.19). Protection standards will be based on hazard events with a 100 year average return interval but also must take into account the potential for erosion, storm surge, land subsidence and sea level change taking into account IPCC projections (p. 20).

In relation to protection works

While most protection works are carried out by Councils, the CPB supervises and assists with the funding of their installation. These include the construction of structures such as sea walls or through schemes of beach nourishment (p.23). Funding would be available where there is a benefit to the general public such as the maintenance of public access along the coast. CPB does not hold the view that government funds should be available to protect new development approved against its advice. CPB notes that the policy not to protect private property was 'affirmed by the State Government in 1980' and has been applied since then (p.25).

Living Coast Strategy (2004)

The *Living Coast Strategy* (2004) is a wide ranging policy that takes a holistic view of marine, estuarine and coastal environments, how these interrelate with human settlements and how these environments can be encouraged to flourish. For example, the restoration of seagrass is likely to slow coastal erosion. A risk assessment approach is stated as 'required' and the policy notes that CPB conducts regular surveys of the State's coast to measure 'geomorphological processes and determine management requirements (such as beach replenishment) and to guide development assessment'. The State Government states it is committed to working with Local Government to manage and protect beaches from coastal erosion including beach replenishment, dune and cliff stabilisation and improving public access to the coast and construction of protection infrastructure such as seawalls (p. 47-48).

Adelaide's Living Beaches (2005-2025)

The State Government policy, *Adelaide's Living Beaches (2005*) provides a comprehensive review of the management practices of Adelaide metropolitan beaches between 2000 and 2005 as well as the proposed approach for future management.

<u>The review</u>
Most of the land behind the existing metropolitan foreshore (in many cases sand dunes) was developed in the early 1900s. Early coastal protection was in the form of concrete seawalls but in the 1960s these were replaced with large rocks. The prevailing winds shift sand from the south to the north. Without artificial sand replenishment the base of the seawalls would have been eroded decades ago and several metropolitan beaches would not exist in their current sandy form. Therefore sand recycling (moving the sand from the north back to the south) and sand replenishment (importing sand from other sources) has been viewed as a cost effective method for maintaining sandy beaches and preventing storm damage to property over the last four decades (p. 2). Sea walls are regarded as the last line of defence (p.3). Mostly the sand has been transported by trucks while some offshore dredging has occurred at intervals.

A review by Department of Environment and Heritage begun in 2000 identified thirteen different options to maintain Adelaide's beaches against erosion and storm surge threat (p. 10,11) that are summarised in Table 4 on the next page.

<u>The strategy</u>
The main components of the accepted strategy are:

- continue beach replenishment by placing approximately 160,000 cubic metres of sand each year to maintain a sandy foreshore, build up dune buffers, and protect coastal infrastructure;
- recycle sand more effectively using sand slurry pumping and pipelines (rather than trucks);
- add coarse sand from external sources (a source located at Mt Compass);
- build coastal structures such as groynes and breakwaters at strategic locations; and
- integrate sand bypassing at harbours with the beach replenishment program.

A trial breakwater was built at Semaphore in 2003 to ascertain whether it would assist in preventing the drift of sand northward and is proving to be successful. The main components of the strategy are illustrated in Figure 12.

Table 4: Evaluation of alternative strategies for Adelaide Metropolitan Beaches (Adelaide Living Beaches p. 10, 11).

	Strategy	Decision	Reason
1.	Maintain existing strategy (see above)	Reject	Costs are increasing.
2.	Reduce the level of beach replenishment	Reject	Loss of beaches due to sea level rise and increased erosion with poor social and economic outcomes.
3.	Once off major sand replenishment	Reject	No viable sand sources, seagrass buried, and storm water outfalls needing upgrade.
4.	Recycle sand from North to South utilising a pipeline.	Consider	Not all sand accumulating on northern beaches is suitable - this option not feasible on its own.
5.	Retreat and allow sand locked up under existing infrastructure to be released.	Reject	Cost prohibitive to buy properties and relocate coastal infrastructure.
6.	Combination of the installation of a 'groyne field' with major sand installation.	Reject	Too expensive, 2 million cubic metres of sand required, inflexible in relation to sea level rise, loss of pedestrian access.
7.	Install offshore breakwaters with sand replenishment.	Reject	Same reasons as Option 6 but with pedestrian access maintained.
8.	Hybrid field of structures (not explained)	Reject	Same reasons as Option 6.
9.	Use coarser sand	Consider	South-North drift would continue, large enough sand source not available
10.	Sand recycling and/or replenishment combined with structures	Consider	This is a combination of 4 and 8.
11.	Sand recycling combined with structures and replenished with coarse sand	Accept	This is a combination of the best of 4, 8 and 9.
12.	Seawalls	Accept	Sea walls act as a last line of defence but are only considered viable alongside beach replenishment.
13.	Do nothing	Reject	Loss of beach and progressive damage to foreshore infrastructure and buildings.

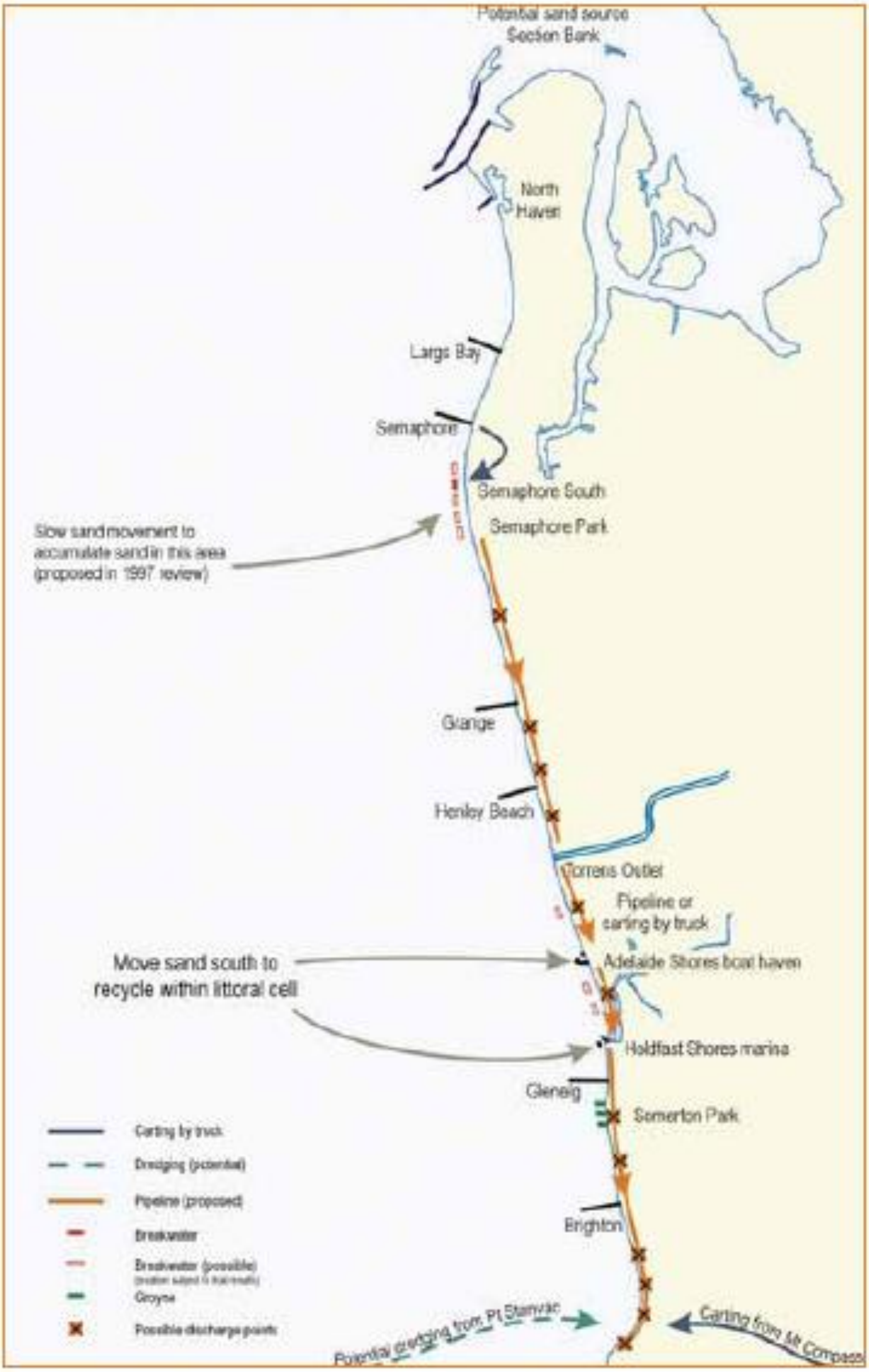


Figure 12: The main components of the management strategy for 2005-2025 (Source: Adelaide's Living Beaches 2005-2025, p. 141).

Prospering in a changing climate (A draft climate change adaptation framework for SA (2010))
The draft climate change adaptation framework policy is still in draft form and awaiting the conclusion of community consultation. While the document deals with climate change adaptation more generally it does identify who is responsible to adapt.

