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Climate Adaptation Outlook

A Proposed National Adaptation Assessment Framework

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Foreword

Australian cities need to prepare for the impacts of climate change.

About this report

The Climate Adaptation Outlook report is the first of a structured series of reports on how well placed Australia — including its businesses, communities and institutions — is to manage the impacts of unavoidable climate change.

The Productivity Commission's recent report, *Barriers to effective climate change adaptation*, highlighted that Australia must work to maintain its prosperity in the face of a changing climate. Yet a number of questions arise: How should Australian governments, businesses and communities respond to changing climate risks? How would we recognise an effective response? What might we need to change in order to do better? All levels of government, businesses and the community share responsibility for finding answers to these questions — and acting on them.

The range of decisions potentially affected by the changing climate, the variety of decision-makers, and the many legal, social, cultural, economic and historical factors that will influence them, mean that a prescriptive approach to answering these questions is unlikely to be helpful.

This report proposes a national assessment framework to assess progress in adapting to the impacts of climate change. It will help shape the response that is needed by business, government and communities. Because adaptation has only recently emerged as a significant issue for decision-makers in Australia and around the world, we would hope to see progress without expecting that the challenge has been fully met.

Chapter 1 outlines the importance and urgency of adapting to the impacts of climate change.

Chapter 2 outlines the approach to developing the assessment framework.

Chapter 3 develops the framework as it applies to Australia as a whole.

Chapter 4 extends the framework to the coastal zone as an example of how progress in managing the impacts of unavoidable climate change might be assessed for a specific sector with its own legal frameworks, governance arrangements and stakeholders.

Chapter 5 focuses on the adaptation challenges south-east Queensland faces and how the assessment framework can be extended to a region.

Chapter 6 presents a set of possible indicators.

This report also provides examples of leading practice for businesses and communities already looking to act.

The Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE) developed this report in association with researchers from CSIRO and the Australian National University. Advice was provided throughout the process by an independent expert group comprising Ms Sam Mostyn (chair), Dr Andrew Ash, Professor Sue Richardson, AM, Ms Romilly Madew, Cr Paddi Creevey, OAM, and Mr David Singleton.

The report draws on the best available research and information about climate change adaptation in Australia and globally. A number of workshops drawing together selected experts and stakeholders from government, industry, the community and academia contributed to the development of the proposed national assessment framework.

Next steps

In the second half of 2013, DIICCSRTE will consult stakeholders on the proposed assessment framework and indicators set out in this report. Those wishing to provide comments on the proposed framework can email them to AdaptationOutlook@innovation.gov.au.

In early 2014, a final assessment framework will be released and the framework will be extended to include a more complete set of key sectors. The final assessment framework will include a set of indicators.

In late 2014, an assessment of Australia's progress in managing the impacts of unavoidable climate change, using the assessment framework, indicators and other evidence, will be released.

Agriculture is one of the priority sectors which will be assessed in the late 2014 report.

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CHATEAU

ES Executive summary

Making good decisions in a changing climate

Australia's continuing prosperity depends on innovative responses to an evolving array of challenges. The impacts of climate change are similar in magnitude and complexity to other major long-term challenges Australia faces, such as the rise of Asia or the implications of an ageing population. Climate change impacts are occurring now and will undermine our prosperity unless we make good decisions to deal with the risks today.

Global business and political leaders recognise that climate change is occurring and the importance of adaptation. In 2013, the World Economic Forum ranked failure to adapt to the impacts of climate change as one of the five highest impact global risks.

For Australia — one of the developed countries most vulnerable to climate change impacts — the stakes are high. Climate change impacts are a significant risk to the economy (billions of dollars worth of assets are exposed to sea level rise, flooding or bushfire; extreme weather can disrupt critical business operations and supply chains), to communities (health risks are serious, disadvantaged groups are highly vulnerable) and to the natural environment. Recent events illustrate Australia's current vulnerability to climate. For example, the Queensland floods of 2010–11 reduced gross domestic product by an estimated 0.5 per cent, and the Black Saturday bushfires of 2009 cost more than $4 billion and killed 173 people.

Leading nations, businesses and communities are already taking serious steps to understand and manage this growing risk. They are acting because of the competitive advantages it offers and because taking all significant risks into account is simply good practice and smart leadership.

It is vital for Australia to evaluate how well it is doing as a nation in adapting to the impacts of climate change. 'Adaptation' means the steps governments, businesses, communities and individuals take to deal with risks from climate change impacts.

What would good adaptation look like in Australia?

The Climate Adaptation Outlook report is the beginning of a structured series of reports about how well Australia is adapting to the impacts of

Opposite page: Good coastal adaptation will help protect our beaches from severe erosion.

climate change. This first report in the series proposes a National Adaptation Assessment Framework that governments, businesses and communities can use to assess national progress, and a set of national indicators.

The framework seeks to build a picture of what Australia would look like if we were doing a good job of adapting to the impacts of climate change. To do so it asks three broad questions:

- What drivers in society and the economy would promote good adaptation?
- What activities would we expect to see now if Australia is adapting well?
- What outcomes do we expect to see from good adaptation?

This report applies the framework to describe the drivers, activities and outcomes we would expect to see across the whole country if Australia was doing a good job of managing the impacts of climate change. Figure ES.1 summarises the framework at the national scale.

Figure ES.1 Drivers, activities and outcomes of climate change adaptation

The main drivers of adaptation are markets (which can provide price signals and promote disclosure of climate change risks), public attitudes, and governance and regulation. It is also critical to ensure that climate change risks are well understood and clearly allocated to those best placed to manage them, while those who benefit pay the costs.

If Australian governments, businesses and households were adapting well we would expect them to be reducing unacceptable vulnerabilities to the current climate, taking climate change impacts into account in decisions with long-term consequences, and building capacity to deal with climate change risk in the future.

A well-adapting Australia would continue to enjoy social and economic opportunities and at the same time ensure that climate risks remain within bounds that are acceptable to the community, avoid passing unmanageable risks onto future Australians and make sure disadvantaged groups are able to manage the climate risks they face.

The report also tailors the framework to the distinctive climate risks and characteristics of the coastal zone, as an example of how 'good management' of climate risks can be described for an important part of Australia. It extends the framework to south-east Queensland as an example of what good adaptation might look like in a region with specific climate risks and vulnerabilities.

Outcomes are mixed

As an example of how indicators might be used to assess national adaptation progress, the report considers whether good outcomes are being achieved. Where evidence is available, climate risks requiring long-term management continue to grow rapidly. For example, an increasing number of buildings are exposed to flood, bushfire and coastal inundation. On the other hand, there has been progress in reducing risks in some areas with where impacts on livelihoods are more immediate — for example through increased capacity to manage risks to activities that depend on water resources. In many cases (such as natural ecosystems) risks are known to be high but it is not possible to say how fast they are changing.

This report demonstrates the importance of a community discussion about whether these risks are acceptable and the legacy of climate risk we are leaving for the future.

Next steps

The Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education will consult with stakeholders to refine the assessment framework as a basis for reporting on national adaptation progress.


THE
SEQUEL

01 Why we should be managing climate risks now

Key points

Australian governments, businesses and households will be better off if they start managing changing climate risks now. The changing climate needs to be considered in a wide range of decisions, from building and infrastructure design to water resource management, to delivery of community services.

This chapter shows the importance of understanding whether Australia is managing climate risks well and therefore provides the context for the proposed national assessment framework.

The climate is changing. Australia is almost a full degree warmer than at Federation, sea levels have risen and rainfall patterns have shifted — further change is unavoidable. Higher temperatures, rising sea levels and increasingly extreme flooding rains, heatwaves, bushfire weather and cyclones create strategic risks to Australian businesses and communities.

Australians will be better off if they start thinking now about how to manage the impacts of a changing climate. This need not imply that immediate, costly action will be necessary, but early consideration and planning means that a broader range of options can be assessed.

Businesses, governments and communities that continue to make decisions based on the historical climate will face higher costs and reduced amenity, and will be less resilient to impacts; those that act on the new reality will reap tangible benefits. In Australia, leading practitioners in business, governments and communities are already factoring the changing climate into their decisions.

Figure 1.1 shows the benefits of adapting to climate change impacts.

Opposite page: Two young men stand at the water's edge as flooding encroaches on Brisbane's CBD in 2011.

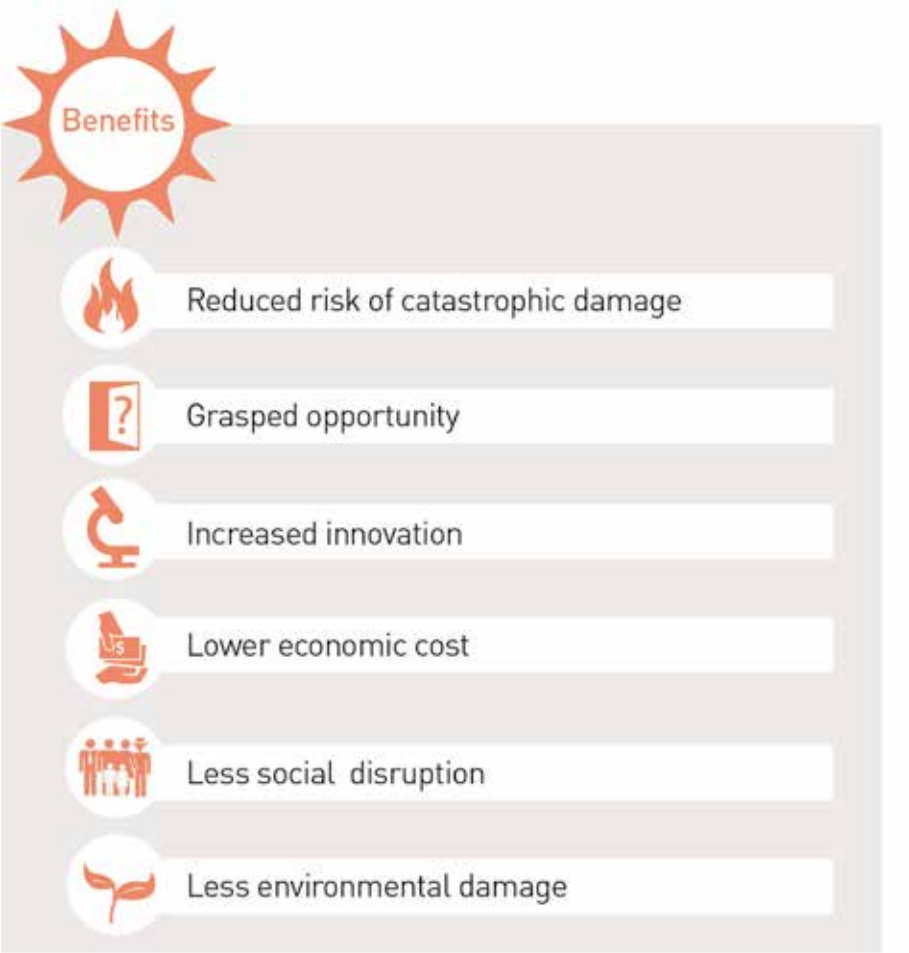

Figure 1.1 The benefits of adapting to climate change impacts

Though the changing climate will seldom be the only important factor in any decision, the consequences of not taking it into account are serious — especially if climate change impacts occur when companies or governments are also under pressure from other financial or environmental stresses. Box 1.1 gives examples of decisions where the changing climate is important.

Good adaptation to climate change impacts will reduce disruptions to the national economy.

Box 1.1 Some decisions where the changing climate is important

Where to build	Rising sea levels and more intense bushfires and floods will affect decisions about how to use land. For example, a site at high risk of inundation from rising sea levels may be suitable for a golf course but not for a major hospital.
How to promote good health	Heat-related deaths are a significant health problem. In the longer term we will need to be more vigilant about vector-borne diseases like dengue fever and Ross River fever.
Designing buildings and infrastructure	More extreme heat, stronger winds, heavier rain and rising sea levels have implications for the design of houses, bridges, railways, urban drainage systems, airports, sea ports and energy infrastructure.
What to grow and where	Rising temperatures, shifting rainfall patterns and more severe drought will affect agricultural industries. In the short term farmers will need to become even more resilient to our already variable climate. Some producers will need to consider more significant changes in the longer term.
How to manage national parks	Species and ecosystems shift their ranges as the climate changes, and there is strong evidence that this is already happening. More broadly, a changing climate has profound implications for how natural ecosystems are managed across Australia.
Supplying fresh water to cities	Perth's catchments are already drier because of anthropogenic greenhouse gas emissions and a changing climate will magnify risks to the freshwater supplies of other major Australian cities.
Managing rural water resources	Climate change is a threat to streamflows and shallow aquifer recharge in most of Australia's major catchments. Water resource managers and irrigators will need to factor increased risks to water resources into their planning.
How to deliver community services	Community service organisations provide critical support for many disadvantaged people, but many organisations are themselves vulnerable to extreme climate events and may not be able to provide services following natural disasters.[a]
Where to invest	Climate change could affect the value of a wide range of assets and corporations. Mining operations, for example, can be disrupted by cyclones or flooding, and coastal infrastructure is vulnerable to rising sea levels. Some major investors are already considering how a changing climate will affect the value of their portfolios.

a K Mallon, E Hamilton, M Black, B Beem & J Abs, *Adapting the community sector for climate extremes*, National Climate Change Adaptation Research Facility, Gold Coast, 2013.

Changing climate risks and opportunities

Australia's climate creates significant risks for governments, businesses and communities.

Some of these risks manifest through major events such as bushfires, floods, cyclones and droughts. The social, economic, environmental and human costs can be high. The Queensland floods of 2010–11 caused significant private losses, and reduced gross domestic product (GDP) by an estimated 0.5 per cent.[1] Since 2010–11, the Australian Government has paid $5.7 billion to state governments to support disaster relief. The Black Saturday bushfires of 2009 cost more than $4 billion and killed 173 people.[2]

Other risks are less visible. Australia's highly variable rainfall drives up the cost of ensuring a reliable water supply to our major cities. Sydney, for example, has enough water storage capacity to maintain supply for more than five years (based on water supplied in 2009–10).[3] High temperatures cause many deaths each year. Engineers must design railway lines, power transmission systems and other structures to cope with the extremes of heat.

Climate change magnifies risks and may create new ones, such as areas newly vulnerable to coastal inundation. The social, economic and environmental stakes are high:

- Social: If poorly managed, a changing climate will damage the health of Australians and disrupt communities. For example, in 1990, Australia had around 5800 temperature-related deaths but with unmitigated global warming this is projected to increase to almost 10,000 by 2070.[4] A changing climate is expected to promote the spread of mosquito-borne diseases such as dengue fever,[5] and increase injuries from natural disasters. Some members of the community, such as people with disabilities, the elderly and low-income groups, are especially vulnerable to a changing climate. Natural disasters disrupt the services upon which they depend for day-to-day support.[6]
- Economic: Growing exposure of built assets such as houses, bridges, roads and rail to climate risks has already led to escalating damages from storms, floods, bushfires and other natural disasters (see Box 6.1). A record heatwave in

1 M Blythe, *Costing the floods*, Global markets research: economic update, 27 January 2011, Commonwealth Bank of Australia, 2011, viewed 23 May 2013, <www.commbank.com.au/corporate/research/publications/economics/economic-update/2011/270111-Costing_Floods.pdf>.

2 2009 Victorian Bushfires Royal Commission 2010, *2009 Victorian Bushfires Royal Commission: final report*, Parliament of Victoria, Melbourne.

3 Productivity Commission, *Australia's urban water sector*, report no. 55, Final Inquiry Report, Productivity Commission, Canberra, 2011, p. 19.

4 H Bambrick, K Dear, R Woodruff, I Hanigan & A McMichael, *The impacts of climate change on three health outcomes: temperature-related mortality and hospitalisations, salmonellosis and other bacterial gastroenteritis, and population at risk from dengue*, paper prepared for the Garnaut Climate Change Review, Canberra, 2008.

5 H Bambrick, K Dear, R Woodruff, I Hanigan & A McMichael, *The impacts of climate change on three health outcomes: temperature-related mortality and hospitalisations, salmonellosis and other bacterial gastroenteritis, and population at risk from dengue*, paper prepared for the Garnaut Climate Change Review, Canberra, 2008.

6 K Mallon, E Hamilton, M Black, B Beem & J Abs, *Adapting the community sector for climate extremes*, National Climate Change Adaptation Research Facility, Gold Coast, 2013.

south-east Australia in 2009 illustrated the vulnerability of our cities to climate extremes. Infrastructure failure disrupted electricity supplies and transport services, and financial losses from the event have been estimated at $800 million. At one stage, up to half a million properties were without power.[7] Economic activities such as agriculture, tourism and health services are also at risk from a changing climate. The Garnaut Climate Change Review found that, even with some adaptation, the impacts of unmitigated climate change could reduce GDP by more than 6 per cent in 2100 compared with a world with no climate change.[8]

- Environmental: Natural ecosystems have limited capacity to respond to a climate that is changing rapidly.[9] This capacity is further constrained by pressures such as land clearing, the introduction of invasive species, and land use patterns that limit opportunities for species and ecosystems to migrate as the climate shifts. As a consequence, early impacts of climate change on natural ecosystems are already observable. For example, high sea surface temperatures have caused frequent coral bleaching events on the Great Barrier Reef since the 1970s, contributing to a decline in coral cover.[10]

Opportunities will come from learning early how to manage the impacts of a changing climate

Climate change will bring some opportunities. There are some anticipated benefits from climate change. There will be fewer cold-related deaths. Yields of some crops are likely to increase in some places because of fertilisation from extra carbon dioxide in the atmosphere, but this will be temporary as decreasing rainfall and higher temperatures overwhelm the benefits of extra carbon dioxide.[11]

Opportunities will come from learning early how to manage the impacts of a changing climate. In particular, there may be opportunities for Australian businesses to develop new products and services to help manage climate risks, and to market these internationally. For example, BlueScope Steel is improving and developing products to deal with rising temperatures, bushfires and other hazards.[12]

Changing climate risks need to be managed in a world where many other pressures apply, some of which may seem more immediate. The potential for simultaneous shocks creates fresh risks. The World Economic Forum rates failure of climate change adaptation as one of the five highest impact global risks (the others were major systemic financial

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7 Queensland University of Technology, *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009*, report to the National Climate Change Adaptation Research Facility, QUT, Monash University & University of Southern Queensland, Brisbane, 2010.

8 R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Port Melbourne, 2008.

9 A Fischlin, GF Midgley, JT Price, R Leemans, B Gopal, C Turley, MDA Rounsevell, OP Dube, J Tarazona, AA Velichko, 'Ecosystems, their properties, goods and services', in ML Parry, OF Canziani, JP Palutikof, PJ van der Linden & CE Hanson (eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007, Cambridge University Press, UK, 2007.

10 G De'ath, KE Fabricius, H Sweatman & M Puotinen, 'The 27-year decline of coral cover on the Great Barrier Reef and its causes', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 109, no. 44, 2012, pp. 17995–99.

11 F Tubiello, J Schmidhuber, M Howden, PG Neofotis, S Park, E Fernandes & D Thapa, *Climate change response strategies for agriculture: challenges and opportunities for the 21st century*, The World Bank, Washington DC, 2007; S Crimp, M Howden, B Power, E Wang & P De Voil P, *Global climate change impacts of Australia's wheat crops*, technical paper prepared for the Garnaut Climate Change Review, 2008.

12 BlueScope Steel, *Design for climate*, BlueScope Steel, 2013, viewed 24 May 2013, <http://sustainability.bluescopesteel.com.au/design-for-climate?>.

failure, water supply crises, chronic fiscal imbalances and diffusion of weapons of mass destruction).[13] Systemic financial failure together with poor management of changing climate risks could pose serious risk to our future prosperity. Climate change could also increase the risk of global insecurity, with implications for Australia as a provider of humanitarian assistance and disaster relief.[14]

Appendix 1 provides more information about Australia's changing climate risks.

Some Australians are already considering how climate change could affect them and their businesses.

Prospering through change

Australians are skilled at coping with change.

Recent decades have seen significant social changes (e.g. rapid uptake of information technologies such as the internet and mobile phones) and major economic changes (such as floating the dollar, removing trade barriers and structural changes that have led to some industries shrinking and others growing).

Adapting to a changing climate will require the same innovation and flexibility that allowed Australians to prosper through these earlier changes.

This uncertainty may tempt businesses, governments or households to postpone thinking about how to manage the attendant climate risks until we know more about them. Many climate-sensitive decisions have traditionally assumed that the historical record is a reliable source of information about the range of climate events that need to be considered. This assumption is no longer valid because of the changing climate. At the same time, the inherent unpredictability of climate means that science is not able (and will never be able) to provide complete certainty about the future.

But many decisions made today will have consequences well into the future. A new port, for example, may continue to have a useful economic life for 50 years or more after it is planned,[15] bridges have design lives of up to 100 years and people may keep living in a new suburb for a century or longer. Climate risk is a factor in all these decisions. Ports must be able to operate despite storms and king tides, bridges must withstand floods and high winds, and suburbs must not be at unacceptable risk from bushfires, floods or cyclones.

(See Box 1.2 for examples of how some international leaders have already factored climate change into their decision-making.)

13 L Howell, *Global risks 2013*, World Economic Forum, Switzerland, 2013.
14 A Press, A Bergin & E Garnsey, *Heavy weather: climate and the Australian Defence Force*, ASPI Special Report, Issue 49, March, Australian Strategic Policy Institute, Canberra, 2013.
15 National Transport Commission, *National ports strategy: infrastructure for an economically, socially and environmentally sustainable future*, Infrastructure Australia, Canberra, 2012.

Box 1.2 Examples of international leaders

New York City has taken a proactive and collaborative approach in addressing climate change to become a leader in climate change adaptation. The mayor of the city launched the cross-sector Climate Change Adaptation Taskforce in 2008 to secure the city's infrastructure from the effects of climate change, and established the New York City Panel on Climate Change which advises the taskforce. Hurricane Sandy showed that adaptation saves lives. For example, based on New York City Climate Change Panel projections the threat of flooding to subway tunnels was well understood. The city shut down all subway operations as Hurricane Sandy bore down, and prevented loss of life.[a] On 11 June 2013 the Mayor of New York released *A stronger, more resilient New York*, a report setting out proposals to increase the resilience of infrastructure and buildings across the city.

In the United Kingdom, many councils are also responding to climate change. For example, the Worcestershire County Council redeveloped Red Hill Primary School by identifying priority risks such as higher rainfall in winter, hotter and drier summers, and increased wind speeds. Some of the adaptation features at the school include zinc sheet roof coverings, which are more wind resistant, and a sustainable urban drainage scheme for flushing toilets.[b]

a W Solecki, *Reality, meaning, and legacy in New York City*, International Human Dimensions Programme on Global Environmental Change, United Nations University, 2013, viewed 23 May 2013, <www.ihdp.unu.edu/article/read/reality-meaning-and-legacy-in-new-york-city>.

b G Cavan, *UKCIP Adaptation Wizard case study: Red Hill Primary School*, UK Climate Impacts Programme Adaptation Wizard, 2007, viewed 23 May 2013, <www.ukcip.org.uk/wizard/wizard-case-studies/redhill-school>.

