5.2 Implications for infrastructure and services

Climate change impacts on infrastructure are expected to include accelerated degradation of materials and foundations of buildings and facilities, mainly due to rising sea levels, increased ground movement, changes in ground water affecting the chemical structure of foundations and fatigue of structures from extreme storm events.[158]

Increased temperature and solar radiation may also reduce the life of building and facility elements due to increased expansion and materials degradation of concrete joints, steel, asphalt, protective cladding, coatings, sealants, timber and masonry. Increased humidity in the coastal zone will also affect the rate of corrosion and material degradation. This has the potential to reduce the life expectancy of buildings, structures and facilities. Such degradation also increases the probability that extreme weather events will result in structural failure.[159]

Impacts on infrastructure in the coastal zone will have broader consequences for the community. A preliminary analysis of the location of infrastructure and community services reveals a large number of facilities within 200 metres and 500 metres of the coastline, and potentially at risk under a changing climate (Table 5.3).[160] Of concern is the number of hospitals, police, fire and ambulance stations very close to the coast. Compromising the functionality of these services during an extreme weather event can result in significantly greater impacts than might otherwise occur and could have life and death consequences.

This section summarises the likely implications of climate change for ports and airports in the coastal zone and the provision of essential services.

5.2.1 Transport infrastructure – ports and airports

Ports

Ports and shipping are crucial to Australia's international trade carrying 99 per cent of Australia's total merchandise trade and 75 per cent of its value.[161] Climate change will bring more intense storm events including chaotic, heavy precipitation, high wind velocity, increased wave action and higher storm surges.

These events will lead to a range of impacts including: increased runoff and siltation requiring increased dredging; disturbance and distribution of currently entrained heavy metals and other pollutants; increased high wind stoppages under Occupational Health and Safety requirements; delays to berthing and cargo handling; coastal flooding; and required engineering upgrades to wharfs, piers, gantries and other cargo handling equipment.

The extent to which a port is affected by climate change is dependent on whether the port is exposed or sheltered and its location. Generally container ports are located in sheltered harbours close to cities, whereas bulk ports are often in open-ocean locations, close to production sites or transport hubs.

Port operation, particularly in draught-restricted ports, is highly dependent on predictability of tide, wave and weather patterns. Changes to those patterns may affect the ability of harbour masters to manage them safely and efficiently.[162] Sea-level rise may result in greater penetration of wave energy into harbours potentially causing increased coastal erosion, navigation difficulties and damage to port infrastructure.[163]

Table 5.3 Transport and services infrastructure and facilities within 200 m and 500m of the Australian coastline.

	within 200m of the coastline	within 500m of the coastline
Regional infrastructure	120 ports 5 power stations/substations 3 water treatment plants 170 unidentified industrial zones 1,800 bridges	120 ports 11 power stations/substations 3 water treatment plants 170 unidentified industrial zones 2,795 bridges
Community services and facilities	258 police, fire and ambulance stations 75 hospitals and health services 46 government administration facilities 360 universities, colleges and schools 102 retirement/nursing homes 11 emergency services facilities 41 waste disposal facilities	702 police, fire and ambulance stations 199 hospitals and health services 107 government administration facilities 992 universities, colleges and schools 296 retirement/nursing homes 35 emergency services facilities 92 waste disposal facilities

Source: Geoscience Australia 2009, NEXIS database


Photo credit: Gladstone Port Authority

Port of Gladstone.

Of particular concern to port operation, climate change could increase the severity of cyclones in northern Australia, and possibly extend their southward tracks along the Queensland and Western Australian coasts. This will increase the number of port closures, possibly quite significantly by mid-century.[164] Some ports for example require closure whenever a cyclone moves within a 300 kilometre radius of the port. The migration of cyclone affected areas southward will bring a new and complex set of challenges to ports, such as Brisbane, not currently cyclone affected.

An increase in the number of very hot days can also lead to increased downtime in ports as Australian stevedores stop work at 38° Celsius. While the number of days exceeding this threshold is expected to increase only slowly for the next couple of decades, in northern Australia the number increases considerably in the latter half of this century.

There are a range of economic consequences of port closure or downtime, including costs associated with the backlog of ships waiting to enter or leave the port, costs associated with providing assistance to vessels caught up in a storm event and broader economic impacts on port reliant businesses, freight transport networks and consumers.

The infrastructure analysis commissioned by the Garnaut review identified climate change impacts on (i) port productivity as a result of increased downtime, on (ii) capital expenditure to allow for changes in design and protection in response to sea-level rise and cyclones, and on (iii) operational expenditure from additional maintenance and repair costs. The following table shows the percentage shocks for select states for the best estimate climate change scenario. These shocks were utilised in economic modeling of the costs of climate change impacts.

Port infrastructure can also be degraded by corrosion arising from ocean acidification, in combination with increased temperatures and sea-level rise. The most corrosive environment is the aqueous, high oxygen area of the inter-tidal splash zone which can lead to aggressive and rapid corrosion. The result will be a loss in the strength of the concrete – as the silicate structure is destabilised, leaching of the calcium from the concrete occurs and voids form within the concrete structure.[165] Higher sea levels also expose more of the jetty or wharf structure to corrosion.


