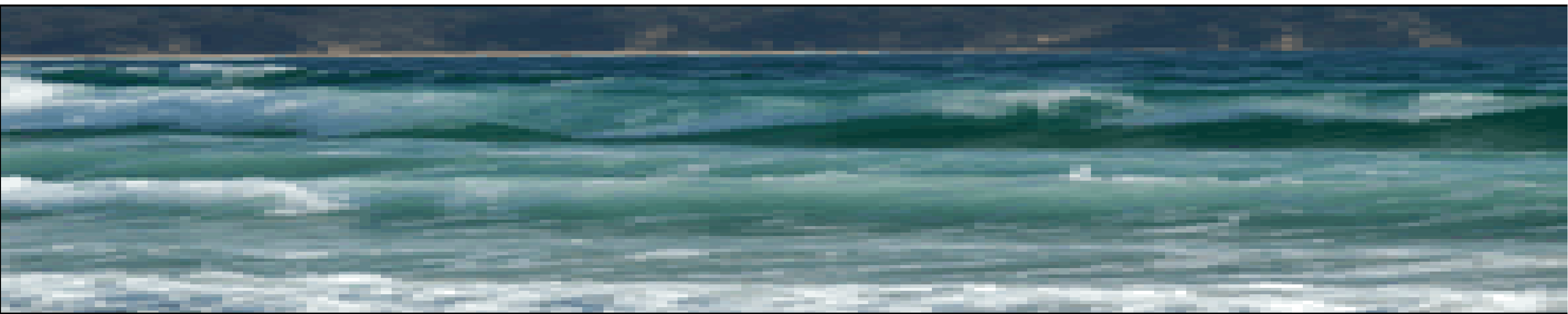
Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

Assessing and mapping Australia's coastal vulnerability to climate change :

Expert Technical Workshop



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Background and Australian Government Context

Australia's coastal zone is increasingly under pressure with some 85% of Australia's population now living near the coast and the demand to live there is increasing. The coast also supports important activities and features such as: tourism, infrastructure, agriculture, fisheries, coastal wetlands and estuaries, mangroves and other coastal vegetation, coral reefs, heritage areas and threatened species or habitats. The likely impacts of climate change will increase the challenge of sustainable management of the coastal zone and it is likely that the current coastal development patterns are increasing vulnerability to climate change.

Likely impacts of climate change on Australia's coast and oceans include:

- a rise in sea-level and increased frequency or intensity of extreme storms
- warmer ocean temperatures leading to increased frequency of coral bleaching events, impacts on aquaculture operations, and potential impacts on biodiversity through changing the distribution patterns of marine organisms
- changes to major fisheries (these have historically shown change in concert with climate variations – so are likely to be sensitive to climate change)
- increased carbon dioxide concentrations in sea water is altering ocean chemistry, making it more difficult for calcitic organisms such as corals to grow and function
- changes in climate over land will cause changes in run-off reaching coastal and marine systems and alter the availability and quality of freshwater – this has implications for productivity and ecosystem function of coastal and estuarine environments.

There is increasing evidence that a number of these changes are already occurring.

An assessment of coastal vulnerability to climate change is needed in order to prepare for and adapt to the likely impacts of climate change. The assessment will also need to recognise the range of pressures on the coastal zone, of which climate change is one. Outcomes of the assessment must support decision-making and the identification and management of risk. The Australian Government's interests in assessment of coastal vulnerability include:

- understanding risks to and opportunities for areas of public investment – infrastructure, natural resources and biodiversity, markets, and health
- facilitating information dissemination and development of methods to assist communities to identify and manage risks
- providing the rigour to underpin longer term and sustainable land use planning, and
- ensuring that governments, business and industry have the tools to maintain service delivery and manage productivity.

The national policy framework for integrated coastal zone management, *Framework for a National Cooperative Approach to Integrated Coastal Zone Management (ICZM)*, has the objective to 'improve understanding of the impacts of climate change on the coastal zone'. An identified action, 3.1.2, is to 'build a national picture of coastal zone areas that are particularly vulnerable to climate change impacts to better understand the risks and interactions with other stresses in the coastal zone'. The Framework is overseen by the Marine and Coastal Committee (MACC) which reports to the Natural Resource Management Ministerial Council (NRMMC). The MACC has interpreted action 3.1.2 as including spatial mapping.

Concomitantly, the national *Climate Change Risk and Vulnerability: Promoting an efficient response in Australia* report was released by the Minister for the Environment and Heritage to assist the setting of priorities for the *National Climate Change Adaptation Programme* (NCCAP). The NCCAP aims to commence preparing governments and vulnerable industries and communities for the unavoidable consequences of climate change. The report identifies the coast as a priority, and refers to the need to factor climate change issues into coastal land use planning. In addition to improving the knowledge base and addressing areas of national significance or vulnerability, a key element of the NCCAP is the provision of information and tools so that regions and sectors can understand the likely changes in climate, and access tools to identify and manage risks. Mapping Australia's coastal vulnerability to climate change would form an important component of this research.

The role of the Australian Greenhouse Office (AGO) in coastal vulnerability activities includes the delivery of NCCAP and taking a lead in key climate change actions in the ICZM framework. The work will be progressed in consultation with the States and Territories under the auspices of the Climate Change in Agriculture and NRM (CLAN) and the Intergovernmental Coastal Advisory Group (ICAG). An important and key responsibility is facilitating the development of a national approach for assessing, mapping and communicating coastal vulnerability to climate change.

As a major first step in this process, the AGO held an Expert Technical Workshop in December 2005 which was attended by some 45 technical coastal experts and practitioners from around Australia. This report forms a record of the outcomes of the workshop. The workshop was designed to identify key issues, share information, seek clarification and develop recommendations on the knowledge and methodologies required to assess, map and communicate Australia's coastal vulnerability to the impacts of climate change. Following a series of scene-setting presentations, participants engaged in a mixture of group and plenary discussions. Major themes for the breakout sessions were:

- climate and oceanographic drivers
- biophysical models
- information systems, applications and user needs, and
- socio-economic integration – models, data and stakeholders.

A workshop agenda is provided at <u>Appendix 1</u>, a table of group participants and discussion questions is provided at <u>Appendix 2</u>, and a full list of delegates is provided at <u>Appendix 3.</u>

Setting the Scene

Overview of climate and oceanographic drivers – John Church, CSIRO

The coastal zone will be significantly affected by social and environmental changes during the 21st century. Our love of the coast means that significant population growth is occurring in coastal regions, resulting in increased urban development, land and mangrove clearing and industrial development. These activities impact on coastal fore-dunes, the health of coastal waterways, commercial and recreational fishing, and create competition for locations for coastal facilities (e.g. marinas, aquaculture). In trying to assess the impacts of climate change on the coastal regions, it is important to remember that climate change is occurring now and that some changes are long term and ongoing. It is also prudent to realise that climate change, climate variability and weather variability all interact and this will lead to changing intensity/frequency of extreme events. Climate variability and climate change also interact with and can exacerbate other drivers of change. The coastal region is impacted by many of the same drivers that affect other regions but there are also drivers which are specific to the coast (e.g. sea-level rise).

Some of the main climate drivers affecting the coastal region are:

Sea-level rise - sea level is now rising faster that it did over the several previous millennia and recent analyses have shown that the rate of rise increased during the 20th century (**Figure 1**). Current Intergovernmental Panel on Climate Change (IPCC) projections are for a sea-level rise of between 9 and 88 cm between 1990 and 2100. There are a number of recent studies showing increased contributions of ice sheets and in the longer term, sea-level rise is likely to be several metres unless there are significant reductions in greenhouse gas emissions. Globally, sea level rise will also be felt through changes in the intensity/frequency of extreme events, and potentially many millions of people will be affected by coastal flooding events each year by 2100. It is likely, however, that this outcome will be less severe for Australia, recognising our relatively small population.

Changes in ***tropical cyclone intensity*** - there is a possibility of a modest increase in the intensity of tropical cyclones during the 21st century. Recent papers have highlighted increases in the intensity of tropical cyclones over the last 50 years but there is not yet consensus that these changes are due to climate change, at least in part, because of problems with the tropical cyclone data base. Note that the magnitude of wind effects and storm surge heights and resulting damage, all increase rapidly with increased intensity of tropical cyclones.

Water supply - water supplies in a number of coastal areas are already under stress as a result of increased demands and decreased rainfall over parts of coastal Australia over the last 50 years (**Figure 2**). Future precipitation changes are difficult to model but for much of Australia, the projected changes are for a decrease in the atmospheric moisture balance (rainfall minus potential evaporation). While there may be a reduction in average rainfall, extreme rainfalls (and hence flooding) may increase.