In regard to responsibility and liability
The framework calls for a 'bottom-up approach' to develop adaptation responses, with an emphasis on the regional community which will inform sectoral and state-wide approaches (p. 2). In answer to the question 'Who is responsible?':

> *'Given that most assets and activities at risk of climate change are owned or managed by businesses or the community it is reasonable to expect businesses and the community to manage their exposure. Given this and the scale and range of predicted impacts it is not feasible for governments to bear all the costs of adapting to the impacts of climate change' (p. 13).*
>
> *'Adaptation is a shared responsibility …it involves joint effort by all levels of government, business, communities and individuals' (p. 13).*

The draft policy then describes the roles of the three levels of government, private parties and research institutions (p. 13-16). Four broad roles for the State Government include:

- encouraging climate resilience and adaptive capacity including by utilising regulatory and policy instruments;
- providing relevant science and information;
- managing public assets, infrastructure, and service delivery; and
- cooperating with other governments.

General adaptation framework
The South Australian Government recognises that climate change impacts will manifest differently in various locations. Therefore it has divided the state into 12 regions. Councils, Boards, and other organisations will cooperate together within these regions to conduct Integrated Vulnerability Assessments (IVA's). Resulting adaptation actions will be described into regional adaptation agreements under Section 16 of the *Climate Change and Emissions Reduction Act,* 2007 (SA).

In relation to coastal management
The draft policy states that the South Australian sea level rise benchmarks are under review in response to the findings of the IPCC *Fourth Assessment Report* (2007). The draft policy states that an estimated 60,000 buildings along the SA coast are likely to be at risk in the absence of any adequate protection measures. Modelling indicated that a 0.5 metres sea level rise would flood the centre of Port Adelaide and cause the current 100 ARI flood to occur annually (p.34). The policy notes that the South Australian Supreme Court rejected a developer's appeal for an 80 lot subdivision at Marion Bay in March 2008 on the grounds of risk posed by future sea level rise (p. 34). The proposed adaptation responses include:

- increasing the CPB's power of direction over applications in coastal zones;
- conducting Integrated Vulnerability Assessments in coastal zones; and
- developing adaptation responses.

Specific South Australian legal issues

Baker and McKenzie (2011) identified that South Australia (and Northern Territory) should '*implement statutory reform with respect to civil liability of public authorities as the other jurisdictions have done. This would create…greater protection for Councils'* (p.85). Despite this observation, common law does provide similar protections from litigation but is less clear than for other States. In South Australia there is a specific exemption stating that Ministerial approval is not required to acquire land to prevent flooding. However, it is not entirely clear in the *Development Regulations* (2008) if this exemption extends to coastal inundation (p. 86). In relation to 'duty of care a Council is only liable under limited circumstances if they have a special measure of control over safety of citizens'.

South Australian summary and conclusions

South Australia has been a leader in implementing policies and strategies to deal with coastal matters, including the risks associated with rising sea levels. Since coast protection legislation was introduced in 1974, the CPB has acted as an independent statutory body conducting research and issuing policy and advice to South Australian constituents. Since 1989, CPB resolved to use what it calls the 'best scientific advice' the IPCC median sea level predictions as part of its hazard policy. Since 1993, all development in the designated coastal zone has been referred to the CPB for 'direction' or 'regard'. In relation to the latter, for the most part Metropolitan Councils have followed this advice, whereas, rural Councils have shown less propensity to do so. In summary, development in SA for the last 20 years has taken into account IPCC projected sea level rise projections. In relation to the liability of Governments this would seem to place Councils in a good position where they have followed the advice of the CPB.

SA faces some challenges in the light of predicted sea level rise. The Metropolitan beaches require continual sand nourishment to mitigate the northward drift of sand but this may be mitigated with the installation of groynes in accordance with the policy set out in *Adelaide's Living Beaches 2005-2025*. Additionally, the further north one travels up Gulf St Vincent the closer the water front land becomes to sea level. Areas such as Semaphore and Port Adelaide are much more susceptible to inundation than Onkaparinga in the south. In spite of this, it is almost certain that these areas will be protected by governments with hard defences and sand nourishment as the sea level rises. Baker and McKenzie are of the view that South Australian governments could strengthen their legal position in regard to possible litigation relating to sea level rise by enacting similar legislation to that of NSW.

MAJOR CASE STUDY: BYRON SHIRE COUNCIL

Introduction

Baker and McKenzie cite numerous legal cases (Baker and McKenzie 2011 Appendix 4- summary of cases) but only one case, Vaughan v Byron Shire Council (No 2) [2009] NSWLEC 110, relates to existing development. Byron Shire Council has had a policy of planned retreat since 1988 and is regarded as 'a pioneer in tackling the issue of climate change and in particular, developing a response to sea level rise' (Norman 2009, p. 62). The *Byron Coastline Management Study* (2004) classified two areas as 'substantial development under immediate and longer-term threat from erosion: Belongil Beach and New Brighton Beach' (WBM Oceanics 2004, p. xii). This case study focuses primarily on the policies, research and management strategies that relate to Belongil Beach (Figure 13).

Figure 13: Belongil Beach, Byron Bay Council, New South Wales (Source: WBM Oceanics 2004, p. 2-5)

Historical Background of Byron Bay Shire coastline

In 1974 storms caused significant damage to the village of Sheltering Palms north of Brunswick Heads and by 1977 all of these houses were voluntarily abandoned and the settlement removed. Also in the 1970s, storms and erosion caused the loss of houses and a road at Belongil Spit, a dune separating the sea from Belongil Creek (Byron Shire Council 2012a). In 1984 Esplanade Road on Belongil Beach was lost to the sea via erosion and extensive erosion from storms and large swells were endured in 1996, 1999, and 2001. In May of 2009 extensive erosion again occurred with the combination of an East Coast Low and king tide swell (Byron Shire Council 2009, p.ix). The latter event formed the backdrop to the legal action between Vaughan and Byron Shire Council.

In 1978 the NSW State Government Public Works Department assessed coastal processes and erosion rates in the Byron Shire and a ‘policy of relocation’ was suggested as a possible management strategy. At the time of this study, residents were implementing various ad-hoc protection works in an attempt to stop the erosion. In the early 1980’s an artificial headland and protection works were created at the Memorial Pool car park in an attempt to halt the northward erosion of sand from Main Beach and Clarks Beach. The Byron Shire Council acknowledges that these works are likely to be 'exacerbating down drift erosion impacts on the Belongil Spit' to the North of this artificial headland (Byron Shire Council 2009, p. 26).

Planned Retreat

Subsequent to the study by the NSW State Government Public Works Department, Byron Shire adopted the *Byron Local Environment Plan* (1988) and *Development Control Plan 1* (1988). Part J of *Development Control Plan 1* (1988) and the more recent *Development Control Plan* (2002) (DCP) as the basis for the policy of planned retreat. A public hearing was held prior to the adoption of the 1988 instruments and community members and scientists presented submissions were taken into account prior to the adoption of the new policy (Byron Shire Council 2009, p. xi).

Byron Shire Council defines planned retreat as a management approach that:

> *'aims to allow natural processes to take place without building large engineering structures to attempt to counteract those processes. On an eroding coastline this will require the retreat of development and infrastructure as the erosion escarpment (most landward limit of erosion) moves landward' (Byron Shire Council Fact Sheet 2012a, n.p).*

Key points from the Byron Development Control Plans (both 1988 and 2002) are:

- Hazard areas were identified by lines on maps and classified as Planning Precinct 1, the immediate hazard area; Planning Precinct 2, the 50 year hazard area; and Planning Precinct 3, the 100 year hazard area (p. xi).
- Since 1988, any new development or approved additions to existing development have been approved based on the requirement that the development be relocated or removed once the erosion escarpment encroaches to within a certain distance (usually 20 metres).
- Since 1988, buyers of coastal hazard properties have been made aware of the risks to that land via information included in Section 149 certificates (p. xi). The information on the certificates also indicated the restrictions on the type of development that could be constructed on the site (i.e. must be relocatable).

Planned retreat endorsed by NSW Government

The *NSW Coastline Management Manual* (1990) was designed to assist Councils develop plans of management for the coastline and endorsed Byron Shire's policy of planned retreat stating, 'by this approach Byron Shire facilitates a planned retreat from a receding coastline while encouraging responsible use of hazardous coastal areas at minimum future cost to Council'. The principles of planned retreat were also enunciated in the *NSW Coastal Policy*, 1997 and in *NSW Sea Level Rise Policy Statement,* 2009 (Byron Shire Council 2009, p. xxii and xxiii).

Planned retreat upheld by courts.

Table 5 contains the cases that Byron Shire Council maintains are 'case law precedents' for planned coastal retreat.

Table 5: Case law precedents pertaining to planned coastal retreat (Source: Byron Shire Council 2009 Draft Coastal Zone Management Plan, Section C- Technical Information, Appendix J).

