Climate change impacts on coastal settlements and infrastructure

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Impact Sheet 2

Contents

Coastal settlements and infrastructure in Australia

Climate change projections for Australia have a range of significant social, economic and environmental implications for coastal settlements and infrastructure. Increased temperatures result in more frequent extreme bushfire conditions; rising sea levels raise the risk for coastal flooding and, coupled with likely changes in wave climate, increase the erosion risk for beaches and foreshores; and ocean acidification impacts on fisheries and fishing industry.

The Australian continent is a land of climatic extremes, so much so that past events such as Cyclone Tracy, the Black Saturday bushfires and the Millennium drought are central to our cultural narrative. While Australian society has recovered from and displayed resilience to these events, the impacts are significant. The Reserve Bank of Australia has identified reductions to GDP and increases in the Consumer Price Index arising from the 2010–11 Queensland floods, and the Australian Government enacted a special income tax levy to fund recovery from inundation damage to settlements and infrastructure. In this context, climate change impacts, which can exacerbate the magnitude and frequency of extreme events, will be a particular challenge to settlements and infrastructure.

Figure 1 displays the population density of Australia using data from the 2011 Australian Census. Present-day settlement is concentrated along the edges of the continent in response to better access to natural resources, particularly fresh water when compared to the aridity of the interior. Within the coastal zone, the rich floodplain soils and opportunities for transport by sea have seen settlement further concentrated around estuaries. Australia's infrastructure is also concentrated in the coastal zone. However, the large areas of low-density population between settlements have created particular challenges for the provision, maintenance and operation of linear infrastructure such as roads, rail, electricity distribution, telecommunications and water supply.

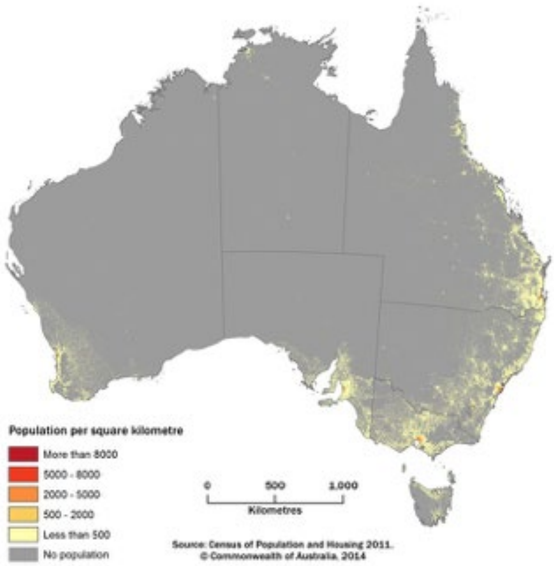

Figure 1: Australian population density in 2011. Source: Census of Population and Housing 2011. © Commonwealth of Australia 2016. Taken from the Australian Bureau of Statistics website with permission http://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.007.

Climate change projections for Australia

Within Australia, there is a wide range of climate systems, from tropical monsoonal in the north through to arid, moist temperate and alpine moving to the south. Natural climatic variability is high and influenced by regional climate drivers: the El Niño–Southern Oscillation, the Southern Annular Mode, the Indian Ocean Dipole and the Pacific Decadal Oscillation. For more detailed information on drivers of climate variability in Australia, see http://www.bom.gov.au/climate/ (accessed 18 March 2016).

The recently published Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment chapter on Australasia (Reisinger et al. 2014) found high confidence in the evidence of warming air temperatures across Australia, with projections for continued increase over the coming century. Changes to precipitation as a result of climate change are subject to significant uncertainty. South-western Australia is expected to be dry, and winter rainfall amounts are expected to decrease. Other projected changes about which there is at least high confidence include regional increases in sea surface temperature, the occurrence of more hot days, more extreme fire weather in southern Australia, rising mean and extreme sea level and ocean acidity; and decreases in cold days and snow extent and depth (see Table 1).

Table 1: Climate change observations and projections for Australia.
Source: Bureau of Meteorology and CSIRO 2014.