Photo credit: Arthur Mostead

Table 5.4

State	Productivity		Capital expenditure		Operational expenditure	
	2031–2070	2071–2100	2031–2070	2071–2100	2031–2070	2071–2100
Vic	4 per cent	5 per cent	9 per cent	11 per cent	7 per cent	8 per cent
NSW	4 per cent	5 per cent	11 per cent	13 per cent	7 per cent	8 per cent
WA	7 per cent	10 per cent	11 per cent	15 per cent	8 per cent	10 per cent
NT	5 per cent	9 per cent	6 per cent	10 per cent	6 per cent	9 per cent
Qld	8 per cent	11 per cent	13 per cent	17 per cent	9 per cent	11 per cent

Source: Maunsell 2008

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Box 5.13 Concrete Structures and the implications of Climate Change

Concrete is one of the most common construction materials. Increased atmospheric carbon dioxide concentrations, temperature (and humidity) increases, and sea water splash can all accelerate the degradation process of concrete.[166] This will require costly and disruptive repairs during the service life of many concrete structures. [167]

A study examined the stresses, corrosion and shear failure of a typical reinforced concrete bridge girder over a 100 year period and found that the probability of corrosion initiation is up to 720 per cent higher for the worst case scenario.[168] Probabilities of failure are also up to 18 per cent higher in the worst than the best mitigation scenario.[169]

Image courtesy of the Port of Melbourne Corporation

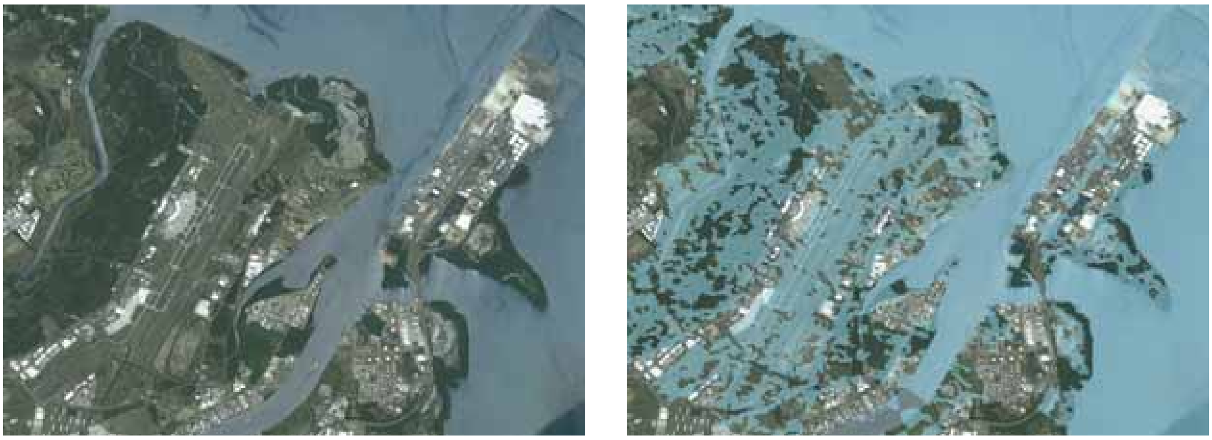

Figure 5.48 Images of Brisbane airport in 2009 and with simulated inundation from a sea-level rise of 1.1 metres using medium resolution elevation data (not suitable for decision-making). © CNES 2009 / imagery supplied courtesy of SPOT Imaging Services and Geospatial Intelligence PTY LTD

Airports

There are a number of airports in low-lying areas in the coastal zone and at risk of inundation in the coming century as a result of climate change. Significant disruption can be expected to regional economies if a major capital city airport closed even for a short period of time. While there has been no comprehensive assessment of climate change risks to Australian airports, in the medium term it is possible that consideration will need to be given to protective works for a number of key airports, particularly Sydney and Brisbane.

5.2.2 Essential services

Similarly there has been little analysis of the implications of climate change for the provision of essential services in the coastal zone. Table 5.3 indicates facilities that are underpinning delivery of services are in close proximity to the coast and could be at risk of inundation and erosion as a result of climate change. Clearly any impact on such facilities would have broader consequences across the community. Following is a summary of potential impacts of climate change for water and wastewater, waste management and energy supply in the coastal zone.

Water and wastewater

Securing a reliable water supply for Australia's coastal residents outside of the capital cities is not only crucial for the survival of those communities but is also important for the Australian economy and society.[172] With much of Australia's population living within the coastal zone, significant water and wastewater infrastructure has been built to accommodate coastal cities and communities, with some assets located in very close proximity to the coast (Table 5.3).

A survey of coastal councils in 2005 noted the ability to provide good quality water to the community as a significant concern.[173] For many coastal councils' the most pressing water supply issue was associated with population pressure, as coastal towns were not planned as high growth communities. Many coastal communities also rely on local freshwater aquifers for the town water supply as well as irrigation

Box 5.14 Sea-level rise a threat to Sydney Airport

Sydney Airport is the busiest airport in Australia, handling 31.9 million passengers and 290,346 aircraft movements in 2007.[170] Situated next to Botany Bay, the airport has three runways, known as the 'East-West', 'North-South' and 'Third' runways. The airport is managed by Sydney Airport Corporation Limited.

Sydney Airport is almost entirely surrounded by waterways, with Botany Bay to the south, Botany Wetlands (incorporating the Sydney Airport Wetlands) to the east, Alexandra Canal to the north and the Cooks River to the west. The airport's proximity to Botany Bay and tidal waterways makes it vulnerable to future sea-level rise and storm surge. A sea-level rise of 1.1 metres combined with a storm surge would inundate parts of the airport, interrupting operations and causing damage to infrastructure.

Vulnerable areas include sections of runways, taxiways and aprons, and the northern perimeter road. The lowest lying areas (and hence the most vulnerable) are in the north section of the airport. For example, an open drain flowing under Qantas Drive and into the Alexandra Canal has a pipe with an invert level (IL) at minus 1m Australian Height Datum (AHD), meaning it is already below Mean High Water Level and at risk from relatively small rises in sea level. The northern airside perimeter road, which is critical for aircraft servicing, re-fuelling aircraft and moving freight, also runs through this section of the airfield, and is at a level of 1.5m AHD.

The physical effects of inundation would compromise seawall stability, degrade drainage and pavements, and damage airfield lighting/electrical systems, navigation aids and Air Traffic Control facilities. Significant rises in inundation levels would also affect the surrounding arterial road network and other facilities.