YEAR	LEGALS
1985-86	Court upholds Council refusals and of condition of approval lapsing subject to proximity to escarpment – 54 m, 80 m, (Hogan, Belongil by the Sea, Cooper & Greaves)
1988	Demolition orders upheld – Bolens. Trainor
1990	Court upholds refusal of large demountable dwelling – Vaughan
1991	Challenge s88E Restriction on Use – Court upheld as valid – Veila
1996	Court upholds Council refusal of a seawall DA to protect several houses – Scott
1999	Council unsuccessful in application for injunction to stop emergency rock works by residents under State Emergency and Rescue Management Act 1999 – Vaughan & others
1999	Consent orders – works installed under police emergency notice only 'interim protection works'
2003	Appeal against DA refusal for a rock wall dismissed on grounds that the application was 'unclear' as to what effect the construction of the proposed wall would have on adjoining properties and the DA was deemed to be invalid – Parkes
2004	Court upholds Council refusal of application for change of use of house to bed and breakfast dismissed – Parkes
2004	Application seeking declaration that property has "existing use rights" refused by the Court. The realisation of the coastal erosion trigger in the s88E Restriction of Use rendered the development unlawful and it had no 'existing use rights'. – Kendall St
2006	Court upholds refusal of application to replace a previously existing building in the same location dismissed – Van Haandel

Preparing a Coastal Zone Management Plan

The Coastline Management Manual (1990) set out the process by which a Council was to prepare a Coastal Zone Management Plan (CZMP). The following points explain how the CZMP relates to wider state legislation and policy:

- Part 4A of the *Coastal Protection Act* (1979) contains provisions for preparation of a CZMP by Local Government and approval of the CZMP by the Minister for Climate Change and Environment. Following the approval by the Minister, the CZMP becomes a statutory document whereby any action against the provisions identified in the CZMP is considered to be an offence (Part 4A, Division 2, 55K-M);
- the *NSW Coastal Policy* (1997) identifies coastal zone management plans (CZMP's) as an appropriate mechanism for ensuring effective management of development and resources on the coastline; and
- for the purposes of S.733 of the *Local Government Act* (1993), preparation of a CZMP in accordance with the Coastal Protection Act (1979) and Coastline Management Manual provides the basis for the Council's decisions to act in good faith in relation to flood-liable land and land in a coastal zone. In other words, a Council acting in good faith in accordance with its CZMP would be protected from liability under S.733 of the *Local Government Act* (1993).

The preparation of a CZMP was defined as an eight step process:

1. *Establish a Coastline Management Committee* – Byron Shire formed the committee in 2000.
2. Undertake a Coastline Hazard Definition Study – Byron Shire completed 2000 (WBM Oceanics, 2000).
3. *Undertake a Coastline Management St*udy - This is to consider all feasible management options while also addressing the social, economic, aesthetic, recreational and ecological issues associated with land uses of the area (completed in 2004 by WBM Oceanics).
4. *Prepare a draft Coastal Zone Management Plan* - The Plan is to identify the best combination of options for dealing with the issues and hazards. It is to describe how the coastline will be used and managed to achieve defined objectives (prepared in 2009).
5. *Review draft Coastal Zone Management Plan* - A draft of the Plan is subject to public display and review providing all interested or affected parties with the opportunity to assess what is proposed and register any objections or suggestions (resolved for public exhibition on 8th October 2009).
6. *Submit draft Coastal Zone Management Plan for Approval* – to be submitted to the Minister for approval when finalised (Submitted by Byron Shire but withdrawn on 27 April 2011).
7. *Prepare and Publish Coastal Zone Management Plan* – Once approved by the Minister, Council is required to prepare the Final Coastal Zone Management Plan and publish it in the Government Gazette.
8. *Implement Coastal Zone Management Plan* - Once finalised, the Coastal Zone Management Plan is formally implemented using a range of planning and regulatory controls as well as physical works and other measures.

The Byron Coastline Management Study 2004 (Step 3)

Summary of Findings

The Byron Coastline Management Study was completed by WBM Oceanics Australia in 2004 and was an extensive review of coastal management options for the Byron Shire. The report identified a number of strategic issues facing the Byron Shire in relation to coastal management. The following points related specifically to Belongil Beach (WBM Oceanics 2004, p. i & ii):

- there are immediate threats to urban land uses arising from coastal erosion;
- the current planning framework is not effective in managing the erosion threats in Byron Shire noting that the planned retreat policy has not succeeded for 15 years);
- decisions must be made to either hold the coastal alignment in one of many ways, or to retreat and let nature take its course;
- decisions must also be made on how to fund any strategies to address coastal erosion, raising issues such as: what is the equitable balance between community and private contributions;
- there exists a history relevant to equity issues, whereby prior to 1978, the coastal problems were not common knowledge. During the period 1978 to 1988, the State and Council were aware of the problems, however, only limited information was available to the community. After 1988, the community was aware of the coastal erosion problems and the current planning framework was established;
- strategies must be devised for the very long term; and
- strategies must be ecologically sustainable, which includes being economically and socially sustainable. That is, having community support, available resources and a sound legal basis over the long term.

WBM Oceanics (2004, p. i, ii) also noted that planned retreat had been in effect since 1988 but suggested that the strategy has been 'severely compromised by a number of issues including':

- unchecked proliferation of ad-hoc protection works;
- lack of consistent and concerted application of the provisions of the instrument, in particular, lapsing consent and relocation/removal orders;

- the inability of the planning instruments to cater for development existing when the LEP/DCP was introduced (1988); and
- the DCP is a relatively weak planning instrument being readily modified over time and is generally seen by the Courts as a guideline rather than statute.

WBM Oceanics coastal management strategies - Belongil Beach
Initial consideration was given to removing the Memorial Pool protection works, but it was resolved to retain these to continue to slow the erosion on Main Beach. The report acknowledged that this removal would result in less erosion to the North (on Belongil Beach), but that ongoing erosion would still threaten the settlement in the long term. In an interview in 2009, Dr Brander, School of Biological, Earth and Environmental Sciences at UNSW cited a study by Dr. Ian Goodwin, a coastal geomorphologist at Macquarie University, which estimated that the artificial headland and associated groyne at Jonson Street had caused Belongil Beach to erode back 30-35 metres. The main reason for this erosion was the reduced supply of sand from the south due to the headland and groyne works while sand continued to drift northwards from Brelongil Beach toward the river mouth. However, Dr Brander also concurred with the Council that the properties on the Spit would have been under threat eventually despite this factor (Nettle S, 2009).

The report identified a number of strategies to cope with erosion at Belongil Beach (and New Brighton Beach) shown in Table 6:

Table 6: Adaptation options to deal with coastal erosion at Belongil Beach (Source: WBM Oceanics 2004, p. v.).

	Belongil	New Brighton
Protection Options – Structural Basis		
A - Seawall alone	√	√
B - Groynes alone	√	√
Protection Options – Beach Nourishment Basis		
C - Beach nourishment alone		√
C2 - Beach scraping		√
C - Beach nourishment with end control	√	
C2 - Beach nourishment with end control and seawall	√	
D - Beach nourishment with groynes	√	√
E - Beach nourishment with offshore breakwaters	√	√
Planned Retreat Options		
F - Retreat under public ownership	√	√
G - Retreat under private ownership	√	√
H - Retreat under private and public ownership	√	√

The study assessed these management options against twelve decision criteria shown below in Table 7.

Table 7: Decision criteria against which coastal erosion management options were to be assessed (Source: WBM Oceanics, 2004, p. v).

Policy Criteria

1. To protect, rehabilitate and improve the natural environment;
2. To recognise and accommodate natural processes and climate change;
3. To protect and enhance the aesthetic qualities of the coastal zone;
4. To protect and conserve cultural heritage;
5. To promote ecologically sustainable development (including use of resources and human settlement);
6. To provide for appropriate public access and use;
7. To provide information to enable effective management;
8. To provide for integrated planning and management;

Financial Criteria

9. To minimise capital cost;
10. To minimise operational costs;
11. To maximise consequential benefits;
12. To maximise certainty.

A cost benefit analysis was completed on each of the options ticked under Belongil Beach on Table above (WBM Oceanics 2004, pp. 6.7; 6.53). Three options are described below:

Option A: Construct a sea wall

Option A entailed constructing a 2 km (approximately) rock mound sea wall from the Memorial Pool car park protection works to the northern end of the existing settlement of Belongil Beach. While this option appeared financially viable the following problems were associated with this option:

- loss of beach in front of the sea wall;
- exacerbation of the erosion rate to the north;
- community workshops in Byron Shire rated this as the least preferred option; and
- it was contrary to the objectives of the *NSW Coastal Policy* of enhancing the natural environment and aesthetic qualities of the coastal zone and preference for soft options rather than hard engineering options.

Following preliminary assessment of the options, the Byron Coastline Management Committee resolved that structural options alone should not be pursued (WBM Oceanics 2004, p. 6-11).

Option C (and C2) – Beach nourishment with end control

Option C (Figure 14) involved the initial importation of 1,000,000 m^3 of sand from an external source to be placed on the beach for a length of approximately two kilometres. Because of the high erosion rate, the construction of a 'control structure' was to be installed at the northern end of Belongil Beach to minimise the dispersion of the sand northwards. The structure could be in the form of an artificial headland or substantial groyne. The longevity of this option was expected to be 20-30 years with another top up of 500,000 m^3 of sand likely to maintain the beach further into the future.

