University of Wollongong

House of Representatives
Standing Committee on Climate change, Water, Environment and the Arts
Inquiry into climate change and environmental impacts on coastal communities

Submission by PROFESSOR COLIN D. WOODROFFE

I would like to make a submission to the inquiry into climate change and environmental impacts on coastal communities, based on my experience as an Australian coastal geomorphologist, my involvement as a lead author on the coastal systems chapter of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report, and my participation in several assessments of the vulnerability of parts of the Australian coastline, including as a member of the steering committee for the first-pass national mapping of shoreline stability.

Summary

Sea-level rise poses particular threats that exacerbate existing natural hazards for coastal systems around the world, with heavily populated delta plains of Asia and the low-lying islands on coral atolls particularly at risk.

Whereas Australia appears less vulnerable than these international hotspots, the Australian coast seems likely to be especially impacted by climate change because such a large proportion of the Australian population lives along, or visits, the coast, and tide gauges indicate that the sea is rising at an accelerating rate, with several places experiencing rates that are above the global average.

The National Cooperative Approach to Integrated Coastal Zone Management provides a framework but needs further implementation. There is an important role for national coordination, for example in determining sea-level trends and their implications around the nation.

As population pressures increase in the coastal zone it is important to maintain the natural functioning of coastal systems.

There are 6 climate drivers that can have an impact on the coast (sea-level rise, temperature rise, carbon dioxide concentrations, storm occurrence, wind-wave changes and changes to rainfall and runoff). Sea-level rise poses the greatest challenge, but particularly when associated with extreme events such as storm surges.

It will be essential to adapt to the consequences of climate change on the coast, and the range of options include protection, accommodation and retreat. Prudent planning now can minimise future disruption.

It is necessary to extend preliminary assessments of coastal vulnerability, and to develop tools and models to undertake more detailed appraisals of vulnerability.

Decision making is particularly fragmented in relation to the coastal zone, and national coordination is needed, with wider availability of coastal data.

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Introduction

Australia has a particularly varied and iconic coastline and a large proportion of the population lives along the coast. Many aspects of both natural and socio-economic systems on the coast are threatened by climate change. Australia probably encapsulates a wider range of coastal systems than any other nation, from diverse coral reefs of the tropics, through a range of temperate shorelines, to the rugged and isolated shores of its various island and Antarctic territories.

International perspective

Recent tragic events, such as the Indian Ocean tsunami (2004), Hurricane Katrina (2005) and Cyclone Nargis (2008) have served to emphasise that coastal areas are already vulnerable to numerous hazards. Although tsunami are unrelated to climate change, and the other disasters are within the magnitude of events already known to affect their regions, the impact of such catastrophes seems certain to increase in the future, primarily because of the growing coastal populations that mean larger numbers of people and more intense development concentrated in the coastal zone. In Australia, the memory of the devastation caused by Cyclone Tracy, which was not an especially intense storm, tends to have faded. The preparedness of north Queensland communities meant that Cyclone Larry (2006) resulted in less destruction than that wreaked by lesser events such as Katrina elsewhere, and the impacts that Cyclone Ingrid (2005) caused to aboriginal communities in remote Northern Territory islands received less attention than the devastating events overseas.

I believe that my role in reviewing literature as part of the IPCC process enables me to take an international perspective. The IPCC correctly emphasised the vulnerability of low-lying deltaic plains, particularly the large deltas of the neighbouring Asian region with rapidly expanding megacities such as Shanghai, Guangzhou, Hanoi, Ho Chi Minh City, Calcutta and Rangoon, that share with New Orleans a susceptibility because they are founded on low-lying plains that are subsiding or compacting, and which are already subject to inundation through a combination of tidal and riverine processes accentuated as a result of climate change (particularly sea-level rise). For example, Bangladesh is a nation, the greater part of which is formed by the delta plains of the Ganges and Brahmaputra rivers and is inundated each year during the monsoon, with coastal regions repeatedly threatened by cyclones from the Bay of Bengal. In Europe, the Netherlands has traditionally empoldered intertidal land by building dykes, and much of coastal land is below high tide level, and continues to subside, requiring further protection by seawalls. Another very vulnerable type of coast comprises low-lying islands, and those nations that consisting entirely of atolls face particular threats. The Maldives is one such nation, comprising more than 1000 islands with almost no land rising more than 3 metres above sea level, and where most of the villages lie only a few tens of centimetres above high tide level.