Changes in ecosystems - potential ecosystem changes include: a poleward and regional movements as the oceans warm and regional currents change (such a change is thought to be occurring off the east coast of Tasmania); coral bleaching;

loss of mangroves and coastal wetlands; nutrient and pollution loading (i.e. eutrophication and contamination); acidification of the ocean; and impacts on biodiversity, aquaculture and fisheries (both commercial and recreational).

Health issues - possible health issues include greater summer heat stress and associated deaths, mosquito born diseases may move poleward, food and water borne disease with changing health of the coastal regions and potentially greater impacts on indigenous peoples.

Heritage issues – risk of loss of values of heritage listed places, e.g. Great Barrier Reef, Kakadu, 12 Apostles – western Victoria.

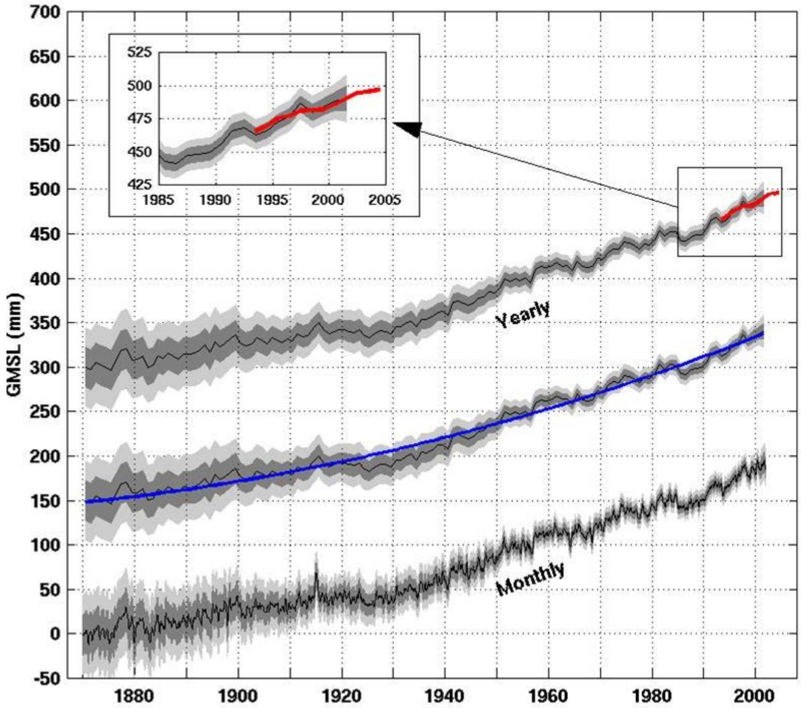

Figure 1. Global mean sea level for January 1870 to December 2001. The monthly global average, the yearly average with the quadratic fit to the yearly values and the yearly averages with the satellite altimeter data superimposed are offset by 150 mm. The one (dark shading) and two (light shading) standard deviation error estimates are shown. (From Church and White, 2006, *Geophys. Res. Lett*.)

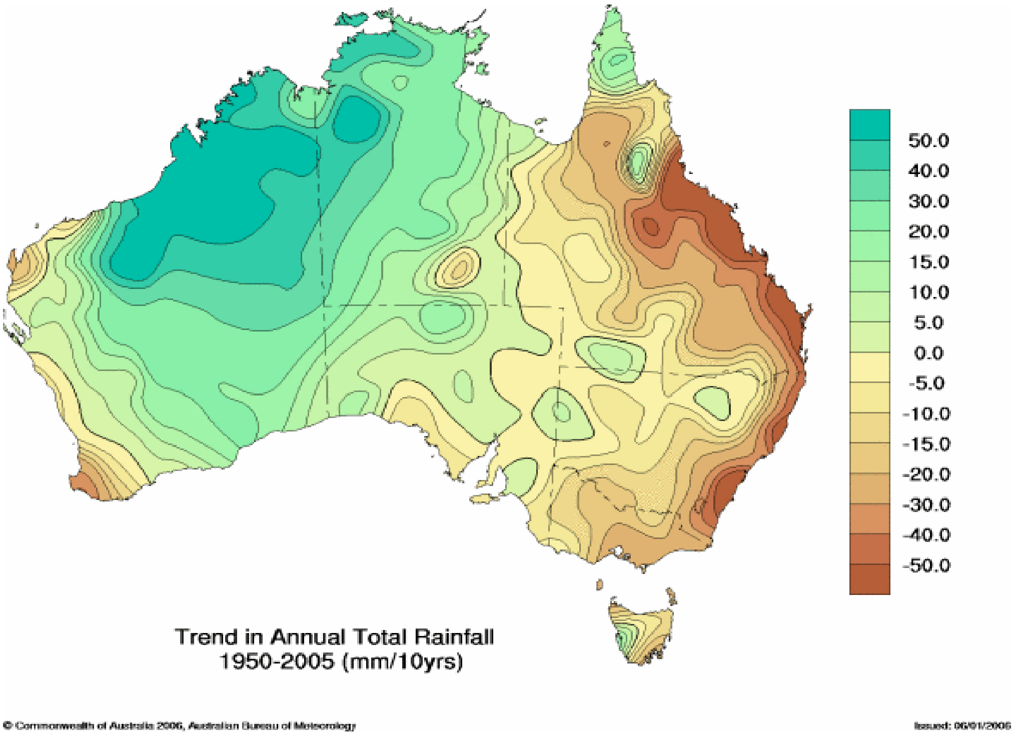

Figure 2. Rainfall trend 1950 to 2005. Bureau of Meteorology. [Note: the extent of the decline in rainfall is less apparent when the commencement year used for this figure was earlier or later than the 1950's, i.e. the 1950's were wetter than average.]

Overview of current coastal vulnerability assessment models – Colin Woodroffe, University of Wollongong

There have been a number of vulnerability assessments undertaken at a global scale, as well as national approaches adopted overseas, that may provide a useful starting point to assess vulnerability of the Australian coastal zone to climate change. There have also been several different methodologies already used around the coast of Australia, which are outlined briefly here. In an attempt to encourage a systematic approach to vulnerability analysis, a Common Methodology for coastal vulnerability assessment to sea level rise was developed by a working group of the IPCC in 1991. However, this was widely criticised in its application, particularly as it lacks flexibility, focuses on only one element of change in the coastal zone, and can not be readily incorporated in integrated assessment approaches.

Another approach at the global level has been the development of a typology, such as that developed within the Land-Ocean Interactions in the Coastal Zone (LOICZ) core project of the International Geosphere Biosphere Program (IGBP), and the related Web-LoiczView, a web-based graphical user interface to a set of clustering and visualising datasets.

There have been two attempts to develop tools using a computer program based on the Bruun Rule. One is the DIVA (Dynamic Interactive Vulnerability Assessment) tool, and the DINAS-Coast (Dynamic and Interactive Assessment of national, regional and global vulnerability of Coastal Zones to Climate Change and Sea-level Rise) database, developed by a European team, involving British, German and Dutch scientists. The other is the SimCLIM Open Framework Software System (Simulator of CLIMate Change Risks and Adaptation Initiatives), developed in New Zealand.

There have also been tools developed in the USA to assess coastal vulnerability. The Coastal Services Centre of NOAA has developed a community vulnerability assessment tool (CVAT) that supports the linking of environmental, social and economic data in the coastal zone. Another approach adopted in the USA is the coastal vulnerability index (CVI), developed by the United States Geological Survey (USGS), based on the relative contributions of six variables:

- tidal range contributing to inundation hazards
- wave height linked to inundation hazard
- coastal slope (susceptibility to inundation and rate of shoreline retreat)
- historic shoreline erosion rates, geomorphology (relative erodibility), and
- historic relative rates of sea-level rise (eustatic and hydroisostatic).

A recent extension of this has also incorporated socio-economic data.

Within Australia there have been at least five different approaches to assessing vulnerability that have been adopted in different parts of the country (see **Figure 3**). Wetland mapping has been advocated in the coastal wetlands of the Northern Territory (A). Mapping of geomorphological units has been undertaken in South Australia as a basis for inferring vulnerability to sea-level rise (B). In Queensland there has been a detailed program of mapping in relation to storm surge levels (C). Study of New South Wales beaches forms the basis for a probabilistic approach to determining future patterns of coastal erosion (D), and in Tasmania there has been a program of mapping beaches in terms of Bruun-type retreat (E).

A suite of sophisticated new technologies, such as laser mapping, offer unprecedented accuracy and could form the basis for a much more detailed assessment of coastal terrain. It is important to recognise that different factors dominate change at a series of scales around the Australian coast, and that further research is needed to determine how effectively alternative approaches, whether adopted from overseas or developed within Australia, can be used to assess or communicate vulnerability. Different climate drivers may be important in different situations, and a particularly useful framework within which to determine the relative significance of these has been proposed by the National Committee on Coastal and Ocean Engineering of Engineers Australia (NCCOE) – see **Figure 4**.