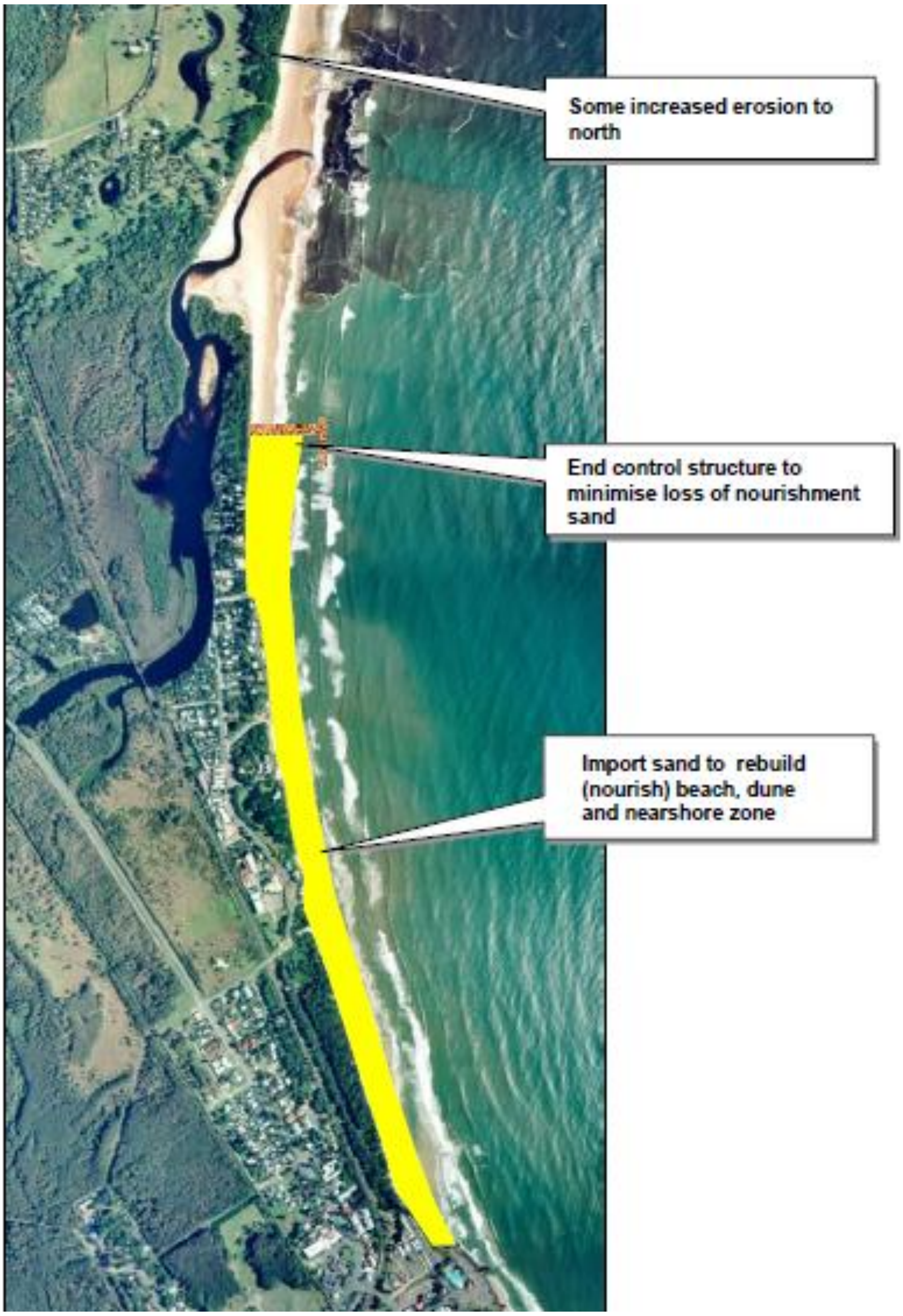


Figure 14: Option C – Beach nourishment with end control (Source: WBM Oceanics 2004, p. 6.23).

<u>Option C2</u>

Option C2 involved construction of a two kilometres sea wall of smaller dimensions than Option A, that would normally be covered by the sand. This addition to Option C was to act as a safety measure against larger storm bites in times when sand was not readily available. The measure would also consolidate the ad hoc defence measures that have been installed along the beach by residents (p. 6-20). The report also noted that 'from the point of view of the public interest, this option is financially viable. It could reasonably be funded partly by the private property owners who will also directly benefit from the works' (p. 6, 22).

The approximate 50 year costs in present day dollars for Option C2 were summarised as shown in Table 8.

Table 8: Approximate costs for Beach Nourishment with end control and terminal protection Option C2 (Source: WBM Oceanics, 2004, p. 6-26).

• Design optimisation, EIS and approvals		$0.5M
• Capital Costs:		
▪ Initial nourishment (1,000,000m^3)		$13M
▪ Control structure		$3M
▪ Seawall Upgrade		$3M
▪ Dune stabilisation		$0.5M
• Maintenance Costs:		
▪ Renourishment (500,000m^3 every 25 years)		$9M
▪ Structure (1%/yr)	$0.03M/yr	$1.5M over 50 years
▪ Seawall (1%/yr)	$0.03M/yr	$1.5M over 50 years

Accordingly the present value of the cost of this option discounted at 7% over 50 years is approximately $26.7M ($32M @ 0% discount rate)

Option C2, when analysed against the twelve criteria above was viewed as the preferred choice by the consultants.

<u>Option F: Planned retreat as public land</u>
Option F required the acquisition of all properties under threat and allowance of the sea to erode the coast naturally. However, while this option presented significant management advantages there was no viable means of funding the acquisition and no contribution could be expected from the owners as their land was purchased.

<u>Option G: Planned retreat as private land</u>
Option G was essentially the status quo under the current planning mechanisms of the Development Control Plan but with the intention to embed planned retreat within the proposed Coastline Management Plan. The report noted that the status quo had had poor performance in the past and poor outcomes were likely in the future. The report also noted that the success of planned retreat under the current planning instruments was related to a mixture of: the political will to enforce the regulations; the legal robustness of the regulations and the ability to enforce them; and the availability of funds to implement works and defend decisions (p. 6.40). This option assumed the following:

- land (currently privately owned) would remain in private ownership when it is lost to erosion;
- no further coastline protection works being permitted;
- private individuals (post 1988) would be responsible for their own planning in terms of loss of building, infrastructure and relocation; and
- all land within the 50 year hazard line would ultimately be lost or purchased under the planned retreat policy (Option G).

The report estimated that about half the properties (i.e. those developed prior to 1988) would need to be purchased at current value of $28.6 million.

Option H: Planned retreat as both public and private land

Option H assumed a strict enforceable legal framework led by the NSW Government. The option was designed to maximise the advantages of planned retreat while avoiding the implementation problems that had been experienced over the past 15 years. The very high costs of public retreat in public ownership (Option F) are avoided, as some of the private land owners bear the cost of the land loss (i.e. those who constructed their houses after 1988). The very poor compliance of public retreat in private ownership (Option G), as the legal mechanisms would ensure effective enforcement of the provisions. Politically, the State management of the decision making process and implementation of the enforcement proceedings would better ensure consistent decision making. It was estimated that approximately half the properties would require purchase at Belongil, which could amount to up to $28.6 million (present value discounted at 4% over 50 years).

WBM Oceanics – the preferred management option

Option C2 - beach nourishment with end control (and low rock sea wall) was the preferred option by WBM Oceanics as it performed best when assessed against the 12 decision criteria. However, the option was contingent on finding a suitable deposit of sand. Option H – planned retreat as both public and private land was the preferred option of the retreat options and the second preferred option overall. In relation to these options, WBM Oceanics (2004, p 6.51) posed four key questions:

1. Will a source of suitable sand be accessible initially and over the long term to support the nourishment strategy under Option C2?
2. Alternatively, will adequate money be made available to implement retreat strategy under Option H?
3. Will it be politically acceptable to implement State control of the planned retreat process?
4. Will it be possible and will there be the political demand to improve and legally enforce the existing planned retreat policy under Option G?

The model Byron Bay Shire adopted

After considering the Coastline Management Study, and the submissions received during public exhibition of the study, Bryon Shire Council resolved on 21st December, 2004 to ‘select retreat under public and private ownership as its preferred hazard management option for the Belongil / Cape Byron Beach and New Brighton compartments’ (Byron Shire 2009 citing resolution 04-1057, p. xvi). Despite this conclusion, in 2006 the Byron Shire Council undertook a feasibility study to ascertain whether the Byron Bay Sand Lobe was a suitable source of sand for beach nourishment programs, but after consideration of the complexities and perceived costs associated with accessing the lobe resolved to abandon any further consideration of sand nourishment. The Council then resolved to prepare the Draft Coastal Zone Management Plan as a document that identified strategies and actions that are required to implement ‘planned retreat’ (Byron Shire Council 2009, p. xvii).

The year 2009 – ‘The perfect storm’

Two main events occurred in 2009 that resulted in a political backlash against the ‘planned retreat’ management concept:

- a strong storm that hit the coastline of Byron Bay in May; and
- the release of the Draft *Coastal Zone Management Plan* in October.

Storm damage and loss of property to Vaughan (May 2009)

Byron Shire Council vs Vaughan; Vaughan vs Byron Shire Council (No 2) [2009]

In late May 2009 the Byron Bay coastline was subject to larger than normal storm surges due to the occurrence of king tides combined with an East Coast Low. Over five days the seas pounded the property of John and Anne Vaughan on the Belongil Beach. On the third day the sandbag wall that had protected their property from erosion collapsed and about 10 metres of their property was lost to the sea (ABC Radio National 2010). The sandbag wall was originally constructed in or around 2002 by the Byron Shire Council after it had given itself development consent to do so.

John Vaughan notified the Council via email that the wall had collapsed and requested that they reinstate it in accordance with the original development consent issued in November 2001. Due to the climatic conditions at the time the Council refused, so John Vaughan made his intentions known to the Council that he intended to restore it himself and organised contractors at his property to begin the work. The Council believed his intention was to install rock protection and the court records seem to bear this out (Baker and McKenzie 2011; Preston 2011). Beside the fact that the Vaughans required development approval for this action, the installation of rock as a beach protection method was forbidden in the Byron Shire Council Development Control Plan 2002 (Byron Shire Council 2002).

On the evening of the 27th May the Council commenced an action against the Vaughans to stop them from carrying out the erosion protection work. The Vaughans then brought an action against the Council alleging a breach of the Council of the conditions of the 2001 development consent granted to the Council itself for the construction of the wall. The Vaughans sought to ‘enforce the development consent by mandatory injunctions that the Council construct the wall in accordance with the consent’, or alternatively sought a ‘declaration or order that the applicants are entitled to do so, and claiming damages and other relief for nuisance and negligence’ (Baker and McKenzie 2011, p. 25).