Everybody has a reason to think about climate change risks

Climate change risks affect nearly all governments, businesses and communities.

The Australian Government is exposed to significant climate change risks in four ways:

- as custodian of the national economy. Australia's economy will be more productive if climate change risks are well managed. Climate change impacts could reduce GDP
- as a provider of services. The Australian Government provides many services that will be affected by a changing climate. These include national security, environmental protection and management of national parks, scientific research, and overseas aid and development

- as a funder. The Australian Government provides funds for goods and services such as health care, infrastructure development and emergency management that will be affected by a changing climate. Under current arrangements for disaster recovery and relief, the Australian Government will fund up to 75 per cent of the assistance available to individuals and communities. Poor management of climate change risks by third parties could expose the Australian Government to substantial fiscal risk
- as a guarantor of social equity. Disadvantaged groups are likely to be disproportionately affected by climate change impacts (see Chapter 3). Poor management of climate change risks to disadvantaged groups may compromise social equity goals.

Australian businesses are exposed to significant climate change risks through:

- risks to assets. The changing climate may damage major assets such as sea ports, airports, railway tracks, energy infrastructure and communications facilities, or force owners to retire assets early or make major upgrades.
- risks to operations. More frequent or intense extreme weather events may disrupt business operations. Examples include the effect of floods on mining operations, disruption of sea transport by cyclones, the effect of drought on agriculture, and reduced productivity of outdoor workers due to high temperatures.
- critical dependencies. Extreme weather events may interrupt supply chains or services such as transport, electricity, gas or water supply on which businesses depend. A changing climate may also affect global trading patterns, for example, by changing the supply of agricultural products.
- national economy. Climate change impacts are a potential drag on the national economy, with a flow-on effect to individual businesses.
- insurance and capital markets. Climate change shocks may affect the availability of insurance and access to capital, either locally or worldwide.

Australian communities are exposed to significant climate change risks through:

- values. Climate change will affect beaches, parks, reserves and infrastructure that are owned by or managed for the community. It will also impinge on matters such as land use planning, protection of natural ecosystems and management of natural resources where community values are an important factor in decision-making.
- equity. Some groups in the community are particularly vulnerable to the impacts of climate change because of social, physical or economic disadvantage.
- wellbeing. Climate change will affect the health of many people, and the economic and environmental opportunities available to Australians.

Box 1.3 Adaptation and mitigation

Reducing greenhouse gas emissions ('mitigation') and managing the impacts of unavoidable climate change ('adaptation') are complementary strategies to deal with the challenge of climate change — Figure A shows the relationship between them.

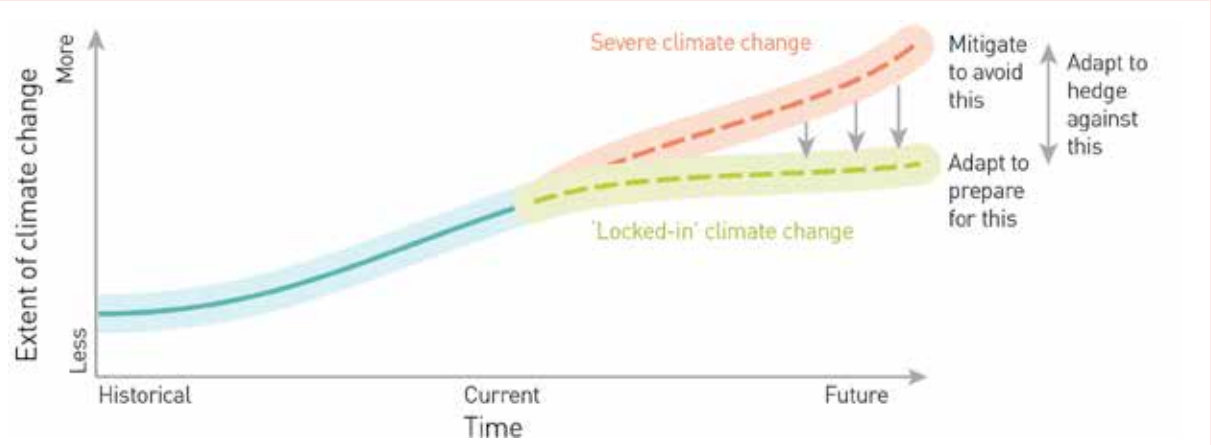

Figure A The relationship between climate change adaptation and mitigation

Some global warming has already occurred and more is unavoidable. There is global agreement and concerted action to limit global average warming to 2 °C. Effective global mitigation will increase the probability of realising this goal. However, the magnitude of additional warming depends on how sensitive the global climate is to atmospheric greenhouse gas concentrations as well as on future emissions. So even with strong global mitigation, future warming may exceed the agreed target if climate sensitivity is high. Adaptation is therefore necessary both to deal with climate change already locked in and hedge against the possibility of more severe climate change.

In practice, no trade-offs are available between mitigation and adaptation (e.g. mitigating less and relying more on adaptation). Strong action is needed on both. On the mitigation front, a large body of analysis indicates that limiting global average warming to 2 °C will mean taking advantage of the full range of economically and technologically feasible mitigation options.[a] On the adaptation front, global average warming of 2 °C would still leave Australia with substantial climate risks to manage.

Some climate change impacts are likely to be unmanageable and these can only be avoided by limiting warming. For example, global warming of 5 °C or more may mean that summer temperatures in many locations routinely reach levels where health authorities recommend that all outdoor physical activities cease.[b] More moderate changes could also prove unmanageable. The Garnaut Climate Change Review found that under a 'hot dry' climate change scenario (involving warming of about 4.5 °C) agriculture in the Murray–Darling Basin would be virtually wiped out.[c]

We do not know what other unmanageable impacts we may face as the world warms. Lenton et al. list a number of 'tipping points' in the climate system that could lead to abrupt and difficult-to-manage changes, such as changes in the Indian Summer Monsoon.[d] The best way to manage these risks is to limit global warming by reducing global greenhouse gas emissions.

a See, for example, J Rogelj, DL McCollum, BC O'Neill & K Rioahi, '2020 emissions levels required to limit warming to below 2 °C', *Nature Climate Change*, vol. 3, 2013, pp. 405–12.

b KM Willett & SC Sherwood, 'Exceedance of heat index thresholds for 15 regions under a warming climate using the wet-bulb globe temperature', *International Journal of Climatology*, vol. 32, 2012, pp. 161–77.

c R Garnaut, *The Garnaut climate change review*, Cambridge University Press, Port Melbourne, 2008.

d TM Lenton, H Held, E Kriegler, JW Hall, W Lucht, S Rahmstorf & HJ Schellnhuber, 'Tipping elements in the Earth's climate system', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 100, 2008, p.1786–93.

02 How to assess progress in managing climate risks

Key points

The proposed national assessment framework is based on three questions:

- What drivers in society and the economy would promote good adaptation?
- What activities would we expect to see now if Australia is adapting well?
- What outcomes do we expect to see from good adaptation?

To know how well Australia is managing the impacts of unavoidable climate change it is necessary to decide what 'good management' would look like. It is then possible to consider what Australians are actually doing and judge progress against an agreed model of good management. The National Adaptation Assessment Framework will build this model.

Climate change impacts will vary from place to place, as will the natural ecosystems, assets and activities Australians want to keep enjoying. In addition, individuals, communities and businesses may respond to these challenges in different ways. Good management of climate change risks will mean different things to a small coastal community facing rising sea levels and a large city with transport and energy infrastructure at risk from more frequent heatwaves.

The assessment framework therefore cannot be too prescriptive. It should guide valid judgments about what good management of climate change risks would look like for Australia.

Climate change has already started to affect Australia (see Appendix 1), but the most serious challenges lie in the future and we cannot be sure of their timing and magnitude.

In some cases it will be sensible to make changes now, to cope better with the climate change we have already seen or to be better prepared for the changing climate of the future. For example, community education and warning systems can reduce deaths from heatwaves now, and improvements to the design of our buildings and cities can help prepare for the more severe heatwaves we are likely to see as the century unfolds.

Opposite page: An engineer maps out plans for a new road

In other cases, it could make better sense to assess climate change risks but wait before taking costly steps to deal with them. For example, the Thames Barrier that stops the City of London being flooded during extreme tides will one day need to be upgraded to cope with rising sea levels. The United Kingdom Government has developed a strategy for upgrading the Thames Barrier, noting a number of trigger points where it will need to decide between different engineering options.[1]

The assessment framework must recognise that the ideal pace of adaptation will vary from place to place, sector to sector, and even from individual to individual.

The United Kingdom has a strategy to upgrade the Thames Barrier to cope with sea level rise.

The assessment framework

The proposed assessment framework asks three broad questions:

- What drivers in society and the economy would promote good adaptation?
- What activities would we expect to see now if Australia is adapting well?
- What outcomes do we expect to see from good adaptation?

The rest of this report will refer to these elements of the framework as 'drivers', 'activities' and 'outcomes'. They are related by a simple notion of cause and effect: the right drivers will lead to the right activities, which will lead in turn to good outcomes (Figure 2.1).

The framework also allows for cross-checking. For example, in the absence of good adaptation outcomes it would be necessary to check

1 UK Environment Agency, *Thames estuary 2100: managing flood risk through London and the Thames Estuary—TE2100 plan*, UK Environment Agency, London, 2012.

whether good drivers are in place and if they are able to overcome barriers to action.

The framework should also help identify policies that governments can adopt to put Australia in a better position to adapt. Governments are in a unique position. They must manage changing climate risks to assets they own (such as schools, sporting fields, roads and national parks) and services they deliver (such as health care and national security). But they are also able to change (or influence) the drivers that help determine how well Australia will manage the impacts of unavoidable climate change.

Figure 2.1 How the elements of the framework are related — the drivers, activities and outcomes of climate change adaptation

Scale

Because the framework is intended to assess how well Australia is managing the impacts of climate change, it will be applied at the broadest possible scale.

Sometimes this will mean looking at the whole of Australia. This is possible when outcomes, activities or drivers are relevant to a broad range of places, activities and natural or built assets.

For example, the cost and availability of insurance affects decisions about where assets are built and activities take place, and about how these assets or activities are designed. Climate affects the cost of insurance: all other things being equal, insurance will cost more if a building is in a floodplain, bushfire zone or cyclone zone. Insurance companies may also choose to offer lower premiums in return for steps to manage these climate hazards (e.g. by raising floor heights in flood zones). So insurance is a 'driver' of adaptation. Insurance is also available for a wide range of assets and activities, and across most of Australia.

On the other hand, some outcomes, activities or drivers will only be relevant to specific sectors or regions. It will not be possible to develop a picture of 'good adaptation' in Australia without considering the unique characteristics of important sectors.

The coast, for example, is significant for Australia. Most Australians live near the coast, most of our economic activity is concentrated there, and Australians place a high value on beaches and coastal ecosystems. Because the coast is a highly valued complex environment, specialised laws, policies, institutions, and scientific and professional disciplines have been developed to manage it. The assessment framework will therefore need a specialised coastal component.

Beach goers gather at the northern end of Bondi Beach on a hot Sunday afternoon.

This report develops a proposed assessment framework covering the drivers, activities and outcomes for the whole of Australia. It also deals with the unique activities and drivers needed for good management of climate change risks on the coast as an example of how the framework can be extended to a sector or region.

Subsequent instalments of the Climate Adaptation Outlook report will refine the assessment framework and extend it to other key sectors and regions.

Indicators

An assessment of progress requires evidence of the drivers that are operating, the activities that are taking place and what outcomes are being achieved.

A small set of high-impact indicators will form the backbone of future Climate Adaptation Outlook reports. Such indicators will be easier to interpret and communicate than a larger group. The indicators will need to be carefully interpreted, and other evidence will be required to gain a full appreciation of Australia's progress in managing the impacts of unavoidable climate change.

This report provides examples of indicators that might be used for Climate Adaptation Outlook reports.

03 What good climate change adaptation would look like for Australia

Key points

This chapter sets out the assessment framework for the whole of Australia. It identifies:

- the cross-cutting drivers required to promote good adaptation
- the activities that should be happening now to achieve good adaptation
- the outcomes Australia would achieve if it was managing climate change risks well.

The assessment framework is summarised in Figure 3.1.

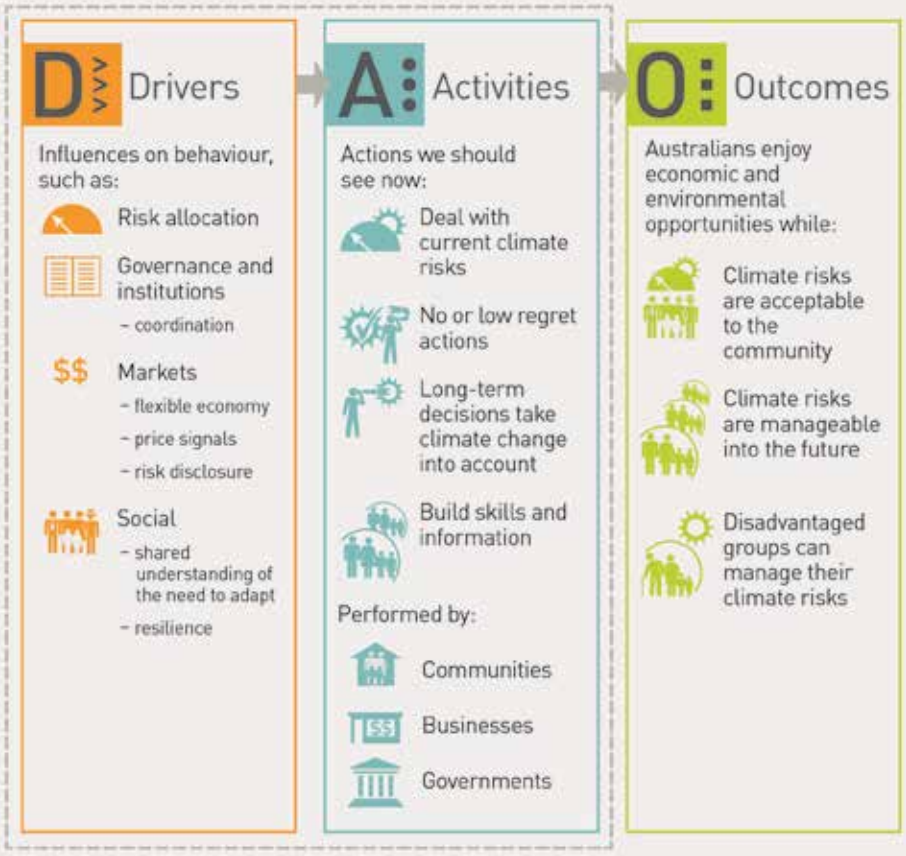

Figure 3.1 Drivers, activities and outcomes of climate change adaptation

Opposite page: A farmer teaches his son about the land

This chapter develops the assessment framework for the drivers, activities or outcomes that are relevant to a broad range of places, activities and natural or built assets.

Good drivers

This section considers what drivers are needed to promote good adaptation in Australia. These include:

- risk allocation
- governance and institutions
- markets
- public attitudes.

Risk allocation (who bears the risk?)

Assets and activities at risk from climate change are dispersed throughout society and most are owned or undertaken by households, businesses and communities.

However, many of these assets and activities are supported by services or infrastructure provided by governments, such as roads, hospitals, schools or law enforcement. Some privately owned and operated assets, such as energy distribution networks, can affect many individuals and organisations if they fail. The wellbeing of Australians would also be affected if poorly managed private risks became a drag on the national economy.

It is in everybody's interests to ensure that risks that affect a large proportion of the community are well managed. Four characteristics of risk allocation, if present, will maximise the chance this will happen.

First, it should be clear who is responsible for managing the risk.

Houses, infrastructure and other assets may be at risk from climate change.

Second, the characteristics of the risk (such as timing, magnitude, challenges and opportunities) should be understood well enough for people or organisations to develop effective management strategies.

Third, the person or organisation responsible for managing the risk should be the one best placed to do so. Businesses, individuals and governments will often be best placed to manage their own risks because they understand the specific local circumstances, and because the private benefits of managing the risk provide incentives for action. However, it is important to note that this will not always be the case.

Finally, those who benefit from risk management should bear the costs of managing the risk, otherwise there may be incentives for them to act in ways that increase the risk.

It may not always be possible for the allocation of risk to have these desirable characteristics. For example, equity considerations may mean that disadvantaged groups are not asked to bear the full costs of managing all the risks they face.

Appendix 2 describes what these characteristics mean in practice for three important climate risks.

These considerations lead to the proposition that one important driver of good adaptation is that:

Climate risks are well understood and clearly allocated to those best placed to manage them, while those who benefit from risk management pay the cost.

Governance and institutions

Governance and institutional arrangements have a strong influence on how climate risks are managed. Allocating climate risks in a way that has the characteristics discussed above is one important role, but there are others.

Effective strategies to manage climate risks will sometimes need to be implemented across jurisdictional or organisational boundaries. For example, cooperation may be needed to manage ecosystems spread across state boundaries. In the case of the Great Barrier Reef, management responsibility is shared between the Australian and Queensland governments through arrangements such as the Great Barrier Reef Marine Park Authority. The Murray–Darling Basin is held by five jurisdictions, requiring cooperation between Australian, state and territory governments to manage it effectively.

Cooperation between governments — and sometimes between governments and the private sector — will be important to promote good management of climate change risks in Australia. For example, large concentrations of existing assets are at risk from climate change impacts in some locations and ownership of these assets is shared between governments at all levels and the private sector. (See Chapter 4 for further details.)

On 16 November 2012, the Select Council on Climate Change (comprising relevant ministers from all jurisdictions) adopted *Roles and responsibilities for climate change adaptation in Australia* as a statement of common understanding. This document sets out the principles for allocating the management of climate change risks, and roles and responsibilities for adapting to climate change within Australian, state, territory and local governments.

These considerations lead to the proposition that one important driver of good adaptation is that:

Effective coordination mechanisms are in place where action across jurisdictional boundaries is needed to manage climate change risks.

Appropriate regulation can help establish governance, institutions, markets and the risk allocations that drive good adaptation in Australia. For example, state governments have regulatory systems that govern land use planning, while the federal government regulates insurance markets.

In some instances specific regulations will affect adaptation in particular sectors. The Building Code of Australia, for example, sets minimum standards of construction for buildings, some of which relate to variables such as extreme wind, flooding or bushfire. These regulations will be discussed when the assessment framework is applied to particular sectors (either in Chapter 4 of this report or in later reports in this series).

Construction standards can help make buildings more resilient.

$$ Markets

Insurance, capital and asset markets can support effective management of climate change risks through price signals and by encouraging risk disclosure.

In a market where climate change impacts are taken into account, an asset exposed to high risks should be worth less than an otherwise identical asset exposed to lower climate change risk. The cost of insuring it or borrowing money against it should be correspondingly higher.

However, there may be limits to how effectively price signals can help control the climate risks passed on to future generations. Insurance premiums are generally calculated on an annual basis and commercial discount rates mean that investors may not consider how much assets will be worth 50 or 100 years into the future.

Price signals can only operate effectively if the market understands climate change risks. By encouraging disclosure of climate change risks markets could provide incentives to manage them.

Box 3.1 Land prices and climate

In 2011, Fletcher et al[a] studied how vulnerability to inundation affects land prices in parts of Australia. They found that houses on the edge of a 1-in-100 year inundation region are devalued by 1.3 per cent. Every additional metre of inundation by a 1-in-100 year event decreases land value by another 5.3 per cent.

Fletcher et al, used their results to assess the costs and benefits of different options for managing risks from rising sea levels. They found that taking the effect of sea level rise on land values into account makes a significant difference to which options have net economic benefits.

Although the study shows that markets can take matters like vulnerability to flooding into account, no information is available about whether these valuations are fully informed or the extent to which markets account for risks associated with future climate change.

a CS Fletcher, RJ McAllister, AN Rambaldi & K Collins, *The economics of climate adaptation to coastal inundation*, report for the Australian Government Department of Climate Change and Energy Efficiency, CSIRO, Australia, 2011.

Box 3.2 Investors and climate change

Weather variability and extreme events such as droughts, heatwaves, floods or severe storms can threaten the condition or performance of some infrastructure assets. AustralianSuper has recognised that understanding the potential impacts of climate change and extreme weather impacts on infrastructure assets is the first step towards assessing the vulnerabilities of assets, and figuring out how best to manage the risks. Good risk management requires that controls are in place to monitor, mitigate and respond to the new conditions and challenges that may arise.

In 2011, AustralianSuper, together with 13 global institutional investors and Mercer, undertook a project to examine, via a range of scenarios, the potential impact of climate change on different types of investment assets. The Mercer public report is entitled *Climate change scenarios — implications for strategic asset allocation*.[a] Infrastructure is one of the hardest investment asset classes to predict the impacts of climate change, because it is highly dependent on the type, age and location of each individual asset.

Impact on valuation of infrastructure assets

Climate change has the potential to affect the valuation of infrastructure assets by impacting cash flows, operational cost and capital expenditure. The risk posed by climate change is not necessary to the asset itself, but to the goals and objectives that may be compromised if the asset is impacted or damaged. The primary risks that need to be considered are those to the reliability and performance of the assets, and whether relevant targets could continue to be met.

Further assessment

AustralianSuper has engaged an Australian engineering firm to commence an assessment of the extent to which specific infrastructure assets in their portfolio may be vulnerable to a changing climate, and the types of primary risks that may arise.

The aim is to understand the physical impact risks in the medium term (2030) and the long term (2070). The assets include airports, a sea port and a toll road. The assessment is expected to be completed by end of 2013.

The main benefits to AustralianSuper from this assessment will be a better understanding of the vulnerabilities and risks that may be associated with climate change on AustralianSuper's larger infrastructure assets. The assessment will inform AustralianSuper, relevant fund managers and asset operators of the risks at operational and organisational levels, and highlight potential adaptation actions that can be undertaken.

a Mercer, *Climate change scenarios — implications for strategic asset allocation: public report*, Mercer, 2011.

A flexible economy will promote effective adaptation by allowing for structural adjustments after climate shocks or in response to more gradual climate change. Economic flexibility can be increased by removing economic barriers to adaptation activities (e.g. tax barriers to moving capital or assets, or employing labour flexibly).[1]

These considerations lead to the proposition that important drivers of good adaptation are that:

Insurance, capital and asset markets incorporate climate risks into prices.

Markets promote disclosure of risks from climate change impacts.

A flexible economy (labour, product and capital markets) allows resources to be effectively allocated after climate shocks or in response to more gradual climate change.

Public attitudes — Recognising the need for change

In many cases individuals, businesses and governments will need to make changes — to planning, policies or on-ground activities — in recognition of the changing climate risk.

This does not mean that these changes will be made independently of other considerations. In most cases climate risks should be considered in the context of an organisation's broader goals and operations. One strategy for making sure this happens is 'mainstreaming'. That is, making sure that the changing climate risks are a routine consideration in all relevant decisions an organisation makes. Mainstreaming is a difficult task in practice and is likely to require considerable effort.[2]

Awareness and acceptance of the need for some things to be done differently in a changing climate is critical. Managers in business and government must be willing to consider the implications of a changing climate for their operations. Without public understanding and acceptance it may be difficult for governments and businesses to make some of the decisions that might be necessary to manage climate change risks.