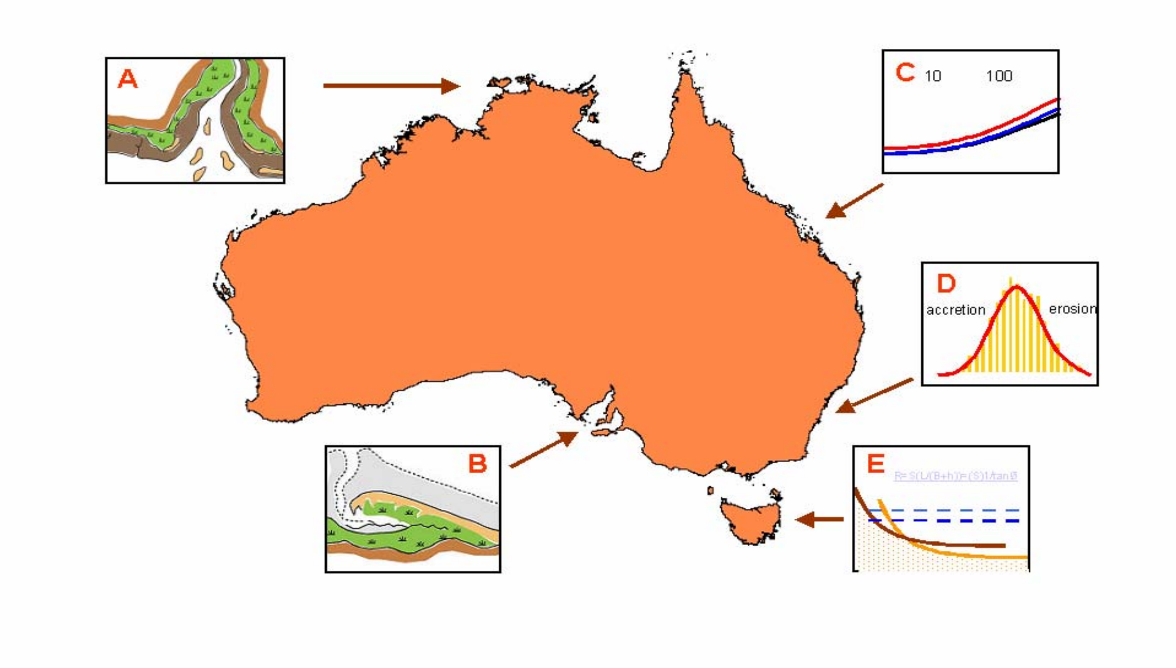

Figure 3. Schematic representation of five different approaches to assessing vulnerability around the Australian coastline.

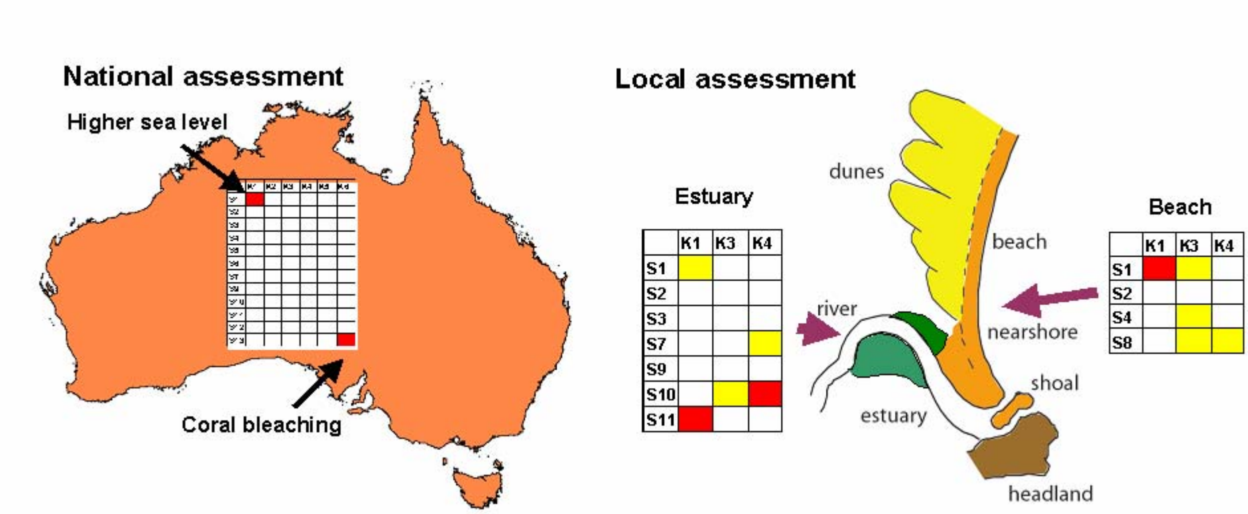

Figure 4. NCCOE Interaction Matrix Template and its possible application to climate driver characterisation at national and local scales of assessment (with prioritisation of impacts)

Risk assessment and the coastal zone - John Schneider, Geoscience Australia

A wide range of risks are present in the coastal zone, ranging from rapid-onset hazards such as tropical cyclones (wind and storm surge) and floods, to slow-onset hazards such as sea-level rise, coastal erosion and estuarine contamination. The main objective of developing risk models is to forecast the potential impact of future disasters in order to assist society in making informed risk management decisions. The challenge is to integrate approaches to risk assessment for different hazards that have been developed within different disciplines and often for different stakeholders into a consistent and holistic approach to risk management.

Natural or environmental risk models try to capture information gleaned from historic events or present-day processes, and use them to forecast the future. These models represent a simplification of the underlying physical, social or economic processes and associated impacts of various hazards (**Figure 5**).

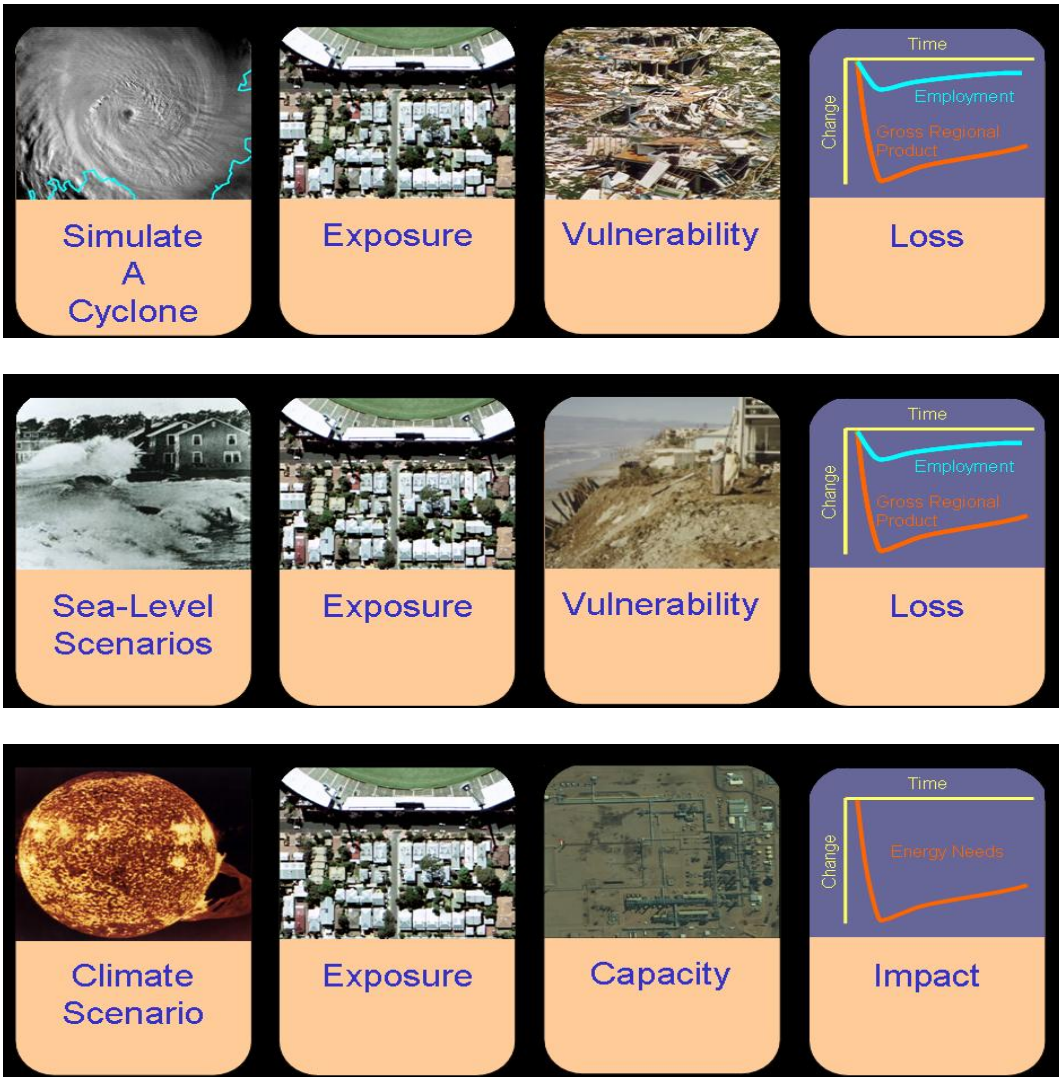

Figure 5. Schematic diagrams showing the components of a risk assessment for several different hazards including the possible effects of climate change: (top) increased occurrence of extreme events (e.g., tropical cyclone); (centre) rise in sea level and increased rates of erosion; and (bottom) increased energy demands.