The combined effects of sea-level rise, storm surge and tidal action resulting in significant inundation of the airfield movement area could effectively close the airport. Any significant disruption to air services would have a compounding effect on airline networks and would cause problems to both domestic and international traffic because of the reliance of airlines on maintaining their schedules. A lengthy disruption caused by inundation of the airfield would cause airline network problems around Australia and internationally with economic losses to the airport, airlines, business and the tourist industry.

As the probability of airport closure and expected costs increases, some adaptation options include raising seawalls around the airport or installing locks in the Cooks River. If these activities were insufficient to adapt to sea-level rise, it may become necessary to raise the airfield and associated facilities by up to one metre (not over the entire airfield but principally the northern airfield areas). This would involve raising seawalls, importing fill, reconstructing runways and taxiways, and relocating air navigation and air traffic control facilities. It is estimated the cost of this would exceed $1 billion.

Consideration of possible sites for a second major airport for Sydney have taken place periodically over the past 60 years. However, community concerns, social, economic and environmental costs have so far proved a barrier to the construction of another site. The Australian Government and New South Wales Government have agreed to participate in a joint study to assess options, identify potential sites and evaluate investment strategies for delivering additional airport capacity for the Sydney region.

Note: heights above (or below) AHD are from Australian Mapping GIS and are accurate to the nearest 0.5m.

Source: AECOM 2009[171]

Sydney airport.
Source: Photolibrary

Simulated inundation of Sydney airport for the first half of next century.

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and industrial processes. A number of coastal freshwater aquifers will be increasingly exposed to saline groundwater intrusion with rising sea levels. Freshwater contaminated by seawater at the level of only 5 per cent renders it unsuitable for domestic water consumption and for some irrigation and industrial uses.[174] Rising sea levels can also raise coastal water tables, with these higher water tables potentially impacting infrastructure, including leakage to septic tanks, sewer systems, and basements and causing instability of swimming pools, tanks and some other subsurface structures.

Water and wastewater infrastructure can have an effective operational life of many decades. Stormwater pipes and drainage assets will also be exposed to the impacts of rising sea levels and may not be adequate to accommodate future changes in extreme rainfall and storm surge. Increasing maintenance and renewal costs of drainage assets and an increased risk of local flash flooding are likely to result. Saltwater may increasingly enter because of factors such as cracks in pipes caused by ageing or movement, and the presence of seawater reduces system capacity and increases operational costs.

Sydney Water undertook an initial assessment of the impacts of climate change on its water and wastewater operations. Six general areas of adaptation response were identified: *material selection*, researching new material resilient to climate change; *design standards* to cope with the change in extreme events; *maintenance regimes* to accommodate acceleration in the degradation of material and structures; *technologies* for alternative or new early warning and information systems; *planning* to meet changed physical conditions; as well as *cultural change* to raise organisational awareness.[175] Additionally the assessment identified stormwater assets at risk from sea-level rise and has an established work program to reduce the amount of saltwater entering the sewers that are laid below the high tide level.[176]

Waste – landfill

Waste management practices have evolved considerably in Australia since European settlement. Whereas waste was once burnt in open air dumps, now there is an emphasis on recycling with the disposal of residual waste in fully engineered landfills.

5

Box 5.15 Sydney Water – drainage assets and climate change

Sydney Water has implemented an inundation program to measure both flow and salt levels in sewers so that faults can be identified and fixed. Repairs reduce the energy and amount of chemicals used in the sewerage system. With sea-level rise, the frequency and extent of exposure to saltwater intrusion will rise, increasing costs.

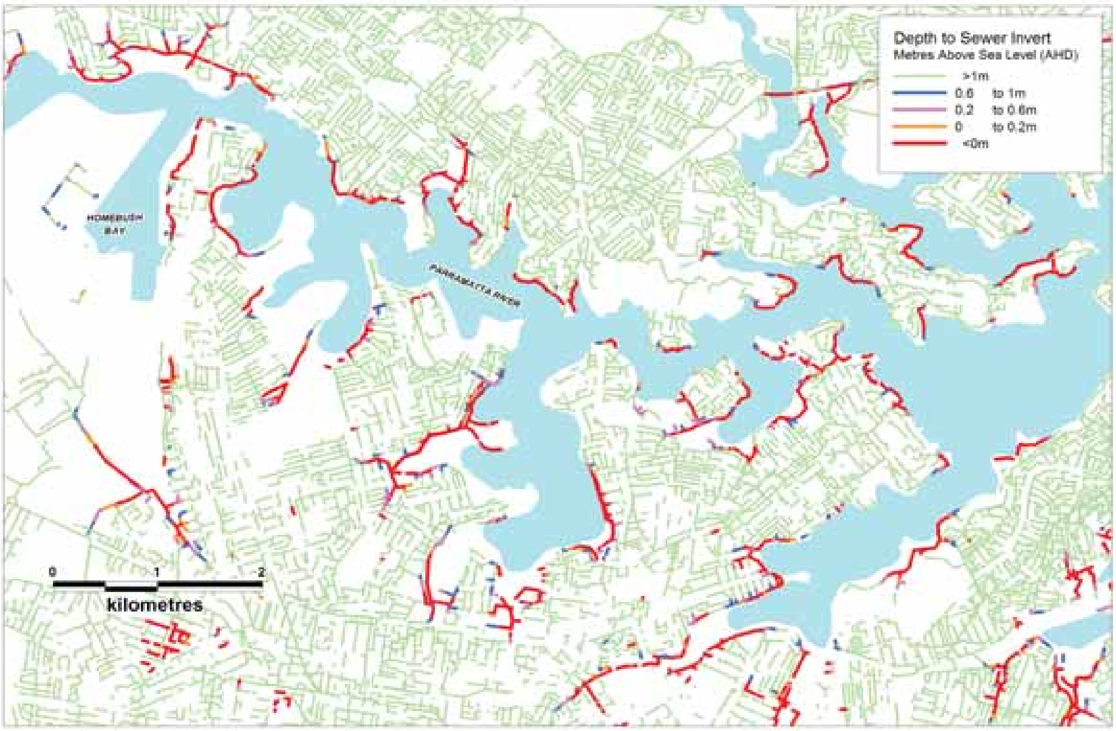

Figure 5.49 Sydney Water drainage assets at risk from sea-level rise.
Source: Sydney Water Corporation