In particular, the way climate change science and impacts is sometimes presented in public debate is an impediment to decision-making over climate change adaptation and risk management. Introduction of scientifically inaccurate material into the public debate makes it difficult for many decision-makers to recognise the need to do some things differently in the future and explain those decisions to their stakeholders.

1 Productivity Commission, *Barriers to effective climate change adaptation*, report 59, Final Inquiry Report, Productivity Commission, Canberra, 2012, pp. 323–9.

2 J Palutikof, M Parry, M Stafford Smith, AJ Ash, SL Boulter & M Waschka, 'The past, present and future of adaptation: setting the context and naming the challenges', in J Palutikof, SL Boulter, AJ Ash, M Stafford Smith, M Parry, M Waschka & D Guitart (eds), *Climate adaptation futures*, Wiley-Blackwell, Chichester, 2013, pp. 3–29.

These considerations lead to the proposition that an essential driver of good adaptation is that:

The public and decision-makers accept that it may be necessary to do some things differently in a changing climate.

Box 3.3 Public understanding of climate change adaptation

In 2008 and 2010 Gardner and Roan[a] asked a sample of businesses, local governments and community organisations about what (if anything) they were doing to plan for the impacts of climate change. A total of 483 organisations participated, with 201 participating in both 2008 and 2010. In both years the sample was deliberately skewed towards organisations whose activities were more likely to be at risk from climate change impacts and towards larger organisations more likely to have the capacity to respond.

The survey results suggest that understanding of adaptation is variable (and mostly poor) among organisations at risk from climate change impacts. Fewer than half the organisations surveyed in 2010 had assessed their vulnerability to climate change impacts, down from almost 60 per cent in 2008. While failure to assess vulnerability does not necessarily indicate poor understanding, the number of reported vulnerability assessments also dropped among organisations surveyed in both 2008 and 2010. Since a vulnerability assessment cannot be undone, this result suggests that some organisations misunderstand what 'adaptation' involves.

In 2013, Leviston et al.[b] asked 5081 people representative of the broad Australian population about their understanding of climate change adaptation. Only 18.1 per cent were familiar with the term but roughly a third of the sample said they had done something to adapt to the impacts of climate change. However, few nominated activities could be construed as adaptation. This suggests adaptation is poorly understood.

A 2011 study by Ashworth et al.[c] also found that public understanding of climate change was moderate to low. However, most respondents were in favour when asked about support for specific measures to prepare for the impacts of climate change.

a J Gardner & J Roan, *Adaptation benchmarking survey: final report*, CSIRO, Australia, 2011.

b Z Leviston, I Walker & S Malkin, *Australian climate change adaptation attitudes and behaviours*, CSIRO, Perth, 2013.

c P Ashworth, T Jeanneret, J Gardner & H Shaw, *Communication and climate change: what the Australian public thinks*, CSIRO, Australia, 2011.

Social resilience

A high level of trust, cooperation and interconnectedness within communities promotes effective cooperation, which is essential for managing many climate change impacts. Informal cooperation is very difficult without strong community networks or if people and organisations are unwilling to trust one another. Informal cooperation and a high level of trust and cooperation allows communities to cope better with natural disasters. Resilience is the ability to adapt, learn and bounce back from disasters. Green Cross Australia[3] defines community resilience as the capacity of groups to withstand, recover from and respond positively to crisis or adversity. This community resilience is important in many areas — for example, social relationships between small and medium enterprises (SMEs) and support organisations (such as business associations) are critical to enhancing the capacity of SMEs to adapt to climate change.[4]

Trust, cooperation and interconnectedness also contribute to the success of formal working arrangements. The features of social life that enable people and organisations to work together to pursue shared objectives are often referred to as 'social capital'.[5]

These considerations lead to the proposition that an important driver of good adaptation is that:

There is a high level of trust, cooperation and interconnectedness within communities.

Social connections have helped communities recover from natural disasters, such as after the 2011 Brisbane floods

3 Green Cross Australia, *Disaster resilience: preparedness and recovery*, Green Cross Australia, Brisbane, 2013, viewed 27 May 2013, <www.greencrossaustralia.org/our-work/disaster-and-community-resilience.aspx>.

4 N Kuruppu, J Murta, P Mukheibir, J Chong & T Brennan, *Understanding the adaptive capacity of Australian small-to-medium enterprises to climate change and variability*, National Climate Change Adaptation Research Facility, Gold Coast, 2013.

5 R Putnam, 'Bowling alone: America's declining social capital', *Journal of Democracy*, vol. 6, no. 1, 1995, pp. 65–78.

Good activities

Some things could be done now to reduce the risks from a changing climate. For example: avoid construction in areas that are vulnerable to future climate impacts or build to a higher standard in those areas, nourish beaches to defend against rising sea levels, build levees to protect against floods, or create patches of habitat where threatened plants and animals will be sheltered from harmful changes in climate. But these things would come at a cost and governments, businesses and communities need to balance that cost against the benefit of decreased climate risk they would face if action was taken.

Whether an action is worth taking will often depend on local circumstances such as the cost of land and construction, how vulnerable the location is to a climate threat such as rising sea levels, and the preferences of local businesses and communities. Some actions may even be counterproductive. For example, building a levee might protect high-value assets in the short term but it could also encourage further development in an area that would be at risk of flooding if the levee were to fail in a more extreme future climate.

In some cases, risks from current climate are unacceptably high and will increase as the climate changes

The timing of activities can be important. In some cases it will make sense to delay expensive engineering works until threats are more immediate — for example, works to protect a key asset against half a metre of sea level rise may not be required until mid-century or later. In other circumstances it may be more cost-effective to make design changes to major infrastructure, such as bridges, at the time assets are built.

A further complication is that some activities that help deal with climate risks may be motivated by something other than awareness of climate change. For example, an irrigator may adopt water efficient practices and technologies to reduce costs even though he or she does not accept that the climate is changing.

Despite these difficulties, it is possible to identify some generic circumstances under which we would expect action now to manage climate change risks:

- to address adaptation deficits
- to undertake no or low-regret activities
- to plan for longer-term climate change impacts
- to build capacity to manage climate change impacts.

Adaptation deficits

In some cases risks from current climate are unacceptably high, and climate changes will increase these risks. This is sometimes referred to as an 'adaptation deficit'. The immediate benefits of managing current risks better will always justify prudent action to reduce adaptation deficits.

Possible examples of adaptation deficits include current vulnerability to inland flooding, bushfire, deaths from heatwaves and drought.

Public attitudes — no or low-regret adaptation activities

No or low-regret adaptation activities offer net benefits under most or all climate change scenarios. Such activities could increase flexibility in the future, or have co-benefits unrelated to climate change impacts.

Examples might include water conservation in areas that may suffer a drier climate, installing insulation in homes or industrial buildings, or relocating expensive equipment from the basement to higher floors when buildings are renovated in areas at risk of flooding. (See Box 3.4 for an example of an action that offered benefits for climate change impacts and co-benefits for existing weather patterns.)

Box 3.4 Cyclone Yasi and Stockland Cairns shopping centre

At the end of the 2011 summer, Cyclone Yasi (a category five storm) approached the far north Queensland coast. The food court section of Stockland Cairns shopping centre had been built to withstand the impact of a major storm, making it the obvious choice as an evacuation centre.

Working closely with Cairns City Council, Stockland centre management converted the food court into an emergency evacuation centre for the duration of the storm. Some 2400 people, mainly local residents and tourists, were given refuge throughout the event.

Stockland's centre management team took the lead role in hosting police, State Emergency Services, Red Cross and other members of the community, and worked with local authorities and the community to ensure the safety and wellbeing of the evacuees. ABC television was based at the centre and broadcast throughout the night to provide communications to local residents. Woolworths supermarket distributed food to the evacuees.

Stockland played a major part in the community's response to the crisis. Although Cyclone Yasi eventually made landfall further south, Cairns was hit with strong winds. The resilience of its shopping centre meant that there were no injuries or loss of life.

Source: Stockland, *Stockland corporate responsibility and sustainability 2011*, Stockland, Sydney, 2011, p. 29.

Planning for longer-term climate change impacts

Decisions with long-term implications may 'lock in' vulnerability to future climate change impacts. Examples of such decisions include land use planning, management of conservation estates and building long-lived infrastructure. Even where there is not a case for investing now to manage these impacts, it is prudent for planning associated with these decisions to consider the implications of future climate change in an explicit and rigorous fashion. (See Boxes 3.5, 3.6 and 4.2 for examples of long-term planning that takes climate change into account.)

Box 3.5 Winemakers preparing for climate change

Climate change will alter the growing seasons of grapes and affect the quality of Australian wines. This is already happening. Australian grapes ripened earlier at the rate of 1.7 days a year from 1993 to 2009 compared with 0.8 days a year from 1985 to 2009.[a]

Wine makers are adapting by relocating to cooler regions. For example, Treasury Wine Estates, the world's second-largest listed wine company, is seeking vineyards in cooler regions. Treasury is looking to buy and lease vineyards in Tasmania,[b] and reports that harvests are already starting as much as a day-and-a-half earlier each year as a result of climate change. Treasury's growers are also monitoring growing seasons to update their forecasts of local climate change impacts, and delaying pruning to give time to harvest grapes as seasons move later.

Brown Brothers Wineries has started relocating production of cooler varieties to Tasmania's Tamar Ridge winery.[c] Winemaker Shaw and Smith has also indicated that the future impact of climate change was a key driver for their investment in Tasmania.[d]

a L Webb, W Penny, W & B Edward, 'Observed trends in winegrape maturity in Australia', *Global Change Biology*, vol. 17, no. 8, 2011, pp. 2707–19.

b The Sydney Morning Herald Business Day, *Treasury hunts for cooler vineyards as climate shifts*, The Sydney Morning Herald, 12 April 2013, viewed 27 May 2013, <www.smh.com.au/business/carbon-economy/treasury-hunts-for-cooler-vineyards-as-climate-shifts-20130412-2hp48.html>.

c R Burton-Bradley, *Climate change threat to Australia's top wines*, News.com.au, 15 June 2011, viewed 27 May 2013, <www.news.com.au/features/environment/climate-change-threatens-australias-wine-industry-study-warns/story-e6frflp0-1226068502698>.

d Tasmania Department of Economic Development, Tourism and the Arts, *The wine industry in Tasmania: a guide for investors*, State of Tasmania, 2012.

Mining operations could be affected by climate change impacts.

Box 3.6 Fortescue Metals Group Extreme Weather Events Risk Assessment project

In 2011, Fortescue Metals Group commissioned an extreme weather events risk assessment for their expanding Pilbara iron ore and infrastructure developments.

Fortescue was about to make a significant investment in mine and associated infrastructure expansion. The infrastructure assets will have a life of many decades so Fortescue wanted to be sure design parameters were robust to future climate change impacts to minimise any reduction in revenue from climate-related down time.

Fortescue gathered Pilbara-specific climate change science and projection information, raised awareness across the organisation, gained high-level support for the project from senior management, and assessed and updated engineering design thresholds to take climate change into account. The information was included in company infrastructure design documentation to facilitate uptake by development staff.

Lessons from the project include:

- the climate risk assessment process is valuable even if no changes are required, because it provides a fresh perspective on business risk and processes, and may identify opportunities for cost and risk reductions
- identify where the biggest risk areas lie and prioritise them
- carefully consider the time horizon of infrastructure and weigh the cost and benefits of upgrading
- obtain the best climate change data and use it in a robust climate change risk assessment tool
- turn these data into useable, valuable inputs into the business's own risk assessment frameworks and processes
- communicate in terms that are meaningful to the intended audience
- business continuity is the most convincing reason for senior personnel to take an interest, as downtime is a huge and virtually unrecoverable cost.

Source: B Loechel, *Mining adaptation case study report: learning from the Fortescue Metals Group (FMG) Extreme Weather Events Risk Assessment project*, EP126964, CSIRO Earth Sciences and Resource Engineering, Pullenvale, 2012.

Box 3.7 Australian Government investments in information and skills

Australian Climate Change Science Program (ACCSP): provides $7.8 million each year to improve our understanding of the causes, nature, timing and consequences of climate change.

Regional Natural Resource Management (NRM) Planning for Climate Change Fund: is providing $15 million over four years to produce regional-level climate change information, and provide guidance on the integration of that information into regional NRM and land use planning. This will allow natural resource managers to make the most of adaptation opportunities and take advantage of programs such as the Carbon Farming Initiative and the Biodiversity Fund.

Australian Rainfall and Runoff handbook (ARR): is being updated by Engineers Australia with the support of the Australian Government through the National Climate Change Adaptation Program and the National Flood Risk Information Project. The ARR is the key source of technical information for designing infrastructure to withstand the impact of extreme rainfall, flooding and storm surge, and the update includes information that takes the changing climate into account.

National Flood Risk Information Project. Geoscience Australia has received $12 million over four years to improve the quality, consistency and accessibility of flood risk information.

Bushfire and Natural Hazards Cooperative Research Centre (CRC): will build on the work of the existing Bushfire CRC and expand research efforts into other natural hazards. The Australian Government will contribute up to $47 million over eight years to establish the CRC from June 2013.

Sustainable Yields Projects. The Australian Government commissioned CSIRO to assess current and future water yields in several regions of Australia. Assessments have been completed for the Murray–Darling Basin (2008), northern Australia (2009), south-west Western Australia (2010), Tasmania (2010) and the Great Artesian Basin (2013).

CSIRO Climate Adaptation Flagship: harnesses the resources of Australia's leading research organisation to deliver scientific information, solutions and expertise to support Australia's efforts to manage climate risks.

National Climate Change Adaptation Research Facility (NCCARF): was established to lead the research community to generate information that decision-makers need to manage climate change impacts. NCCARF managed 144 research projects in 2008–13. This research will be made widely available through a Climate Change Adaptation Information Hub to be developed by Griffith University in partnership with the Queensland Cyber Infrastructure Foundation as part of a $500 000 grant under the Australian National Data Service partnership.

Climate change and agriculture research programs: include the Climate Change Research Program, which tested responses of key crops to increases in temperature and carbon dioxide, monitored ways to manage heat stress in livestock, examined potential new shrub-based forages for livestock and evaluated the relocation of various crops to northern Australia; and the Carbon Farming Futures Filling the Research Gap Program, which is investing over $9 million in new climate change adaptation research under Round 2 funding.

Skills for the Carbon Challenge: is providing $5.64 million over four years to build the capacity of the tertiary education sector to supply the skills needed for workers and businesses to prosper in a low-carbon economy.

Building skills and information

Information is only beneficial if people and organisations have the capacity to use it well

Individuals, businesses and communities need information to manage climate risks. This includes information about the range of plausible future climates and their possible impacts, options for managing impacts, and guidance on how to use this information to make good decisions.

Governments will generate some of this information, particularly where they need the information for their own purposes and can provide it to the public at minimal extra cost. In other cases information will be commercially valuable and the private sector would be expected to generate it.

Information is only beneficial if people and organisations have the capacity to use it well. The skills required to make decisions — for example about land use planning or engineering— in a changing climate may be different to those required in a climate that is not changing. Australia will need to consider whether current training equips key professional groups such as planners, architects, engineers, agricultural scientists and risk managers with the necessary skills. There is evidence that some of these skills and information are underdeveloped (e.g. skills required to make decisions under climate uncertainty, information about flood hazards).[6] Further, a lead time of years to decades is required to develop them. It is therefore reasonable to expect action now to address any deficit.

These considerations lead to the proposition that the following activities should be happening now for Australia to do a good job managing the impacts of unavoidable climate change:

Reducing unacceptably high vulnerabilities to the current climate.

Identifying and taking no or low-regret actions.

Taking climate change impacts into account when making decisions with long-term consequences (e.g. land use planning, design of major infrastructure).

Building skills and information needed to manage climate risk now and in the future.

6 A Lyth, S Nichols & D Tilbury, Shifting towards sustainability: education for climate change adaptation in the built environment sector, report prepared by the Australian Research Institute in Education for Sustainability *for the Australian Government Department of the Environment, Water, Heritage and the Arts*, Australian Research Institute in Education for Sustainability, Sydney, 2007.

Good outcomes

Good adaptation outcomes are about balancing opportunities and risks as the climate changes.

Our climate brings both opportunities and risks, which cannot be separated because both flow from the same climate. For example, it is reasonable to expect that people who choose to live beside the water will accept that rivers flood and coastal waters inundate the land during storm surges and extreme tides. Farmers know that there will be drought years as well as years of abundance.

Whether consciously or not, Australians make collective decisions about how to trade-off climate risks against climate opportunities. These decisions may not always be explicit, but they are revealed in land use planning systems; policies for managing the environment, water and agriculture; disaster recovery arrangements; and even support for appeals on behalf of those who have suffered from natural disasters.

Building near a river carries the risk of inundation.

Climate change will magnify climate risks while bringing few new benefits.

There are two main reasons for this. First, the impacts of climate change are likely to be largely negative, as our society and environment have developed to suit the historical climate. For example, we have built cities and established industries that suit the historical climate; and natural ecosystems have evolved, over a long period of time, in harmony with the historical climate.

Second, risks are magnified because climate change makes the future more uncertain than it would be in a stationary climate. In some cases the direction of future climate change is certain but the magnitude is not. Sea levels are likely to rise by as much as a metre even if global warming is limited to 2 °C however, we are not sure how fast the rise will occur. In other cases the direction of change is also uncertain. The south-west of Australia will continue to dry, but rainfall on the east coast of Australia may either increase or decrease. Further, we cannot be certain how much these changes in the climate will affect our infrastructure, industries and environment, particularly if the climate shifts outside historical bounds. Plausible extreme outcomes define the risk envelope. Uncertainty is not a reason to ignore the risks. Rather, it increases the value of strategies for coping with the range of possible future climates.

This raises a critical question: how much extra climate risk is the community willing to accept in order to continue enjoying the opportunities our climate brings?

As a national assessment, the Climate Adaptation Outlook report focuses on collective (or societal) decisions about how much extra climate risk to accept in order to continue enjoying the opportunities climate brings. These decisions are partly revealed by how much risk individuals, communities and businesses will bear before governments provide assistance or compensation. The flipside of this is how much risk Australians are prepared to bear collectively, particularly through governments.

One of the difficulties in assessing where this trade-off lies is that most individuals and organisations have not thought about it very much. There has been extensive public debate about other significant risks such as national security and the challenges of an ageing population, but limited public discussion of how to manage the impacts of unavoidable climate change.

These considerations lead to the first of three propositions about what good adaptation outcomes are:

Australians are able to enjoy economic, social and environmental opportunities, and are flexible and resilient to climate change impacts, while the level of risk from climate change impacts is kept within limits acceptable to the community.

Figure 3.2 illustrates this concept.

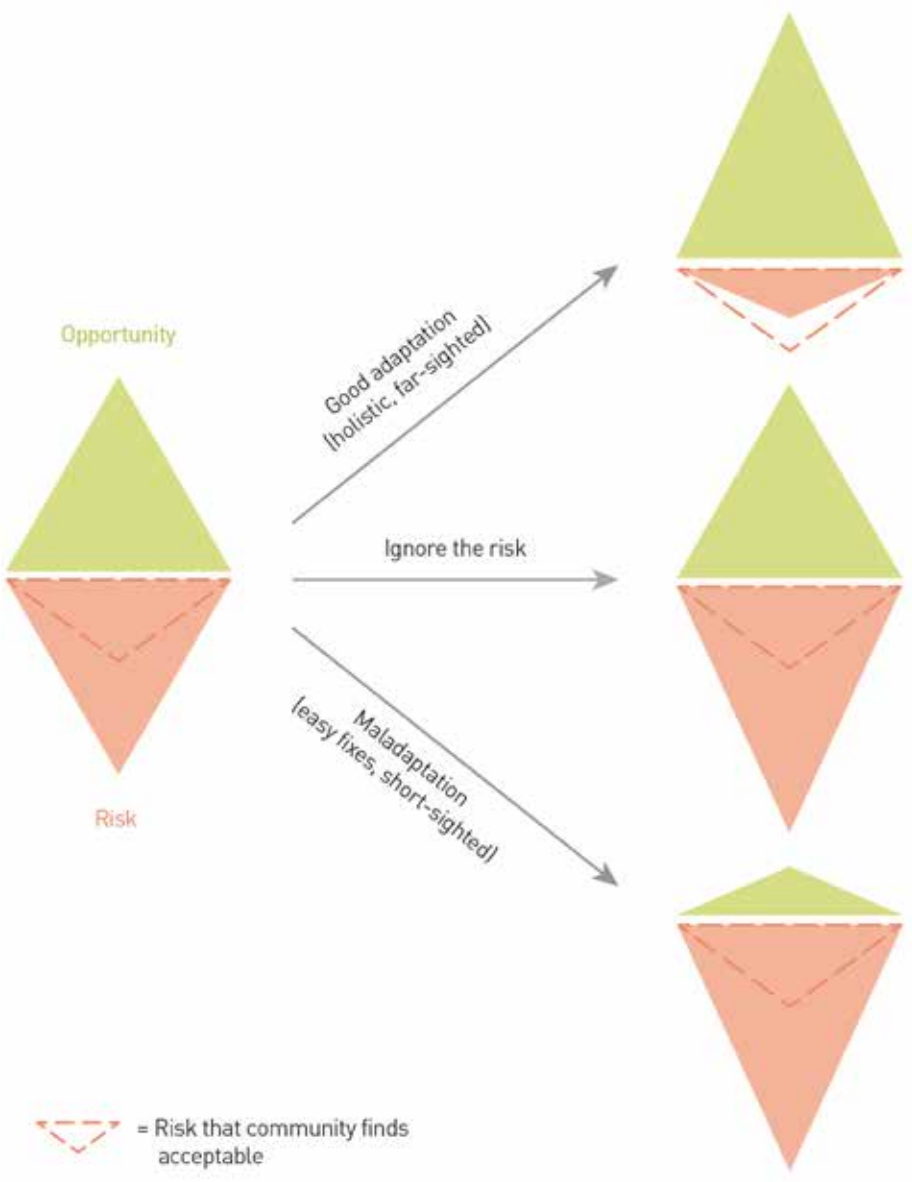

Figure 3.2 How adaptation affects risks and opportunities

Future generations

Decisions made today have the potential to constrain future options for managing climate change risks by increasing vulnerability to climate extremes, for example, or reducing flexibility in land use or engineering design.

Given the potential for severe climate change towards the end of the century, such constraints would be felt most strongly by future generations. People in the future will have to decide how much climate risk to bear in order to enjoy opportunities and may have different preferences to people today. Their choices will be compromised if decisions made today leave them with high risks and limited options for managing them. This danger may be partly offset because we can expect that future generations will be wealthier than us and have access to more advanced technology.

Decisions we make today will affect future generations.

These considerations lead to the second of three propositions about what good adaptation outcomes are:

Management of risks from climate change impacts today does not compromise the capacity to manage risks from climate change impacts in the future.