As such, while it is important to make best estimates of the impact or risk, it is equally important to capture the uncertainty. This uncertainty or variability can be divided into two sources: 1) random variability, which is inherent in nature (e.g., location or magnitude of the next event), and 2) knowledge variability, which is due to our lack of knowledge (e.g., the amount of temperature rise due to climate change).

In the context of any given model or current understanding, the random component is essentially irreducible, but the knowledge component can be reduced with better data or information. Often, multiple hypotheses or model assumptions are used to capture this knowledge variability. In the coastal environment the uncertainty in climate change potential (knowledge variability) is often the largest source of uncertainty in assessing risk. Thus, this uncertainty must be captured in any risk assessment (**Figure 6**).

Risk assessments contribute to the capacity to make informed decisions about likely climate change impacts and adaptation. Risk models need to be developed to better understand the potential social, environmental and physical impacts, to understand where the greatest impacts will be, and to develop the most cost-effective adaptation or mitigation options for society.

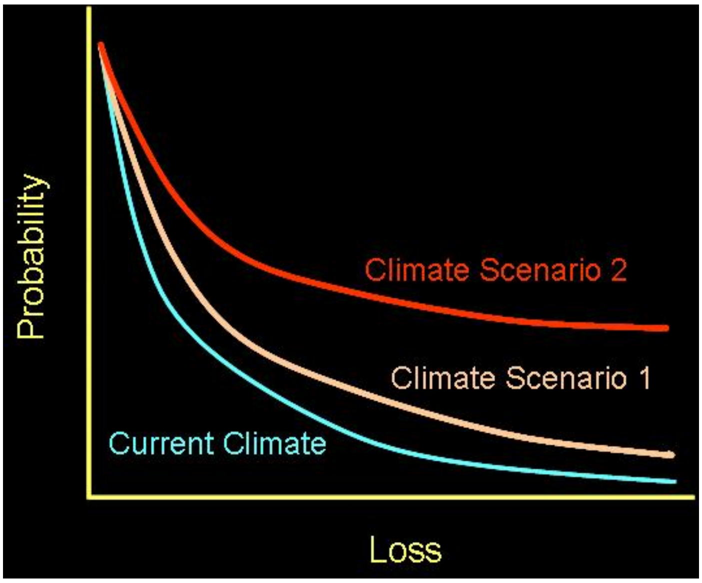

Figure 6. Risk curve showing schematically how uncertainty (knowledge variability) in climate change scenarios might be represented in representing the hazard impact.

Group Reports on Key Elements of a National Approach

Group 1: Climate and Oceanographic Drivers and Data

The group recognised that the climate and oceanographic drivers, which bring about changes at our coastlines, vary on a range of spatial and temporal scales. These drivers vary with natural climate variability such as that caused by ENSO (El Niño/Southern Oscillation), and the impacts are generally felt most strongly through changes in the intensity and/or frequency of extreme events, often associated with an El Niño or La Niña event. Anthropogenic climate change clearly adds another dimension or multiplier to the potential for impacts on the coastal environment. The drivers identified in the workshop are provided in *Table 1*, along with the processes or systems which these drivers are expected to influence. The group did not focus on biophysical aspects but noted that potential climate change impacts on biodiversity were complex and probably less well understood.

Drivers of coastal change vary on a range of time scales, although there is much overlap. Those that are expected to vary on longer time scales (hundreds of years) include sea level rise, ocean and atmospheric temperature increases, carbon dioxide increase and, potentially, changes in ocean and thus coastal circulation patterns. On medium time scales (years to decades), variations are likely to occur to coastal currents, sea and air temperature. On this timescale natural variability, such as that associated with ENSO, also operates, which in itself causes changes in other drivers such as sea level, sea temperature, coastal currents and so on. On the shorter time scale, extreme weather events such as tropical cyclones and mid-latitude storms, which in turn drive extreme oceanic conditions such as waves and storm surge, are major drivers of change at the coast. From the land side, flooding associated with severe storms also has the potential to affect coastal morphology in and around estuaries.

Sea level rise

Global tide gauge and satellite altimeter data have been used to develop spatial patterns of sea level change across the globe and more recently to detect a 20th century increase in the rate of sea level rise. These data provide a global picture of the state of sea level rise over the latter half of the 20th century. However, at local scales, many factors in addition to thermal expansion and glacier and ice sheet melt affect the relative height of sea level to the land. Examples include subsidence of adjacent coastal land due to ground water extraction or soil compaction due to building developments, as well as movements on long time scales in response to changes in ice/ocean loading since the last glacial maximum. As tide gauges are measuring the sea level relative to some surveyed land mark, any movements in land must also be quantified. These measurements can be accomplished using a CGPS (Continuous Global Positioning System) network to measure land movements. While a CGPS network has been established to accompany the tide gauge network deployed in the South Pacific as part of the AusAID funded SPSLCMP Phase III project, as yet Australia's own baseline array of tide gauges does not have a dedicated system. This deficit could be remedied by some combination of dedicated CGPS stations near existing tide gauges and the linking of tide gauge bench marks to CGPS stations run for other purposes.

Table 1: Drivers and the processes, systems or locations on which they are expected to impact.

Climate & Oceanographic Drivers	Systems, Processes and Impacts
Sea level rise	• coastal erosion • inundation • salt intrusion into groundwater, estuaries & wetlands • changes to maximum due to extreme events like storm surges
Carbon dioxide increase	• increased ocean acidification • changes to coastal chemistry • increased ocean acidification • changes to coastal chemistry
Coastal currents	• East Australian Current • Leeuwin Current
Sea surface temperature	• coral bleaching • terrestrial & marine biodiversity change
ENSO* and decadal variability	• increased frequency and intensity of ENSO • ENSO effects, e.g. storm tracks
Cyclones and storms	• change to frequency & intensity of storms & storm surges • change to storm tracks – exposing vulnerable coast • high wind and rain + low pressure drive storm surges and high waves • exacerbate coastal flooding
Wind	• wind climatology (direction & strength) changes wave climatology • likely increase in severe events
Precipitation (rain)	• storm strength rainfall causing coastal flooding • changes to precipitation affect estuarine & wetland processes
Waves	• severe event waves occur with storms & storm surges • wave climate characterises wave height, period and direction over annual cycle; has waves that propagate from remote ocean + swell

*ENSO = El Niño/Southern Oscillation

The baseline network of tide gauges in Australia does however represent a valuable database for which further analysis could be undertaken. For example, limited analysis by the National Tidal Facility has noted that sea level extremes around Australia can be characterised into zones of similar behaviour, such as the south coast, west coast etc. This differentiation is likely due to the behaviour of prevalent synoptic weather situations. Australian research on synoptic typing of weather associated with sea level extremes has revealed that the extremes in higher latitudes are driven primarily by cold fronts which affect the entire south coast in a coherent manner. While work on the modelling of storm surges under current and changed climate conditions is underway, further analysis of existing tide gauge records and an expanded modelling effort using this data are areas where more work could be carried out. Furthermore, many historical data exist, including a number of long records that are not yet in digital form. While a rough estimate to digitise all available historical tide gauge data would amount to about 100 person years of work, the most important gauges should be identified and these records digitised to harness to most useful information.

An overarching need for all coastal work (including sea level analysis), is high resolution spatial bathymetric and topographic data. Digital terrain models exist for some areas but there is no common repository for such data and most of the coastal regions do not have digital terrain models with the required resolution and accuracy.