In comparison with these nations, the coast of Australia would appear to have far fewer imminent threats. However, there is no justification for complacency. Although the Australian continent is generally stable, remote from former icesheets and hence those areas that are undergoing subsidence in response to the isostatic compensation associated with icemelt, and does not have the enormous populations of more populous coastlines, there are causes for concern. The suite of high-resolution

SeaFrame tide gauges installed to monitor sea level around Australia since the 1990s show a rising trend at all stations, with rates that significantly exceed the global average in northern and western Australia. An unusually high percentage of the Australian population is focused along the coast, and rapid rates of coastal population increase will accentuate the threat to coastal communities. Indigenous communities, such as those of the central Torres Strait islands, and communities with a low adaptive capacity such as the Cocos Malays on the Cocos (Keeling) Islands, present a unique set of concerns.

Existing policies and programs – coastal zone management

Although there are an increasing number of policies and programs related to coastal zone management at state and federal level in Australia, these are fragmented, and have evolved in a piecemeal way. Despite the large number of coastal inquiries and reports in the 1980s and 1990s, the outcomes that have eventuated since these reviews do not adequately reflect the apparent concern for the health of Australian coasts. As previous reviews have indicated, the coast suffers from a division of responsibilities over three tiers of government and agencies have jurisdictions that do not take into account the dynamic nature of the coast. Various responsibilities are circumscribed by tidal levels that do not translate into clear or logical boundaries on the ground. In this regard, it would be far better to treat the coast as seamless between hinterland and shallow water, rather than to define according to arbitrary lines such as high water mark that cannot be readily identified.

The Commonwealth government should provide clear guidance and leadership at a national level, and there is a need for closer working relationships with states. A clear example of a need is to define a rate of sea-level rise and to take action in terms of elevations at which building might be allowed, floor levels in relation to flood or storm surge, or setbacks that should be enforced. The approaches adopted by different states vary in this respect. No single value is likely to apply across the nation, but a framework is needed within which such an issue is considered. Compounding any basis for such levels is the complexity of tidal processes and shoreline processes, such that even where the frequency of rare events may be known from tide gauges, it remains difficult to translate this to adjacent embayed or low-lying coasts, and probably totally misleading to apply to remote coasts, such as those of northwestern Australia.

The National Cooperative Approach to Integrated Coastal Zone Management, framework and implementation plan, formulated by the Natural Resource Management Ministerial Council in 2006, sets the right directions, but relatively little progress appears to have been made towards its implementation. In terms of climate change, section 3.1 outlines a three point strategy. The first stage involves identifying international best practice, national research and response priorities and potential impacts on the coastal zone. I was involved in assessing international approaches and have been part of initial attempts at national assessment, but believe that much more can be done in this regard. The second component involves building a national picture of vulnerable coastal areas and better understanding risks and interactions with other stresses. This is an important and complex task and requires a clearer national focus, and further resourcing. The third part addresses coastal modelling and this should be based on wide consultation. It is inevitable that at this stage there will be different

approaches that have attracted some preliminary research in various states, but broader discussion and workshops are needed at national level to assess the strength of various different approaches and build a network of researchers.

Section 3.2 of the framework and implementation plan recommends development of guidelines and tools for coastal managers and planners, including risks, liabilities and adaptation options. This has not commenced and a key foundation for this will be better availability of information on coasts and some form of coastal information system as discussed below.

Coastal population growth and sustainable use of coastal resources

The rapid growth of population in coastal towns, together with the 'seachange' phenomenon is well documented and has led to the formation of a Seachange Taskforce. Such growth of people living and holidaying on the coast has resulted in various impacts, such as pollution and loss of habitat. I will not list these impacts, although they are certainly cause for concern. It is also important to recognise that there is vastly more of the Australian coast that is remote and inaccessible, and also a significant proportion that is already part of a national park, a marine park, Aboriginal land, or otherwise afforded some protection.