Variable	Projections
Sea-level rise	Sea-level rise around the Australian coastline by 2100 is likely to be similar to the projected global rise of 0.28–0.61 m for low emissions and 0.52–0.98 m for high emissions, relative to 1986–2005. Even higher sea levels by 2100 are possible if there is a collapse of sectors of the Antarctic ice sheet grounded below sea level. There is medium confidence that such an additional rise would not exceed several tenths of a metre by 2100. Under all scenarios, sea levels will continue to rise after 2100, with high emissions leading to a sea-level rise of 1 m to more than 3 m by 2300. Increases in mean sea level will increase the frequency of extreme sea-level events.
More frequent and extreme storm events	Fewer tropical cyclones are projected for the Australian region, on average, with an increased proportion of intense cyclones. However, confidence in tropical cyclone projections is low.
Increasing temperatures	Australian temperatures warmed by 0.6°C between 1910 and 1990 and are projected to continue to warm, rising by 0.6–1.5°C by 2030 compared with the climate of 1980–1999. Warming by 2070, compared to 1980–1999, is projected to be 1.0–2.5 °C for low greenhouse gas emissions and 2.2–5.0 °C for high emissions.
More severe fire weather	The number of extreme fire-weather days is projected to grow in southern and eastern Australia, by 10–50% for low emissions and 100–300% for high emissions by 2050 compared with the climate of 1980–1999.
Altered patterns of wet and dry periods	Further decreases in average rainfall are expected over southern Australia compared with the climate of 1980–1999 although the range of model estimates is wide. By 2070, a 0–20% decrease is projected for low emissions, whereas for high emissions the projected range is from a 30% decrease to a 5% increase by 2070, with largest decreases in winter and spring. For northern Australia, the projected changes in rainfall range from a 20% decrease to 10% increase by 2070 for low emissions and a 30% decrease to 20% increase for high emissions. Droughts are expected to become more frequent and severe in southern Australia.
Increase in extreme rainfall	An increase in the number and intensity of extreme rainfall events is projected for most regions.
Ocean acidity	Ocean acidity levels will continue to increase as the ocean absorbs anthropogenic CO_2 emissions.

These projected changes to Australia's climate will affect the frequency and/or magnitude of risks to which coastal settlements and infrastucture are exposed. The impact on settlements and infrastruture will depend on local conditions and the sensitivity of a particular asset or structure. In determining how climate change will impact on infrastructure, it is important to recognise that much of our infrastructure comprises networks; the conseqences of the failure of one point within a network can flow across the network, depending on the redundancy within that network. For example, where a flood event or bushfire causes a road to close, the impact of the closure can be contained if there is an alternative route. However, if there is no alternative route, the impact of the closure has consequences that could spread across the entire network.

Table 2 below descibes the effects of the projected changes listed in Table 1 on existing and future settlements and infrastructure.

Table 2: Direct impacts of climate change on coastal settlements and infrastructure (adapted from Victorian Coastal Strategy [State of Victoria 2014] and the national coastal risk assessment [Department of Climate Change 2009]).

Climate variable	Direct impact
Sea Level Rise	More frequent and extensive inundation of low-lying areas Cliff, beach and foreshore erosion Altered saltmarsh and mangrove habitats – their protective function may be lost Loss of, damage to and reduced functionality of infrastructure Loss of and damage to private property; changes to land use Loss of coastal Crown land for tourism and recreation
More frequent and extreme storm events	Loss of and damage to private and public property and infrastructure Beach, foreshore and cliff erosion Pollution from sewer overflows
Increasing temperatures	Increases in the severity and frequency of heatwaves with extensive impacts such as power outages and performance failure of rails and road surface
More severe fire weather	Where bushfires occur, potential for loss of property, damage to infrastructure and failure of utilities – power, water and sewage treatment. Risk of contaminated water supply from burnt over reservoir catchments.
Altered patterns of wet and dry periods	Changed salinity, nutrient and sediment flows Changed estuaries, greater extremes of high and low freshwater input Reduced water clarity Increased frequency and intensity of fires on land Increased visits to the coast in hot, dry periods
Increase in extreme rainfall	Increased risk of flooding of coastal settlements and infrastructure; flooding of electricity and water supply infrastructure may lead to power outages and contaminated water supply. Flooding of sewage works may put them out of action leading to risks to public health.
Ocean acidity	Few risks for settlements and infrastructure, although loss of coral reefs may put coastal tourism operations at risk with knock-on effects for coastal settlements.