Summary of major gaps and priority needs: sea level rise

- Mapping of land motion
- CGPS linked to the Australian Baseline Tide Gauge network
- Beach/ coastal mapping of terrain height
- Regional mapping/characterisation of extremes including observations and modelling, and any changes in the characteristics of extremes
- Digitisation of selected historical tide gauge records

Weather and Climate

The group assessed that weather and climate data are generally good shape owing to the fact that weather observations and forecasting are managed by one central, national authority - the Bureau of Meteorology. In contrast, other sources of data critical to coastal assessment such as, Digital Elevation Models, some tide gauge data, data on coastal currents, stream flow and waves, reside with State and local authorities and the private sector. However, even with meteorological data, there were some gaps and needs identified.

Firstly, there is a considerable amount of pre-1950 data not yet digitised. There are also untapped sources of data in logs from lighthouses and ships that could be analysed. Other known sources that reside outside the Bureau include Harbour Master records and State Government archives.

There is an urgent need for a consistent reanalysis of tropical cyclone data. Many techniques for estimating cyclone characteristics stem from research in the U.S. where more detailed observations are collected via aircraft reconnaissance and these may not be applicable to cyclones in the Australian region. More observations need to be taken during Australian cyclones and pilotless aircraft were discussed as a possible way in which this could take place. The methods, technology and instruments used to measure cyclone characteristics have changed over the past several decades and there is a need to homogenise these data (i.e. correct for instrument/method calibration, variability etc.). Furthermore reanalysis techniques for cyclones have changed over time and have not been applied consistently across the entire historical record.

Also discussed was the need for an Australian gridded high resolution atmospheric reanalysis dataset to provide an archive of meteorological conditions at regular intervals in time and space over at least the second half of the twentieth century. This reanalysis would form a benchmark for many studies on weather and its impacts on the coastal region. Two global reanalysis data sets are available to Australian scientists: the National Centre for Environmental Prediction (NCEP) and the more recent European Centre ERA40 data set which provide global data on key weather variables such as temperature, rainfall, pressure, humidity and wind every 6 hours from about the 1950s to present. However the spatial resolution of these data sets is coarse (about 250 km) meaning that they do not adequately represent small scale features of the weather that are important for coastal impacts. The Bureau of Meteorology LAPS (Limited Area Prediction Scheme) model could be used to generate an Australian (and surrounding oceans) reanalysis of hourly data at about 20 km separation across Australia and possibly at higher resolution over smaller populous regions of Australia. This scale of reanalysis would be especially important for generating a data archive on wind, which is the driver of ocean waves and one of the drivers of coastal currents.

More work on the analysis of extreme weather events, particularly extreme rainfall and winds, is needed along with the use of palaeoclimatological techniques for estimating extremes events before written records. Limiting analyses of extreme events to only a century or so of instrumental data means that particularly rare extreme events would not be captured.

Summary of major gaps and priority needs: weather and climate

- Pre-1950 data not digitised – opportunities for 'data archaeology'
- Need for consistent storm reanalysis
- Need for high resolution Australian reanalysis (hourly at 20 km resolution 1950 to present)
- More work on palaeoclimatology for extreme events
- More detailed observations in cyclones
- Analysis of relationship between large scale changes and changes in extremes

Waves

Waves are the process by which coastal erosion occurs. However, there has been little work on wave characteristics in the Australian region and how they may be changing with time. While it was recognised that satellites provide a source of offshore wave data from the early 1990s to present, in the nearshore region the wave rider buoy network is patchy with reasonable coverage on only some coastlines (e.g. NSW) and almost no coverage on others (e.g. South Australia). The wave parameters that are essential for coastal impact work are wave height, frequency (or period) and direction. There is probably considerable wave data held in the private sector (engineering consultants, oil companies and so on) and some discussion occurred on how researchers might get commercially owned data into the public domain. It was suggested, for example, that such data may be less commercially valuable after several years and that it may be possible therefore to get less sensitive and older data sets released into the public domain. The overarching need for a national approach to data management, which would bring together datasets relevant for coastal research and make them accessible to the research community, was also discussed.

In general, it was accepted that more wave modelling and analysis work on available data was needed, as this is an area where a major research effort has not as yet been undertaken. This effort would include incorporation of wave set-up in storm surge models and the verification of these models.

Summary of major gaps and priority needs: waves

- Inadequate wave rider buoy array for near shore waves in some regions
- Analysis of available wave data to develop wave climatology and trends in Australian region
- Wave modelling to assess how changes in offshore wave conditions change wave conditions at the coast
- Making wave data more accessible through a freely accessible web site
- Incorporation of wave set-up in storm surge models and the verification of these models

Changing ocean conditions

Changes in coastal conditions – temperatures, coastal currents, nutrient supplies and water quality – will potentially have significant impacts on the coastal region, coastal ecosystems and our use and appreciation of the coasts. Because of time limitations there was only a brief discussion of these issues at the appropriate scale for regional/coastal impact studies. The models and techniques available for estimating sea surface temperatures and ocean currents at high resolution are becoming available through the BlueLINK project, part funded by the Royal Australian Navy. The next generation model will have a resolution of about 6 km. However, the simulations will only be completed for the period 1993 to date. For climate change purposes longer simulations are required. These could be undertaken if the appropriate people and resources were available.

Climate change scenarios for the Australian ocean region and the coastal region are also required. Initial estimates of these scenarios can be constructed from the current range of World Climate Research Programme (WCRP)/IPCC model projections for the 21st century and beyond. Further work is also required to link the changing physical conditions to biogeochemical changes and the impacts on ocean ecosystems.

Summary of major gaps and priority needs: ocean conditions

- Easily accessible estimates of physical conditions (temperatures, currents) around the Australian coastline over the last several decades.
- Scenarios of future climate change for the Australian ocean and selected coastal regions.
- Linking these physical changes to changes in biogeochemical conditions and ecosystem impacts.

Group 2: Biophysical Models

In considering biophysical models the group first discussed some higher level issues. Coastal vulnerability was seen largely as influenced by erosion, but also temperature changes, rainfall, nutrient/sediment inputs (i.e. oligotrophic conditions very sensitive to these changes), biological impacts, wetland salinisation, coral reef impacts, aquaculture impacts, national heritage value, etc. The underlying principle was highlighted that climate change will affect the continent unequally, so this must be considered when developing national assessment/modelling approaches.

The group agreed that we should not only focus on the human/built environment but must also focus on the natural environment (with its own intrinsic value), and the interaction of people with the environment. It is also important to recognise that humans will respond to changes in the natural environment and there is a need to understand what the responses will be and measure them accordingly. A target outcome should be guidance for planning and conservation measures. It was considered that priority things we are trying to protect and manage with respect to climate change adaptation are losses in lives and dollars, environments, and sustainable development.

The group agreed that first order mapping for Australia should be based on geomorphology and concomitant to this shorelines should be classified based on erodability (i.e. a primary vulnerable aspect). However it seems we do not have existing information to do the latter at this time. It was considered that of the existing biophysical models familiar to the group, there was some complementarity and possible integration amongst them – it should be possible to develop a matrix of models relative to decision maker needs.

A number of selected coastal environments around Australia do have good maps or charts, for example the OzEstuaries database developed by Geoscience Australia on Australia's some 1000 estuaries, and Short's beach database that has characterised some 10,000 beaches around the country (although need to ascertain if it is digital and therefore GIS accessible). In addition, there have been a small group of good regional assessments undertaken of coastal vulnerability (or that could contribute well to coastal vulnerability), for example see Figure 3. While models such as the BRUUN rule for beaches may help identify which beaches are more likely to erode versus prograde, there is a major application problem if the rule is used out of context (i.e. it needs calibration for Australia). Looking at secondary variables may be valuable, such as sediment budgets and longshore drift, as may geomorphic indicators, such as receding coasts. It is important to also capture historical movements, storm cut and fill, etc. and relate this information to sediment budgets, however, the geomorphological historical record has not been well captured. Validation for secondary variables via case studies was seen as essential. As there is currently no basic national coastal map for Australia, the group considered that a quick brush approach was needed – including topography (STRM) and nearshore (<50 m) bathymetry.

The group identified four major gaps:

- *High-resolution topography data for the coast – especially bathymetry.* To adequately address climate change for the coast we need high-resolution

DEMs (digital elevation models), datasets for modelling (because the effects are going to be very gradual). A high level of precision is essential.

- *Representative coastal models.* A range of models are needed that will predict responses to climate change from all types of coastal systems. It will be important to determine the noise from the signal in the models.

- *Consistent geomorphology/habitat mapping of the coast*. It is important to facilitate comparative coastal mapping through cross-jurisdictional consistency of data scales and mapping methodologies. This might be achieved via a National Marine Data Committee and should involve the national Mapping Division (formerly Auslig) of Geoscience Australia.

- *Integrated, seamless relational database*. Currently terrestrial and marine data tend to be collected in a non-integrative fashion, e.g. bathymetry. There is an urgent need to develop seamless datasets for the coast that mesh terrestrial and marine derived information, e.g. we need an OzCoasts similar to the OzEstuaries prepared by Geoscience Australia.