After an urgent hearing by Pain J on 29th May 2009, an interlocutory injunction against the Vaughans was granted to the Council that restrained them from undertaking any erosion protection works on or adjacent to their property (Baker and McKenzie 2011, p. 25). The Council argued that since 1988 it had had a policy of planned retreat and also relied on expert evidence that the structure would cause damage to other properties that were not protected, by exacerbating existing, cumulative, down drift erosion impact, and that the structure would also impede public access to the beach (Preston 2011). Judge Pain seemed to agree with this assessment stating, ‘[the evidence] reinforces my view that the work done on one property in isolation is likely to have adverse impacts on neighbouring properties in the immediate vicinity and more generally along the Belongil Spit (Byron Shire Media Release 22nd June, 2009).

The parties later agreed to vary the interlocutory injunction, so as to allow the owners to rebuild the wall using geo-bags and sand. The case was ultimately settled and did not proceed to final hearing. In February 2010, the Court made consent orders declaring that the 2001 consent was a valid consent which applied to the owners’ lands and approved interim beach protection works, that the terms of the 2001 consent obliged the Council to monitor, maintain and repair the interim beach protection works it had erected, and that the owners were entitled to but not obliged to maintain, repair and restore the interim wall. The Court also ordered the Council to restore the interim wall to its height and shape before the May 2009 storm (Preston 2011). ‘In addition, the Vaughans had the option of bringing an action in negligence or nuisance in the Supreme Court seeking damages for the loss of their property’ (Baker and McKenzie 2011, p. 26).

The ‘Court of Public Opinion’

The legal dispute over the protection works at the Vaughan’s property attracted significant attention in the media. The following section is a short analysis of the way in which the event was dealt with in the media.

The Council

The Byron Shire Council, especially through the efforts of its mayor, Jan Barham attempted to defend its actions and its policy of planned retreat more generally:

> *‘Planned retreat was a policy inherited from State Government’*

'For years we have advised that certain coastal areas of the Shire have a degree of risk from coastal erosion'.

'People who buy into planned retreat areas are informed of the restrictions for development. They purchase with knowledge of the risk …information on coastal hazards is also placed on Section 149 Certificates to inform prospective buyers of restrictions'. (Byron Shire, 2009, Planned Retreat, Media Release, reported in Far North Coaster on 22nd June 2009).

'It's Council applying a duty of care to look at the big picture…we've seen the future and we've planned for it. We've taken a precautionary approach and that is now being looked at as being a template for a lot of other Councils'.

(Jan Barham interviewed by McCutcheon, P, 2009, Waterfront property owners told to let nature take its course, 7.30 Report on ABC on 24th June 2009).

'There will be no retreat from Byron Bay's controversial planned retreat policy on beach front living, the NSW resort town's defiant Greens mayor insisted yesterday' (Elks and Salusinszky, 2009, The Australian Newspaper, 23rd September 2009).

The Media

The media reporters generally characterised the Council as 'green' and 'intransigent' while the property owner was portrayed as the 'little Aussie battler' fighting injustice. That Mr Vaughan (Figure 15) had developed his property subsequent to 1988 with full knowledge of the risks and restrictions was never mentioned:

'The Greens dominated Council…has stopped Mr, Vaughan from upgrading the wall in front of his house to match the standards of those protecting his neighbours'. (Robins, B, 2009, Byron beachfront goes begging, SMH, 2nd June 2009.

'John Vaughan's lengthy court battle over valuable Byron Bay real estate is being viewed as a test case not only for coastal planning but also for potential sea level rise… A green Council argues it's paving a way for the future' (McCutcheon, P, 2009, Waterfront property owners told to let nature take its course, 7.30 Report on ABC on 24th June 2009ABC 730 report interview, 24th June 2009).

Carrick: '..the local shire Council, which is controlled by the Greens, says the coastline is constantly changing….ultimately the coast around here is indefensible, so it makes no sense to defend it…'

Vaughan: 'Yes, well that is the rationale for their policy, but that is not the actual situation as far as the scientific facts, what is happening to the coast. The coast in fact has been quite stable. In fact I'm living on a dune that's been here for 6,000 years and is largely unaltered in that state until man-made structures were built further up the coast, which has impacted on the Belongil beach which has realigned the coast. That is our danger, it's man-made structures, not natural processes'.

Carrick: 'Not climate change?'

Vaughan: 'Definitely not climate change. This whole court case has had nothing to do with climate change… this is a consequence of man-made structures impacting on a natural coastline'.

(ABC Radio-Carrick D, 2010, Interview with J Vaughan and J McDonald, ABC Radio National 9th February 2010)

Figure 15: 'A cry for help… John Vaughan surveys his fast disappearing front lawn' (Source: Sydney Morning Herald, 2nd June 2009. Reproduced with permission from photographer Paul Harris).

The locals

The difference between the situations of land owners is made obvious in this report. Some landowners who developed prior to 1988 have the security of rock wall protection, while those adjacent, such as Vaughan do not. The same storm that did severe damage to Vaughan's property did no damage to those with rock wall protection at locations adjacent.

Furious locals are calling for the State Government to intervene blaming the erosion on work done near the town that has stopped the natural flow of sand along Belongil Beach, leaving it increasingly exposed during storms, especially king tides'.

John Callanan stated, I've got a rock wall. It works well, as does the wall protecting Jonson Street at the centre of town, and which is the cause of the problems…Council has numerous reports recommending a continuous rock wall, but its implementation has been hindered by the Green Council. They call it a 'planned retreat' – although there is nothing planned about it – which will see flooding of the town'.

(Wilkinson, M, 2009, Sydney Morning Herald, 2 June 2009).

Ed Ahern (President, local chamber of commerce): The green ideology in our Council says a lot more about stopping things than doing things….it's just un-Australian. I just can't understand why they'd be going off to courts getting injunctions and – to stop them protecting their property….'

Professor Ralf Buckley (Belongil landowner): We don't' have the option to take the whole of Sydney and move it inland a few feet every year. It's not going to happen. So it shouldn't happen at Belongil either.

(McCutcheon Presenter, 2009 ABC 730 Report, 24 June 2009).

The battle to save some of the state's most spectacular beachfront properties from severe erosion is set to escalate after lawyers for more Byron Bay residents sent letters to the local Council demanding they be allowed to protect their properties.

The Mayor of Byron Shire, Jan Barham, said the Council's lawyers received new demands on Friday. This followed a recent legal agreement that allowed a local property owner, John

Vaughan, to rebuild a sandbag wall in front of his property at Belongil Beach where severe erosion is threatening his home. "Each day we get a new legal threat," Cr Barham said.
(Wilkinson M, 2009, Sydney Morning Herald, on 29 June 2009).

Byron Shire releases Draft Coastal Zone Management Plan (22 October 2009)
On 22nd October 2009 Byron Shire Council released the Draft *Coastal Zone Management Plan* (2009) (DCZMP) for public comment. The adoption of the DCZMP, and subsequent approval by the Minister, would allow the Council more legal leverage to enforce the provisions of planned retreat that had been in its development plan since 1988.

Additionally, previously it was noted that Byron Shire Council had resolved to pursue Option H – planned retreat in private and public ownership. This option was dependent on a partnership with the NSW State Government with the hope that the State Government would legislate and oversee the planned retreat of Belongil and New Brighton Beaches. However, this partnership did not eventuate and it is not clear whether the Council ever sought such a partnership. It seems more likely that Option G – planned retreat as private land was adopted and that the existing planned retreat provisions in the *Development Control Plan* were to be incorporated directly into the *Coastal Zone Management Plan* to improve their legal standing (WBM Oceanics, 2004, p. 6, 52).

The question considered here is why was there such a reaction from the residents upon the release of the DCZMP? The following are key points to understanding the answer to this question. First, the DCZMP (p. 49) adopts planned retreat to manage the threat to life and property from coastal processes by the following strategies:

1. control of development on land threatened by coastline hazards for approvals under the provisions of the *Environmental Planning and Assessment Act*, 1979 via planning controls under Byron Shire LEP, DCP's, and this CZMP;
2. provision of advice to purchasers of property within coastal planning precincts on the hazard risk restrictions associated with that land via issue of Section 149 planning certificates at time of purchase;
3. removal or relocation of development and infrastructure under immediate threat; and
4. removal of unapproved coastal structures.

The explanation of strategy three and four proved to be contentious. In the past, the use of buffer distances (20 metres or 50 metres) and relocation triggers had only related to structures developed post 1988. However, under section 4.3, *Existing development and coastal structures,* the DCZMP appears to incorporate all structures irrespective of when they were developed (pp. 54, 55).

In relation to strategy three the DCZMP stated that the removal or relocation of existing development and infrastructure under immediate threat will occur by:

- voluntary relocation or removal by property owners;
- enforcement by Byron Shire Council of development consent conditions for development approved under the Environmental Planning and Assessment Act, 1979, once the specified trigger distances imposed in the consent have been realised; and
- enforcement by Byron Shire Council (demolition) under recognition of risk to people and the environment from possible dwelling collapse. In all cases relocation or removal of a dwelling will occur at the property owner's expense, in accordance with the Environmental Planning and Assessment Act, 1979 (p. 56, 58).

When these policies are taken into account with the following statements in relation to protection works the reason there was such a reaction becomes clear.