We only really consider coasts as vulnerable if they are inhabited. The greatest destruction and loss from climatic events occur where settlements have been built and it is clear that adequate building codes, timely warnings and an ongoing program of public awareness with evacuation plans will become even more necessary as populations expand in storm-prone areas.

Sustainable use of coastal resources needs to include maintenance of the natural behaviour of coastal systems. For example, the movement of sand along a coast from point of delivery by a river to a point of accumulation (such as the enormous sand islands ie Fraser Island. on the east Australian coast) is easily disturbed by human activities. In Australia there are fortunately relatively few cases where human disruption of such natural processes has resulted in the need for expensive engineering works (the sand pumping at the mouth of the Tweed River is one case), and it will be important both for the preservation of the natural values of the Australian coast as well as for economic reasons to ensure that this remains the case, with careful planning where infrastructure such as ports need to be constructed that will interrupt the natural passage of sediments along the coast.

The impact of climate change on coastal areas

I believe that it is correct to identify sea-level rise as the most significant threat to our coastline, but it is also important to recognise that there are a series of other climate variables that also pose a threat to the coast. There appear to be 6 climate drivers that can have an impact on the coast (sea-level rise, temperature rise, carbon dioxide concentrations, storm occurrence, wind-wave changes and changes to rainfall and runoff).

Carbon dioxide

We are most certain about increased carbon dioxide concentrations. The increase in atmospheric carbon dioxide concentrations is known to be related to anthropogenic forcing through the burning of fossil fuels. Recently it has been realised that this is also related to an increase of carbon dioxide in the oceans, resulting in a decrease in pH, termed ocean acidification, which appears very likely to have negative consequences for calcifying organisms such as corals. Research on this topic is in its infancy, and more needs to be undertaken.

Temperature

There is firm evidence that temperatures are increasing, both over land, and in the ocean. It appears that the Tasman Sea off eastern Australia is one of the fastest warming parts of the Southern Hemisphere ocean due to warming and poleward extension of the East Australia Current. Warming has been associated with poleward extension of the range of some organisms, such as marine algae. There is now incontrovertible evidence that increases in ocean temperature have led to an increased frequency of coral bleaching, in many instances resulting in death of corals and degradation of reefs. The threat to the Great Barrier Reef is a major cause of concern.

Sea-level rise

However, I believe that it is the rise in sea level, associated primarily with thermal expansion of surface waters, but accentuated by icemelt, that remains the most widespread concern in relation to coasts, within Australia and elsewhere. Despite the relatively stable nature of the Australian continent, in contrast to North American and European shores where the impact of sea-level rise is accentuated through gradual subsidence of the land, sea-level rise is detectable. It has been observed both over the long term (the Sydney and Fremantle tide gauge records suggest around 1.2 mm per year of rise on average during the 20th century, slightly below the global average), and since the installation of high-resolution SeaFrame tide gauges in the 1990s. Although these gauges have only been in place for one full 18.6-year lunar (and hence tidal) cycle, all gauges in western and northern Australia indicate a rate of rise that exceeds the global average indicated by satellite altimetry for this period (3.1 mm per year) and only those in southeast Australia show a lesser rate of rise.

It will be very important to monitor the rate of rise in future and continually update projections of future sea-level rise on the basis of the best information available. The IPCC projections of 18-59 cm by 2100, with a suggested allowance of a further 20cm for icemelt, have already been described as conservative because the IPCC process necessitates such a considered view of peer-reviewed and published projections. The figures that are quoted are global averages, and it is clear that there will be regional variations which are not captured with any great precision in global climate models. The patterns and the consequences of sea-level variations will differ around the Australian coast because of a range of complex factors, such as oceanographic processes, complex tidal variations and the subtle topographic configurations of different coastal landscapes. Further research is needed to provide a firmer foundation for the values of sea-level rise that are anticipated, and that need to be built into planning policies and instruments, on our different coasts. The gradual rise of sea level will continue to be almost imperceptible, but it will be the occurrence of occasion extreme events that will cause the greatest concern. For example, inundation during storm surges will be a little greater than present because of the accentuation of the storm surge level by a small increment of sea-level rise, and this will have an

impact in areas where river floods and intense runoff are associated with storms, particularly tropical cyclones, and cause extensive flooding. Situations have arisen in recent flooding, such as the Gippsland floods of 2006 or the Mackay floods of 2008, where the interaction of floodwaters with high spring tides poses additional threats.