Other limitations identified by the group include the need for determining the various threshold values that will trigger change. Biodiversity was seen as another important gap, particularly with respect to the unknown consequences of ocean acidification. Changes to nutrient fluxes/dynamics and other ecosystem services were identified as an area that has received little if any attention – and these aspects may have important consequences for fisheries, or wetland health, etc. Modelling case studies from nationally important areas may help address such gaps. The group also discussed the issue of lack of knowledge of the workings of floodplains – for example, the balance between flooding and ocean dynamics for floodplain evolution. Geomorphic indicators were considered useful for modelling, for example tidal creek expansion can be determined from geomorphology.

Priority needs for Australia

Three areas of priority need were identified by the group:

1. Consistent national picture of Australia's coastal environments (e.g. geomorphology map). This is fundamental to any assessment work on coastal vulnerability to climate change. To achieve this, seamless offshore and onshore DEM's are considered essential because of their proxy for habitat mapping. It was suggested that the Australian coast could be flown with LADS/LIDAR to gain high-quality and high-resolution topography data. At present it is not possible to separate out bathymetry from topography data for the entire coast. There are also major data gaps in shallow nearshore zone which are needed to create models. A stock-taking exercise is needed to fill in the coastal bathymetry for Australia. Also the hotspots need to be identified, i.e. the greenfields that are going to be influenced by development. Definitions of the shoreline need resolving – mangroves, wetlands, etc. Regionalisations are required to guide management plans and their implementation.

There is also an associated important issue of sea level due to the problem with inconsistent height datum on land and for the sea (bathymetry) – i.e. a seamless dataset is required. There is a requirement for better quality and more high-resolution tidal data. Wave models and storms models need to be undertaken at a national level to gain a national perspective.

2. Assessment of models showing coastal changes in condition due to climate change. Although not extensive, the group felt there was enough information available to undertake such an assessment. There have been at least five relevant Australian studies (see Figure 3) and several overseas studies to draw on. It was unclear if we have models that can predict responses of different coastal ecosystems. Other resources identified included DMAP, the DOTARS national framework for national hazards (which is probabilistic) – climate change has limited mention, but this may be considered more in the next version. SIMCLIM and AUSCLIM are front end tools that contain scenario generators – they are an open system so other models can be attached; generates sophisticated scenarios of change, but is scale dependent. A challenge will be the integration of models for management purposes. Research is needed to apply international models (e.g. USGS coastal vulnerability; FIMA, etc.) to the Australian context. Models are also needed to project changes in water temperature, acidity, nutrients etc (i.e. translation of existing models to projections of climate change).

3. Monitoring programme for environmental change is needed to detect natural variability from human-induced (anthropogenic) variability.

Data

The group considered data issues related to biophysical models. Table 2 summarises data requirements identified by the group.

Table 2: Data requirements for biophysical models to assess coastal vulnerability to climate change

Essential	Desirable	Optional
• topography • bathymetry • consistent geomorphology (seamless DEM) • biophysical (temp., nutrients, etc)	• geological maps • aerial photos • satellite images • water levels • sedimentation for climate change time-scales	• predictive models of coast attributes • modelling of entire coastline

The major issues related to data were identified as follows and all were believed to relate to resolution and scale:

- procurement (availability)
- costs
- coverage
- accuracy and precision
- common datums
- applicability

Importantly, it was also recognised that not all data or processes can be mapped and studied at a national scale. The use of case studies was seen as useful for applying high resolution mapping to gain better understanding of the underlying processes (i.e. how and why systems change). This can then feedback into refining the models. The study of pristine systems may provide base line information. Mapping needs to be based on agreed principles and methods.

Top Research Priorities

- Build national picture of coastal environments/habitats based on geomorphology (and incorporate biophysical indicators of climate change).
- Review and assess (verify) existing vulnerability assessment models to Australian coast (e.g. SIMClim, etc).
- Generate first order storm-surge/flooding vulnerability mapping based on national topographic database (DEM). Identify low-lying areas.
- Develop physical models and apply biological information in developing environment management tools. Use a risk research approach (e.g. DMAP).
- Monitoring of coastal biophysical changes (e.g. geomorphology, biodiversity), with the use of a single national organisation for co-ordination, implementation and archiving.

Group 3. Information Systems, Applications and User Needs

General Issues

Gaps in our national data sets need to be identified and existing data sets need to be characterised. For example, descriptions of spatial and temporal scales used to date need to be made available. Finding a means to search records from a range of different agencies was suggested. The focus needs to be on derivation of appropriate and deliverable information from the data rather than on data itself. The group felt there is a need to make remote sensing data more readily accessible to users – this requires adequate infrastructure and interoperability (and funding) issues need addressing (e.g. bringing together of data from different agencies) – particularly in light of web-based user environment. How would a distributed system best work to service the local user? The future may lie with linking remote sensing capability with biophysical modelling capability. Appropriate interpretation of GIS mapping spatial data is required to assist decision-makers.

The need for a maintenance environment rather than a data-capture framework was identified. The need to develop a business case to ensure continued funding for data was also raised. The merging of bathymetry and topography data was highlighted as a critical need. OzEstuaries was mentioned as an example of a good information system (i.e. not just data) – it includes threats and issues. The Sentinal fire management system was also suggested as a good model. A National Coastal Management System to support the assessment of Australia's coastal vulnerability was suggested but there were different viewpoints about what a coastal information system was and what it could provide, including:

- simple database of information about the coast and processes affecting the coast
- real time monitoring system for processes affecting the coast
- database of information coupled with a risk management guideline or framework so that users can apply this to assess coastal vulnerability/risk for their area
- database of information integrated with modeling/assessment tools so that users can calculate coastal vulnerability/risk for their area.

The general consensus was that to be widely used and maintained, the system would need to provide interpretation/analysis/ tools for vulnerability assessment as well as data. The concept would need a strong driver (i.e. Government). A cost benefit analysis of having the information when needed versus not having it was also identified as useful.

An important lack of built infrastructure data was also identified by the group, for example ports are vulnerable to sea level rise and some $210 billion worth of goods go through ports each year. The point was also made that many airports are also only a few metres above sea level and therefore vulnerable to storm surge. We need to look at the potential impacts on transport infrastructure. Apparently one third of ship losses are due to bad weather and an increase in storms is predicted under climate change. Thus there may be the need for more search and rescue operations and there is the potential for an increase in major oil spills. It seems the Australian Maritime Safety Authority funds the States to acquire data – there needs to be collaboration so that data are relevant and shared.

An implementation strategy was seen a crucial to successful integrated coastal zone management (ICZM). This is dependent on clarifying boundary issues, legislative guidelines and decision-making roles. The group felt that integrated assessment needs to happen within a risk management framework to provide the best information. Governance and cross jurisdictional issues need working through. Retrospective trend analysis (against a baseline) was seen as crucial for establishing change and thresholds for change to trigger action.

Scenarios and Case Studies

The question was put to the group, 'How should scenarios and case studies feature and are there any priorities?' The group felt that on the whole scenarios and case studies were both important tools. Case studies were seen as more valuable if they were theme based e.g. residential environments, port environments, natural environments. It was acknowledged that case studies may be useful for demonstrating cost benefit type analyses in priority areas, and for helping to understand the breadth of information needs. A couple of case study approaches were suggested: hazard based approach (define threats and hazards and prioritise), and geographic approach (prioritise regional exposure to hazards).

Fundamental Datasets

The following list was determined by the group as fundamental datasets required to underpin the use of tools for the assessment of coastal vulnerability:

- *Topography/nearshore bathymetry*: a national intertidal elevation model that includes the subtidal zone (+50 to -50m?). This is an important enabling layer for all modeling. A detailed but nationally consistent map of bathymetry integrating seamlessly into topography was considered to be a fundamental data need.
- *Satellite imagery*: the coordinated acquisition and storage of (nationally consistent) satellite data for all to use should be a national goal, e.g. Queensland government is setting up a plan to regularly supply high resolution data and NSW is also doing this for the coastal zone. There is a need for temporal sequence of quality remote sensing data for the whole of Australia to be made widely available – to underpin better informed decision-making and management. A national acquisition plan is needed to collect coastal imagery for the whole of Australia – considered to be an extremely useful tool for addressing a wide and growing range of objectives.
- *Imagery and DEMs* (digital elevation models) are fundamental.
- *Historical data sets*, trends analysis.
- Derived biophysical information from remote sensing at regional to continental scale.
- Ecosystems, planning zones, etc: these are all available already.

Priority needs for Australia

The group identified their six top research priorities and recommended three priority streams of activity:

- Develop a long-term governance framework for the coastal information system underpinned by the drivers.
- Work on priority activities, data collection, e.g. Lidar (mapping of topography).