Potential effects of sea-level rise on settlements and infrastructure

The Australian coast is exposed to a range of natural hazards, from bushfire to tsunamis. Where the term 'coastal hazards' is used, it generally refers to erosion and storm tide inundation. Storm events, particularly tropical cyclones and East Coast Lows, generate powerful waves and winds which drive erosion and storm tide inundation that can cause damage to settlements and infrastructure.

Sea-level rise projections show that climate change will increase the exposure of settlements and infrastructure to these hazards. Figure 2 shows the impact on exposure to inundation of an Adelaide suburb based on a 0.7 metre sea level rise (very high greenhouse gas scenario in 2100).

Erosion of dunes and beaches adjacent to developed coastal areas can cause damage to structures by:

- reducing the stability of foundations, causing settlement of the structure or
- directly undercutting the structure, causing collapse of the footings or exposure to wave action.

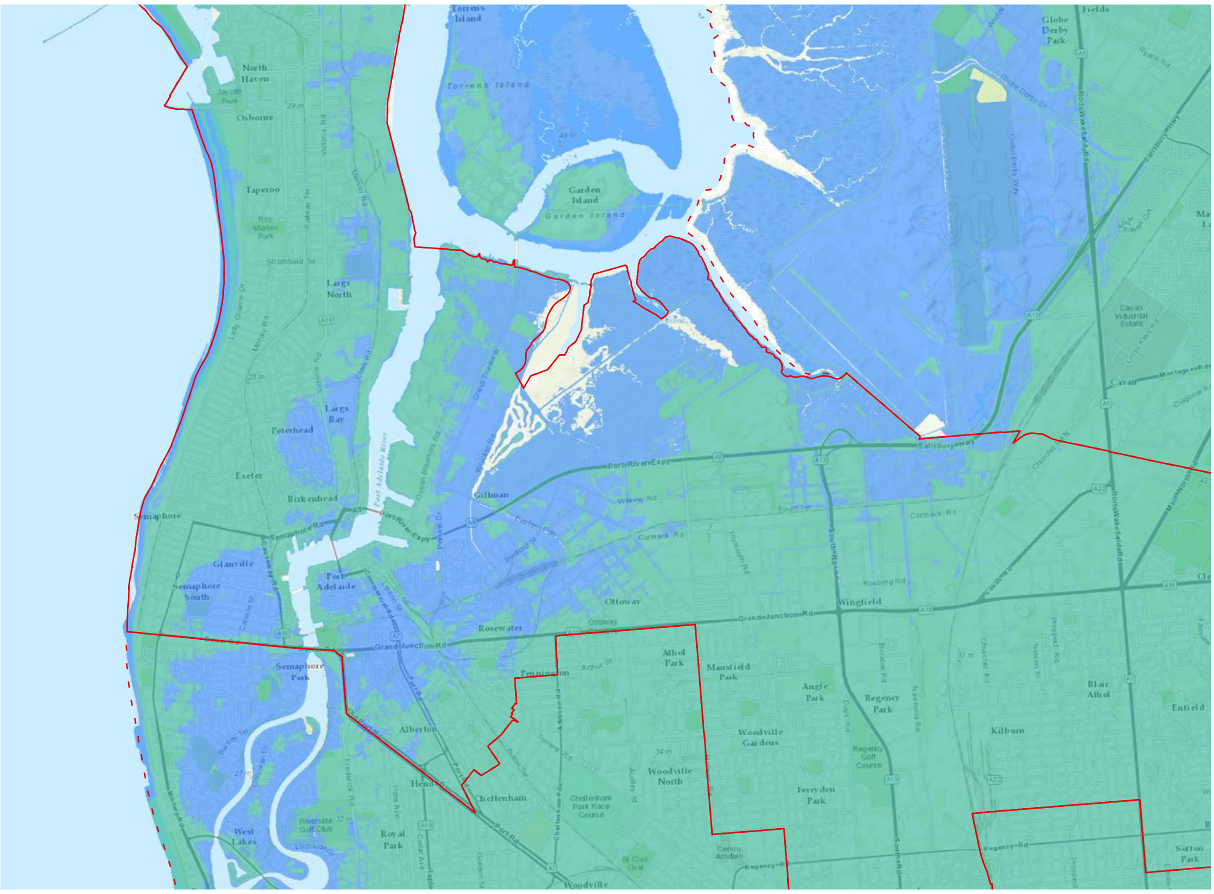

Figure 2: Impact of sea-level rise on inundation hazard for Port Adelaide - Enfield. Map is for a very high greenhouse gas scenario (RCP8.5) in 2100. Source: CoastAdapt.