Storm occurrence

It seems likely that the occurrence of storms will change; there have been some suggestions that storm frequency may change little, but that the occurrence of intense storms will increase. Category 4 and category 5 cyclones already result in enormous devastation, and in addition to those that are known to have occurred, there is some evidence that even more severe storms have occurred in the recent pre-historic past and may recur within the natural variability even without climate change. Low-lying parts of coastal settlements are going to see recurrent flooding with the areas inundated by storm surges gradually increasing.

Rainfall and runoff

Climate change will have effects on the amount of water that rivers bring to the coast and rates of runoff. In many cases these have been further altered through direct and indirect human actions in the catchment. At a global scale, the construction of dams on the majority of the world's major rivers has altered the delivery of water and sediment to the coast in far more dramatic ways than climate change has yet affected such flows. In Australia the coastal effects are most likely to be felt during storms as described above.

Winds and waves

It is also likely that adjustments to the patterns of winds and waves may have some effect. There is some preliminary evidence that waves have increased slightly in wave height over recent decades, and it has also recently been recognised that sand moves from one end of east-coast beaches to another in response to patterns of winds that have different average effects during El Niño and La Niña conditions. Research and monitoring at a fairly modest scale should ensure that coastal managers can work within the natural patterns of behaviour of coastal systems where these gradual movements of sand may have consequences for human use and appreciation of coastal areas.

Strategies to deal with climate change adaptation (sea-level rise)

It is very important that Australia take an active part in efforts to mitigate climate change. Australia, with particularly high emissions per capita, must reduce greenhouse emissions and join, indeed lead, international initiatives to stabilise greenhouse gas concentrations. However, it must be recognised that even although carbon dioxide levels may be stabilised in the 21st century, the consequences of the changes that have already occurred will continue to be felt beyond 2100. This is particularly the case for sea-level rise, which will not halt at the time that greenhouse gas concentrations in the atmosphere stabilise, but will continue because of the lag that occurs between atmospheric conditions and those in the oceans. The oceans will continue to warm, and hence seas to rise, because it takes decades-to-centuries for turnover of the ocean's water. As a consequence, adaptation is going to be very important along the coast. There is a range of ways in which coastal populations can

adapt to climate change on the coast. These are generally considered within three categories: protect, accommodate, or retreat.

The Australian coastline represents one of our most iconic treasures, and it is fortunate that there are relatively few areas of the coastline that have been so built up that they already require protection. This is in contrast to much of the coast of Europe, for example the Netherlands that has had a history of building dykes to protect and indeed claim land from the sea. Seawalls and breakwaters can be constructed at great expense where they are essential for the safe operation of ports, navigable river mouths, and the defence of infrastructure such as airports or industry that requires a seaside location. Such structures require ongoing maintenance that is certain to become more costly as sea level rises.

Soft engineering approaches have been increasingly favoured instead of solid structures. For example, many North American beaches are maintained only through replenishment with sand; this process of beach nourishment is also costly, requiring periodic transport of sand. Such sand replenishment is already adopted along the Gold Coast where the large expenditure associated with transporting sand south again after it has been carried north along the beach by longshore drift is undertaken to maintain aesthetically pleasing and protective beaches. Here, the cost is presumably not out of proportion to the value of the land immediately adjacent. There are several other urban beach fronts, most notably in northern Sydney and in Adelaide, where such practices have either commenced or may become necessary. But such approaches will become increasingly expensive, and they raise issues about the extent to which public money should be spent to protect a few landholdings that occupy prime, though vulnerable, seafront. Far more sustainable is to adopt planning strategies that do not permit construction in areas where protection is going to become necessary.