- Specific research projects – these can be scoped after full workshop outcomes are known.

Top Six Research Priorities

1. An inventory and gap analysis of multi-temporal spatial information, maps, imagery and image analysis products (from the local to the continental scale) including air photos, bathymetry, imagery, etc.
2. The extraction of intertidal and nearshore depth/elevation estimates from multi-temporal Landsat scenes.
3. An analysis of digital airborne (imaging) systems underpinned by the National Coastal Image Acquisition Plan; i.e. scoping what tools are out there, what results are possible. This research should demonstrate current capabilities and compare the potential outputs from available or planned sensors in order to anticipate and plan for future data collection.
4. Determine the scope, i.e. assess stakeholder needs for the coastal vulnerability information system.
5. Participate in hazard driven case studies to demonstrate information needs, develop models and tools, etc.
6. Support the Aus-International Oceans System proposal.

Group 4: Socio-Economic Integration – Models, Data & Stakeholder Needs

General Issues

The group agreed that to date socio-economic integration has not been well addressed and that almost no social and economic research related to climate change and the coast has been conducted as yet. Some important issues identified regarding the directions for socio-economic approaches to coastal vulnerability were:

- *magnitude of damage costs* and identifying indicators of damage cost
- *understanding physical damage* (e.g. of infrastructure or social systems) in order to move to costing damage (e.g. for cyclone damage the direct economic effect is repair cost) [Geoscience Australia has adapted US Hazard program to Australian context]
- *cost benefit assessments of adaptations* (IGCI have developed tools for this)
- *recovery costs*, e.g. case study 'Monash Model' can look at the relationships between different economic sectors
- *infrastructure interdependencies* – e.g. social, agricultural – anything that behaves as a system that we depend on
- *programme for informing people on extreme events* – there is a lack of community understanding; education programmes are required to address this, as well as change management, and risk management (also insurance implications)
- *strategic planning/conceptual framework* – key role for Government coordination – with all levels onboard; good starting point is modelling people movements in the coastal zone in the context of socio-economic factors (e.g. baby boomer effect, trends in tourism) – but how to manage for longer-term?
- *preparedness and awareness* – are coastal communities currently prepared for an extreme event?
- *property rights issues* – people have an expectation that their property rights will be protected (by government). Local governments are restricted in denying development applications due to historical decisions, e.g. canal estates
- *communication* – across all jurisdictions and community; make the science and risks available to property owners. Need a communication strategy and mechanisms for the science to get to the public and to inform the policy framework – needs to be monitored and evaluated for effectiveness
- *health aspects* – likely to affect people quickly, thus community will respond quickly; links between AMA and AGO – need to be part of a communication strategy
- *response to impacts* – educational aspects – community capacity building to be informed by science; evacuation planning.

Stakeholder Tools

The group felt that stakeholders need tools with which to develop and build scenarios. However the tools to integrate the biophysical with socio-economic data are not available as yet. We are also still missing a comprehensive set of tables to document the economic patterns of the coastal zone, i.e. input/output tables are a major gap in our databases. These could form a basis for integration and for examining scenarios. It would be helpful to utilise small-scale GIS grids and link economic values with spatial values – i.e. comprehensive economic data at smaller than LGA levels. Identification and mapping of sectors and features under threat, such as agriculture, forests, ecosystems, was also seen as an important stakeholder tool.

The group identified that we don't currently have a methodology to understand people's perceptions on property rights issues and we don't have a good knowledge of the number of properties in high risk areas. The insurance and banking industries should be engaged in this issue.

A strong need for appropriate planning tools that are jurisdictionally consistent was also identified by the group. The example of South East Queensland was used, where a regional plan was developed, driven by the State treasury and utilising a whole of State government approach. Regarding education and awareness tools for that contribute toward a communication strategy.

Case Studies

The group proposed six case studies that could be presented to a range of stakeholder meetings:

1. The effect of long-term sea level rise on a coastal community, e.g. Tuggerah Lakes, NSW
2. The impact of a category four cyclone on the Gold Coast region
3. The implications of latitudinal shift in land capability of primary industry in the coastal zone of NSW and QLD due to climate change
4. Simulation modelling of damage and loss of a type location to provide 'community awareness' information
5. Evaluation of social and economic drivers in the Bass/Surf Coast of Victoria
6. Assess the vulnerability of marginalised indigenous communities in the Gulf region, northern Australia.

Directions and Research Priorities

The group identified four key steps forward and four major research priorities, with the important take home message being the need for a well defined, well implemented and well evaluated, *Communication Strategy* to help mainstream climate change and assist with adaptation.

The four steps are:

1. Clarify governmental, governance and institutional arrangements in relation to roles and responsibilities for assessing and communicating coastal vulnerability.

2. Initiate processes to aid the mainstreaming of coastal vulnerability into strategic policy and the statutory planning processes in terms of jurisdictionally consistent planning instruments.

3. Develop a proactive and performance monitored communication strategy, and incorporate dynamic community education and awareness tools.

4. Develop and maintain databases that encompass key socio-economic information deficiencies in relation to coastal vulnerability by way of:

- societal perceptions and attitudes to properties at risk and responsibility for protection of private properties;
- adverse biophysical conditions and properties at risk and responsibility for liability; and
- economic data by way of spatially focussed regional input-output tables and related economic information.

Research Priorities

1. Governmental relations, governance and institutional arrangements to address roles and responsibilities for vulnerability assessment and adaptation.
2. Evaluate socio-economic drivers behind people moving to the coast
3. Audit land, properties, industries and people at socio-economic risk.
4. Build communication bridges to facilitate issue driven research as a partnership between stakeholders and scientists (natural, physical, social).

Plenary Discussion: Additional comments

A national cooperative approach to coastal zone management and assessment was called for, with the identification of national and international best practice. To support this, a review of existing models needs to be undertaken and applied to the Australian context. A rapid initial national assessment was considered to be useful, to broadly outline relative vulnerabilities, e.g. identify low lying areas around the coastline. The best datasets would need to be identified and the issue of high water levels needs to be addressed. In the medium-term we need to develop a national picture by developing comprehensive geomorphology/habitat mapping of the coast (the 1970's photography of the coast provides a high resolution contribution). At the more detailed local scale, local case studies where bathymetry and topography have been stitched together are needed, e.g. storm surge. There is a need to model how our coast is going to behave and to develop complementary guidelines and tools – the use of scenarios is valuable here. An Australian coastal monitoring and development strategy was suggested as valuable.

The need to engage users all the way through this work was agreed. The involvement of local government was seen as important to mainstream coastal vulnerability into policy and constituency processes. A need to research the communication bridges between scientists and the community was also highlighted.

Several issues were raised as needing further consideration beyond the focus of the workshop; an integrated coastal observing system; the issue of water quantity and quality; and the implications of climate change to ecosystems and biodiversity. The National Collaborative Research Infrastructure Strategy (NCRIS) was suggested as a source/process to support marine and coastal observing systems. OPSAG (oceans policy science advisory group) was raised as a path to develop relevant observing systems (i.e. as for deep earth sampling via IODP). Integration of ocean and coastal observing systems could be problematic.

Regarding drivers, it seems that spatial differences are significant enough to warrant regional assessments of drivers. Thus one national approach may be problematic and the adoption of multiple approaches may be more appropriate. There are regional realities in Australia, for example the wet/dry tropics, the calcaranite coasts of WA, etc., and the national framework approach is one that should be implemented with regional components. The point was raised that global assessments have already been undertaken, so it would be sensible to look at these and determine what they say about Australia (e.g. LOICZ, SimClim, etc). Concomitantly, it is important to ensure that the IPCC Working Group 2 reflects the way things are for Australia.

In terms of priorities and proceeding, it was suggested that we review existing global assessments and ascertain what they say for Australia, and how this agrees with what we know now (this may potentially form some type of baseline). An audit of work already undertaken in Australia was also identified as a useful basis to guide a more long-term framework approach. Case studies were seen as useful to test proof of concept or to test new methods in data rich areas – also for undertaking modelling or monitoring. The featuring of islands as case studies was also raised due to their higher vulnerability. The importance of balancing biophysical with socio-economic drivers of change was highlighted as was the need to incorporate both aspects into risk assessment. Scenarios were also seen as useful tools to help achieve and communicate this integration. A strong outcome of the workshop that was seen as a high priority by most groups, was the need for seamless topography (DEM) and bathymetry – as this will underlie a lot of coastal issues.

Research Priorities

1. Undertake an initial national assessment of coastal vulnerability to climate change to highlight relative vulnerabilities
2. Review, and utilise where appropriate in the initial assessment, international and regional coastal assessments which generated useful Australian information
3. Develop approaches for the national assessment that allow for incorporation of higher resolution information from case studies
4. Ensure that the initial national vulnerability assessment engages with key stakeholders and decision makers, including local government.