Most state and local governments now prevent the construction of new landfills within 100 metres of a watercourse. However, there is a large legacy of many ‘tips’ and ‘dumps’ long closed, but located in areas vulnerable to the future impacts of climate change and sea-level rise. For example large, multi-million dollar landfills such as Cairns and Brisbane, are located in low-lying areas. At least 41 waste disposal facilities are located within 200 metres of the coastline (Table 5.2). Many town dumps were located in places that were undesirable or not suitable for community needs, were cheap to procure or required filling. As a result many old dumps are sited in or adjoining flood prone and low-lying lands. Areas abutting mangroves and salt marshes were, for decades, preferred places for the local tip.

There are approximately 600 medium to large operating landfills in Australia today and possibly several thousand small tips. These range from containing hundreds of tonnes of waste, up to engineered landfills holding tens of millions of tonnes of waste. Existing clay capping and vegetative cover is unlikely to be able to withstand the erosive power of waves acting directly on the fill batters of a landfill face, especially driven by the power of a tropical cyclone. Permanent inundation of the base of the landfill could also create significant leachate problems. The Cairns landfill for example is in the final stages of its life and is located adjoining low-lying mangroves. A significant rupture of the landfill cap or walls could see hundreds or thousands of tonnes of materials released back into the environment.

What is unclear is how many small dumps may exist, for which on site protection may not be cost effective, but may still cause pollution. The waste from these tips will need to be removed and relocated to inland landfills or recycled. The cost of relocation would range from thousands of dollars, to many millions depending upon the size of the landfill.

It is difficult to specify the types of materials disposed into landfills or the quantity that may be released back into the environment by progressive climate change related erosion. It is known however that most landfills contain quantities of oil, demolition waste, asbestos, pesticides, plastic and heavy metals fixed into the soil/waste matrix. If this were released back to the environment it would constitute a significant environmental hazard.

Energy supply

Many power plants are located in coastal areas for ease of access to sea water cooling, to obtain fuel supplies delivered by sea, and to be close to population centres. At least 11 power plants/substations are located within 500m of the coastline.

For power stations located very close to the coast storm surge and resultant flooding will obviously pose a great risk as will damage to powerlines from destructive winds. Generation facilities may cease operation in preparation for a flood and if infrastructure is flooded, delays in restarting generation will occur. If storm surge travels a long way inland, storm surge protection may be lacking for more inland substations and generators, as occurred for Hurricane Katrina which reached 24 kilometres inland and resulted in the replacement of over a million powerlines.[177]

Destructive winds can also increase salt aerosols deposits on electricity conductors, leading to flashovers and corrosion. Electrical components are particularly vulnerable to corrosion from saltwater, even with pressure cleaning immediately after a flood exposed equipment will have to be replaced sooner than would otherwise be the case.[178]

Any saline water intrusion in freshwater coastal aquifers or streams used as a supply for cooling water for a generator will also cause problems. Increases in cooling water temperature will also reduce the efficiency of the energy production cycle. Many power stations are subject to an upper temperature limit for discharged cooling water. On hot summer days the temperature of cooling water can be close to this specified limit and the power station will have to operate at a reduced load to accommodate water temperature requirements, and hot summer days are often times of peak energy demand.

5.3 Vulnerable communities

The analysis in section 5.1 highlights the risks to Australia’s coastal communities from rising sea levels and other climate change impacts. Some coastal settlements will clearly be more vulnerable than others. Socio-economic characteristics will also influence the vulnerability of coastal settlements, however there has been very limited assessment of this to date.

The Sea Change phenomenon of the last few decades has brought with it a greater focus on community vulnerability. The Sea Change Taskforce, established to help coordination across local councils under pressure from rapid population growth, has funded a number of analyses about the social drivers and costs of the population shift. Generally coastal communities outside the capital cities have the highest proportion of low income households, the highest proportion of families receiving income support benefits, the highest median age and the highest ‘elderly dependency’.[179,180] The sea change phenomenon impacts on many coastal communities within coastal towns. Much of the growth associated with sea changers are new jobs in occupations such as retail, restaurants, tourism and care giving sectors, with these jobs often being part-time or subject to seasonal fluctuations.[181]

Box 5.16 Climate Change Vulnerability in Torres Strait

The Torres Strait is a broad stretch of shallow water between the tip of Cape York and Papua New Guinea. The region includes over a 100 islands, coral reefs, sand banks and cays.

The region is home to 17 Island communities with a total population of around 8,700 people. The inhabited islands vary significantly in their geography, from the low-lying mud islands of Boigu and Saibai close to Papua New Guinea coastline, to the western continental islands (which have similar geomorphology to the Australian mainland), the central coral cays of Poruma, Warraber, and Masig, and the eastern volcanic Islands of Mer, Erub and Ugar.

The communities which inhabit the region have strong cultural, economic, social and spiritual connections with their land and sea country which are governed by their distinct *Ailan Kastom* (Island custom).

Many communities are subject to significant coastal hazard issues with erosion and inundation directly threatening housing, infrastructure including roads, water supply systems, power stations, community facilities, cultural sites including cemeteries, traditional gardens and ecosystems. An anomalous high spring tide in January 2009 resulted in extensive flooding of island settlements (see photo).

Given the low-lying nature of several islands, and the extent of current inundation problems, vulnerability to sea-level rise is extremely high, particularly for Boigu and Saibai but also for the central coral cay islands, as well as several other communities located on low coastal flats.[186] Even small increases in sea level due to climate change are likely to have a major impact on these communities, with increasing frequency and extent of inundation, although for the coral cay islands there is some potential for moderation of this impact through onshore transport of reef sand and associated island growth. Large sea level increases could see several Torres Strait islands completely inundated, thus having enormous implications for the communities involved, their culture and identity, and may have implications for the security of Australia's northern border. As noted by Green[187] and Mulrennan[188]; under worst case sea-level rise scenarios it is likely that eventually relocation would be required from several communities involving considerable cost culturally, spiritually and economically.