> *In accordance with the planned retreat approach, this CZMP does not support construction of new or maintenance of coastal protection works, with the exception of Jonson Street Protection Works. The Jonson Street Protection Works that protect the Byron Bay town*

> *centre…represents the only exception from the planned retreat approach adopted for the entire Byron Shire coastline.* (p. 58).
>
> *Removal of protection works' the CZMP seeks to implement the following two actions: make a risk analysis of erosion protection structures; and 'develop a plan that describes how to remove structures and works, which will be ranked according to the impacts and issues identified in the risk assessment in accordance with the objectives of Planned Retreat as described in this CZMP.* (p. 58).

Finally the DCZMP does canvas the possibility of a voluntary acquisition scheme but concludes:

> *It should be noted that NSW Government funding for coastal management is limited and will be allocated according to state-wide priorities. It is unlikely that Government funding will be available for the voluntary purchase of coastal properties.* (p. 63).

The Council supported its argument for the above policies by opening the section with a reminder to the reader that there was a history of court cases in which the policy of planned retreat had been upheld including the demolition of dwellings and the prohibition of installing rock protection (p. 51, 52).

Discussion: Implications of DCZMP

The implications of the DCZMP were that existing development, whether developed prior or post 1988 would all be subject to a 20 metres trigger erosion zone. Once the erosion escarpment came within 20 metres, development had to be relocated or removed. In conjunction with this trigger, land owners would be prohibited from installing any protective measures. Furthermore, the Council planned to do an audit and remove all unauthorised protection structures as well. Thus, property owners who refused to relocate their houses would be forced to allow erosion to take its course and then when the house was in danger of collapse, the Council would demolish it at the owner's expense in accordance with Section 121 of *Environmental Planning and Assessment Act*, 1979.

The court of public opinion

The Byron Shire Council had almost completed the draft *Coastal Zone Management Plan* (DCZMP) when the storm event of 25 May occurred. Approximately one month later the final draft was presented to the Council meeting of 2 July 2009 with a recommendation that the DCZMP be presented for public exhibition. However, and for reasons that are not entirely clear, the resolution to place the DCZMP to public exhibition did not occur until 8 October, with the exhibition time set for 22 October to 22 December 2009. It may be possible to speculate that the ongoing court case with Vaughan (Byron Shire Council vs Vaughan; Vaughan vs Byron Shire Council (No 2) NSW [2009]) and the increased media attention on the concept of 'planned retreat' may have contributed to the delay.

The NSW Government intervenes (September 2009)

The catalyst for the public comments by the NSW Government was a letter from the NSW Department of Environment and Climate Change to the Byron Shire Council that was leaked to the Australian newspaper on 23 September 2009. It is likely that this leak and the public comments were inspired by the proposed DCZMP that was about to go on display in Byron Bay.

> *'NSW Premier Nathan Rees last night backed the rights of Byron Bay landowners… The NSW Government does not support restrictions on owners being able to reasonably use their land', Mr Rees told the Australian…. 'Any planned retreat strategy should aim to allow landowners to continue to use their property while ever it is safe to do so' and, '…any coastal management plan should take a reasonable approach to managing any ad-hoc rock seawalls' (Contents of leaked letter from Simon Smith, Deputy Director for Climate Change Policy and Programs to Byron.)*

> *(Elks and Saluskinszki, 2009, The Australian 23 September 2009)*

Byron Shire Council responds (19 October 2009)
Subsequent to making public comment, it became public knowledge that the NSW Government intended to legislate on protection measures to beach front properties. The Byron Shire Council responded:

> *'Byron Shire Mayor Jan Barham said she had not seen any information from the NSW State Government concerning the proposed new measures to allow beach front landholders to build defences'.*
>
> *'Mayor Barham said according to media reports, under the State's plans beach front landholders will be required to pay for any defences, ensure that works did not transfer erosion from one spot to another and commit permanently to paying for sand nourishment'.*
>
> *(Byron Shire Council, 2009, Coastal protection works, Media Release: 19 October 2009)*

The Court issues orders in relation to the Vaughan case (1 February, 2010)
On 1st February, 2010, the court issued orders in relation to the dispute between Vaughan and Byron Shire Council. The Australian newspaper reported:

> *'BYRON Shire Council's plan to roll back beachfront living was effectively demolished yesterday, when a court upheld a home owner's right to protect his property from the sea….Byron Shire Council had put itself at odds with residents and the NSW government by denying beachside householders the right to erect or reinforce storm walls under the "planned retreat" policy, which was aimed at pushing development back from the seafront.*
>
> *Byron Shire Council's general manager, Graeme Faulkner, said the court order undermined the long-term strategy of planned retreat.*
>
> *Yesterday's decision comes as Byron Shire Council considers a coastal development policy that would institutionalise the policy of planned retreat. The NSW Government, which must approve such a policy, has already signalled that it is unlikely to do so.*
>
> *(Fraser A, 2010, Byron Bay owners win right to protect beach property, The Australian, 2 February 2010).*

This report contained some factual errors as the Court ruling gave no general right to coastal protection. The Court had only ruled that the Council had a duty to maintain the protection works that it had obtained development consent for, and had erected itself.

Byron Shire adopts Draft Coastal Zone Management Plan (28 May 2010)
Despite the opposition from the public and the NSW Government, Byron Shire Council adopted the DCZMP and issued this media release:

> *Byron Shire Council resolved to adopt a Coastal Zone Management Plan. A report on the public exhibition of the draft CZMP to Council, noted 654 submissions were received from 622 people.*
>
> *(Byron Shire Council, 2010, Draft Coastal Management Plan adopted, Media Release, 28 May 2010).*

New NSW State Legislation

On the same day Byron Shire Council announced that it had adopted the Draft *Coastal Zone Management Plan*, the ABC reported that new legislation was being considered by the State Government. John Vaughan was again interviewed. It is pertinent to note that there is no mention in this interview that John Vaughan was aware of the risks and responsibilities when he purchased and developed his property, rather he is portrayed as the one 'battling' against the Council.

> *New legislation on the management of the coastal erosion has once again stirred debate over the amount of control landowners should be given to protect their properties. NSW is putting together legislation which could for the first time give land owners the right to erect emergency barriers to protect their properties.*
>
> *Over the past decade Mr Vaughan has been fighting to defend his property from the encroaching sea, but he says his biggest battle has been against the local Council in the courts. 'I have already moved the house back once in 1999, and hopefully won't have to do that again'…*
>
> *But under the legislation being considered by the NSW Government, he would not have needed Council approval to protect his land.*
>
> *The Green's Mayor of Byron, Jan Barham, says the proposed legislation flies in the face of the Council's planned retreat policy which would see properties like Mr Vaughan's demolished or relocated. She says the new legislation will throw seaside Councils into a state of confusion.*
>
> *'It is not backed up by good evidence and good science, or information that would inform Councils as to what might happen should this bill go through and people be allowed to undertake works along the beachfront. It is the Local Government who will end up living with this'.*
>
> *(Casben, L, 2010, ABC News 28 May 2010).*

The *Coastal Protection and Other Legislation Amendment Act,* 2010 came into effect on 1 January 2011.

More legal action against Byron Shire Council

Kelsey Munro (2011) reporting for the Sydney Morning Herald on 11 January 2011 stated that residents were stepping up legal action to sue the Council over beachfront property. From the media reports it appears that the main argument was that the Council's own protection works at Johnson Street had caused the erosion of Belongil Beach. This fact had been conceded by the Council as far back as 2004 as reported in the WBM Oceanics (2004) *Byron Bay Coastal Management Study*. However, WBM Oceanics also reported at that time that erosion would be a long-term issue on Belongil Beach irrespective of the protection works at Johnson Street.

> *'Owners of properties at Belongil Beach in Byron Bay have launched a $100 million lawsuit against the Council for damage they claim has been caused to their properties by the Council's own beach protection system.*
>
> *The Belongil property owners claim the artificial headland built by the Council in the 1970s in front of Johnson Street in the town centre has caused major erosion of the beach further west, putting their properties at risk of continuing erosion and storm events.*
>
> *The lawsuit comes amid an escalating dispute between Belongil property owners and the Greens-led Byron Shire Council of the Council's new coastal zone management plan which is awaiting approval by the Environment Minister, Frank Sartor. If approved, the*

plan would prohibit beachfront owners from constructing protective seawall or nourishing beach sand to protect their properties. It would expose up to 16 homes to a demolition order if Council considers them at risk from storm seas.

Mr Vaughan, [one of the ten plaintiffs] said the major problem was not sea level rise but the Council's artificial headland.

A spokesman for Byron Shire said lawyers for the Council's insurer would provide Council with advice in due course.

(Munro, K, 2011, Sydney Morning Herald, 11 January 2011).

The ABC News, North Coast NSW (2011) on 4 March reported that the landowners on Belongil Spit were challenging the validity of the Council's Draft *Coastal Zone Management Plan*,

Landowners on the erosion prone Belongil Spit are launching fresh action against the Byron Shire Council. Both the Council and the State Environment Minister, Frank Sartor, have been summoned to appear before the Land and Environment Court in a case due to start today.

The residents are challenging the validity of the Council's draft coastal zone management plan, which forms the basis of the controversial planned-retreat strategy.

Geoff Tauber, from the Byron Preservation Association, says a recent report shows the rock wall built at Main Beach has exacerbated erosion problems at Belongil. 'There would be an additional 20 metres of beachfront in front of all the properties which would provide substantial protection against storm events', he said. "We believe the minister is attempting to bring about a state of affairs where he can in fact certify that plan before the election, after which time the Council would be able to order the removal of rock-wall protection and the demolition of homes,' Mr Tauber said.