Socially or economically disadvantaged groups

Disadvantaged groups are generally less able to manage risks of all types because they lack financial, social, educational or other resources.[7] It is likely that disadvantaged people will also have greater difficulty in managing increased climate risk as a result of global warming.[8] They may, for example, be unable to protect their homes against higher temperatures (making them more vulnerable to heat stress). (See Box 3.8 for further information about heatwaves and how they affect different groups.)

While the largest risks from climate will occur towards the end of the century and affect future generations, for disadvantaged groups the climate of the next couple of decades is more critical.

These considerations lead to the last of three propositions about what good adaptation outcomes are:

Disadvantaged groups have the resilience and capacity to manage risks they face from climate change impacts.

7 A Sevoyan, G Hugo, H Feist, G Tan, K McDougall, Y Tan & J Spoehr, *Impact of climate change on disadvantaged groups: issues and interventions*, National Climate Change Adaptation Research Facility, Gold Coast, 2013.

8 Productivity Commission, pp. 1–25.

Box 3.8 Heatwaves and socioeconomic disadvantage

Death associated with heatwaves is a serious climate risk Australians must manage today that will become more serious as the climate changes (see Appendix 1). However, not all Australians face the same risk.

People living in housing with poor insulation, shading or cooling are more at risk because they are less able to escape the heat. People suffering from socioeconomic disadvantage are at greater risk of dying during heatwaves[a] and people with a pre-existing mental illness are three times more likely to die in a heatwave than the general population.[b]

The Victorian Council of Social Services (VCOSS) released a report[c] following the 2009 Melbourne heatwave, in which there were 374 excess deaths associated with the extreme heat. Based on interviews with community sector organisations working with high-risk groups, VCOSS reported that:

- vulnerable people were living in public housing properties, rooming houses and caravans that staff described as 'hot boxes' and had no access to cool areas
- vulnerable people had to walk in extreme heat because they were unable to access other transport options and had medical or other appointments
- people in some types of accommodation, or who were homeless or living rough, lacked access to drinking water.

The elderly are especially vulnerable to heatwaves.

a A Hansen, P Bi, M Nitschke, P Ryan, D Pisaniello & G Tucker, 'The effect of heat waves on mental health in a temperate Australian city', *Environmental Health Perspectives*, vol. 116, no. 10, 2008, pp. 1369–70.

b A Bouchama, M Dehbi, G Mohamed, F Matthies, M Shoukri & B Menne, 'Prognostic factors in heat wave-related deaths: a meta-analysis', *Archives of Internal Medicine*, vol. 167, no. 20, 2007, pp. 2170–76.

c Victorian Council of Social Service, *Feeling the heat: heatwaves and social vulnerability in Victoria*, VCOSS, Melbourne, 2013.

Summary of what good climate change adaptation would look like for Australia

To have good drivers of adaptation Australia needs to make sure:

- climate change risks are well understood and clearly allocated to those best placed to manage them, while those who benefit from risk management pay the costs
- effective coordination mechanisms are in place where action across jurisdictional boundaries is needed to manage climate change risks
- insurance, capital and asset markets incorporate climate change risks into prices
- markets promote disclosure of risks from climate change impacts
- a flexible economy (labour, product and capital markets) allows resources to be effectively allocated after climate shocks or in response to more gradual climate change
- the public and decision-makers accept that it may be necessary to do some things differently in a changing climate
- there is a high level of trust, cooperation and interconnectedness within communities.

The following adaptation activities should be happening now:

- reducing unacceptably high vulnerabilities to the current climate
- identifying and taking no or low-regret actions
- taking climate change impacts into account when making decisions with long-term consequences (e.g. land use planning, design of major infrastructure)
- building skills and information needed to manage climate risk now and in the future.

Australia will be managing the impacts of climate change well if:

- Australians are able to enjoy economic, social and environmental opportunities, and are flexible and resilient to climate change impacts, while the level of risk from climate change impacts is kept within limits acceptable to the community
- management of risks from climate change impacts today does not compromise the capacity to manage risks from climate change impacts in the future
- disadvantaged groups have the resilience and capacity to manage risks they face from climate change impacts.


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04 What good climate change adaptation would look like in the coastal zone

Key points

This chapter extends the assessment framework for the coastal zone. The national-scale framework developed in Chapter 3 is relevant to the coastal zone and this chapter identifies:

- additional drivers required to promote good adaptation in the coastal zone
- specific activities that should be happening now to achieve good adaptation in the coastal zone
- outcomes Australia would achieve if it was managing climate change risks well in the coastal zone.

The framework is summarised in Figure 4.1.

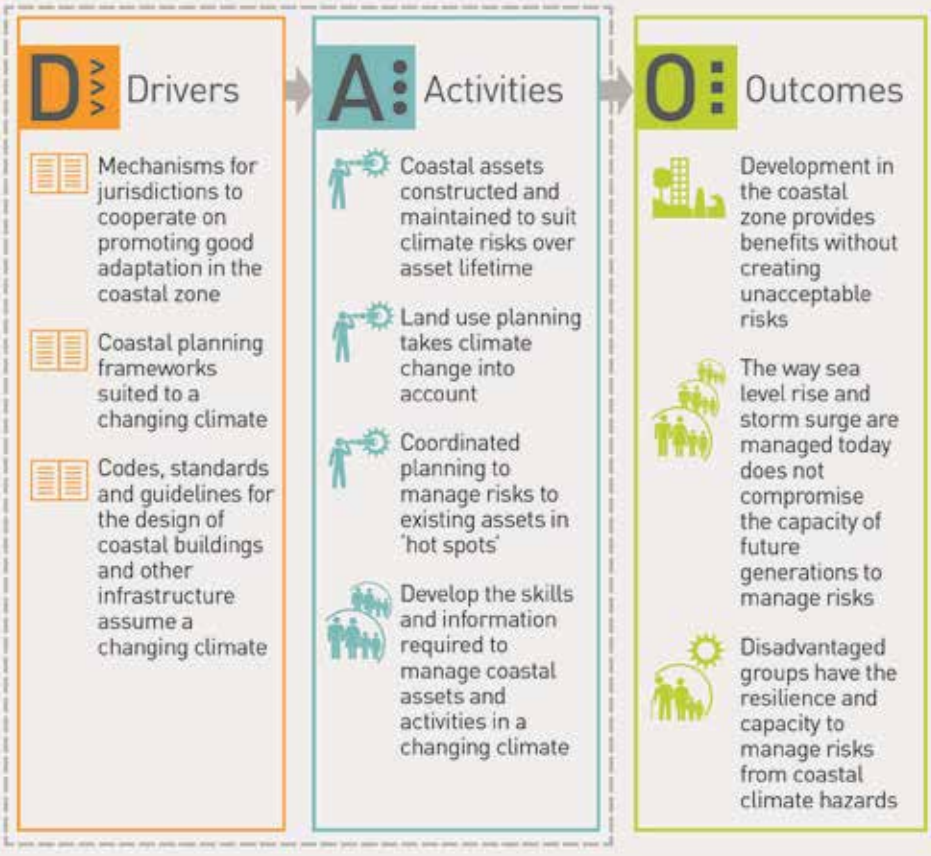


Figure 4.1 Drivers, activities and outcomes of climate change adaptation for the coastal zone

Opposite page: Lifeguards monitor the surf on Manly Beach, Sydney.

The coastal zone is subject to serious climate risks — most notably, sea level rise and increased storm surge due to more intense storms and tropical cyclones. Rising sea levels will bring the risk of coastal erosion and inundation to coastal areas not currently at risk. More than $226 billion in current commercial, industrial, road, rail and residential assets are located in areas of Australia that would be at risk if sea levels rose by 1.1 metres.

This chapter extends the assessment framework to the coastal zone as an example of how good management of climate risks can be described for an important sector.

The drivers, activities and outcomes at the national scale (described in Chapter 3) are relevant to the coast. This chapter describes additional elements of the assessment framework that apply specifically to the coastal zone.

Good drivers

The coastal zone has unique governance and regulatory arrangements that are important for managing risks from the impacts of unavoidable climate change. These include government-appointed advisory boards such as the Victorian Coastal Council and clusters of local councils that cooperate to improve coastal management (see Box 4.1 for examples). All coastal jurisdictions have policies or regulations for land use planning that apply specifically to the coastal zone, and most have coastal management strategies.[1]

Coastal zone governance

Most land use planning decisions in the coastal zone are made by local governments operating within regulatory and policy frameworks established by the relevant state or territory government. The Australian Government has an interest in coastal planning because of the fiscal implications (e.g. infrastructure funding or possible payments under the Natural Disaster Relief and Recovery Arrangements) and the importance of the coastal zone for the national economy.

There are clusters of local councils that cooperate to improve coastal management

It is important for governments to cooperate in the coastal zone for a number of reasons. Many coastal processes operate on spatial scales that cross local (or even state) government boundaries. For example, sediment (sand) circulates between beaches in 'coastal compartments' that are typically larger than local government areas. Developers and other businesses will be able to operate more efficiently if there are no unnecessary differences in policy and regulation between areas in which they work. Information needed to make good decisions about managing coastal climate risks may be generated more efficiently at a larger spatial scale (i.e. by state or national governments). There is therefore value in a mechanism for jurisdictions to cooperate on promoting good

1 M Gibbs & J Hill, *Coastal climate change risk — legal and policy responses in Australia*, report prepared by Blake Dawson for the Department of Climate Change and Energy Efficiency, Canberra, 2011.

management of coastal climate change risks. Desirable characteristics of such a mechanism include:

- a shared vision for the management of coastal climate change risks
- a policy framework with agreed principles for managing risks
- agreement on risk allocation
- facilitated sharing of information.

At a smaller scale, regional governance arrangements, where adjacent local councils collaborate on coastal management, can use resources more efficiently, facilitate technical assessment of hazards, and provide regional consistency for businesses and communities (see Box 4.1).

Coastal zones cross jurisdictions so cooperation is necessary and important.

Box 4.1 Examples of regional cooperation on coastal adaptation

Hunter region

In 1993, 14 local councils in the Hunter and Central Coast regions created the Hunter & Central Coast Regional Environmental Management Strategy (HCCREMS) to coordinate the efforts of member councils to address regional environmental issues.

HCCREMS projects investigated the likely climate impacts to the Hunter region and identified key risks to councils and communities. These include bushfire risk due to increased temperatures, flooding and inundation due to sea level rise, and implications for community services such as road and water services. The group has built on this risk assessment to develop and implement adaptation strategies to manage priority risks.

A multidisciplinary team designs and implements the programs in concert with member councils and managers, and in partnership with Australian and state government agencies, other regional groups of councils, universities, and industry and community groups.

Sydney Coastal Councils Group

The Sydney Coastal Councils Group, comprising 15 councils, formed in 1989 to help coordinate sustainable management of the urban coast. The group has investigated risks to Sydney's beaches, and explored systems approaches to regional climate change adaptation, options for adaptation by local government, and ways to monitor and evaluate adaptation. The group also developed tools to help managers identify priority adaptation activities.

The group has entered into partnerships with universities and other regional organisations to share knowledge and resources.

Tasmanian partnership

The Local Government Association of Tasmania, the Tasmanian Office of Climate Change, the Tasmanian Planning Commission, the University of Tasmania and four coastal councils (Break O'Day, Clarence, Kingborough and Latrobe) formed a partnership in 2011 to improve the ability of Tasmanian decision-makers and communities to plan for and respond to likely climate scenarios for coastal communities.

Planning frameworks

Planning frameworks are made up of statutory and common law provisions and a variety of state, regional or local planning instruments and practices. Planning frameworks can vary considerably in how prescriptive they are, but most now explicitly refer to risks from rising sea levels.

Characteristics that will help coastal planning frameworks promote effective management of climate change risks include:

- a risk management approach to planning.[2] A risk management approach identifies the range of possible climate change impacts (social, environmental and economic) and their likelihood, and the costs and benefits of alternative risk management approaches. It entails regular reassessment as new information emerges or circumstances change. Risk management approaches may be easier to implement if a range of conditional planning instruments, such as time-limited development approvals, is available[3]
- involving the community. Some decisions about what levels of climate change risk are acceptable in land use planning involve public assets such as beaches, roads, schools and hospitals, while in other cases regionally consistent approaches can reduce costs for private developers. Involving the community will help ensure that decisions about acceptable levels of climate change risk are seen as equitable and therefore more likely to be accepted over the long term
- adequate underpinning science and understanding of coastal climate change risks. Planning frameworks play a large role in determining how climate risks accumulate in the coastal zone. Strong underpinning science is needed to fully and accurately characterise these risks
- clear articulation of values that need to be protected for the long term. Climate change presents long-term risks to both built and natural assets. If future generations are to retain the capacity to enjoy social, economic and environmental benefits from the coastal zone, some values must be protected for the long term
- development within a strategic planning framework. Strategic planning frameworks help focus on values that require long-term preservation (see above) and provide a clear regional context for local planning decisions. A regional context will often be important because of coastal processes that operate (and need to be managed) across local planning boundaries

2 See, for example, Productivity Commission, *Barriers to effective climate change adaptation*, report 59, Final Inquiry Report, Canberra, 2012.

3 A Mackintosh, 'Coastal climate hazards and urban planning: how planning responses can lead to maladaptation', *Mitigation and Adaptation Strategies for Global Change*, 15 July 2012, pp. 1–21, doi:10.1007/s11027-012-9406-2.

- legal protections for decision-makers acting in good faith, based on sound science.[4] Decision-makers will often be required to make decisions that affect the financial and other interests of private individuals and the community in the face of significant uncertainty. There is a risk that fear of legal consequences will prevent decision-makers from acting on the best scientific evidence.

Design standards for buildings and other infrastructure

Coastal climate change risks to buildings and other infrastructure depend on how assets are constructed and where they are located. Design options that take climate change risks into account include increased resilience (such as elevating structures or using stronger materials), flexible approaches that facilitate upgrades to cope with a more extreme future if necessary or cheaper structures with shorter lifetimes.

A range of codes, standards and guidelines influence the design of coastal assets. Some are mandatory (such as the National Construction Code) while others are voluntary (such as the standards developed by Standards Australia). These codes, standards and guidelines have generally been based on the historical climate, although some recent examples explicitly recognise the changing climate (see Box 4.2).

Box 4.2 Engineers Australia's coastal engineering guidelines

The National Committee on Coastal and Ocean Engineering (part of Engineers Australia) recognises that changing climate is a key agent affecting coastal management practice in Australia and future decision-making for management of the coastal zone.

In 2012 the National Committee on Coastal and Ocean Engineering released *Guidelines for responding to the effects of climate change in coastal and ocean engineering*; *Coastal Engineering guidelines for working with the Australian coast in an ecologically sustainable way*; and *Climate change adaptation guidelines in coastal management and planning*.

This set of documents provides guidance to coastal engineers, coastal managers and planners in responding to the challenges of a changing climate.

4 Coasts and Climate Change Council, *Council advice to Minister Combet — December 2011*, Australian Government Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education, Canberra, 2011, viewed 4 June 2013, <www.climatechange.gov.au/climate-change/adapting-climate-change/australias-coasts-and-climate-change/xxxx-adapting-coastal--1>.

These considerations lead to the following propositions about what drivers we might expect to see if Australia is doing a good job of managing the impacts of unavoidable climate change on the coast:

Mechanisms are in place for jurisdictions to cooperate on promoting good adaptation in the coastal zone.

Coastal planning frameworks take a risk management approach, involve the community, are based on adequate underpinning science, clearly articulate values to be protected in the long term, are developed within a strategic planning framework and provide legal protections for decision-makers acting in good faith based on sound science.

Codes, standard and guidelines for the design of coastal buildings and other infrastructure assume a changing climate.

The community needs to be involved in managing our coasts.

Good activities

Chapter 3 noted four circumstances under which activity to manage climate change risks is expected now:

- where current climate risks are unacceptably high and will increase as the climate changes (adaptation deficits)
- no or low-regret adaptation activities, which offer net benefits under most or all climate change scenarios
- where decisions with long-term implications may 'lock in' vulnerability to future climate change impacts
- where skills and information need to be developed now to manage climate change impacts, even if those impacts lie in the future.

Rising sea levels and increased storm surge should be considered in coastal land use planning .

In some places built assets and coastal ecosystems are at high risk from coastal erosion and inundation even in the historical climate. However, the most serious climate risks arise from anticipated changes, particularly sea level rise (see Appendix 1).

A range of no or low-regret activities is available to manage climate risks, but the costs and benefits often depend strongly on local conditions so it is difficult to identify generic low-regret activities for the whole coastal zone. Maintaining and upgrading existing small seawalls is an example (see Box 4.3).

Box 4.3 Maintaining and upgrading small seawalls[a]

There are many small seawalls around Australia's coast, often owned or managed by local councils. Increased flooding, wave loading and scouring will make some seawalls ineffective as the climate changes. This will ultimately result in damage to assets the seawalls are supposed to protect.

A recent study by the Sydney Coastal Councils Group found potential benefits in maintaining or upgrading small seawalls, although each seawall would need to be considered on an individual basis. In some instances there may be immediate benefits because seawalls are at risk under current conditions. For example, three seawalls at Clontarf were investigated and found to be vulnerable to undermining from storm erosion and ongoing recession even without the additional risk from further sea level rise.

a Based on Sydney Coastal Councils Group, *Assessment and decision frameworks for seawall* structures, report by Coastal Environment Pty Ltd, Newcastle, 2013, viewed 4 June 2013, <http://www.sydneycoastalcouncils.com.au/Project/assessment_and_decision_frameworks_for_seawall_structures_project>.

Planning for climate risks on the coast

Much of Australia's economic development takes place on the coast. New land is released, existing assets are redeveloped and new assets are built

in already developed areas. Many areas that are developed or proposed for new development are at risk from rising sea levels and more intense storm surge. While the specific on-ground actions to manage these risks, and the timing of those actions, will depend on local circumstances, the need for long-term planning does not. Local authorities will need to consider rising sea levels and increased storm surge in land use planning and development control processes. Similarly, businesses and governments will need to consider changing coastal climate risks when planning major infrastructure such as ports, airports, water treatment plants, railways and bridges. (See Box 4.4 for an example of long-term infrastructure planning for climate change.)

These considerations lead to the following proposition about what activities we might expect to see if Australia is doing a good job of managing the impacts of unavoidable climate change on the coast:

Taking coastal climate risks (including sea level rise and more intense storm surge) into account in land use planning, development controls and plans for major infrastructure.

Box 4.4 Climate change and Brisbane Airport[a]

Brisbane Airport is the principal international and domestic gateway to Queensland and Australia's third-largest airport by passenger volume, handling more than 21 million passengers annually. Passenger volumes have grown strongly since the airport was privatised in 1997 and the owners decided that building a new runway was the best option for keeping up with passenger demand.

Brisbane Airport is built on a low-lying coastal site susceptible to flooding events. The new runway was expected to be in service for several decades, so rising sea levels were an important consideration in its design.

The airport commissioned the Antarctic Climate and Ecosystems Collaborative Research Centre to evaluate the various runway height options in light of the most recent climate and sea level data available. After considering a range of design, regulatory, stakeholder and financial factors, the owners decided to build the runway at a height of 4.1 metres above sea level. This exceeded the minimum level recommended by engineering consultants (3.5 metres) and the current 1-in-100 year storm tide level (2.3 metres). The runway development will also include tidal channels and a new seawall along the northern boundary of the airport to hold floodwater out of the site.

a Colonial First State, *Climate change adaptation at Brisbane Airport*, Colonial First State, 2012, viewed 20 May 2013, <www.cfsgam.com.au/uploadedFiles/CFSGAM/PdfResearch/Infrasrtucture_Brisbane_Airport_Dec12.pdf>.

Box 4.5 Do local governments consider climate change risks in land use planning?

In a survey of 49 local governments in non-metropolitan coastal areas, Gurran et al. found that less than one-fifth had changed their planning controls to reflect a changing climate.[a] However, more than half the respondents had commenced reviewing and amending their planning schemes, and almost all intend to do so in the near future. Some early movers have commenced climate planning with detailed risk analysis, although most have advanced no further. Other local governments have neither engaged, nor anticipate engaging in, adaptation planning activities.

CSIRO surveys in 2008 and 2010 covered 102 local councils, finding that the extent of adaptation activity was highly variable.[b] Barriers to adaptation planning included a lack of information and resources (money, people and time), a lack of policy clarity and/or government support, scepticism about climate change impacts, and a culture of conservatism within the organisations.

The study also found that adaptation planning is more likely to occur if an organisation has:

- information from a vulnerability assessment specific for their organisation
- a better understanding of adaptation and mitigation issues
- a stronger sense of the importance of both adaptation and mitigation
- contact with external organisations specifically to discuss adaptation
- longer strategic planning horizons.

a N Gurran, B Norman, C Gilbert & E Hamin, *Planning for climate change adaptation in Coastal Australia: state of practice*, report 4 for the National Sea Change Taskforce, Faculty of Architecture, Design and Planning, University of Sydney, 2011.

b J Gardner & J Roan J, *Adaptation benchmarking survey: final report*, CSIRO, Australia, 2011.

Box 4.6 Australian Government departments considering climate change risk in the coastal zone

The box provides two examples of Australian Government departments working to address the risks of climate change in the coastal zone.

The Department of Defence is undertaking an assessment of climate change impacts on its coastal assets

Recognising the challenges posed by climate change, the Department of Defence initiated a two-stage climate change assessment process in 2011. The first stage involved a high-level assessment of the sites' likely risk exposure to climate change (sea level rise and coastal flooding), which enabled the department to decide which sites required detailed investigations. The second stage involves a more detailed study to enable the department to determine their next steps — from knowing which bases are likely to be at most risk, to understanding in greater detail their actual risk exposure and which adaptation measures are likely to minimise these future risks.

To guide the detailed site assessment, a site assessment methodology and framework was developed. The framework provides a step-by-step methodology for the assessment of climate change impact at Defence sites. It is currently being applied to the assessment of selected coastal Defence sites across Australia.

Risks are being assessed for 2040, 2070 and 2100, and risk treatment options are prioritised using a multi-criteria analysis to address risks identified as medium, high and very high by 2040. The multi-criteria analysis considers effectiveness to reduce the risk, cost, significance of the action, community acceptance and urgency.

The Department of Regional Australia, Local Government, Arts and Sport is developing a climate adaptation strategy for the Indian Ocean Territories

The Australian Government administers government services to the Australian external territories of Christmas Island and the Cocos (Keeling) Islands, known as the Indian Ocean Territories. The territories are small islands located around 2000 kilometres west of Western Australia and became part of Australia in the 1950s. The islands are administered by the Department of Regional Australia, Local Government, Arts and Sport.

In 2008, the department commissioned a comprehensive assessment of the risks posed by climate change for key services and the long-term viability of settlements in the territories, and in 2010 updated the risk assessment in order to develop the Indian Ocean Territories Climate Change Adaptation Strategy. The strategy was developed by the department in 2011 and aims to increase the natural resilience of the territories and reduce their vulnerability to present-day weather events and the effects of climate change. The strategy has enabled the communities in the territories to set priorities to lead programs and projects that address the vulnerabilities identified in the risk assessment. The strategy identified four key elements of focus for climate change adaptation — information and education, future planning, communication plans and community action plans.

The department and the communities in the territories continue to work together to adapt the islands to the impacts of climate change. A third risk assessment update is expected to take place in 2014.