Other potential impacts of climate change including changes to rainfall patterns, hotter weather and spread of diseases, as well as changes to ecosystems may also significantly impact Torres Strait Island communities, whose culture, subsistence and livelihoods involve traditional and commercial fishing, hunting and gardening and who are already vulnerable due to socio-economic factors and remoteness.

The extent of vulnerability of the region and its peoples to climate change together with the human rights implications are highlighted in the 2008 Native Title Report by the Aboriginal and Torres Strait Islander Social Justice Commissioner, which along with recent submissions[189] by the Torres Strait Regional Authority emphasise the need for immediate and comprehensive action to address the climate change concerns in the region.

Source: Dave Hanslow, Torres Strait Regional Authority

Photo credit: David Hanslow

King tide, Sabai January 2009.

The IPCC AR4 also notes that Indigenous communities in the tropical north, home to about 87,000 Indigenous people, are also considered to be very vulnerable to the impacts of climate change. Such communities often live in isolated areas that are poorly resourced, and tend to have greater health issues and lower incomes than other communities.[182]

A recent assessment of the implications of climate change for Indigenous communities noted a number of serious potential impacts, particularly around basic living conditions.[183] Current temperature and humidity in the tropical north can already be a challenging environment in which to live. Living conditions are likely to become more difficult with climate change expected to increase average temperatures by up to 3°C by 2070. Existing health issues may be exacerbated by climate change and new health risks are likely to emerge, including heat stress, respiratory illness and mosquito-borne diseases. Local energy provision and the maintenance of services, such as water, sewerage and transport, are also likely to require new critical investments, particularly in isolated indigenous communities.

Box 5.17 The vulnerability of the Australian Indian Ocean Territories

The Cocos Islands are a group of 27 low-lying coral atolls located in the Indian Ocean almost 3,000 kilometres north west of Perth. The economy of Cocos is basic and mainly driven by the public sector and Gross State Product is only $15 million.

Sea-level rise will be particularly challenging for the Cocos Islands since the island elevations range from only 1 to 4 metres above existing sea level. Any change in mean sea level combined with storm surge would have significant consequences for settlements and human activity, particularly for Home and West islands. About 80 per cent of the Cocos islands 600 inhabitants live on Home island and most of the houses are low set and exposed to inundation and flooding even during relatively low level events. Currently none of the buildings on Cocos islands are designed to cyclone rating standard. Transport infrastructure including two ports, roads, the airport, buildings and water resources are all at 'definite' risk of damage due to climate change (primarily sea-level rise and cyclone activity).

Christmas Island in contrast is the top of a sea mount rising 360 meters above sea level at its highest point and is located 360 km south of Java. The Island has almost 1,500 residents and the major economic activity is phosphate mining which represents a third of Gross State Product (total Gross State Product $71 million). While the mining activities are not particularly exposed to climate change impacts, the port is. In addition to exports, almost all non-perishable goods to Christmas Island are delivered by sea. The main port at Flying Fish Cove already has restricted access due to ocean swells for much of the year and climate change is expected to exacerbate that constraint.

Photo dredit: iStockphoto.com/Alexander Hafemann

An island of the Cocos Keeling Island chain.

Source: Maunsell Australia 2009.[190]

While research identifying changes in tropical cyclone events is still preliminary, there is some indication that cyclone intensity may increase, which would require improved building standards. Climate change is also likely to cause disruption to the operation of transport and communications infrastructure, and the importance of airfields for emergency evacuation is likely to become even more critical if more frequent or intense storm activity is realised.

Torres Strait island communities face particular challenges in living on small low-lying and exposed islands, several of which already suffer from inundation under king tides. Continuing inundation events for these islander communities will require the development of short-term coastal protection and may require long-term relocation plans for approximately 2000 Torres Strait islander peoples (Box 5.17).[184,185]

In total there are around 8,000 islands of Australia that are spread across the Pacific, Indian and Southern Oceans. The location and geomorphology of Australian islands will largely determine the extent in which they are impacted by climate change although in comparison to mainland Australia, settlements on islands are very isolated. Damage and destruction in such remote locations will be difficult and costly to recover from.

5.4 Risks to Industry

As outlined in Chapter 1 much of Australia's industry occurs in or passes through the coastal zone. Climate change will increase a number of risks faced by industry, and bring new risks to some industries not previously exposed. This section provides a summary of existing knowledge on climate change risks to tourism, insurance, fishing, and oil and gas industries. Information in the section is illustrative; very few comprehensive assessments have been undertaken and publicly released of risks likely to faced by industry as a result of climate change.

5.4.1 Tourism

Tourism is one of Australia's major export earners and is a mainstay of many local regional communities. It is a key component of the economy of the Australian coastal zone.

Australia's tourism industry is particularly vulnerable to the effects of climate change and sea-level rise. Many of our tourism icons such as the Great Barrier Reef and coastal islands and beaches are in regions that are likely to be affected by storm surge, sea-level rise or increased cyclone intensity.

Photo Credit: Newspix/Kellie Block

Twin Falls, Kakadu National Park, Northern Territory.