At this stage no-one from the Council is willing to comment on legal issues.

(ABC News, North Coast, NSW, 4 March 2011).

<u>Byron Shire Council withdraws draft Coastal Zone Management Plan (27 April 2011)</u>

Byron Shire Council has resolved to withdraw the current draft Coastal Zone Management Plan. A new Coastal Zone Management Plan (CZMP) will now be prepared under the new coastal laws that commenced on 1 January 2011.

Council's general manager Graeme Faulkner said a discrepancy between the new coastal protection laws and Local Government Act had resulted in the need for a new Byron Shire CZMP.

It is regrettable that Council has the expense and time, Mr Faulkner noted, of preparing a new plan but the need arises from the State Government change in philosophy and laws.

(Byron Shire Council (2011) Media Release, 27 April 2011).

<u>Letter received from Office of the Hon. Robyn Parker MP, Minister for the Environment received by Byron Shire Council on 26 May 2011.</u>

While this letter is not a media release it rounds out this episode effectively. The letter is addressed to the General Manager Mr Faulkner, and states the following:

- the Byron Shire Coastline CZMP will not be authorised under Section 55G;

- it requests that the Council advise the State Government where the discrepancy exists between the Coastal Protection Act 1979 and Local Government Act 1993;
- it stipulates that the Council must prepare an emergency action subplan by 31 November 2011; and
- It stipulates that the Council must prepare a draft CZMP for certification by 31 December 2012.

Discussion

As the only case in Australia that has so far that has dealt with an action of the sea in relation to existing development and protection structures this case demonstrates:

- The complexity of dealing with coastal protection matters that may involve many and varied parties such as: the Council; the State Government; the locals who may support the Council action; particular land owners who do not support the Council action; the media and its influence on public opinion; and the scientists (science) all interacting with different agendas;
- The difficulty of dealing with the political aspect of coastal protection matters. Despite having development control measures in place since 1988, the voice of the Council trying to explain that many people purchased or developed properties knowing the risk and the restrictions was drowned out in the public domain by the image of a lone man battling to save his house against the fury of the ocean and the ‘green controlled’ Council;
- That adopting a blanket policy of ‘planned retreat’ is likely to engender immediate retaliation in the courts. The dispute in the media became between ‘planned retreat’ and the right for owners to protect their property rather than the assessment of localised development, each with its own characteristics;
- That the ruling by the Court in the Vaughan vs Byron Shire case did not mean that the Council owes a level of protection to its ratepayers. The issue in this case was that the Council had provided protection works under its own DA and then not maintained them;
- The issue of protection works is crucial. When a storm surge crosses the beach and damages properties without protection it is unlikely the Council will be held liable. However, when protection works are introduced a whole new range of liabilities may be incurred. Secondly, works completed at one place may adversely impact another section of the coast and who is liable becomes difficult to determine;
- The amendments to the NSW *Coastal Protection Act*, 1979 has resolved the former problem to some degree, in that it has legislated that Governments will not be liable for protection works but it may have made it impossible for planned retreat to be effectively carried out.

Other Minor Case Studies, Resources and Tools

Resources and tools to assist with adaptation to climate change have been previously prepared by the Federal Government (e.g. *Climate Change Impacts & Risk Management – A guide for Business and Government* (2006*)* and *Climate Change Adaptation Actions for Local Government* (2010)). The former guide was used by all Councils in Victoria as a starting point for dealing with climate change impacts (Municipal Association of Victoria, 2011). The latter guide sets out how climate change impacts may affect infrastructure, recreational facilities, health services, planning and development approvals, and natural resource management within the existing Australian and New Zealand Standard AS/NZS 4360 Risk Management standard.

Two reports that begin to address the need for cost-benefit analysis on adaptation options in coastal regions have been prepared. The CSIRO Climate Adaptation National Research Flagship released *Coastal inundation under climate change: a case study in South East Queensland* (CSIRO, 2010) and the Department of Climate Change and Energy Efficiency released the *Coastal Inundation at Narrabeen Lagoon: Optimising Adaptation Investment* (2010).

The NCCARF Local Government Portal (2012) has around 280 links to tools and resources from all around the world. The vast majority of reports issued by Australian Federal and State Governments appear to be on this list as well. Those that related more directly to this study are listed in Appendix 1, with special note taken of any that included economic modelling.

Finally, work by Professor Jan McDonald, from the University of Tasmania Law School, in the project *Limp, leap or learn? Developing a legal framework for adaptation planning in Australia*, under the National Climate Change Adaptation Research Facility (NCCARF) will examine the role of law in driving and enabling urban climate change adaptation. Outputs will compare and contrast legal frameworks for planning for coastal impacts of climate change and those for the increased risks of bushfire. The analysis will consider formal planning laws, coastal and emergency management laws, property law, liability and insurance regimes and will nicely complement the work undertaken here as part of this project.

APPENDIX 3 – THE THEORETICAL CONTEXT OF DECISION MAKING

The two key general objectives of this project are as follows:

- the research undertaken in this project will develop a framework methodology that can model the financial cost of different policy approaches that deal with coastlines threatened by inundation and erosion as a result of climate change; and
- the key outcome of the research will be delivery of a pilot decision support framework and decision tool that includes the evaluation of cost effective policy options based on real data and a financial model.

These objectives are now analysed from the perspective of decision theory.

Decision analysis has moved from a relatively abstract mathematical discipline, embedded in operations research and focused on identifying optimal decisions, to “a framework for thinking that enables different perspectives on a problem to be brought together with the result that new intuitions and higher-level perspectives are generated.” (Phillips L, cited in Goodwin and Wright 2004 p.5). The emphasis of contemporary decision analysis is therefore not on solving a decision problem, but on producing insight into the problem and promoting creativity when addressing it.

Decision theory is distinguished as either *descriptive* or *normative*. The focus of descriptive decision theories is to explain and predict how people actually make decisions and is an empirical discipline derived from experimental psychology. Normative decision theory focuses on what decision makers are rationally required to do. The analytic position taken here is that of normative decision theory as it underpins the pragmatic decisions that managers are required to take. However, it is recognised that non-rational elements of decision-makers - beliefs and values of various kinds, including risk-aversion (Peterson 2009, pp.179-187), - are closely linked to decision making and must be allowed for in the decision framework.

Decision theory begins with a *decision problem* and a *decision maker*. The decision maker is the individual, entity or group of individuals who have charge of the decision. That is, the decision maker is taken as having complete control over the decision regardless of what influences may be brought to bear on the environment in which the decision is taken or on the individual decision maker directly. The decision-maker in the end must make the decision (Resnik 1993).
The normative approach assumes that the decision will be taken for reasons that can be rationally, or logically, tabulated: “... the decision maker chooses to do what she has most reason to do at the point in time at which the decision is made.” (Peterson 2009, p. 5). Three elements are significant in this definition: ‘*choice*’; ‘*reason*’; and ‘*time*’. In the instrumental view of rationality, a fourth element is added: the approach assumes that the decision maker has some *aim* relevant to the decision required. The aim is external to decision theory, although it is agreed that it cannot be irrational (it can, however, be comprised of sets of aims that are inconsistent). So, from the normative perspective, to be instrumentally rational means to do whatever the decision maker has most reason to expect, at the time of the decision, will fulfill her aim: “If the decision maker is prepared to accept a set of rules (or axioms) which most people would regard as sensible then, to be rational, he or she should prefer the indicated course of action to its alternatives.” (Goodwin and Wright 2004, p. 5).

In summary, all four elements of aim, choice, rationale and time must be present for the decision to be formally considered ‘rational’ (Levi 1989; Luce 2005).

With reference to the project brief:

Decision maker	Local Government entity.
Aim (decision problem)	Identify the best management actions that can be taken in response to the threats likely to be generated by climate change on local government coastal zones.
Choice	Management actions available to local government entity.
Rationale	Effectiveness and cost.
Time	Forward defined period.

Typically decision problems are comprised of *states*, *outcomes*, and *acts*, defined briefly as follows (Peterson 2009: 17-39; Gilboa 2011):

> *'States' refer to states of the world (parts of the world that are not outcomes or acts) within which the decision is being taken. Only states that may influence the decision maker's choice between acts need be taken into account. Only states that are causally independent of acts are included in the decision formalization. States can include acts, and their outcomes, that are performed by others.*
>
> *'Acts' have their common meaning, but can also, in the decision formalization, be conceived of as functions, which take states as their arguments and outcomes as their return. Acts are particular acts, rather than general, and chosen from alternative sets. Clearly acts can belong to more than one alternative set.*
>
> *'Outcomes' are the results of making particular choices from the alternative set of acts. Outcomes are ranked in different ways, from best to worst, with reference to the decision-maker's aims. The comparative evaluations of value by the decision-maker are termed utilities.*

With reference to the project brief:

States	Defined by combinations of inputs from physical climate impacts, physical conditions of local coastal zones, existing protection structures, ownership and valuation of assets at risk, liabilities and exposure, benefit/cost factors, and other factors, such as political and social.
Acts	Specific action strategies available to Councils for dealing with climate-induced states. These include retreat, accommodate, defend, defer or do nothing actions.
Outcomes	Include infrastructure asset protection, financial outcomes, political and social outcomes.

Decisions about choices among acts are required when the outcomes are unknown to some degree. For decisions made in the context of *risk*, the probability of possible outcomes is known. For decisions made in *ignorance*, the probabilities are either unknown or unknowable. *Uncertainty* is typically used as an umbrella term to include both risk and ignorance (Gilboa 2009).