Around the extensive coastline of Australia, by far the largest area is uninhabited and largely inaccessible. In the coastal towns and suburbs, there are many advantages in maintaining public access to foreshores, and using the backshore for open public spaces rather than high-rise apartment blocks, so that property is not at threat by gradual erosion.

In considering how shorelines may respond to sea-level rise in the future, existing models of coastal behaviour are generally inadequate. It is worth considering that the sea has been rising over the past few decades, as tide gauges have shown, and yet in few places have there been documented impacts as a consequence of that rise. Over the past several decades the sea has risen a few centimetres along much of the coast of east Australia. Coastal management programs have not been designed to counter that rise, but in many cases have accommodated it without noticing. The impacts of large storms and the gradual recovery following those storms have been far more apparent. Much could usefully be learned from the behaviour of shorelines over this period. For example, the widespread introduction of dune management, incorporating dune fencing, dune access through walkways, exclusion of four-wheel drives, and revegetation would appear to have reduced and in places reversed retreat that might have been anticipated as a result of the gradual rise of mean sea level. These management procedures offer a good basis that could be expanded with further research as adaptive measures in the face of future sea-level rise, at least in the short term.

In relation to housing in areas subject to coastal flooding, two measures deserve discussion. First protection with a coastal embankment can be used to prevent inundation during high water. An alternative measure that is aimed to accommodate higher water level is to build floor levels to a higher level such that houses are not subject to flooding. These alternative strategies might be used in combination, as discussed in a NSW strategy document. However, it is worth pointing out that construction of an embankment is likely to be undertaken by local government whereas a policy of raising floor levels transposes the responsibility to individual landholders. It is also worth pointing out the consequences that occur when an event is experienced that exceeds the embankment height. This was tragically demonstrated in New Orleans, where much of the city including potential evacuation routes was under water.

The other strategy is retreat. This includes planned measures such as rolling easements, managed realignment, and the necessity to buy back properties where it is deemed that the threat over the long term just does not warrant its defence in the short term. There are probably relatively few places where retreat is already necessary in Australia, but it is highly desirable that future expansion of coastal settlements occurs within a planning context that is fully aware of the topography and elevation of coastal areas, and the likely future heights to which inundation may occur. This can be rapidly assessed to a precision that is adequate for such planning through the use of air-borne Lidar surveying and other sophisticated techniques described below.

Promoting sustainable coastal communities

Minimising vulnerability to climate change is an important element of promoting sustainability. It is necessary to extend the coastal vulnerability assessment process at a series of levels. The national first-pass assessment and mapping process, popularly known as the Smartline approach, provides a classification of shoreline stability that can be used to prioritise areas in terms of their likely vulnerability. However, at this stage it is a static classification identifying particular types of shore (ie. low-lying sandy shores backed by low-lying plains, for example), but without either modelling of how these shoreline types might behave in response to future drivers such as sea-level change, or incorporating second-pass factors such as observed rate of past change, tidal or sea-level trends, or wave exposure. Use of this classification in conjunction with other assessment techniques, particularly the climate-change template compiled by Engineers Australia (NCCOE), offers great potential. Some useful lessons can be learned from the more active programs of vulnerability mapping undertaken overseas, but the Australian coast poses some unique challenges and Australian researchers have a high international profile and are better placed to produce solutions that best serve the Australian environment.

For example, the city of Cairns appears particularly at risk. A relatively short historical set of data provides an idea of recurrence interval for different flood levels associated with storm surge, although different researchers have interpreted this in different ways. Many parts of the centre of the city are at levels that are already subject to flooding by events that have a recurrence of less than 1 in 100 years. Although the details of how this will change in future are contentious, it is clear that these levels will be experienced with greater frequency in future (as a result of either

sea-level rise or storm intensification, or both). Growth of development along the foreshore has seen loss of natural protection such as mangroves, and reclamation of the seafront. There is even some evidence that considerably larger events have occurred in the recent geological past. Translating these differing views into a uniform set of guidelines to ensure that the city copes with future extreme storms will not be easy, but would be prudent in order to avoid disasters of the sort that have befallen New Orleans.