There are several locations around Australia's coastline where development (often initiated before climate change risks were understood) has created 'hot spots': concentrations of economically, socially and environmentally important assets at risk from rising sea levels. Port Phillip and Botany Bay are examples. The value of these assets means that measures to protect them against climate change are likely to be more cost-effective than retreat from the coast as sea levels rise. Protective measures may not be needed immediately, but early planning will help to identify and capitalise on lower-cost options for managing climate risks. Australian, state and local governments, businesses and individuals share ownership, management and regulatory oversight of the assets in these 'hot spots', suggesting that a degree of coordination will be required to manage climate change risks. The findings of both the Productivity Commission[5] and the Coasts and Climate Change Council[6] support this conclusion.

These considerations lead to the following proposition about what activities we might expect to see if Australia is doing a good job of managing the impacts of unavoidable climate change on the coast:

Identifying 'hot spots' with concentrations of economically, socially and environmentally important assets at risk from rising sea levels and developing collaborative strategies to manage climate change risks to them.

Building capacity

A number of local councils and corporations have started preparing for the impacts of rising sea levels, more intense storm surge and other coast climate change hazards.[7] Based on these experiences and related research, it is possible to identify some information that is needed to support good management of coastal climate change risks.

Decision-makers need clear advice on sea level rise and storm surge projections. It is not possible to eliminate uncertainty so governments (particularly local governments) and businesses need to understand how to make decisions despite irreducible uncertainty. A number of methods and approaches are available.[8]

Rising sea levels and other changes in the climate have implications for hazards such as coastal erosion. Hazard modelling that supports decisions about land use planning and infrastructure design and

5 Productivity Commission, *Barriers to effective climate change adaptation*, report 59, Final Inquiry Report, Productivity Commission, Canberra, 2012.

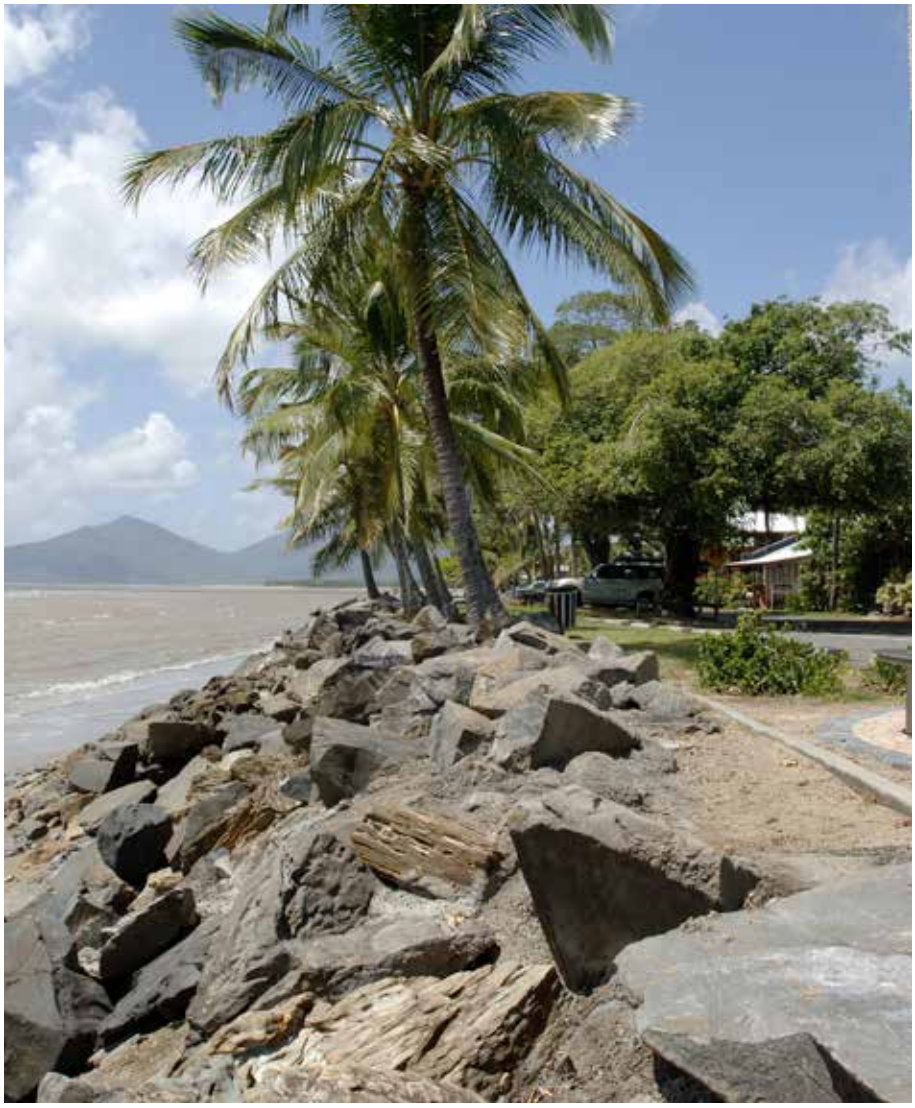
6 Coasts and Climate Change Council

7 For example, City of Mandurah, *Coastal zone climate change risk assessment and adaptation plan report*, report prepared by Coastal Zone Management Pty Ltd, 2009, viewed 20 May 2013, <www.mandurah.wa.gov.au/ClimateChangeStrategy.htm>; Clarence City Council, Clarence Bushland and Coastal Strategy, Clarence City Council, 2011, viewed 20 May 2013, <www.ccc.tas.gov.au/page.aspx?u=1584>; Sydney Water, Climate change adaptation: program summary, Sydney Water, Parramatta, n.d., viewed 20 May 2013, <www.sydneywater.com.au/SW/water-the-environment/what-we-re-doing/energy-management/index.htm>.

8 For example, H Kunreather, G Heal, M Allen, O Edenhofer, CB Field & G Yohe, 'Risk management and climate change', *Nature Climate Change*, vol. 3, 2013, pp.447–50.

management on the coast must absorb these implications but current approaches may not be suited to doing so. Important issues include:

- the potential for higher sea levels to accelerate erosion of many beaches over the longer term; beaches can switch from accreting sand (and therefore being relatively stable) to losing sand and therefore receding, but the thresholds for this switch are not well understood[9]
- the effect of simultaneous coastal erosion and increased inundation from extreme tides
- the effect of experiencing storm surge at the same time as catchment flooding, especially for areas that are close to the coast and have a major river drainage outlet; clustering of storms can also affect coastal erosion and inundation.



Coastal assets in northern Queensland

9 Department of Climate Change, pp. 21–38

A number of professionals have important roles in managing coastal climate change risk. These include planners advising local councils on land use planning and development applications, and engineers responsible for designing coastal structures. These professionals will require specific skills and expertise to access, understand and make good use of information about coastal climate change risks and options for managing them. A lack of skilled planners, engineers and other professionals is an obstacle to effective coastal management in some regions.[10]

These considerations lead to the following proposition about what activities we might expect to see if Australia is doing a good job of managing the impacts of unavoidable climate change on the coast:

Developing the specialised information and skills required to manage climate change risks in the coastal zone.

Good outcomes

Good adaptation outcomes in the coastal zone will be broadly consistent with good outcomes at the national scale (described in Chapter 3). As at the national scale, the key issue is balancing risks and opportunities while taking the needs of disadvantaged groups and future generations into account.

Specific climate risks in the coastal zone will affect understanding of what good adaptation outcomes would look like. These considerations lead to the following propositions about what good adaptation outcomes in the coastal zone are:

Development in the coastal zone provides social, economic and environmental benefits without creating risks from sea level rise and storm surge that are unacceptable to the community.

The way risks from sea level rise, storm surge and other coastal climate risks are managed today does not compromise the capacity of future generations to manage risks they may face from coastal climate hazards.

Disadvantaged groups have the resilience and capacity to manage risks they face from climate coastal climate hazards.

10 Department of Climate Change, *Climate change risks to Australia's coast: a first pass national assessment*, Department of Climate Change, Canberra, 2009, pp. 138–9.

Summary of what good climate change adaptation would look like in the coastal zone

Good drivers of adaption in the coastal zone include:

- mechanisms are in place for jurisdictions to cooperate on promoting good adaptation in the coastal zone
- coastal planning frameworks take a risk management approach, involve the community, are based on adequate underpinning science, clearly articulate values to be protected in the long term, are developed within a strategic planning framework and provide legal protections for decision-makers acting in good faith based on sound science
- codes, standard and guidelines for the design of coastal buildings and other infrastructure assume a changing climate.

The adaptation activities that should be happening now in the coastal zone include:

- taking coastal climate risks (including sea level rise and more intense storm surge) into account in land use planning, development controls and plans for major infrastructure
- identifying 'hot spots' with concentrations of economically, socially and environmentally important assets at risk from rising sea levels and developing collaborative strategies to manage climate change risks to them
- developing the specialised information and skills required to manage climate change risks in the coastal zone.

Good adaptation outcomes will be achieved in the coastal zone if:

- development in the coastal zone provides social, economic and environmental benefits without creating risks from sea level rise and storm surge that are unacceptable to the community
- the way risks from sea level rise, storm surge and other coastal climate risks are managed today does not compromise the capacity of future generations to manage risks they may face from coastal climate hazards
- disadvantaged groups have the resilience and capacity to manage risks they face from coastal climate hazards.

05 What good climate change adaptation would look like in south-east Queensland

Key points

This chapter extends the assessment framework to south-east Queensland to explore what good adaptation would look like in a region.

The framework is summarised in Figure 5.1.

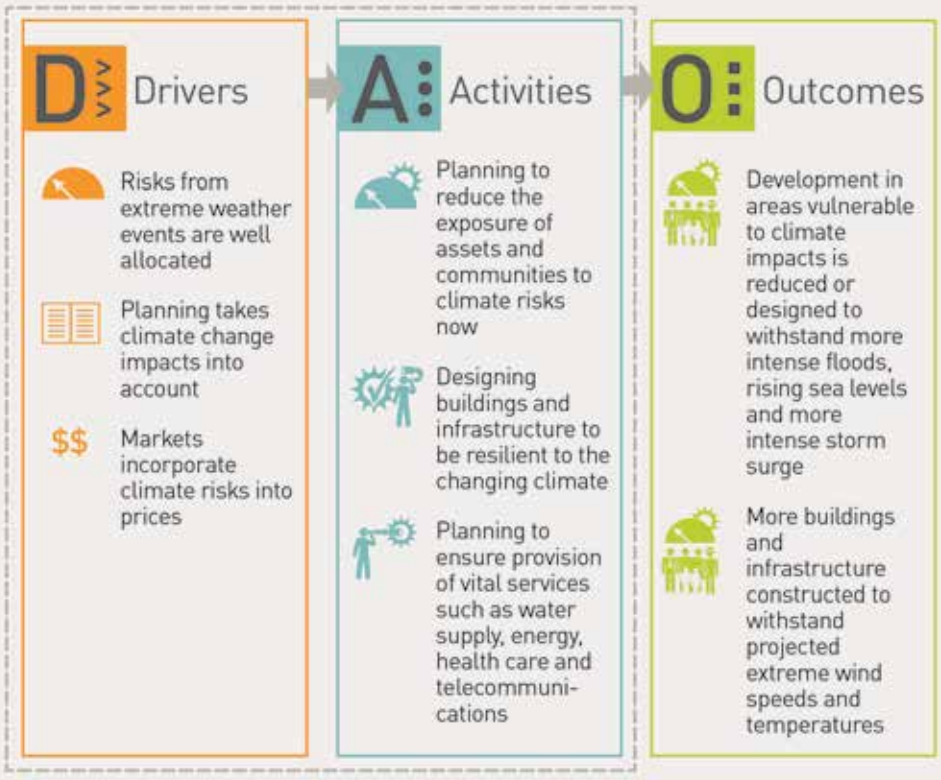


Figure 5.1 Drivers, activities and outcomes of climate change adaptation

Opposite page: Two onlookers watch the Brisbane River break its banks during the 2011 Queensland floods

Local circumstances can affect our understanding of what it means to manage climate risks well. The nature and magnitude of existing climate risks, the natural environment, the pattern of development, and local governance and preferences are all potentially important. This chapter explores these implications by considering how the assessment framework might be extended to south-east Queensland. This chapter is not an assessment of adaptation progress in south-east Queensland.

In 2007 the Intergovernmental Panel on Climate Change identified south-east Queensland as an area that is highly vulnerable to climate change impacts.[1] More recently, CSIRO and its research partners conducted a multi-year study of the region's adaptation needs.

South-east Queensland's vulnerability is a result of its coastal location, topography, climate, and the distribution and location of its rapidly growing population.[2] Built assets are at risk from rising sea levels, more severe floods and increased bushfire risk. By 2030, a 1-in-100 storm surge would inundate 61 500 residential buildings and cause estimated damage of $2.0 billion (assuming a 20 centimetre of sea level rise).[3]

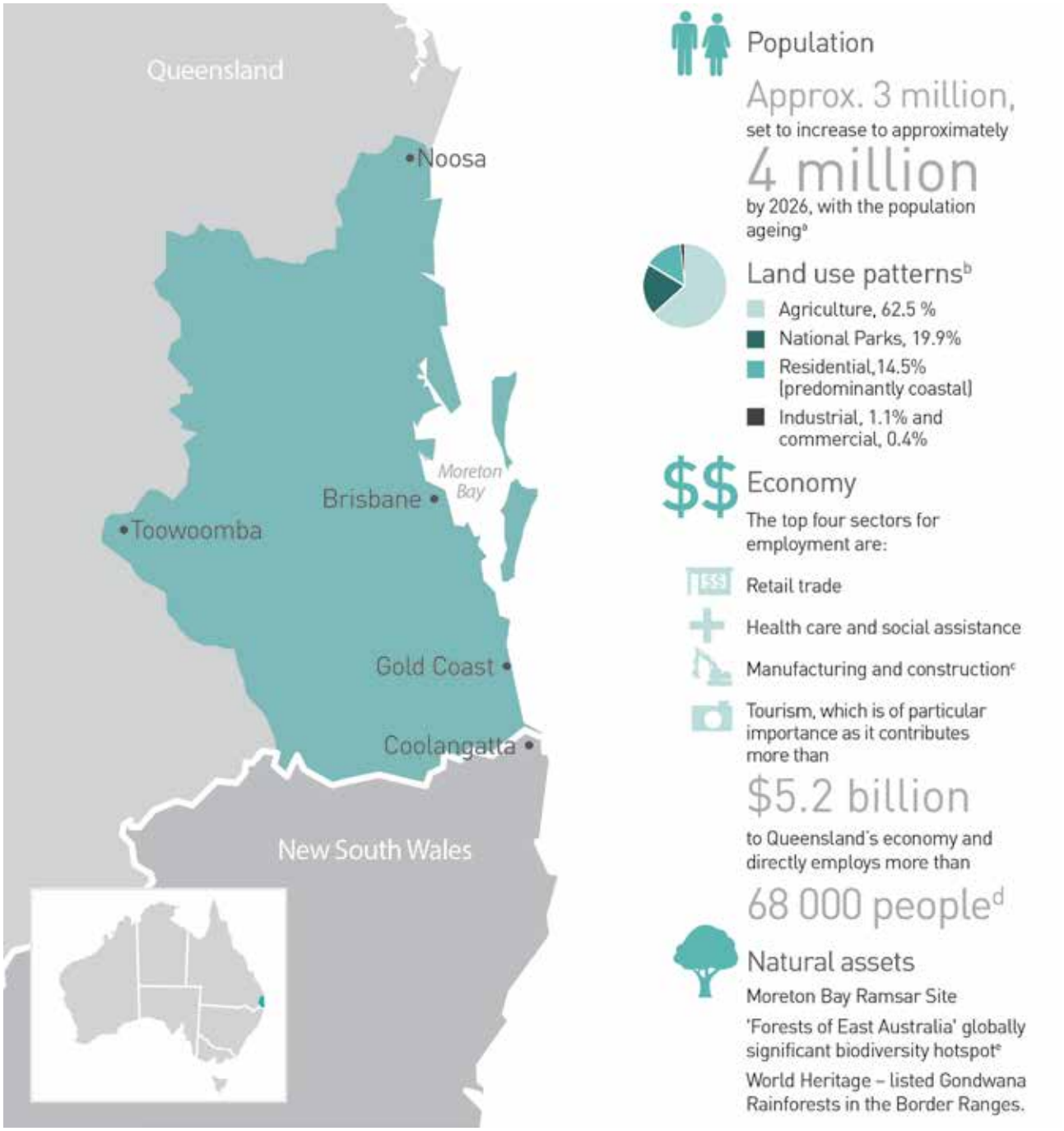
In the last decade a severe drought followed by serious flooding has highlighted climate vulnerability in south-east Queensland (see Box 5.1).

Coastal erosion is a significant challenge for south-east Queensland.

1 K Hennessy, B Fitzharris, BC Bates, N Harvey, SM Howden, L Hughes, J Salinger & R Warrick, 'Australia and New Zealand', in ML Parry, OF Canziani, JP Palutikof, PJ van der Linden & CE Hanson, (eds), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, 2007, pp. 507–40.

2 D Low Choy, S Serrao-Neumann, F Crick, G Schuck, M Sanò, R van Staden, O Sahin, B Harman & S Baum, *Adaptation options for human settlements in south east Queensland: main report*, report for the South East Queensland Climate Adaptation Research Initiative, Griffith University, 2012; S Serrao-Neumann, F Crick, B Harman, M Sanò, O Sahin, R van Staden, G Schuck, S Baum & D Low Choy, 'Improving cross-sectoral climate change adaptation for coastal settlements: insights from South East Queensland, Australia', *Regional Environmental Change*, March 2013, doi: 10.1007/s10113-013-0442-6.

3 X Wang, M Stafford Smith, RRJ McAllister, A Leitch, S McFallan & S Mehang, *Coastal inundation under climate change: a case study in South East Queensland*, CSIRO Climate Adaptation Flagship Working paper 6, CSIRO, Australia, 2010, p. 6.



a OESR (Office of Economic and Statistical Research Queensland Treasury) 2011, *Queensland Government population projections to 2056: Queensland and statistical divisions (2011edition)*, Queensland Government, Brisbane. Available at http://www.oesr.qld.gov.au/products/publications/qld-govt-pop-proj-qld-sd/qld-govt-pop-proj-2056-qld-sd-2011.pdf. Accessed on 9 April 2013.

b ABS (Australian Bureau of Statistics), 2010, *National Regional Profile (2006 – 2010)*, Australian Bureau of Statistics, Canberra.

c A Roiko, R Mangoyana, S McFallan, RW Carter, J Oliver and TF Smith, 2012, 'Socioeconomic trends and climate change adaptation: the case of South East Queensland', *Australasian Journal of Environmental Management*, vol. 19, pp. 35-50.

d DSDIP (Department of State Development, Infrastructure and Planning) (2009) South East Queensland Regional Plan 2009 – 2031, http://www.dsdip.qld.gov.au/resources/plan/seq/regional-plan-2009/seq-regional-plan-2009.pdf. Accessed on 9 April 2013.

e Shoo LP, O'Mara J, Perhans K, Rhodes JR, Runting R, Schmidt S, Traill LW, Weber LC, Wilson KA and Lovelock CE (unpubl.) Adaptation for the maintenance of biodiversity with climate change. Report to SEQCARI; MD Crisp, S Laffan, HP Linder and A Monro, 2001, 'Endemism in the Australian flora', *Journal of Biogeography*, vol. 28, no. 2, pp.183–198; KJ Williams, A Ford, DF Rosauer, N De Silva, RA Mittermeier, C Bruce, FW Larsen, and C Margules, 2011, 'Forests of east Australia: the 35th biodiversity hotspot' in FE Zachos and JC Habel (eds) *Biodiversity hotspots: distribution and protection of conservation priority areas,* Springer, London, pp 295–310.

Figure 5.2 A snapshot of south-east Queensland

Box 5.1 Drought and flood

South-east Queensland's vulnerability to the effects of extreme weather was recently demonstrated by the impacts from the worst drought on record (2000–09), and the intense post-drought rains in late 2010 and early 2011 that flooded much of the region and inundated Brisbane.[a]

The floods were one of Brisbane's largest in the last century. Private costs were substantial. Since 2010–11, the Australian Government has paid $5.7 billion to the states to support disaster relief.

The floods affected an estimated 18 000 residential and commercial properties in Brisbane and Ipswich. Brisbane's central business district closed and work halted on commercial projects.[b] The Chamber of Commerce and Industry Queensland conducted a survey on direct and indirect productivity impacts, for which 34.4 per cent of survey respondents were from Brisbane.[c]

Respondents indicated that the 2011 floods:

- forced business closures (due to loss of power etc.) with resultant lost sales
- affected customers
- affected suppliers
- made employees unable to attend work
- caused loss of appeal of Queensland as a tourist destination, with a public perception that all businesses in all of Queensland had been impacted, through negative media portrayals; cancellation of bookings; and reduced tourist numbers
- caused loss of access for local visitors due to road closures
- meant businesses could not move or receive freight by road or ports
- increased prices of some goods (fresh produce)
- caused loss of communication networks
- caused loss of office records.

The average number of days businesses were forced to close was 8 (median of 4 days) and the average number of days before their businesses returned to normal operations was 31 days (median of 10 days).

Loss of earnings was significant, with average expected losses per business at around $900 000.

a G Laves, S Kenway, D Begbie & A Roiko, 'Still waters running deep: building adaptive capacity in the south east Queensland water supply sector through research', *Regional Environmental Change*, (under review).

b IbisWorld, *Queensland floods: the economic impact*, Special Report January 2011, IbisWorld, Melbourne, viewed 6 June 2013, <www.ibisworld.com.au/common/pdf/QLD%20floods%20special%20report.pdf>.

c Chamber of Commerce & Industry Queensland, *Impact of the Queensland floods on business: CCIQ survey*, Chamber of Commerce & Industry Queensland, Brisbane, 2011.

Coasts are important for culture and recreation in south east Queensland.

Good drivers

The national-scale drivers identified in Chapter 3, and the coastal drivers identified in Chapter 4 are broadly relevant to south-east Queensland. Regional characteristics will determine the way many of those drivers work in practice and their relative importance.

Governance

South-east Queensland has 11 regional and city councils. As in many areas around Australia, much development planning and local management is delegated to local governments. The small number of relatively large regional and city councils in south-east Queensland offers economies of scale and may make regional cooperation between councils easier, because fewer parties are involved.

As outlined in Chapter 4, cooperation between governments in the coastal zone is important. The same applies within regions. For south-east Queensland, many natural coastal processes such as sand movement occur across local government boundaries. Coastal erosion management measures, such as seawalls and beach replenishment activities, may affect adjacent local government areas to their benefit or detriment. Coordination along the coast to ensure equitable management of coastal impacts will be important, with sea level rise and increased storm activity in the future.

Planning frameworks will also be of particular importance in regions such as south-east Queensland that are developing rapidly while exposed to significant — and growing — climate risks. Chapter 4 outlines some characteristics that will help planning frameworks promote effective management of climate change risks. These included a risk management approach to planning, involving the community, adequate underpinning science, clear articulation of values to be protected for the long term and a strategic planning context.