Courtney (2001) identified four levels of uncertainty with reference to strategic decision problems:

1. A clear, single view of the future.
2. A limited set of possible future outcomes, one of which will occur.
3. A range of possible future outcomes.
4. A limitless range of possible future outcomes.

For each level particular analytic tools are utilized. Thus, forecasting is typical of level 1, decisions trees of level 2, simulation of level 3, and reference cases of level 4.

With reference to the project brief, climate change impacts are regarded as having level 2 and level 3 characteristics:

Level 2 uncertainty	Well-defined alternate futures under a defined number of alternative actions (as detailed under 'acts' above). Relevant tools are sequenced process mapping, decision trees, scenario planning.
Level 3 uncertainty	Plausible alternate futures within a range of possible scenarios, with substantial uncertainty (combinations of inputs under 'states' above). Relevant tools are branching process mapping, scenario planning, simulation.

It should be noted that in decision theory *subjective factors* are recognised as having a material influence on the handling of uncertainty. Concave utility functions, which display declining rates of utility increase with increasing risk (as risk increases, utility levels off), represent the typical case (French 1988; Slovic 2000). In addition, it is recognised that cognitive framing of the decision will influence decision makers, regardless of the rational analysis of decision choice. Such frames may include habits of favouring complexity, imposing imaginary constraints and false assumptions on a range of options, narrow bracketing of decisions, cognitive inertia in the face of dissonant information (Tversky and Kahneman 1981, Goodwin and Wright 2004), and 'groupthink' (Mullen et. al. 1994). Many of these frames resolve into the history of decisions taken by the decision maker, a factor that is likely to have relevance in the local government context. It is not, however, within the scope of the brief, and is simply noted here as an area of decision making that may warrant further research.

More directly relevant for this project, are structural characteristics of the decision environment that increase uncertainty (Goodwin and Wright 2004, p. 5):

- *Multiple objectiv*es - no course of action achieves all objectives, therefore trade-offs between benefits offered by different actions in the alternative set must be considered;
- *Complexity* - derives from the number of potential actions in the alternative sets, their interlinkages and potential sequence effects (Mitchell 2009); and
- *Multiple stakeholders* - although the decision maker has sole authority to make the decision, the effects of the decision impact other individuals or groups, with their own values and satisfaction structures, and their own direct or indirect claims on the decision.

With reference to the project brief:

Multiple objectives	Primary objectives include developing local government management responses to climate change threats in coastal zones; choosing management actions that are most cost effective; minimizing legal liability for Council; meeting the political requirements of Council as a governing entity.
Complexity	Complexities are inherent in the climate impact science, data and projections; the variation in potential management actions; the potential interlinkages of these actions; probabilistic character of key physical and financial drivers; the future trajectories of the state and federal political and regulatory environment.
Multiple stakeholders	Stakeholders include Council elected members and staff; ratepayers; local communities; state and federal government agencies; neighbouring Council areas and communities; tourist and visitor populations.

The *decision pathway* for this project is based on the above analysis, and is structured in three phases:

1. Decision mapping: this phase draws on the techniques of decision flowcharting and process mapping to analyse in detail the decision environment outlined above, and to provide input into the next phase.
2. Financial modelling: this phase captures the financial implications of actions in the alternative set, utilising the discounted cash flow and net present value approaches of standard financial modelling, and Monte Carlo simulation techniques to handle uncertainty effects, typically those of levels 2 and 3 as outlined above (Damodaran 2006). Discounted Cash Flow DCF valuations can be subjected to standard sensitivity analysis with One-Way Data Sensitivity testing or by using Tornado Charts that show how sensitive an output is to several different inputs (Powell and Baker 2009).

3. *Development of the decision table*: this phase applies to the decision matrix tools of decision analysis to the final decision to be taken by the decision-maker, the local Council. These tools include Multi-Criteria Analysis (MCA), which handles otherwise incommensurable values (financial, environmental, social, political etc.) in a systematic way (Munier 2011), and risk-management rules, which identify outcomes indicated by the risk acceptance or aversion priorities of the decision maker (Peterson 2009, pp.40-52, DCLG 2009). The development of MCA and risk management rules were outside the scope of this project but are discussed in more detail in the final chapter of the report.

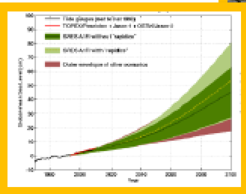
APPENDIX 4 – TWO PAGE PROJECT SUMMARY HANDOUT

Climate Change Decision Support Tools for Coastal Councils

A Coastal Adaptation Decision Support Pathways project funded by the Department of Climate Change and Energy Efficiency has developed a decision pathways map and financial model for Councils that have responsibility for existing coastal developments at risk from climate change driven inundation and coastal erosion including residential and commercial buildings, roads, footpaths and sea walls.

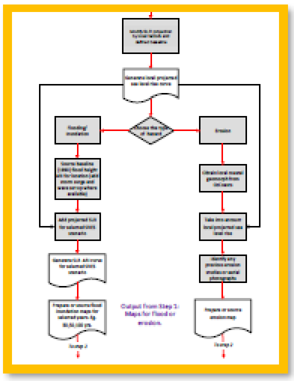
The tools developed evaluate the cost effectiveness of various adaptation options including the costs associated with, and optimum timing for, accommodating, retreating, defending or delaying action. The tools have been tested using real data from the Onkaparinga City Council and Mallala District Councils in South Australia and have been designed for easy used by coastal planners and Council staff.

Problem:
Increasing sea levels and changes to the frequency of severe weather events will result in damage to existing coastal infrastructure this century.



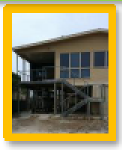
Question:
How do Councils decide which adaptation options will be politically and legally acceptable to implement, what is the likely costs of those options to 2100 and when should they be implemented?

Solution:
The decision map and financial model developed provide a step by step guide to collating the data required to determine the most appropriate course of action.



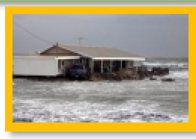
Retreat

Accommodate



Defend

Do Nothing



Local Government Association of South Australia
University of South Australia
COAST PROTECTION BOARD
Government of South Australia Department of Environment, Water and Natural Resources
CITY OF ONKAPARINGA

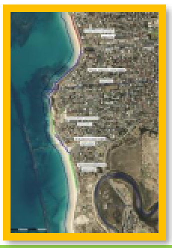
Climate Change Decision Support Tools for Coastal Councils

The methodology developed is provided in a simple decision map that involves six steps.

1 Analyse the climate impact

The assessment location is identified first due to the site specific nature of data inputs. Changes to climate change stressors (sea level rise and erosion events) are quantified. Maps depicting the resulting inundation and erosion are developed at a resolution that allows for the identification of individual assets.

2 Analyse existing protection structures and strategies



The history and performance of existing structures constructed to protect against inundation and erosion are reviewed. Information includes the timing, process and conditions relating to the approvals provided for construction of the protection measures. The responsibilities of Councils must be identified. Previous performance of the measures is assessed and any previous claims or legal actions pertaining to the measures noted. The gap between existing protection measures and those necessary to protect against identified future threats is quantified.

3 Establish the profile of the assets at risk

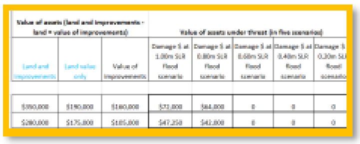
Assets at risk from inundation or erosion identified from the maps in Step 1 are quantified. The ownership of each of the assets is identified as either: Private, State / Federal or Council owned.

4 Determine Council Liability

The legal and political liability for each of the asset classes described in Step 3 is determined in collaboration with legal expertise where necessary. Outputs of this step is a list of all assets that are both at risk and for which Council has liability.

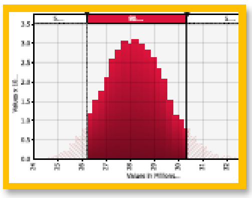
5 Determine monetary value of assets at risk

This step involves site visits and collation of site and infrastructure / improvements value for all assets listed in Step 4. A measure of floor heights is also needed for inundation assessments.



Value of assets (land and improvements - land = value of improvements)			Value of assets under threat (in five scenarios)				
Land and improvements	Land value only	Value of improvements	Damage $ at 1.00m SLR flood scenario	Damage $ at 0.80m SLR flood scenario	Damage $ at 0.60m SLR flood scenario	Damage $ at 0.40m SLR flood scenario	Damage $ at 0.20m SLR flood scenario
$350,000	$190,000	$160,000	$72,000	$64,000	0	0	0
$280,000	$175,000	$105,000	$47,250	$42,000	0	0	0

6 Analyse actions



The financial model allows for the assessment of the costs associated with a range of adaptation actions classified as either retreat, accommodate, defend, defer or do nothing. The up-front and ongoing costs associated with each option is calculated as either a one-off initial investment to contend with end of century projected impacts, incremental planned investments or action in response to inundation or erosion events.

This DCCEE funded Coastal Adaptation Decision Support Pathways project was run in collaboration with the Local Government Association of South Australia, South Australian Department of Premier and Cabinet, the Institute of Public Works and Engineers Australia, University South Australia and the South Australian Department of Environment and Natural Resources Coast Protection Board. ***For more information please contact:*** *Adam Gray, Senior Policy Officer, Sustainability & Environment, Local Government Association of South Australia , 148 Frome Street Adelaide SA 5000.*

APPENDIX 5 – PROJECT SUMMARY POSTER (A0)