A World Tourism Organisation report for the Second International Conference on Climate Change and Tourism in Davos, Switzerland in 2007 stated

> 'Climate, the natural environment and personal safety are three primary factors in destination choice, and global climate change is anticipated to have significant impacts on all three of these factors at the regional level. Tourists also have the greatest capacity to adapt to the impacts of climate change, with relative freedom to avoid destinations impacted by climate change… As such the response of tourists to the complexity of destination impacts will reshape demand patterns and play a pivotal role in the eventual impacts of climate change on the tourism industry.'[191]

A number of Australia's key tourism regions are at high risk to climate change impacts, notably the Great Barrier Reef and Ningaloo Reef, Kakadu and the Top End coastal wetlands. International tourists tend to seek out the most spectacular of Australia's tourist attractions. In fact 5.8 million visitor nights (35 per cent of total inbound tourism) are spent in tourism regions regarded as 'extremely vulnerable' to the effects of climate change.[192]

Due to the risk of increased cyclone intensity, increased sea surface temperatures leading to coral bleaching, and increased ocean acidification resulting in reduced coral formation, tropical north Queensland is probably the most threatened tourism region in Australia in terms of absolute numbers of holiday visitors exposed to the effects of climate change. It is also the region most researched and best understood.

North Queensland tourism's contribution to the national economy is estimated at greater than $2 billion per year.[193] Almost 10 million holiday visitor nights are spent in North Queensland and of these 50 per cent represent international tourists.

Photo Credit: Jean-Paul Ferrero/AUSCAPE

Bondi Beach, Sydney, New South Wales, Australia.

The proportion of visitors arriving for reef related tourism was 92 per cent for interstate tourists and 93 per cent for international tourists.[194]

Oxford Economics assessed the present value of the Great Barrier Reef to the Australian economy as 4.7 per cent of annual GDP. They valued the loss of the reef from coral bleaching as 3.5 per cent of annual GDP. Put another way they found the reef's Present Value to the Australian economy was $51 billion; the cost of coral bleaching would erode $38 billion of that value.[195] Kakadu in the Northern Territory is vulnerable to sea-level rise. Kakadu's unique freshwater wetlands are highly vulnerable to saltwater intrusion. A loss of wetlands, and the birds, reptiles and other animals it supports would result in a rapid decline in tourism numbers.[196] Increased temperatures will also reduce visitor comfort and increase the incidence of heat stress or heatstroke. Increased rainfall as a result of climate change will also extend periods of inaccessibility of park features, reduce visitor enjoyment and increase damage to tourism infrastructure.[197]

Highly developed areas such as the Gold Coast and Sunshine Coast also depend on tourism to support regional economies and are vulnerable to sea-level rise, erosion and storm surges. The low-lying nature of many of the tourism and housing developments, particularly canal estates and coastal housing, leave these areas vulnerable to storm inundation and beach erosion.

The tourism industry as a whole has shown itself to be highly adaptable and resilient to shocks. However, a large part of the industry consists of small operators who are more constrained in terms of mobility and flexibility to adapt to the impacts of climate change. They are therefore more vulnerable to significant economic losses.

The difficulties of adaptation faced by the tourism industry are clearly articulated by the Sustainable Tourism CRC

> 'Very few Small to Medium Enterprises (the vast bulk of the Australian tourism sector) are able to plan on time frames longer than a couple of years. As a result, making changes now (with associated costs) to address threats that may or may not eventuate in 10, 40 or 60 years time is not something that many of these smaller operators are willing (or able) to do.'

> 'If adaptation and mitigation strategies are to be implemented successfully, they need to be simple, cheap and effective with clear benefits.'

5.4.2 Insurance

The coastal zone is particularly vulnerable to sea-level rise and flooding, more damaging cyclones and catastrophic storms, and erosion as a result of climate change. The coastal zone also contains much of the infrastructure (homes, commercial and industrial buildings, ports and other physical assets) that is the client base of the insurance industry. Climate change will therefore significantly increase the exposure of residential and other buildings to potential loss and damage. But it will be the insurance industry which will be the first to bear the cost of any damages and losses resulting from any increase in extreme weather events.[198]

The specific costs to the insurance industry from climate change are difficult to predict with certainty. In a number of parts of Australia the insurance industry does not offer residential flood insurance. This is because until recently insurers have not been able to map, understand and price the risk of flooding in order to set a premium. The Australian insurance industry also does not generally cover the risks of storm surge, landslip and sea-level rise.[199] Risks from climate change will build on and compound these areas of existing risk and uncertainty.

Apart from increasing the difficulty in pricing risk, climate change affects the insurance industry's ability to pool risk. Already, 19 of the 20 largest property insurance losses in Australia have been weather related. Climate change exacerbates extreme weather events and reduces the ability to spread risk. As the Institute of Australian Actuaries noted in their submission to the Garnaut Review

> 'Independence of risk – the provision of insurance is premised on the 'rule of large numbers' such that risks are spread. The diversification of risk available from largely independent events allows insurers to operate with capital well below the total level of sum insurance coverage provided by the insurer. The greater the correlation of risks, the greater the requirement of insurers for access to capital and/or reinsurance, with a consequent increase in costs. Climate change, particularly if coupled with increased concentration of exposure in vulnerable locations, may exacerbate correlation of risks.'[200]

Notwithstanding these challenges, there is a broad move within the Australian insurance industry to understand and cope with the insurance impacts of extreme events. In particular, the insurance industry in Australia has already taken a proactive approach to improving understanding of flood hazard mapping and climate change risks.

Photo Credit: Gold Coast City Council Local Studies Library

Car bodies used to try and stop the progress of erosion on the Gold Coast, 1967.

Photo Credit: Gold Coast City Council Local Studies Library

Forty-four gallon drums filled with concrete to prevent further beach erosion on the Gold Coast, 1967.