Risk allocation

South-east Queensland's high vulnerability and rapid rate of development places a premium on ensuring sound allocation of climate change risks. The 2011 floods in south-east Queensland illustrated the current incongruence between where fiscal risks reside and where decision-making powers to reduce vulnerability to hazards rest.

$$ Markets

The significant and growing risks to assets in south-east Queensland from climate-related hazards such as flood and coastal inundation should be reflected in prices for land and insurance. Price signals can provide an incentive for more effective management of these climate risks.

Public attitudes

Recent experience in south-east Queensland demonstrates how local circumstances can shape public understanding of what is required to manage climate risks.

With the construction of the Wivenhoe Dam for flood mitigation after the 1974 Brisbane floods, there was a widely held view in the community that south-east Queensland was 'flood-proof'. This led to a reduction in community focus on future flood risk.[4]

In addition, because of the drought of 2000–09, south-east Queensland completely transformed the water supply grid, shifting the focus from flood mitigation to water security.[5] During the drought there was also an influx of new residents with little local knowledge or experience of floods.[6] Consequently, the community was not expecting and was not prepared for the extreme flooding of 2010–11.[7]

These considerations lead to the following proposition about what drivers we might expect to see if south-east Queensland is doing a good job of managing the impacts of unavoidable climate change:

Risks from extreme weather events are well allocated, planning takes climate change impacts into account and markets incorporate climate risks into prices.

Milton Road is inundated during the 2011 floods in Brisbane.

4 EL Bohensky & AM Leitch, 'Framing the flood: a media analysis of themes of resilience in the 2011 Brisbane flood', *Regional Environmental Change*, March 2013, doi: 10.1007/s10113-013-0438-2.

5 G Laves, S Kenway, D Begbie & A Roiko, 'Still waters running deep: building adaptive capacity in the south east Queensland water supply sector through research', *Regional Environmental Change*, (under review).

6 DU Keogh, A Armando & S Mushtaq, 2011, 'Resilience, vulnerability and adaptive capacity of an inland rural town prone to flooding: a climate change adaptation case study of Charleville, Queensland, Australia', *Natural Hazards*, vol. 59, pp. 699–723.

7 Bohensky & Leitch

Good activities

As noted in Chapter 3, there are four circumstances where activity would be expected now to manage climate change risks:

- where Australia may face unacceptably high risks from current climate, and such risks would increase as the climate changes ('adaptation deficits')
- no or low-regret adaptation activities that offer net benefits under most or all climate change scenarios
- where decisions with long-term implications may 'lock in' vulnerability to future climate change impacts
- where skills and information need to be developed now to manage climate impacts even if those impacts lie in the future.

Dealing with adaptation deficits

The 2011 floods in south-east Queensland are estimated to have cost over $5 billion for governments alone. These costs were further increased with subsequent floods in 2013. Extreme rainfall events leading to flooding are expected to become more frequent, and will be exacerbated by sea level rise in coastal areas where most south-east Queenslanders live.

These considerations lead to the following proposition about what activities we might expect to see if risks from flooding in south-east Queensland were being managed for current and future climates:

Planning to reduce the exposure of assets and communities to climate risks now and into the future.

No or low-regret activities

Many assets in south-east Queensland are vulnerable to the impacts of climate. For many assets, design changes can reduce future climate damages under most or all plausible future climates, often at a cost that is significantly less than likely benefits. For example, a study on extreme wind[8] found that increasing design wind speeds for foreshore locations in Brisbane would result in a benefit of $202.7 million (net present value) given the historical climate. Under a moderate climate change scenario, the average net benefit of increasing design wind speeds to foreshore locations in Brisbane is $38 million for 2030, $142 million for 2050, $240 million for 2070 and $340 million for 2100.

8 MG Stewart & X Wang, *Risk assessment of climate adaptation strategies for extreme wind events in Queensland*, CSIRO, Canberra, 2011.

Box 5.2 Suncorp Stadium building back better

In 2011, Suncorp Stadium underwent major reconstruction (worth $16 million) necessitated by extensive flooding damage to the facility. The AEG Ogden management team saw the repairs as an opportunity to integrate advanced sustainable products and technologies into the design.

A number of initiatives were implemented to mitigate against future flood damage:

- The main switchboard room was elevated above the flood level so that it can continue to operate via generator power until mains power is reinstated to the building, meaning no future loss of power to the stadium.
- The fire-panel system was also raised above the flood level to ensure the stadium continues to be connected to Brisbane's fire services and that fire alarms are monitored at all times.
- Flood resistant materials were used wherever practical, such as block walls and elevated and relocatable fixtures and fittings.

Flood waters inundate Suncorp Stadium in Brisbane in 2011.

These considerations lead to the following proposition about what type of no or low-regret activities we might expect to see if risks from wind speeds for current and future climates were being managed well:

Designing buildings and infrastructure to capture the benefits of becoming more resilient to the changing climate.

Planning for long-term impacts

Higher temperatures, more intense flooding, potentially longer or more acute dry periods, and more extreme bushfire weather will affect electricity, water and telecommunications infrastructure and the services they support. Long-term planning will need to take these impacts into account. Box 5.3 outlines some recent long-term planning for water and electricity supply in south-east Queensland.

These considerations lead to the following proposition about what type of activities we would expect to see if long-term climate risks were being managed well:

Planning to ensure the continuation of provision of vital services such as water supply, energy, health care and telecommunications under future climate scenarios.

Box 5.3 Securing water and electricity supply in south-east Queensland

Climate change projections indicate that the south-east Queensland region is likely to become hotter and experience a greater frequency and intensity of extreme events such as droughts[a] and floods.[b]

The water security crisis during the 'millennium drought' stimulated the development of the South East Queensland Water Strategy 2010, with a number of 'hard' and 'soft' components. Hard components included increasing supply efficiency through linking established dams, and improving diversity of supply and long-term preparedness through better wastewater treatment, and reuse and desalination.

These hard components were supplemented by a number of soft components, including behaviour modification through the 'Target 140' campaign to reduce water consumption to 140 litres per person per day (L/p/d). The campaign was extremely successful, with demand falling as low as 126 L/p/d, and, as at 2010, consumption remained at 148 L/p/d compared with 300 L/p/d before the drought.[c]

The Queensland Government has recently commenced a planning exercise for electricity supply across Queensland. It is well recognised that current electricity supplies have become strained and uncompetitive.[d] The strategy directions paper that was released for public consultation in 2012 explores the factors affecting energy supply, including impacts from weather events on infrastructure, to policy impacts on the range of technologies and carbon intensities for sourcing energy in the future. This document does not explicitly address changing energy demand profiles in response to a changing climate. However, it does refer to generalised sources of uncertainty in future demand levels, and commits to designing in-built flexibility to be able to address different sources of uncertainty in the future.

a D Kent, W Cai, & K Nguyen, *Projections of exceptional climatic events in south-east Queensland produced by a dynamical Regional Circulation Model*, Urban Water Security Research Alliance Technical Report 62, CSIRO, Brisbane, 2012.

b W Cai & P van Rensch, 'The 2011 southeast Queensland extreme summer rainfall: a confirmation of a negative Pacific Decadal Oscillation phase?', *Geophysical Research Letters*, vol. 39, 2012, L08702.

c Queensland Water Commission, *South east Queensland strategy*, Queensland Water Commission, Brisbane, 2010, pp. 107–8.

d Queensland Department of Energy and Water Supply, *The 30-year electricity strategy: directions paper*, DEWS, Brisbane, 2012.

Good outcomes

A description of good adaptation outcomes in south-east Queensland will build on national adaptation outcomes. For particular regions it is possible to be more specific about risks from climate change impacts and the degree to which they may already be moving outside bounds the community finds acceptable. Some climate risks in south-east Queensland are known to be very high already, as outlined earlier in this chapter, and may be higher than the community is prepared to accept. Rapid development means that risks arising from historical development patterns will certainly be increased unless future development takes the changing climate into account. This leads to the conclusion that development patterns that reduce overall risk would be a good outcome in this region.

These considerations lead to the proposition that the outcomes one might expect to see if south-east Queensland was managing for adaptation to a changing climate include:

Development (residential and infrastructure) in current and projected flood and inundation- prone areas is reduced or designed to withstand more intense floods, rising sea levels and more intense storm surge.

More buildings and infrastructure are constructed to withstand projected extreme wind speeds and temperatures.

Infrastructure constructed today needs to withstand climate extremes in the future.

Summary of what good climate change adaptation would look like for south-east Queensland

Good drivers of adaptation for south-east Queensland include:

- risks from extreme weather events are well allocated, planning takes climate change impacts into account and markets incorporate climate risks into prices.

Adaptation activities that should be happening now include:

- planning to reduce the exposure of assets and communities to climate risks now and into the future
- designing buildings and infrastructure to capture the benefits of becoming more resilient to the changing climate
- planning to ensure the continued provision of vital services such as water supply, energy, health care and telecommunications under future climate scenarios.

South-east Queensland will be managing the impacts of climate change well if:

- development (residential and infrastructure) in current and projected flood and inundation-prone areas is reduced or designed to withstand more intense floods, rising sea levels and more intense storm surge
- more buildings and infrastructure are constructed to withstand projected extreme wind speeds and temperatures.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06 Towards indicators of national adaptation progress

Key points

This chapter describes 12 possible indicators to track progress against elements of the proposed national assessment framework. It also describes how indicators might be used, together with other information, to help inform judgments about whether Australia is achieving good adaptation outcomes.

A set of indicators will be developed to support assessment of national progress against the assessment framework. Indicators will provide an anchor for ongoing assessment of national adaptation progress but other information and evidence will also be needed.

This chapter discusses the characteristics that indicators for a Climate Adaptation Outlook report should have and presents some possible indicators as a starting point for consultation with stakeholders. Where possible, indicators will draw on existing data sources including by adopting indicators used for other purposes.

Indicator characteristics

Desirable characteristics of individual indicators for the Climate Adaptation Outlook report are:

- salience. Indicators should relate as directly as possible to the elements of the framework they are intended to monitor progress against and be relevant to policy and stakeholders
- clarity. Indicators should have an unambiguous interpretation; this will require that indicators be considered within the climate adaptation outlook framework and interpreted in concert with other indicators
- power to detect trends. Indicators should be able to identify trends in the elements of the framework they are intended to monitor progress against; possible confounding factors should be identified and confusion minimised
- ability to provide advance indication of how adaptation is tracking where possible

Opposite page: Flood markers indicate the depth of water at crossings.

- ability to identify maladaptation. Where possible, indicators should be chosen for their capacity to identify where current activities, policies or market conditions are reducing Australia's capacity to manage the impacts of unavoidable climate change
- Information availability. Reliable, regularly collected information should be available to support the indicator.

Desirable characteristics of the set of indicators are:

- limited size. A small number of high-impact indicators will be easier to interpret and help communicate key messages; a potential disadvantage of a limited indicator set is that attention may be focused on the specific measures rather than the broader conclusions about national adaptation
- framework span. Indicators should cover the main elements of the framework, noting that it may not be possible to develop practical indicators for some elements
- continuous improvement. The indicator set should be continuously tested and improved.

Possible national indicators

This section discusses possible indicators for the drivers, activities and outcomes that are relevant to a broad range of places, activities and natural or built assets.

National indicators of drivers

Indicator 1: Number of major climate risks satisfying all criteria for good risk allocation

This indicator could be used to track progress against the framework element 'climate change risks are well understood and clearly allocated to those best placed to manage them while those who benefit from risk management pay the costs'.

Appendix 2 assesses the allocation of three major climate risks (risk to rural water resources, natural disaster management and local government liability for climate change impacts) against four desirable characteristics of risk allocation. This indicator would expand this assessment to a larger set of major climate risks.

Unlike most other indicators discussed here, this indicator is qualitative. Major climate risks could be identified and assessed against risk allocation criteria by an expert panel.

Indicator 2: Effect of climate hazards on land prices

This indicator could be used to track progress against the framework element 'insurance, capital and asset markets incorporate climate change risks into prices'.

The indicator seeks to measure how climate risk affects land prices because data are likely to be accessible and climate signals are more likely to be detectable than for other asset markets or for insurance or capital markets.

As noted in Box 3.1, land prices in Australia are sensitive to the degree of flood risk. This indicator would use hedonic analysis to assess how sensitive land prices are to a range of climate hazards.

Trends in this indicator may be difficult to interpret. Ideally, a baseline would be established by calculating the sensitivity of land prices to climate hazards in a period when the market was unlikely to be taking climate change into account (say 1980–90). Increased sensitivity of land prices to climate hazards compared to the baseline period would suggest that markets are factoring increased climate risk into prices.

Indicator 3: Percentage of corporations disclosing climate risk

This indicator could be used to track progress against the framework element 'markets promote disclosure of risks from climate change impacts'.

Surveys could assess how many publicly listed corporations are disclosing climate risks. The Investor Group on Climate Change has designed and used a possible survey instrument.[1]

Indicator 4: Percentage of the public who accept that some things may need to be done differently in a changing climate

This indicator could be used to track progress against the framework element 'the public and decision-makers accept that it may be necessary to do some things differently in a changing climate'. It could be monitored using surveys (such as those described in Box 3.3) of individuals, small and large businesses, and community organisations.

National indicators of activities

Because it is difficult to prescribe adaptation activities at the national scale, only two potential activity indictors have been identified.

Indicator 5: Percentage of organisations considering climate change in long-term planning

This indicator is a direct measure of the framework element 'taking climate change impacts into account when making decisions with long term consequences'. It would only cover organisations responsible for making decisions with long-lasting consequences such as land use planning, construction of major infrastructure or management of ecosystems. It would be based on repeated surveys such as those described in Boxes 3.3 and 4.5.

Indicator 6: Proportion of tertiary courses in engineering, architecture, planning, natural resource management and other relevant disciplines where climate change is integrated into training

This indicator is a partial measure of the framework element 'building skills and information needed to manage climate risk now and in the future'. It would track the extent to which key professionals are being trained to operate effectively in a changing climate. Data could be collected by a regular survey of Australia's tertiary education providers. The indicator would test whether training was provided but not the quality of that training.

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1 Institutional Investors Group on Climate Change, Investor Network on Climate Risk & Investor Group on Climate Change 2011, *Global investor survey on climate change: annual report on actions and progress* 2011, IIGCC, INCR & IGCC, 2011.

National indicators of outcomes

The proposed framework described good national adaptation outcomes in terms of the magnitude of climate risk, whether the risks are acceptable to the community, whether risks are manageable into the future and whether disadvantaged groups can manage their climate risks.

This section proposes four indicators that would help track the magnitude of climate risks and how they are changing. The indicators capture some important climate risks across a range of domains (some economic, some social, some environmental) rather than attempting to be comprehensive.

Judgments would need to be made about whether risks are acceptable to the community and manageable into the future, and the capacity of disadvantaged groups to manage. It is not possible at this stage to develop indicators of community willingness to accept risk or of the capacity of disadvantaged groups to manage their climate risks.

Indicator 7: Change in the replacement value of built assets in bushfire, flood and coastal erosion and inundation zones

A form of this indicator is discussed in Box 6.1.

The value of assets located in areas that are vulnerable to climate impacts now or in the future is a leading indicator because it gives an idea of the potential for damages in a more extreme future climate. Data are available from the NEXIS database maintained by Geoscience Australia.

As noted in Box 6.1, climate vulnerability depends on the design of assets, and the presence or absence of protective works such as seawall or levees, as well as their location. The indicator would therefore need to be supplemented by information about changes in asset design.

Bushfire risk increases as temperatures rise.

Indicator 8: Damages from natural disasters

Damages from natural disasters are a function of the frequency and intensity of extreme weather events, the value of assets exposed and the sensitivity of those assets to climate extremes. This indicator could therefore be considered together with indicator 1. Indicator 1 is a leading indicator (because it can show trends in potential exposure to future climate extremes), whereas indicator 2 is a lagging indicator.

Total damages from natural disasters could be estimated by combining insurance losses from major events with government payments for disaster relief and recovery and estimates of non-insured losses.

Indicator 9: Sensitivity of the value of agricultural production to climate extremes

This indicator would measure how much the value of agricultural production declines in response to climate extremes. A smaller decline in the value of production indicates lower climate risk. Interpreting this indicator would require a method for comparing the sensitivity of agricultural production to extremes of different severity and areal extent. This may require some modelling. A sub-indicator might focus specifically on irrigated agriculture.

The approach suggested here may be initially applied to a limited range of climate extremes because of the need for historical datasets. Some data are available for drought, for example (see Figure A1.2).

This is a lagging indicator. Supplementary indicators such as the value of agricultural production per megalitre of water may provide some leading information.

Indicator 10: Extent and condition of key climate-sensitive ecosystems

Some ecosystems, such as montane ecosystems and coral reefs, are particularly sensitive to a changing climate. Changes in the extent and condition of these ecosystems could serve as an indicator of changes in climate risk to natural ecosystems. Information about the extent and condition of different vegetation types in Australia is available from state of the environment reports.[2]

A decline in the extent and condition of key climate-sensitive ecosystems might indicate either that climate risks are being realised (if the decline is due to climate change) or that climate risk are increasing (if the decline is due to other pressures). Increased extent and/or improved condition would suggest reduced climate change risk. A more sophisticated approach could compare observed trends in extent and condition with trends that would be expected on the basis of climate change drivers alone. A trend that is more positive than the projected trend would suggest reduced climate change risk.

2 State of the Environment 2011 Committee, 'Biodiversity', in *Australia: state of the environment 2011*, Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra, 2011, pp. 567–689

Poor data quality and a range of confounding factors may make it difficult to detect trends in this indicator. Potential supplementary indicators that, while less revealing of overall changes in risk may be more tractable, include:

- changes in the range of selected climate-sensitive invasive species
- changes in the number of climate-sensitive species and ecological communities listed as threatened.

Indicators for the coastal zone

This section describes possible indicators for some elements of the framework that are specific to the coastal zone (as discussed in Chapter 4).

Indicator 11: Capacity of planning frameworks to support effective management of climate risks in the coastal zone

This indicator could be used to track progress against the framework element 'coastal planning frameworks take a risk management approach, involve the community, are based on adequate underpinning science, clearly articulate values to be protected in the long term, are developed within a strategic planning framework and provide legal protections for decision-makers acting in good faith based on sound science'.

The indicator would assess the various planning frameworks against the criteria in the framework element. Unlike most other indicators discussed here, this indicator is qualitative. An expert panel could assess the planning frameworks against the criteria using a table or matrix.

Indicator 12: Number of local governments considering climate change risks in land use planning

This is a partial indicator of the framework element 'taking coastal climate risks (including sea level rise and more intense storm surge) into account in land use planning, development controls and plans for major infrastructure'. Data could be collected using surveys such as the one described in Box 4.5.

Using indicators — adaptation outcomes

This section shows how indicators might be used, together with other information, to inform judgments about whether Australia is achieving good adaptation outcomes. Fewer data are currently available to support indicators of drivers and activities. Good adaptation outcomes depend on how climate risks are changing and whether those climate risks are acceptable to community, manageable into the future and distributed in a way that allows disadvantaged groups to manage them.

Changes in climate risks

Indicators 7–10 can help assess how climate risks are changing.

Some climate risks are growing (indicators 7 and 8)

Indicators 7 and 8 track changes in the exposure of built assets to climate risks and the actual damage caused by extreme climate events. Box 6.1 sets out the data that are available to support these indictors. Based on this information, it is clear that climate risks to built assets from sea level rise, flooding and bushfire are growing.

Box 6.1 Climate risks to buildings in Australia

An increasing number of built assets in Australia are exposed to the risk of coastal inundation, bushfires and flooding.

Figure A shows how the number of residential buildings in South Australia, Tasmania and the Australian Capital Territory exposed to coastal inundation, bushfires and flooding changed over the 40 years from 1971 to 2011; 135 per cent more residential buildings are exposed today than in 1971. The proportion of buildings located in climate hazard zones has increased from about 12.5 per cent to almost 13.5 per cent over the 40-year period for which data are available. Comparable figures for other jurisdictions are not available.

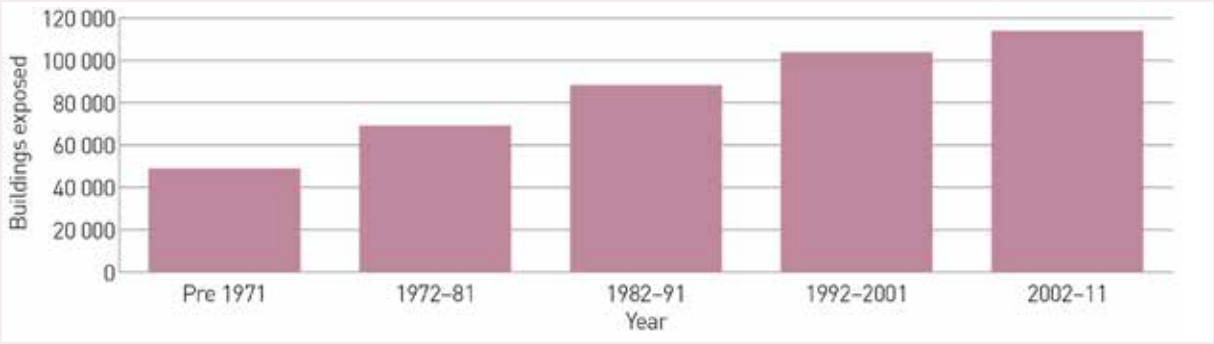
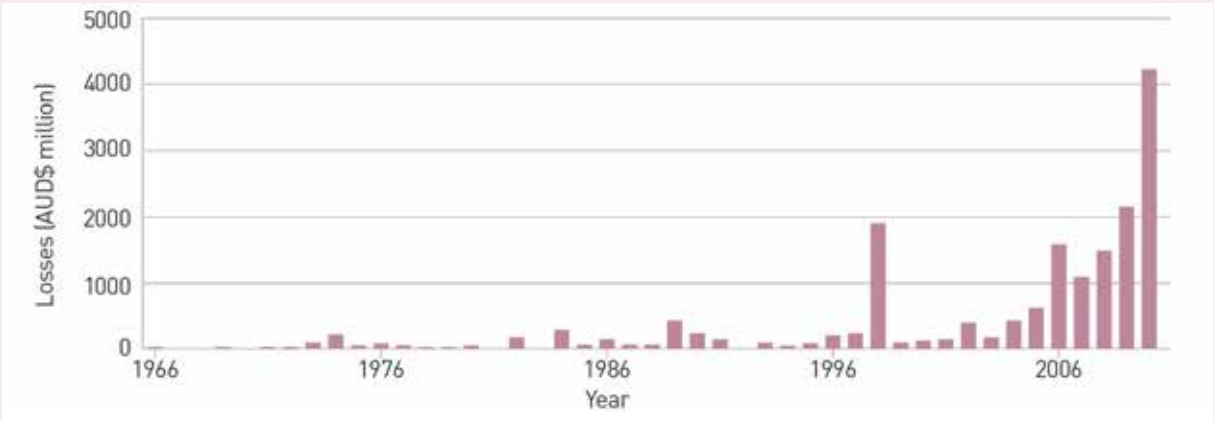


Figure A Residential buildings in South Australia, Tasmania and the Australian Capital Territory exposed to bushfire, flooding or coastal innundation risk, pre-1971 to 2011

The location of buildings is not the only factor that determines climate risk. Building design is also important. Figure B shows insurance losses due to extreme weather events from 1966 to 2008. The increase in losses is largely due to increased exposure of built assets to climate hazards.[a] The steep increase in insurance losses indicates that improvements in building design have not been sufficient to counter the effect of growing exposure to climate risks.