Appendix 1

Australian Greenhouse Office

Assessing and Mapping Australia's Coastal Vulnerability to Climate Change: Expert Technical Workshop

TUESDAY 13 DECEMBER 2005

Session One: Setting the Scene
Chair: Jo Mummery

4.00 Welcome and context: assessment of coastal vulnerability for decision-making and climate change adaptation.
Jo Mummery

4.15 Overview of climate and oceanographic drivers
John Church

4.30 Overview of current coastal vulnerability assessment models
Colin Woodroffe

4.40 Risk assessment and the coastal zone
John Schneider

4.55 Impressions from recent Disaster Reduction Conference
Paul Grundy

5.05 General discussion

from 6.00pm Pre-Dinner Drinks, Common Room University House

6.45 Workshop Dinner: Common Room University House
Dinner Speaker: e.g. *Will Steffen* - Nature of Climate Change and Vulnerability

WEDNESDAY 14 DECEMBER 2005

Session Two: Introduction and Australian Government Requirements
Chair: Jo Mummery

9.00 Australian Government Requirements
Ian Carruthers

9.15 Instructions for Breakout Groups
Gina Newton

Session Three: Breakout Groups on Key Elements of a National Approach
9.30am Expert Breakout Groups x 4

Group 1: Climate and Oceanographic Drivers
Chair: *John Church*
Rapporteur: *Kathy McInness*

Group 2: Biophysical Models
Chair: *Colin Woodroffe*
Rapporteur: *Andrew Heap*

Group 3: Information Systems, Applications and User Needs

Chair: *Robert Kay*
Rapporteur: *Sue Fyfe*

Group 4: Socio-Economic Integration: Models, Data & Stakeholders
Chair: *Peter Waterman*
Rapporteur: *Renee Bartolo*

10.30 to 11.00 Morning Tea

11.00 to 12.00 Breakout Groups x 4 continue

12.00 to 1.00 Lunch
Rapporteurs prepare PowerPoint presentations

Session Four: The Way Forward - Report Back and Discussion
Chair: Robert Kay
[Group Rapporteurs report back with PP presentations: 10 minutes each plus 5 minutes for questions]

1.00-1.15 Group 1: Climate and Oceanographic Drivers
Rapporteur: Kathy McInness
1.15-1.30 Group 2: Biophysical Models
Rapporteur: Andrew Heap
1.30-1.45 Group 3: Information Systems, Mapping and Data Sets
Rapporteur: Sue Fyfe
1.45-2.00 Group 4: Socio-Economic Integration; Models, Data & Stakeholders
Rapporteur: Renee Bartolo

2.00 – 2.40 **Plenary Discussion: A consensus on a national approach (the what)**
Chair: Robert Kay

2.40 – 3.00 **Afternoon Tea**

Session Five: Plenary Discussion: Way Forward – How to Do It
Chair: Will Steffen

3.00- 3.10 Panel of Chairs (4 Chairs x 2minutes each) –
top 4 steps for way forward and top 4 research priorities each

3.10 – 4.00 Discussion – How to proceed – setting priorities Optimal National Approach, Priorities, Meeting other Coastal Objectives

4.00 pm **Workshop Close**

Appendix 2

Assessing and Mapping Australia's Coastal Vulnerability to Climate Change: Expert Technical Workshop, December 2005

Group 1: *Climate and Oceanographic Drivers & Data*	Group2: *Biophysical Models*	Group 3: *Information Systems, Applications & User Needs*	Group 4: *Socio-Economic Integration: Models, Data & Stakeholder Needs*
Chair: John Church	*Chair:* Colin Woodroffe	*Chair:* Robert Kay	*Chair:* Peter Waterman
Rapporteur: Kathy McInness	*Rapporteur:* Andrew Heap	*Rapporteur:* Suzanne Fyfe	*Rapporteur:* Renee Bartolo
Debbie Abbs	Peter Cowell	Brendan Brooke	Pamela Abuodha
Steve Blake	Ian Eliot	Arnold Dekker	Stephen Cole
Bob Cechet	Peter Harris	Trevor Gilbert	Chris Crossland
Mike Coughlan	Matt Hayne	David Hanslow	Paul Grundy
Bill Mitchell	Scott Power	Adam Lewis	David James
Roger McLean	Bob Schwartz	Kirrilly Pfitzner	Michael Nolan
Will Steffen	Chris Sharples	Stuart Phinn	Craig Roy
Neil Tindale	Dick Warrick	Alan Stokes	John Schneider
Rob Tucker		Peter Todd	Bruce Thom
			Peter Urich

All Groups are to consider the following questions in light of their group topic only, also bearing in mind decision-maker needs:

1. What do we know?
2. What worked/s well?
3. What are the major gaps?
4. What are the priority needs for Australia?
5. Data: What is essential, desirable and optional; and what are the issues?
6. What are the issues related to resolution and scale?

Further Group Objectives:

Group 1:
- What are the critical thresholds involved?
- Comment on the NCCOE template.

Group 2:
- What is the utility of the various approaches to Australian context?
- What are the priority research aspects?

Group 3:
- Consider concept of Coastal Information System.
- How should scenarios and case studies feature – and are there any priorities?
- What tools do users need?
- What fundamental data sets underpin the tools?
- Consider issue of topography and bathymetry.
- Consider usefulness of national imagery.

Group 4:
- What are the directions for socio-economic approaches to coastal vulnerability?
- What tools do stakeholders need?
- How should scenarios and case studies feature – and are there any priorities?

Appendix 3

Participants in Assessing and Mapping Australia's Coastal Vulnerability to Climate Change: Technical Workshop; University House, ANU Campus, Canberra

Name	Institute	Field of Expertise
Debbie Abbs	CSIRO MAR	climate change science
Pamela Abuoda	Wollongong University	coastal zone
Renee Bartolo	Consultant, NT	GIS
Steve Blake	ANZLIC	spatial information
Brendan Brooke	Geoscience Australia	coastal section
Ian Carruthers	AGO, DEH	climate change policy
Bob Cechet	Geoscience Australia	climate – extreme events
John Church	CSIRO MAR	oceanographer
Stephen Cole	NAVY	environment
Mike Coughlan	BOM, Nat. Climate Ctre.	climate
Peter Cowell	Sydney University	coasts
Chris Crossland	Uni. Sunshine Coast	coastal studies
Arnold Dekker	CSIRO Land & Water	remote sensing - coastal
Ian Eliot	Uni. Western Australia	coastal geomorphologist
Suzanne Fyfe	ERIN, DEH	Coastal GIS, data
Trevor Gilbert	Aust. Maritime Safety A.	maritime data/disaster
Paul Grundy	Monash University	coastal disaster
David Hanslow	DNR, NSW	coastal management
Peter Harris	Geoscience Australia	geomorphologist; estuaries
Matthew Hayne	Geoscience Australia	geologist
Andrew Heap	Geoscience Australia	geologist
John Higgins	AGO, DEH	climate change policy
David James	Uni. Sunshine Coast	economics, social, impacts
Robert Kay	Coastal Zone Manag.	coastal planner
Adam Lewis	ACRES, Geoscience A	remote sensing
Kathy McInnes	CSIRO MAR	oceanographer
Roger McLean	Uni. NSW, ADFA	coastal
Bill Mitchell	Nat. Tidal Facility	tidal measurement
Jo Mummery	AGO, DEH	climate change policy
Gina Newton	AGO, DEH	climate change policy
Michael Nolan	Maunsell Australia	sustainability consultant
Stuart Phinn	Queensland University	coastal veg; remote sensor
Kirrilly Pfitzner	ERISS, DEH	GIS
Scott Power	BoM, Research Centre	climate modelling
Craig Roy	CSIRO WfO Flagship	marine
John Schneider	Geoscience Australia	risk assessment
Bob Schwartz	Qld	cyclones
Chris Sharples	Tasmania	mapping; geoscience
Will Steffen	ANU, CRESS	climate change
Alan Stokes	Nat. Seachange Taskf.	ED
Bruce Thom	Sydney University	coastal geographer
Neil Tindale	Uni Sunshine Coast	atmospheric chemist
Peter Todd	Qld. Dept. NR & Mines	marine cadastre/legislation
Rob Tucker	Dept. Env. & Cons. SA	coastal engineer
Peter Urich	IGCI, Waikato Uni, NZ	coastal modeller SimClim
Dick Warrick	New Zealand	coastal modeller
Peter Waterman	Uni Sunshine Coast	coastal vulnerability
Colin Woodroffe	Wollongong University	coastal GIS biogeographer