Following storm events, beaches may recover through a process referred to as accretion, where sediment moved offshore by storm waves is returned to shore during calm conditions (Figure 3). In some situations, shorelines will not accrete following a storm event. Often this is the result of an imbalance in sediment, where more sediment is moving out of an area than is being replaced. This long-term erosion is referred to as recession (Figure 4). The vulnerability of a particular area to erosion depends on factors such as its geomorphology, its orientation to wave activity, its proximity to development and the extent of interference in longshore transport.

Erosion and recession can occur on both open coast and embayed or estuary locations.

Strong winds and low air pressure during coastal storms can result in temporary increases to sea levels. The combination of this increase in water level and tide is called a storm tide. Storm tides cause the temporary inundation of coastal areas, which creates the risk of people becoming caught in rising water and drowning.

Often storm tides are accompanied by coastal storms, with extreme waves that further raise water levels at the shoreline due to wave set-up and run-up (Figure 5). Extreme water levels at the shoreline (through combinations of tide, surge and waves) pose a serious risk to buildings and infrastructure, with the potential for inundation to undermine foundations, short-circuit electrical systems and ultimately destroy buildings and infrastructure. The main areas at risk from coastal inundation are low-lying open coast areas that are protected only by narrow natural or artificial barriers and the extensive foreshore areas of estuaries, lagoons and waterways.

As sea levels rise, the frequency of inundation events of a given height will increase and shorelines will erode and accrete as they adjust to increased water levels. These changes will increase the number of buildings and amount of infrastructure exposed to inundation and the frequency with which inundation will impact on buildings and infastructure already exposed.

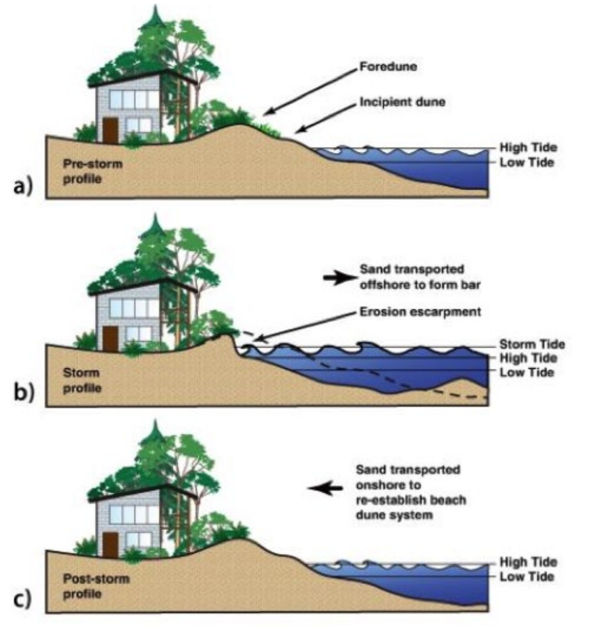

Figure 3: Beach erosion/accretion cycle showing no permanent sand loss or coastline retreat. Source: State of Queensland (Department of Environment and Resource Management) 2011.

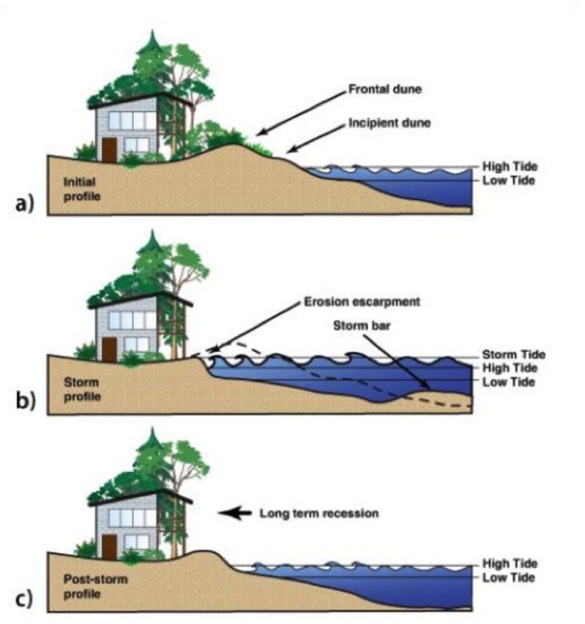

Figure 4: Long-term beach recession showing profile displaced landward due to permanent sand loss. Source: State of Queensland 2011. (Department of Environment and Resource Management) 2011.