Source: Risk Frontiers analysis of Insurance Council of Australia (ICA) data

Figure B Insurance losses due to extreme weather events, 1966–2008

An estimated 1 538 000 residential buildings across Australia are located in areas vulnerable to coastal inundation, flooding or bushfire. On current trends, this could increase to approximately 2 211 000 by 2050 and 2 953 000 by 2100.

Technical details about the data presented in this box are available from the department's website.

a Insurance Council of Australia, 'Submission to the Senate Standing Committee on Environment and Communications inquiry in to recent trends in and preparedness for extreme weather events', submission number 15, Insurance Council of Australia, Sydney, 2012.

Other climate risks are being reduced (indicator 9)

Indicator 9 tracks the resilience of agricultural production to climate extremes. Although complete data are not available for this indicator, there is good information about how the resilience of irrigated agriculture in the Murray–Darling Basin to reduced water availability has improved. This can be supplemented by information about water-dependent ecosystems.

Although climate risks to water resources themselves cannot be reduced (except by effective action to reduce global greenhouse gas emissions), it is possible to reduce risks to activities and ecosystems that depend on them. There is strong evidence that this is happening.

Water entitlement and allocation trading is making agriculture in the Murray–Darling Basin less vulnerable to reduced water supplies. Productivity Commission modelling suggests that water trading could halve the effect of reduced water availability on gross regional product in the southern Murray–Darling Basin.[3] In line with these findings, water trading in the southern Murray–Darling Basin is estimated to have increased Australia's gross domestic product (GDP) by $220 million in 2008–09.[4] Water trading meant that the dairy industry in Victoria and horticultural production in Victoria's Goulburn Valley suffered less than they would otherwise have done from the millennium drought.[5]

The Australian Government is currently recovering water access rights in the Murray–Darling Basin with the objective of returning more water to the environment. This water forms part of the Commonwealth Environmental Water Holdings and is being used in conjunction with water held by Basin states to restore the rivers and wetlands of the Murray–Darling Basin. Collaborative action between the Commonwealth Environmental Water Holder, state organisations and communities, together with efficient river-operating practices, will support ecosystem functions and help improve the resilience of the environment to a changing climate.

Dairy farms can be more resilient through effective water trading.

3 D Peterson, G Dwyer, D Appels & JM Fry, *Modelling water trade in the southern Murray–Darling Basin*, Productivity Commission Staff Working Paper, Melbourne, 2004.

4 National Water Commission, *The impacts of water trading in the southern Murray–Darling Basin: an economic, social and environmental assessment*, National Water Commission, Canberra, 2010.

5 Frontier Economics, T Cummins & Associates, A Watson, E Barclay & I Reeve, *The economic and social impacts of water trading: case studies in the Victorian Murray Valley*, report for the Rural Industries Research and Development Corporation, National Water Commission & Murray–Darling Basin Commission, Canberra, 2007.

In 2011, the National Water Commission[6] found that water plans and environmental management arrangements developed as part of the water reform process are improving Australia's capacity to maintain ecosystem functions that depend on fresh water.

Many major cities in Australia have taken steps to increase water security, and are diversifying water supplies through investments in desalination, stormwater harvesting and water recycling, and water-sensitive urban design. A legacy of managing water during extremely dry conditions has lowered the demand for potable water mainly through the use of water restrictions and water efficiency initiatives.

However, in the longer term, climate risks to water resources and the activities and ecosystems that depend on them still remain high (see Appendix 1).

Trends in many climate risks are difficult to assess on current data (indicator 10)

In many cases it is difficult to assess whether climate risks are increasing or decreasing.

Indicator 10, for example, tracks changes in the resilience of key natural ecosystems to a changing climate. Further work to identify specific climate-sensitive ecosystems to track and a set of supplementary indicators is needed before this indicator can be applied. However, governments, including the Australia Government, have already commissioned research on how to manage natural ecosystems in a changing climate.[7] Recent developments in ecosystem management, such as a landscape-based approach to ecosystem management,[8] the creation of new marine reserves and changes to the management of water resources (see above), are likely to make ecosystems more resilient and therefore reduce climate change risks.

Information about changes in some other important climate risks is unavailable for this report.

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6 National Water Commission, *The National Water Initiative — securing Australia's water future: 2011 assessment*, National Water Commission, Canberra, 2011.

7 M Dunlop, DW Hilbert, S Ferrier, A House, A Liedloff, SM Prober, A Smyth, TG Martin, T Harwood, KJ Williams, C Fletcher & H Murphy 2012, *The implications of climate change for biodiversity conservation and the national reserve system: final synthesis*, report prepared for the Australian Government Departments of Sustainability, Environment, Water, Population and Communities & Climate Change and Energy Efficiency, CSIRO Climate Adaptation Flagship, Canberra; W Steffen, AA Burbidge, L Hughes, R Kitching, D Lindenmayer, W Musgrave, M Stafford Smith & PA Werner, *Australia's biodiversity and climate change: a strategic assessment of the vulnerability of Australia's biodiversity to climate change*, report to the Natural Resource Management Ministerial Council, CSIRO Publishing, Canberra, 2009; KJ Williams, M Dunlop, RH Bustamante, HT Murphy, S Ferrier, RM Wise, A Liedloff, TD Skewes, TD Harwood, F Kroon, RJ Williams, K Joehnk, S Crimp, M Stafford Smith, C James & T Booth, *Queensland's biodiversity under climate change: impacts and adaptation — synthesis report*, report prepared for the Queensland Government, CSIRO Climate Adaptation Flagship, Canberra, 2012.

8 W Steffen et al.

For example, heatwaves will be more frequent and more intense but there is little information about the risk this poses to infrastructure, partly because vulnerability depends on the individual design characteristics of major pieces of infrastructure and the interdependencies between them. Changes in these risks will similarly depend on design details of new infrastructure and upgrades to existing infrastructure.

Heatwaves have killed hundreds of Australians (see Appendix 1). In the wake of recent heatwaves a number of jurisdictions have introduced heatwave management strategies.[9] Experience overseas shows that these strategies can make a big difference to the risk of heat-related deaths[10] but data are not yet available to evaluate their success in Australia.

Acceptability of climate risks

As noted above, it is not possible at this stage to develop indicators of community willingness to accept risk or of the capacity of disadvantaged groups to manage their climate risks. This section includes a discussion of whether risks are acceptable to the community and manageable into the future, and of the capacity of disadvantaged groups to manage. Indicators 7–10 are relevant as a source of information about the risks themselves.

In some cases climate risks may already be unacceptable to the community

Determining how much climate risk the community finds acceptable is difficult and community preferences have received little consideration. Any conclusions are necessarily tentative.

Climate risks to the built environment have received some attention due to recent natural disasters. The floods of 2010–11, for example, resulted in significant costs to households and businesses, and affected economic growth.[11] The costs of natural disasters have led to withdrawal of insurance cover in some areas (subject to review if works are put in place to reduce risks).[12] The Australian Government's National Insurance Affordability Initiative recognises the need to bring some of these risks more in line with what the community is willing to accept.

Climate risks to natural ecosystems are also high, and the character of iconic sites such as the Great Barrier Reef, Kakadu, alpine regions and many of Australia's beaches is threatened. Australians place a

9 See the plans for Geelong (www.geelongaustralia.com.au/common/public/documents/8cc89a238a75537-City%20of%20Greater%20Geelong%20Heatwave%20Management%20Plan.pdf), New South Wales (www.emergency.nsw.gov.au/media/1355.pdf), Swan Hill (www.swanhill.vic.gov.au/quicklinks/emergencymanagement/images/Swan_Hill_Heatwave_Response_Sub-Plan_(Revised_Draft_24_April_2012)1.pdf) and Frankston (www.frankston.vic.gov.au/library/scripts/objectifyMedia.aspx?file=pdf/445/87.pdf&siteID=18&str_title=Part%2010%204%20-%20Heatwave%20Sub%20Plan%20-%20MEMP%202012.pdf) .

10 A Fouillet, G Rey & V Wagner, 'Has the impact of heat waves on mortality changed in France since the European heat wave of summer 2003? A study of the 2006 heat wave', *International Journal of Epidemiology*, vol. 37, 2008, pp. 309–17.

11 M Blythe, *Costing the floods*, Global markets research: economic update, 27 January 2011, Commonwealth Bank of Australia, 2011, viewed 23 May 2013, <www.commbank.com.au/corporate/research/publications/economics/economic-update/2011/270111-Costing_Floods.pdf>.

12 Productivity Commission, 'The role of insurance', in Barriers to effective climate change adaptation, report 59, Final Inquiry Report, Canberra, 2012, pp. 297–321.

high value on many of these sites and ecosystems but there is no clear indication of whether climate change risks to them match the community's preferences.

Future generations are exposed to greater potential damages

Although Australia is already feeling some early impacts of climate change, the most serious potential damages are in the latter part of the 21st century and beyond. The clearest evidence that current decisions are increasing risks is the continued development of houses and infrastructure in areas vulnerable to climate hazards. These decisions are increasing climate risks faced by future generations. Conversely, the clearest evidence that climate risks are being reduced is areas where decisions have shorter-term implications, such as in water resource management.

People experiencing socioeconomic disadvantage are less able to manage climate risks

There is evidence that people suffering from socioeconomic disadvantage are less able to manage climate risks than other members of the community. Much of this evidence comes from experience of extreme climate events in Australia[13] or overseas.[14] Groups at risk include frail older people,[15] people with a disability and homeless people.[16] Community service organisations provide critical support for many disadvantaged people, but many of these organisations are themselves vulnerable to extreme climate events and may not be able to provide services following natural disasters.[17]

13 See, for example, Box 3.9 and Queensland Council of Social Service, *Submission to the Queensland Floods Commission of Inquiry*, QCOSS, Brisbane, 2011.

14 Climate Change Science Program, *Analyses of the effects of global change on human health and welfare and human systems*, US Environmental Protection Agency, Washington DC, 2008.

15 G Horton, L Hanna & B Kelly 2010, 'Drought, drying and climate change: Emerging health issues for ageing Australians in rural area', *Australasian Journal on Ageing*, vol. 29, no. 1, pp. 2–7.

16 B Ramin & T Svoboda, 'Health of the homeless and climate change', *Journal of Urban Health*, vol. 86, no. 4, 2009, pp. 654–64.

17 K Mallon, E Hamilton, M Black, B Beem & J Abs, *Adapting the community sector for climate extremes*, National Climate Change Adaptation Research Facility, Gold Coast, 2013.

Conclusion

Whether Australia manages changing climate risks well depends on all levels of government, businesses, communities and individuals. The benefits of good management are significant: social, environmental and economic damages will be lower, new opportunities can be fully exploited and fresh thinking about climate risks will stimulate innovation.

Given the collective responsibility for action and the high stakes, this report sets out a proposed framework for assessing national progress in managing changing climate risk. The framework is effectively a checklist of what we would expect to see if Australia is adapting well. It asks three questions:

- What drivers in society and the economy would promote good adaptation?
- What activities would we expect to see now if Australia is adapting well?
- What outcomes do we expect to see from good adaptation?

Drivers

Adapting well means making smart decisions now and into the future. Many factors will help shape these decisions.

Risk allocation

Climate risks — from floods, droughts, bushfires, cyclones and heatwaves — are already serious and growing worse as the climate changes. Some are poorly managed. To improve management, risks should be well understood and clearly allocated to those best able to manage them, and beneficiaries should pay the costs.

Governance

Regulations such as building codes, land use planning frameworks and regulation of energy infrastructure should promote effective adaptation. Institutional arrangements should allow for cooperation across and between jurisdictions where it is needed to manage climate risks.

Opposite page: A diver comes across two butterfly fish in the Great Barrier Reef.

Markets

Markets can provide incentives to adapt through price signals and by promoting disclosure of climate risks. A flexible economy will allow resources to be efficiently reallocated following climate shocks or in response to more gradual climate change.

Social

Broad public acceptance that some things need to be done differently in a changing climate is necessary to support adaptation by business, the community and government. A high degree of trust and interconnection will make communities more resilient to climate change impacts.

Activities

Some adaptation activities should be happening now.

Deal with current climate risk

Increasing resilience to bushfires, floods, heatwaves, cyclones, storms and droughts will be beneficial in today's climate and leave us better placed to manage the more extreme climate of the future.

No or low-regret actions

No or low-regret adaptation activities offer net benefits under most climate change scenarios. They might increase flexibility in the future, or have co-benefits unrelated to climate change impacts — for example, increasing water, use efficiency in areas likely to become drier.

Decisions with long-term implications

Decisions such as the location of new suburbs, management of conservation estates and design of long-lived infrastructure may 'lock in' vulnerability to future climate change impacts. Even where there is no case for immediate changes, it is prudent to consider the implications of future climate change.

Build capacity: skills and information

Australia will need information and skills to help governments, businesses and communities adapt. For example, information about how climate risks are likely to change, options for managing emerging risks and strategies for making decisions under climate uncertainty. Professionals such as engineers, architects, planners, and financial analysts will need new skills to make good decisions in a changing climate.

Outcomes

Adaptation is about continuing to improve wellbeing in a changing climate without allowing climate risks to reach unacceptable levels. Australia will be managing the impacts of climate change well if:

Australians are able to enjoy economic, social and environmental opportunities, and are flexible and resilient to climate change impacts, while the level of risk from climate change impacts is kept within limits acceptable to the community

management of risks from climate change impacts today does not compromise the capacity to manage risks from climate change impacts in the future

disadvantaged groups have the resilience and capacity to manage risks they face from climate change impacts.

Next steps

The Australian Government Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education will consult with stakeholders about the proposed framework in the second half of 2013. A final framework will be published in early 2014 and an assessment of national progress will be prepared for late 2014.

A1 Appendix 1 Our changing climate risks

Key points

Australia's climate creates risks that governments, businesses and communities must manage.

0.8 °C of global warming has already made climate risks more serious. Further climate change will magnify these risks even further.

Governments, businesses and communities are making decisions today that will influence how well we are able to manage climate risks in the future. The stakes are high. Climate change impacts could increase mortality, reduce economic growth and devastate natural ecosystems.

Australians deal with risks from their climate all the time.

The world has warmed by 0.8 °C since the beginning of the 20th century, and the changes to Australia's climate have already affected the risks we need to manage. The incidence of extreme fire weather in south-eastern Australia has increased.[1] Anthropogenic greenhouse gases are partly responsible for a decline in rainfall of about 15 per cent in south-west Western Australia.[2] Streamflow into Perth's dams between 1976 and 2000 almost halved as a result.[3] There is scientific evidence that human greenhouse gas emissions were partly responsible for the 'millennium drought' of 1997–2009 in south-eastern Australia.[4] High sea surface temperatures have caused frequent coral bleaching events on the Great Barrier Reef since the 1970s, contributing to a decline in coral cover.[5]

1 C Lucas, K Hennessy, G Mills & J Bathols, *Bushfire weather in Southeast Australia: recent trends and projected climate change impacts*, Bushfire CRC, Bureau of Meteorology & CSIRO Marine and Atmospheric Research, Melbourne, 2007.

2 BC Bates, ZW Kundzewicz, S Wu & JP Palutikof (eds), *Climate change and water*, technical paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 2008.

3 Water Corporation of Western Australia, *Water forever: towards climate resilience*, Water Corporation of Western Australia, 2009.

4 CSIRO, *Climate and water availability in south-eastern Australia: a synthesis of findings from phase 2 of the South Eastern Australian Climate initiative (SEACI)*, CSIRO, Australia, 2012.

5 G De'ath, KE Fabricius, H Sweatman & M Puotinen, 'The 27-year decline of coral cover on the Great Barrier Reef and its causes', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 109, no. 44, 2012, pp. 17995–99.

Opposite page: Extreme weather events are becoming more frequent and intense.

These observed changes to the climate make managing climate risks more challenging. The historical climate record is no longer a reliable guide to the risks we face today, let alone tomorrow.

Further climate change is unavoidable. The greenhouse gases that human activities have put into the atmosphere have not yet had their full warming effect, and global greenhouse gas emissions are still rising despite global efforts to restrain them.

Figure A1.1 shows two possible trajectories for average global temperatures. These scenarios lead to very different outcomes in the second half of the century but there is little difference between them for the period to 2030. This is important because it means that for decisions or activities with shorter time horizons the 'high change' and 'low change' scenarios are effectively the same.

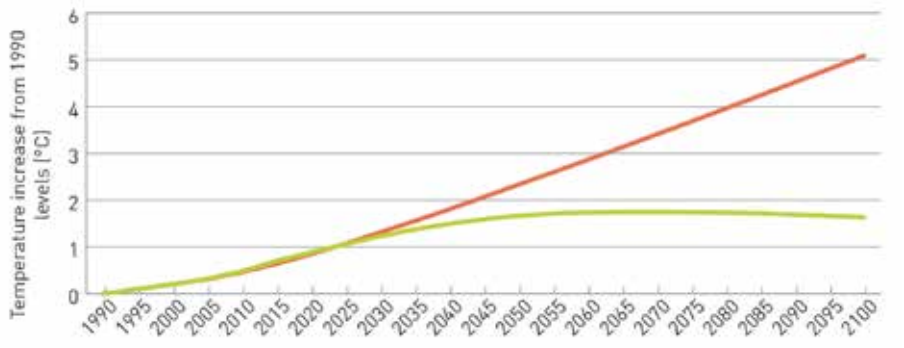

Figure A1.1 Global average temperature outcomes for two scenarios, 1990–2100

Bushfire risk increases as temperatures rise

Even warming of 2 °C would have serious and pervasive consequences for Australia. Heatwaves, bushfire weather, floods and droughts would become more frequent or more intense, and sea levels would rise. Future changes in rainfall patterns are more uncertain. South-west Western Australia is almost certain to become drier. Drying is also the most likely outcome in the south-east of Australia and along the eastern seaboard. With higher global average warming these changes will happen faster and be of greater magnitude. (More details about climate projections for Australia can be found at www.climatechangeinaustralia.gov.au.)

Studies of the implications of changing climate risks for Australia have focused on risks to specific industries, activities or natural ecosystems. Little attention has been paid to how these risks might combine with each other or with broader global risks. There are plausible scenarios under which the consequence of simultaneously realised risks may be more serious than the sum of the consequences of each risk on its own. For example, rapid climate change may make it necessary to simultaneously upgrade or replace a large proportion of Australia's infrastructure and housing stock, causing a significant economic shock through increased prices and pressures on government budgets. This shock would be magnified even further if it happened when many other

countries were also upgrading infrastructure to cope with a changing climate, driving up the cost of capital.[6]

The implications for Australia of climate change in other countries may also be significant. A recent special report by the Australian Strategic Policy Institute highlighted the effect of a changing climate on Australia's national security interests.[7] The impacts of climate change may also affect trade (particularly in agricultural commodities) and migration patterns.[8]

The remainder of Appendix 1 considers six sectors (water, agriculture, infrastructure, human health, natural ecosystems and coasts) where changing climate risks are relevant to decisions Australian governments, businesses and communities are making today. These sectors were chosen because aggregate national risks are high and the risks need to be managed now. Some risks need to be managed now because the current climate — already altered by human emissions of greenhouse gases — presents serious risks, and some need to be managed because decisions being made today have long-term consequences.

This report generally discusses risk in terms of potential loss and damage because the impacts of unavoidable climate change will be overwhelmingly negative. This does not mean that there will be no opportunities. Climate change is likely to bring some benefits such as fewer cold-related deaths and lower heating bills. Yields of some crops may increase in some places because of fertilisation from extra carbon dioxide in the atmosphere, but this is likely to be temporary as falling rainfall and higher temperatures overwhelm the benefits of extra carbon dioxide.[9]

The greatest opportunities will come from learning early how to manage the impacts of a changing climate. Australians will be better off and well placed to market their expertise in climate risk management.

Water

Australia is the driest of the six inhabited continents, and its rainfall is highly variable. Water is critical for Australia's natural ecosystems, economy and health. Our major cities and other settlements need reliable, safe water supplies for drinking and to support business and recreation. Agriculture and mining depend upon water, and natural ecosystems have evolved to fit historical patterns of rainfall and streamflow.

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6 CSIRO, 'Submission 12/448 to the Productivity Commission inquiry into barriers to effective climate change adaptation, CSIRO, Australia, 2012.

7 A Press, A Bergin & E Garnsey, *Heavy weather: climate and the Australian Defence Force*, ASPI Special Report, Issue 49, March, Australian Strategic Policy Institute, Canberra, 2013.

8 ML Parry, OF Canziani, JP Palutikof, PJ van der Linden & CE Hanson (eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007, Cambridge University Press, UK, 2007.

9 F Tubiello, J Schmidhuber, M Howden, PG Neofotis, S Park, E Fernandes & D Thapa, *Climate change response strategies for agriculture: challenges and oppurtunities for the 21st century*, The World Bank, Washington DC, 2007; S Crimp, M Howden, B Power, E Wang & P De Voil P, *Global climate change impacts of Australia's wheat crops*, technical paper prepared for the Garnaut Climate Change Review, 2008.

Current risks

Australia has always been subject to periods of low rainfall, and there have been many recent examples of the severe social, economic and environmental consequences of these events.

In 2002–03, drought subtracted almost 1 per cent from Australia's gross domestic product (GDP).[10] Between 2005–06 and 2008–09 the gross value of irrigated agriculture in the Murray–Darling Basin fell by 27 per cent.[11] The last decade has seen water restrictions applied for various periods in many major cities, including Sydney, Melbourne, Brisbane and Adelaide.[12] The annual welfare loss due to level 2 water restrictions in Sydney for the period June 2004 to June 2005 is estimated at $235 million.[13] The Productivity Commission has estimated that water restrictions cost Australia $900 million in 2005, excluding installing watering systems, time spent watering gardens in permitted labour-intensive ways, and the deterioration in gardens and lawns.[14]

These impacts illustrate climate risks to water resources and the activities that depend on them. In some cases there is strong scientific evidence that human greenhouse gas emissions have contributed to risks, even in the current climate:

- There is strong scientific evidence that human greenhouse gas emissions are partly responsible for a decline in rainfall of about 15 per cent in south-west Western Australia.[15]
- There is scientific evidence that human greenhouse gas emissions were partly responsible for the millennium drought of 1997–2009 in south-eastern Australia. However, the evidence is not as strong as for the rainfall decline in south-west Western Australia.[16]
- There is little or no evidence to suggest that human greenhouse gas emissions played a role in the dry periods experienced on the eastern seaboard in the early part of this century.[17]

Future risks

Further climate change will increase risks to water availability across most of Australia.

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10 L Lu & D Hedley, T*he impact of the 2002–03 drought on the economy and agricultural employment*, Economic Roundup autumn 2004, Treasury, Canberra, 2004.