The lessons that were learned from Cyclone Tracy are all too easily forgotten, and need to be constantly updated. There even seems to be a view that Darwin may no longer be as resilient as it was to the magnitude of storm that has occurred elsewhere in the Northern Territory. Ongoing review of likely projections and wise adoption of a precautionary approach seem the surest way of ensuring that tropical Australia is prepared for a disaster and not reactive as a consequence of such events in the future.

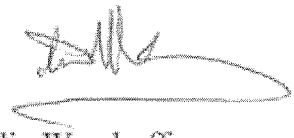
Governance and institutional arrangements for the coastal zone

There have been several reviews of coastal resources and their management in Australia, such as the *Injured Coastline* study in 1991, and all have drawn attention to the fragmented nature of decisions about the coast and the jurisdictional problems that result through the three tiers of government. Despite the pre-eminence of Australian researchers, there is actually a dearth of detailed data about much of the Australian coast, and more systematic handling of data and resources could provide a far better basis for describing and then managing the coast. Even in the case of the Great Barrier Reef, considered an example of best practice in terms of marine managed areas, there is still uncertainty about the nature of many reefs; it has only recently been mapped with inventories of all reefs, and there is much to learn at a time when unprecedented coral bleaching is indicating that the reef is already suffering dire consequences as a result of thermal stress on corals. There have been various attempts to build a coastal information system for the Australian coast, including a pilot online digital coastal atlas. Previous efforts have generally been terminated when temporary funding has been withdrawn. Recently available techniques, including satellite and airborne remote sensing and imagery offer unprecedented resolution, but raw data and derived datasets need to be managed by suitable custodian agencies and widely accessible.

One report prepared for the US coast, termed a geospatial framework for the coastal zone, provides what I believe would be a useful starting point in the Australian context. The study drew together representatives from most of the agencies and organisations that had a direct concern with the coast, and it painted a picture of the US coast that also resembles that of the Australian coast. It pointed to the convergence of sophisticated technology such as remote sensing, GPS positioning, multibeam swath mapping and lidar (airborne laser survey), with the increased awareness of the population pressures on the coast and the need for conservation of natural resources. Australia, even more so than the US, has an overwhelming majority of its population concentrated along the coast. In both cases, I believe that the most pressing need is for a seamless coastal terrain model, in other words we need to develop a highly accurate digital elevation model (DEM) of the land and an adequate picture of the depth of shallow water areas (bathymetry) and link the two together across what is all-too-often the 'white band' along the coast where data is lacking. This challenge is more complex than it might seem because the highly accurate

surveying on land is related to a datum (AHD) that approximates mean sea level, but bathymetry data is acquired in relation to Chart Datum, a low tide mark. Linking the two is not straight forward, as beyond tide gauges we have little idea of tidal planes and even less about the configuration of the intertidal zone. The threats to our coasts mean that we need high-resolution digital terrain models (DTM) of coastal areas, but traditional mapping all too frequently starts with the 10 metre contour, or in some cases the 2 metre contour. Sophisticated airborne technologies such as lidar, LADS and SHOALS can be used to supplement satellite remote sensing. Co-ordinating this will be important, as flights may be commissioned by local government, but keeping a record of data could extend the use; in the US this is done by the National Oceanic and Atmospheric Administration (NOAA). Although the technologies are readily available, there is still a need for much research.

In conclusion, 1974 was a devastating year for the coast of Australia, there were extensive floods in Brisbane associated with Cyclone Wanda, there was severe erosion along much of the coast of NSW as a result of several winter storms, and then on Christmas Day Cyclone Tracy devastated Darwin. If comparable events occurred in the next twelve months, there would be widespread speculation that it was due to climate change. Coastal communities need to be prepared, and coastal managers need to anticipate events of even greater magnitude in the future, because any of these (and other) events could recur and their impacts are likely to be exacerbated by climate change, most obviously by the fact that sea level is already higher and rising at an accelerating rate, and by the rapid growth in coastal populations and settlements over the past 30 years.



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