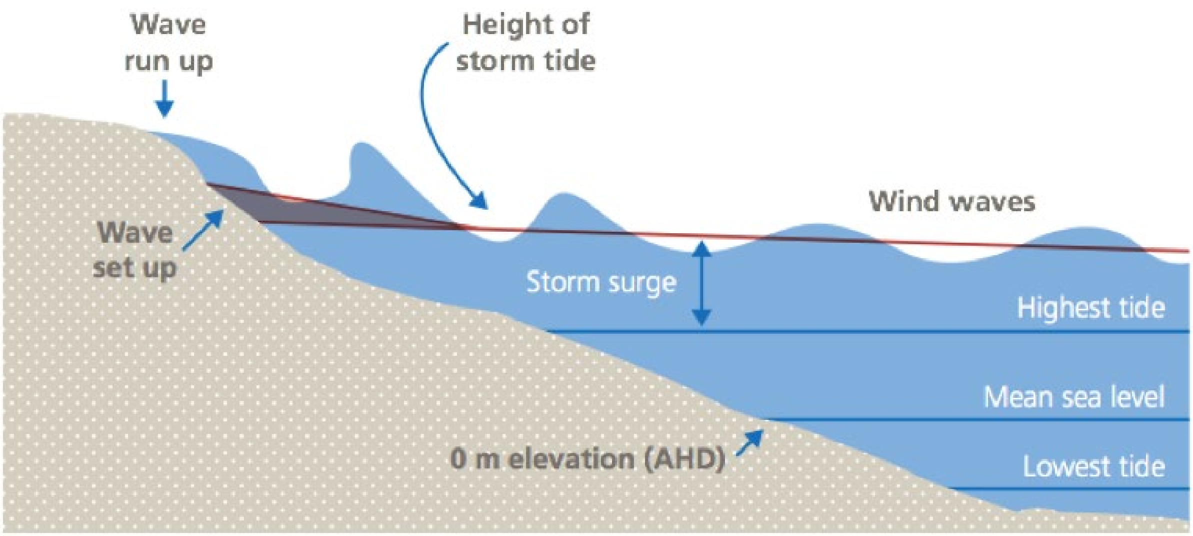

Figure 5: Storm tide source. Source: State of Victoria (Department of Sustainability and Environment) 2012.

Impacts and consequences for settlements and infrastructure

With detailed projections of climate change now available, new settlements and infrastructure can be designed to be resilient to these changes. The challenge is that the majority of our settlements and infrastructure were developed under assumptions of a static rather than changing climate system.

While the climate change projections shown in Table 1 will result in many individual impacts on natural hazards and on coastal settlements and infrastructure, as described in Table 2, these impacts fit within the following three categories:

1. damage to property and infrastructure from extreme events – e.g. water damage from inundation during storm tide
2. accelerated degradation of materials and structures – e.g. high temperatures and solar radiation degrade asphalt road surfaces
3. changes to resource demands – e.g. increasing peak loads on electricity networks during hot weather as air conditioner usage increases.

The consequences of these impacts on coastal settlements and infrastructure include:

- increased maintenance, repair and replacement of:
    - residential and commercial buildings
    - public and service utility infrastructure
    - commercial and industrial facilities
- increase in preventative expenditure and/or upgrade adaptation of seawall protection, sand replenishment, stormwater drainage systems, flood levees, etc.
- reduction in capacity of businesses to operate due to property damage
- reduction in use of buildings and facilities due to inundation, flooding, ground movement and structural integrity
- increased cost of insurance.

Climate change will have serious impacts on the integrity, performance and lifetime of coastal infrastructure, increasing maintenance costs and potentially bringing forward replacement horizons. These new costs will create new burdens for coastal settlements, which will increase pressure on government budgets and require changes to how we live and work across the Australian coast.

The following sections describe key risks to individual sectors within coastal settlements and infrastructure.

Coastal settlements

Across the Australian coast there are between 157,000 and 247,000 residential buildings exposed to inundation under a projected future sea-level rise of 1.1 m. The replacement value of these buildings (at 2008 values) is between $41 and $63 billion (Department of Climate Change and Energy Efficiency 2011). There are also large areas of public land, such as beaches and foreshores, that are exposed to inundation from sea-level rise and to erosion-related hazards. The implications are settlement-wide, particularly where tourism is an important revenue generator.