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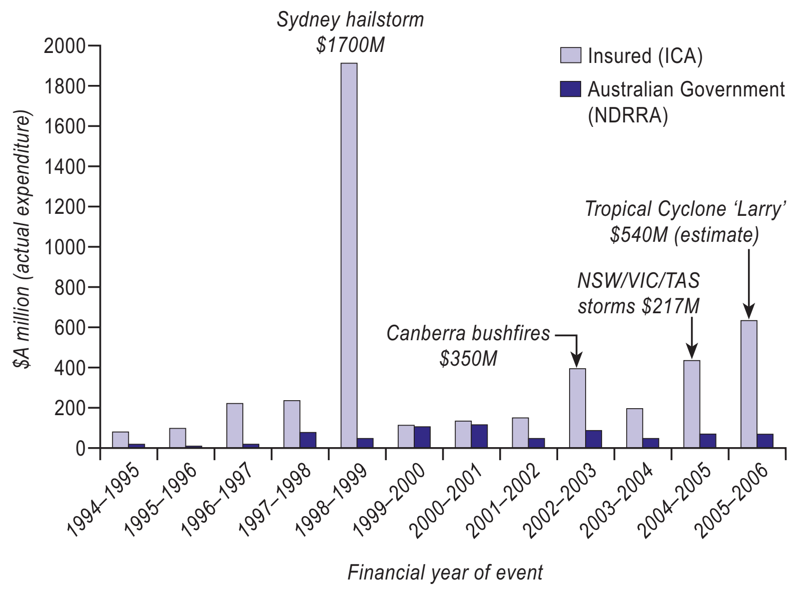

Figure 5.50 Cost of Australian Natural Disasters. Source: Middelmann 2007

However, given the potential change in the structure and magnitude of the insurance industry's revenue base, costs from climate change may have implications for the industry's operation. It is important that the industry plan for these changes and their implications now.

The insurance industry has a key role to play in encouraging adaptation by policy holders through its capacity to provide financial and commercial incentives. Such initiatives could impact on the insurance industry's revenue base in the short term but can be expected to help to minimise costs to the insurance industry in the long term.

The global insurance company, Lloyds, calls for a 'new approach to underwriting'.[201] Historically the Australian insurance industry has operated with an underwriting loss, paying out more in claims than it takes in premiums. The profits derive from investments the insurers have made using a portfolio of premiums as capital. Greater claims might require a restructuring in how the industry underwrites.

Indeed, climate change may provide opportunities for the insurance industry to develop new and innovative products and services and even enhance premium income. For example, there may be important new market opportunities for insurance companies, given their expertise on risk, to provide climate risk management services. A recent report on the insurance industry states that

> 'As the world's largest industry, with unparalleled access to business and consumers, insurers have a matchless but largely untapped opportunity to provide critical risk management services to help society adapt to and mitigate climate change and, at the same time, climate-ready their industry'.[202]

The Insurance Council of Australia has recognised the imperative for the industry to adapt to a changing physical and business environment

> 'Continued development and adaptation of insurance products to suit the needs of the community is a critical issue that is remains at the core of the competitive nature of the industry. As part of this development process it will be crucial to develop commercially viable products that not only serve consumers well, but maintain a sustainable industry capable of responding to extreme events.'[203]

Developing appropriate and effective adaptation responses will not be a simple task. It is likely that different adaptive strategies may be needed in different parts of the coast to take account of specific regional circumstances. It will be important that adaptation initiatives, including for example incentive schemes, are developed on a whole-of-sector basis and co-ordinated carefully with adaptation policies, initiatives and directions in other sectors. Maladaptation whereby policies, decisions, or initiatives result in increased vulnerability to climate change impacts needs to be avoided.

5.4.3 Fishing

As Chapter 1 outlines, the Australian fishing and aquaculture industries contribute over $2.2 billion to the Australian economy per year[204] and are an important part of the social fabric of many of our coastal towns and cities.

Climate change will, over coming decades, increasingly impact upon fisheries and aquaculture sectors. Expected changes to ocean temperature, currents, winds, nutrient supply, rainfall, ocean chemistry and extreme weather conditions will impact on these industries. However, climate change may present some new opportunities as well as challenges and threats for the sector. For example, there may be increased opportunities if tropical species move southward in response to a warming ocean.

According to the recently released report, Implications of Climate Change for Australian Fisheries and Aquaculture – a preliminary assessment

> 'Australian fisheries and aquaculture management policies do not currently incorporate the effects of climate variability or climate change in setting harvest levels or developing future strategies.'[206]

The preliminary assessment finds that fisheries will be impacted differently according to the physical changes in the regional environment. South-east fisheries are most likely to be affected by changes in water temperature while northern Australian fisheries will be more affected by changes in precipitation. Western fisheries could be affected by changes in the Leeuwin Current.

The potential effects of climate change include:

- The South East demersal fishery includes a number of commercial species for which inshore estuarine habitats are important nursery areas. Climate change impacts on these habitats such as different precipitation patterns and sea-level rise could affect the dependent species. Species at the southern end of their range will be adversely affected by projected increasing ocean temperatures, with little room for further southward migration.[207]
- The recruitment of the Western Rock Lobster and other species has a strong link with the Leeuwin Current off the Western Australian coastline. Climate change could cause a systematic shift in the relationship between the Leeuwin current and larval settlement of the Western Rock Lobster.[208]
- Catches of prawns, barramundi and mud crabs in Northern Australia are related to summer rainfall. Changes in rainfall pattern and abundance will impact on these species. Extended periods of extreme temperatures in shallow estuarine waters may affect the distribution of prawn nursery habitat such as seagrasses.[209]

Photo credit: Bruce Miller

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Box 5.18 Tasmanian Rock Lobster Industry: Climate Change Issues

The Tasmanian rock lobster industry is the State's second most important wild harvest fishery with an estimated value of $72 million.

Climate related impacts have already been observed on the fishery and climate change in the future is expected to have further impacts and pose challenges for the industry.

Some of the climate change impacts expected are:

- Continued ocean warming may result in Tasmanian waters being unable to support rock lobster populations of an equivalent size as found today
- Declines in lobster biomass, initially in northern and north-eastern regions before eventually also potentially declining in the south. Significant declines may have implications for the industry
- Warming water temperatures are expected to spread the range of the sea urchin *Centrostephanus* which can significantly degrade marine ecosystems including lobster habitat.