Energy sector

Energy infrastructure involves complex managed systems with multiple actors across increasingly distributed processes of generation, transmission and networks. Climate change impacts such as extreme events may damage assets and reduce continuity of service (Table 3). The exposure of equipment to changed climatic regimes may also result in accelerated degradation, reducing life expectancy of assets and increasing maintenance costs. As renewable electricity generation gains momentum, there will be increased pressure on the grid to accommodate distributed generation. Climate change will lead to increased demand during extreme events; for example, the use of air conditioning increases during heatwaves, which can cause network failures.

Table 3: Energy sector impacts.

Climate variable	Impact
Increased temperature and heatwaves	Increase in blackouts due to increased demand Increased bushfire damage
Changes to wet and dry spells	Decline in the stability of structures and foundations
Increase in intensity of storms	Storm damage to above-ground transmission
Sea-level rise and increase in intensity of storms	Substation flooding Inundation of refineries

Telecommunications

Similar to electricity networks, telecommunications infrastructure is exposed to damage as a result of extreme events and accelerated degradation of materials and structures (Table 4). Both of these impacts will affect the cost and continuity of service provision.

Table 4: Telecommunications sector impact.

Climate variable	Impact
Changes to wet and dry spells	Decline in the stability of structures and foundations
Increase in intensity of storms	Storm damage to above-ground transmission and cell phone towers
Sea-level rise and increase in intensity of storms	Exchange station flooding

Transport

Increases to the intensity of extreme events is a significant risk for transport infrastructure. Across Australia, 26,000–33,000 km of roads and 1,200–1,500 km of rail lines and tramways are exposed to the combined effects of inundation and shoreline recession for a sea-level rise of 1.1 m. Changes to rainfall intensity also have implications for transport infrastructure, such as underground train stations which may flood.

Seaports are an essential component of Australia's international trade and are also highly exposed to climate change hazards – storms, flooding and sea-level rise – because of their location in the coastal zone. Seaports should be considered as a component of a larger transport system when assessing climate change impacts, given that both landside and seaside operations have greater exposure to current climatic variability. Risks include inundation, wave damage, material degradation and delays, which may be either the result of direct climate variables, such as high seas, or indirect, such as the impact of drought or fire on supply chains.

Climate change will impact on maintenance and repair through degradation of materials, decreasing foundation stability, reduced life of asphalt and tarmacs and increased expansion and movement of steel, concrete and coatings.

Systemic challenges

While it is possible to examine impacts and develop adaptation responses at the level of individual infrastructure assets and even at the individual settlement level, the interconnections between infrastructure and settlements, and between settlements, pose particular challenges.

These issues include:

- funding and financing new and upgraded infrastructure
- timing upgrades and replacements to elements within a network, which can either enable or constrain adaptation possibilities
- governance and jurisdiction boundaries and roles and responsibilities between levels of government.

Further reading

Assessment of impacts of climate change on Australia's physical infrastructure http://www.atse.org.au/Documents/Publications/Reports/Climate%20Change/ATSE%20Impacts%20of%20Climate%20Change%20on%20Australian%20Physical%20Infrastructure%202008%20Report.pdf (accessed 18 March 2016)

Coming ready or not: Managing climate risks to Australia's infrastructure. An analysis of Australia's exposure to and preparation for the impacts of climate change on major infrastructure http://www.climateinstitute.org.au/verve/_resources/TCI_ComingReadyorNot_ClimateRiskstoInfrastructure_October2012.pdf (accessed 18 March 2016)

'Box A: *The impact of the recent floods on the Australian Economy' in Statement on monetary policy: February 2011*, An analysis by the Reserve Bank of Australia of the impacts of floods on the Australian economy https://www.rba.gov.au/publications/smp/2011/feb/pdf/box-a.pdf (accessed 18 March 2016)

Understanding future risks to ports in Australia: Work Package 1 of Enhancing the resilience of seaports to a changing climate report series https://www.nccarf.edu.au/sites/default/files/attached_files_publications/McEvoy_2013_Understanding_future_risks_to_ports_in_Australia_WP1.pdf (accessed 18 March 2016)

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