However, a recent study has concluded that the Tasmanian rock lobster industry is reasonably well placed to adapt to and meet the challenges of the climate change impacts

- Although fisheries management policies do not currently explicitly consider climate change, fisheries management is beginning to actively integrate the longer term issues associated with climate change
- Current management of the stock suggests that the industry has the capacity to evolve and respond to longer-term trends

Adaptation options include taking account of climate change in managing lobster catch, establishing a long-term lobster monitoring program, controlling the population of sea urchins, and developing regional rather than statewide management tools for the Tasmanian rock lobster fishery.

Source: Pecl G et al 2009[205]

Photo credit: Bruce Miller

- Seasonal abundance of some pelagic species has been linked to the expansion and contraction of the East Australian Current. Climate change impacts on this interannual variation will likely affect the abundance of these species.[210]
- The Tasmanian Rock Lobster industry is likely to be affected as the biomass of lobsters in the northern and north eastern regions are reduced as a result of higher water temperatures. The Tasmanian rock lobster industry could be ‘an early warning signal’ for other Australian fisheries.[211]

Australia lacks baseline information on many fished stocks and this presents challenges for assessing the effects of climate change on fisheries and the communities they support. It is clear however that climate change will bring with it increased uncertainty for Australian fisheries.

Climate change impacts on existing fisheries will have consequences for coastal communities that are dependent on the fisheries. However, there are adaptation options available to the fishing industry to minimise any adverse impacts and to take advantage of future opportunities. Potential adaptation measures available to the aquaculture industry includes selective breeding, using alternative species, or moving production facilities to more suitable locations.

5.4.4 Oil and gas

The global demand for energy has driven rapid growth in Australia’s petroleum production. Natural gas now provides around 23 per cent of all energy consumed in the world and demand is growing. Oil and natural gas make up 54 per cent of primary energy supply in Australia, coal being the other major contributor.

Australia’s primary domestic sources of oil and gas are offshore, with the majority in Commonwealth waters adjacent to Western Australia. The current value of Australian production is in the order of US$12 billion/year.[212]

The most significant impacts of climate change are any increase in the frequency and severity of cyclones and extreme storm events. Climate change will impact on different components and assets of the oil and gas industry, including fixed and floating offshore facilities, shipping, pipelines and on shore facilities. The impacts will likely be felt across the exploration, production and transport sectors of the industry. By 2030 an increased number of facilities off shore will likely face more extreme conditions more frequently, and this has the potential for incidents with more serious consequences (including damage to infrastructure, losses in production and injury to personnel or communities).

A recent study has found that climate change could reduce productivity in the Pilbara oil and gas sector by a percentage point and reduce the level of production by a further percentage point.[213] A fall in productivity will particularly affect profits earned by the companies, as well as royalties they pay. A fall in production will have flow-on effects to other business, contractors, communities and workers dependent on the oil and gas sector. It will also lead to a reduction in government tax revenues.Impacts on production will affect the national terms of trade.

Looking to the future, increasing frequency of high sea level events and potentially more intense cyclones can be expected to increase the risk of breakdowns and damage to the gas supply system including pipeline delivery infrastructure. The costs of power disruptions to Western Australia from impacts to infrastructure in the Pilbara are currently estimated as reducing Gross State Product by $69 million a day.

Exploration work is also disrupted by the passage of severe cyclones. Jack-up rigs conducting exploration drilling on the sea-bed are evacuated as a storm approaches. There are costs associated with closing down a rig and transporting the personnel to a safe location.

Photo Credit: Warren Faidley/AUSCAPE

Hurricane-damaged oil rig Thunder Horse, in the Gulf of Mexico 2005, a semi-submersible platform owned by BP, was found listing after the crew returned. The rig was evacuated for Hurricane Dennis.

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Box 5.19 The Pilbara oil and gas industry – climate change impacts and costs

The oil and gas industry in the Pilbara region is of national importance. It contributes substantially to national gross domestic product through the export and domestic supply to industry, of oil and gas, contributing to the economic and energy security of Western Australia and Australia. The known reserves and estimated resources off north-west Western Australia are globally significant with the Carnarvon Basin accounting for over 50 per cent of Australia's total known reserves. The recently approved Gorgon LNG project will surpass the NW Shelf as Australia's biggest ever resources development, while another globally significant development, the Wheatstone project, is planned to follow.

Potential climate changes that have implications for the Pilbara oil and gas sector include:

1. Increases in the intensity and frequency of extreme storm events, involving increases in wind speeds, wave heights and storm surges for the 1:100 year event

   These projected changes are likely to increase the annual average number of operational shut downs.

   The area of greatest risk for Pilbara oil and gas is the off shore areas, with some important secondary risk to infrastructure on shore. These areas are currently vulnerable to the threat of cyclones including cyclonic winds, waves, storm surges and flooding.

   Onshore settlements are also at risk with transport links such as pipelines to offshore infrastructure being exposed to the impacts of cyclones.

   It is likely that gas and oil tankers will experience increased disruption to their schedules. Severe storms will cause exploration rigs to cease operations, and production rigs to reduce output.

2. Increases in sea levels

   Sea level changes will increase rates of corrosion for jetties and wharfs due to the projected uplift action of waves on the under-side of jetties. Climate change will increase the need for maintenance on all berths. Extra costs of $8 million per annum have been estimated should companies tighten current five year maintenance cycles to four year cycles over the period to 2030.

3. Increase in average temperature and increase in number of days over 35 degrees C.

   Both increases in temperature and a potential increase in the number of hot days is likely to have an adverse impact on productivity, particularly for outdoor workers.

   Around twenty percent of annual production could be lost over a period of six months while critical infrastructure is repaired. The cost of lost production of LNG and natural gas could be as high as $600 million including a loss of $150 million in associated taxes and royalties.

   (These estimates are borne out by the Varanus Island gas accident which shut down production and cost $113 million in production losses. The total flow on costs to the WA economy has been estimated at up to $2 billion).

Source: SKM Pilbara Coast Case Study 2009 unpub[214], Coakes Pilbara Coast TRC Case Study, 2009 unpub[215]