11 Productivity Commission 2009, *Government drought support*, report 46, Final Inquiry Report, Productivity Commission, Melbourne, 2009, p. 53.

12 Australian Bureau of Statistics, 'Household water use and effect of the drought', *Australian Economic Indicators*, July 2005, ABS, Canberra, viewed 24 May 2013, <www.abs.gov.au/AUSSTATS/abs@.nsf/46d1bc47ac9d0c7bca256c470025ff87/a0b004e8941b6fbfca25702f007a793b!OpenDocument>.

13 RQ Grafton & M Ward, *Price versus rationing: marshallian surplus and mandatory water restrictions*, Australian National University Economics and Environment Network Working Paper, ANU, Canberra, 2007.

14 Productivity Commission, *Towards urban water reform: a discussion paper*, Productivity Commission Research Paper, Productivity Commission, Melbourne, March, 2008, p. xix.

15 BC Bates, P Hope, B Ryan, I Smith & S Charles, 'Key findings from the Indian Ocean Climate Initiative and their impact on policy development in Australia', *Climatic Change*, vol. 89, 2008, pp. 339–54; W Cai & T Cowan, 'SAM and regional rainfall in IPCC AR4 models: can anthropogenic forcing account for southwest Western Australian winter rainfall reduction?', *Geophysical Research Letters*, 33, 2006, L24708, doi:10.1029/2006GL028037.

16 CSIRO, *Climate and water availability in south-eastern Australia: a synthesis of findings from phase 2 of the South Eastern Australian Climate initiative (SEACI)*, CSIRO, Australia, 2012.

17 Climate Commission, *The critical decade: climate change science, risks and responses*, Climate Commission, Canberra, 2011.

Non-urban water resources are generally managed using planning cycles of 5 to 10 years.[18] This means that management decisions are most sensitive to changes in climate risks over the next couple of decades. A series of 'sustainable yields' studies across Australia found that climate change is likely to reduce streamflow across most of Australia by 2030, but that wetter conditions cannot be ruled out in most regions.[19] The results are summarised in Table A1.1.

Table A1.1 Projected changes in streamflow by 2030

	Median projected change in streamflow	Driest case projected change in streamflow	Wettest case projected change in streamflow
Murray–Darling Basin[a]	9% lower	33% lower	16% higher
Tasmania[b]	3% lower	8% lower	2% higher
South-west Western Australia[c]	24% lower	49% lower	4% lower
Northern Australia	Little change		

a CSIRO, *Water availability in the Murray–Darling Basin*, report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project, CSIRO, Australia, 2008.
b CSIRO, *Climate change projections and impacts on runoff for Tasmania,* report two of seven to the Australian Government from the CSIRO Tasmania Sustainable Yields Project, CSIRO Water for a Healthy Country Flagship, Australia, 2009.
c CSIRO 2009, *Water yields and demands in south-west Western Australia,* summary of a report to the Australian Government from the CSIRO South-West Western Australian Sustainable Yields project, p. 7.

Planning for urban water supplies generally takes place on a longer timescale, particularly for major cities. However, the same principle applies: climate change means more uncertainty about future water availability, more likelihood of adverse outcomes and therefore higher risks to manage.

A few studies have considered how climate change will affect the water supply of specific cities over the longer term. In 2005, CSIRO found that average long-term streamflows in the catchments that supply Melbourne could be reduced by 3–11 per cent by 2020, and by 7–35 per cent by 2050.[20]

The critical point is that more uncertainty means greater risk. Even where projections indicate that water supply could either increase or decrease, the potential for serious adverse outcomes needs to be factored into planning.

18 National Water Commission, 'New South Wales' in *National water planning report card 2011*, NWC, Canberra, 2011, pp. 9–172.
19 CSIRO, *Water availability in the Murray–Darling Basin*, report to the Australian Government from the CSIRO Murray–Darling Basin Sustainable Yields Project, CSIRO, Australia, 2008.
20 CSIRO & Melbourne Water, *Melbourne water climate change study: implications of potential climate change for Melbourne's water resources*, CSIRO & Melbourne Water, Melbourne, 2005, p. 15.

Agriculture

Extreme weather events have an ongoing and pronounced effect on Australian agriculture

Agriculture, fisheries and forestry industries contribute approximately 3 per cent of Australia's GDP and 14 per cent ($31 billion) of Australia's total industry exports.[21] Many rural communities are dependent on agricultural production, and farming is an important part of Australia's social and cultural traditions.

Current risks

Weather is a critical driver of profits in agriculture. Extreme weather events such as droughts, storms, floods and heatwaves have an ongoing and pronounced effect on Australian agricultural enterprises. Drought, the most pervasive of these extremes, disrupts cropping, reduces stock numbers, and erodes the resource base of farms.[22] Any increases in the frequency and intensity of droughts may severely affect the viability of primary industry operations in certain regions. Figure A1.2 illustrates the effect of drought on agricultural output since 1963. Experience in rural communities has shown that periods of drought are associated with increased workload, family conflict and withdrawal from social groups and communities.[23]

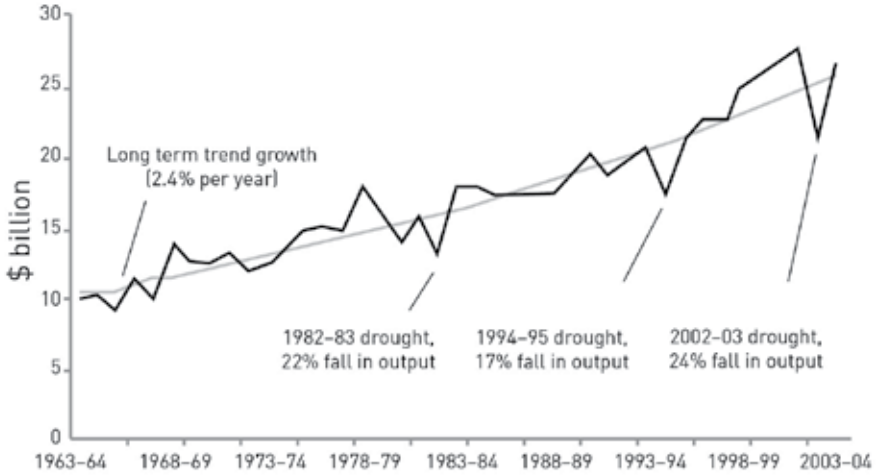

Figure A1.2 Growth in agriculture output, 1963–64 to 2003–04

Other extreme events such as severe storms, hailstorms, cyclones and floods destroy crops, damage infrastructure and interfere with activities such as harvesting and planting. Extreme weather conditions in 2010–11 had significant effects on the Australian production of cereals, sugar, fruit and vegetables, cotton and sorghum grain. This loss was estimated at around $2.3 billion by the Australian Bureau of Agricultural and Resource Economics and Sciences.[24]

21 CSIRO, *Primary industries, enterprises and communities adapting to climate change*, CSIRO, 2010, viewed 19 June 2013, <www.csiro.au/en/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/Adaptive-Primary-Industries.aspx>.
22 Productivity Commission, *Trends in Australian agriculture*, research paper, Productivity Commission, Canberra, 2005.
23 Productivity Commission, *Trends in Australian agriculture*
24 ABARES, *Australian commodities: March quarter 2011*, ABARES, Canberra, 2011, p. 16, <www.daff.gov.au/abares/publications_remote_content/publication_series/australian_commodities>.

To date, the observed effects of climate change on agriculture have been varied. Reduced rainfall in south-west Western Australia (partly due to anthropogenic greenhouse gases, see above) has had limited effects on wheat yields because rainfall has fallen most in months where it usually exceeds requirements for wheat growing. Reduced rainfall may have helped reduce the spread of dryland salinity.[25] On the other hand, the millennium drought reduced agricultural output in the Murray–Darling Basin and, to the extent that climate change was a causal factor, risks to agriculture have increased.

The number of hot days and warm nights per year has increased progressively since 1955[26] and heatwaves have become increasingly common.[27] Heat stress negatively impacts on a variety of agricultural production parameters. In livestock-based industries, heat stress is a significant financial burden affecting, for instance, milk yield and quality, wool growth, live weight gain and feed intake.

Future risks

Some on-farm decisions (such as planting next year's grain crop) are made on a timescale where risks from climate change overlap risks associated with climate variability. Long-term (multi-decadal) climate change will not be important for these decisions, although climate variability will become increasingly difficult to manage as the climate shifts. Risk from climate change impacts to agriculture in the medium to long term are vital for decisions about research and development, workforce training and development, and the roll out of infrastructure such as roads and processing plants required to support farming and farm communities.

Managing climate variability will become increasingly problematic for Australian primary producers, as changes in temperature and precipitation will be superimposed on high climate variability, making it even more difficult for farmers to anticipate and manage for climate-associated risks.[28]

In the short term, farms in some regions may enjoy higher crop yields due to increased concentrations of carbon dioxide in the atmosphere (which has a fertilising effect). In the longer term, these benefits are offset by the negative effects of increased temperatures and reduced rainfall.[29]

Droughts, floods and heatwaves are all likely to become more severe, with notable effects on both crop and livestock production. The Garnaut Climate Change Review found, for example, that under a high global warming scenario, the best estimate for the Murray–Darling Basin is

25 F Ludwig, SP Milroy & S Asseng, 'Impacts of recent climate change on wheat production systems in Western Australia', *Climatic Change,* vol. 92, 2009, pp. 495–517.
26 CSIRO & Bureau of Meteorology, *Climate change in Australia: technical report 2007,* CSIRO, Melbourne, 2007.
27 A Lynch, N Nicholls, L Alexander & D Griggs, *Defining the impacts of climate change on extreme events*, report prepared for the Garnaut Climate Change Review, Canberra, 2008.
28 CSIRO & Bureau of Meteorology, *State of the climate 2012*, CSIRO & Bureau of Meteorology, Australia, 2012.
29 M Howden, R Nelson, S Crimp & S Park, 'Climate change: the future of cropping systems', in AG Brown (ed), *Agriculture in a changing climate: the new international research frontier*, proceedings of the ATSE Crawford Fund Fourteenth Annual Development Conference, Parliament House, Canberra, 3 September 2008, Crawford Fund, Canberra, 2009, pp. 34–8.

that by mid-century it would lose half of its annual irrigated agricultural output. By the end of the century, it would no longer be a home to agriculture.[30]

The effects of insect attack on agricultural crops and pasture lands has also been identified as potentially important in light of climate change, primarily because of their short generation times, rapid abundant reproduction and potentially high mobility making them able to adapt quickly to changing climatic conditions. Higher temperatures are also likely to affect the timing, distribution and severity of plant and animal disease outbreaks.[31] Weed species, with their fast growth rates, high dispersal ability, phenotypic plasticity and tolerance to a wide range of environmental conditions, may also become increasingly problematic for Australian agriculture under changed climatic conditions.[32]

Agricultural enterprises will need to consider future growing conditions and the future viability of operations in their regions. There is some evidence that this is already occurring in certain industries. For instance, some premium wine companies are already diversifying holdings to prepare for climate change (see Box 3.5).

Infrastructure

Australia's infrastructure includes its road and rail systems, ports, airports, communication networks, waterways, power grids, hospitals, aged-care services, schools, universities, museums, libraries and research institutes. Together, they are a platform for Australia's economic development, and social cohesion and stability.[33]

Current risks

Two recent events illustrate the risks to Australia's infrastructure from a climate already changed by anthropogenic greenhouse gas emissions.

Between 27 January and 8 February 2009, a record heatwave in south-east Australia led to major disruptions of services, such as electricity and transport, due to infrastructure failure. Financial losses from the event have been estimated at $800 million. In Melbourne on 30 January 2009, train cancellations peaked with more than 24 per cent of services cancelled due to rail buckling and power failures. The effects of heat on electricity transmission and distribution in Melbourne brought the network near to collapse. At one stage up to half a million properties were without power.[34]

30 R Garnaut, 'Costing climate change and its avoidance', in *The Garnaut climate change review: final report*, University Press, Port Melbourne, 2008, pp. 245–75.
31 CSIRO, *Climate change raises disease threat*, Science Alert Australia & New Zealand, 2008, viewed 24 May 2013, <www.sciencealert.com.au/features/20081812-18603-2.html>.
32 D Kriticos & Filmer, 'Weeds will thrive on climate change', *Farming Ahead*, vol. 182, 2007, pp. 38–40.
33 Infrastructure Australia, *A report to the Council of Australian Governments*, Infrastructure Australia, Canberra, 2008, p. 2.
34 Queensland University of Technology, *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009*, QUT, Brisbane, 2010, p. 4.

In 2010–11, serious flooding across large areas of Queensland resulted in significant costs and loss of life. Since 2010-11, the Australian Government has paid $5.7 billion to the states to support disaster relief.[35]

Future risks

The Garnaut Climate Change Review found that climate change impacts on infrastructure could result in Australia's GNP being 0.53 per cent lower in 2020 than it would be in a world without climate change.[36] The review found that under a high-emissions scenario climate change impacts on infrastructure would reduce GNP by 1.23 per cent in 2050 and 2.42 per cent in 2100.

Infrastructure will have to deal with increased temperatures, more extreme weather and rising sea levels

These findings underline that climate risks to Australia's infrastructure increase substantially because of further climate change. Most of the major infrastructure — ports, railways, bridges, roads, dams, schools, hospitals, energy infrastructure and airports — being planned today will still be operational in 2050. Some will still be providing services in 2100.

Infrastructure will have to deal with increased temperatures, altered rainfall patterns, more severe extreme weather events and rising sea levels. These in turn will lead to increased maintenance and operation costs, decreased longevity and increased costs of retrofitting.

Indirect effects, such as changes in demand patterns and climate change impacts on the workforce, could also be important. For example, a 1 °C increase in average temperatures would be sufficient to increase peak demand in Adelaide and Brisbane, and reduce transmission efficiency. For higher levels of warming, electricity demand in Brisbane, Melbourne and Adelaide will increase, while demand in Sydney will remain at slightly lower levels than present.[37] An increase in the number of very hot days can also lead to increased downtime in ports because Australian stevedores stop work at 38 °C.[38]

Climate change impacts on infrastructure will also cause economic losses and social disruption because of the large number of businesses, services and daily activities that rely on dependable water, electricity, communications and transport.

Sea level rise will increase risks to coastal infrastructure, discussed in more detail in the coasts section of this chapter.

Natural ecosystems

Australia's natural ecosystems help maintain Earth's life-support system. Plants provide the oxygen we breathe, maintain the quality of the atmosphere, moderate climate and its impacts, and regulate freshwater supplies. Plants, animals and microorganisms provide nearly all our food

35 Australian Government Budget paper number 3, Table 42, 2010–11; Budget paper number 3, Table 28, 2011–12, <www.budget.gov.au/past_budgets.htm>.
36 R Garnaut, *Modelling the cost of unmitigated climate change*, Economic Modelling Technical Paper 5, The Garnaut Climate Change Review, 2008.
37 BL Preston & RN Jones, *Climate change impacts on Australia and the benefits of early action to reduce global greenhouse gas emissions*, consultancy report for the Australian Business Roundtable on Climate Change, CSIRO, Canberra, 2006, p. 28.
38 Department of Climate Change, *Climate change risks to Australia's coast: a first pass national assessment*, Department of Climate Change, Canberra, 2009.

and medicine. Australia's landscapes are important to both Indigenous and non-Indigenous culture and attract tourists to Australia.[39]

Current risks

Natural ecosystems have limited capacity to respond to a climate that is changing rapidly.[40] This capacity is further constrained by pressures such as land clearing, the introduction of invasive species, and land use patterns that limit opportunities for species and ecosystems to migrate as the climate shifts.

As a consequence, early impacts of climate change on natural ecosystems are already observable. For example, high sea surface temperatures have caused frequent coral bleaching events on the Great Barrier Reef since the 1970s, contributing to a decline in coral cover.[41] Elsewhere, a number of species have changed their distribution or seasonal patterns of behaviour in response to the warming climate.[42]

Future risks

Further climate change presents enormous risks to natural ecosystems.

Managing Australia's natural ecosystems requires a mix of long-term strategies such as establishing and maintaining a comprehensive, adequate and representative system of national reserves, and short-term actions such as managing invasive species.[43] Climate change risks on a range of timescales are therefore significant to biodiversity managers.

Figure A1.3 is a striking illustration of risks to terrestrial ecosystems from a changing climate.[44] Green indicates the potential occurrence of future environments that are ecologically similar to current environments. Purple indicates the potential occurrence of future environments that are ecologically dissimilar to environments currently occurring anywhere in Australia. Maps are shown for a low-emissions and a high-emissions scenario. To underline the significance for individual species of ecosystems, warming of 1–2 °C would mean

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39 W Steffen, AA Burbidge, L Hughes, R Kitching, D Lindenmayer, W Musgrave, M Stafford Smith & PA Werner, *Australia's biodiversity and climate change: a strategic assessment of the vulnerability of Australia's biodiversity to climate change*, report to the Natural Resource Management Ministerial Council commissioned by the Australian Government, CSIRO Publishing, Canberra, 2009, p. 22.

40 A Fischlin, GF Midgley, JT Price, R Leemans, B Gopal, C Turley, MDA Rounsevell, OP Dube, J Tarazona, AA Velichko, 'Ecosystems, their properties, goods and services', in ML Parry, OF Canziani, JP Palutikof, PJ van der Linden & CE Hanson (eds.), *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* 2007, Cambridge University Press, UK, 2007.

41 De'ath et al.

42 See, for example, PR Last, WT White, DC Gledhill, AJ Hobday, R Borwn, GJ Edgar & G Pecl, 'Long-term shifts in abundance and distribution of a temperate fish fauna: a resonse to climate change and fishing practices', *Global Ecology and Biogeography*, vol. 20, no. 1, 2011, pp. 58–72; and MR Kearney, NJ Briscoe, DJ Karoly, WP Porter, M Norgate & P Sunnucks, 'Early emergence in a butterfly causally linked to anthropogenic warming', *Biology Letters*, vol. 6, no. 5, 2010, pp. 674–7.

43 Natural Resource Management Ministerial Council, *Australia's Biodiversity Conservation Strategy 2010–2030*, Australian Governmnet Department of Sustainability, Environment, Water, Population and Communities, Canberra, 2010, p. 8.

44 M Dunlop, DW Hilbert, S Ferrier, A House, A Liedloff, SM Prober, A Smyth, TG Martin, T Harwood, KJ Williams, C Fletcher & H Murphy, *The implications of climate change for biodiversity conservation and the national reserve system: final synthesis*, report prepared for the Australian Government Departments of Sustainability, Environment, Water, Population and Communities & Climate Change and Energy Efficiency, CSIRO Climate Adaptation Flagship, Canberra, 2012.

a 90 per cent decrease in core habitats for vertebrates in northern Australia tropics and the elimination of acacia species in south-west Western Australia. Warming of 2–3 °C would result in the loss of 80 per cent of freshwater wetlands in Kakadu and a decrease in core habitat of 92 per cent of butterfly species.[45]

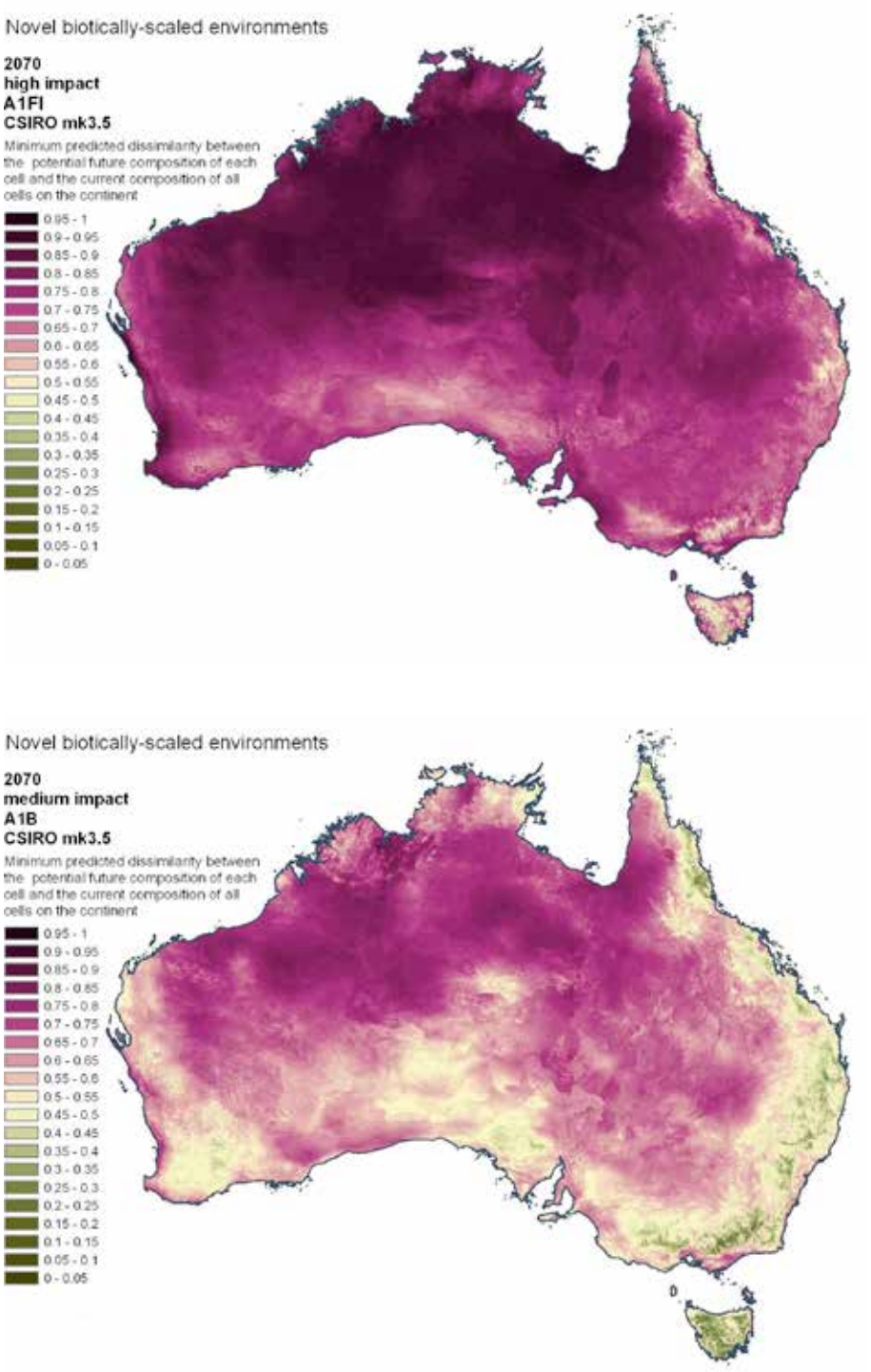

Figure A1.3 The projected impact on Australian ecosystems of climate change

Marine and coastal ecosystems also face high risks from further climate change. In many cases these impacts will be exacerbated by the acidification of oceans as they absorb increasing amounts of carbon dioxide from the atmosphere. The Garnaut Climate Change Review found that even with warming of 2 °C, the structure of corals on the Great Barrier Reef would be largely gone and the system would instead be dominated by fleshy seaweed and soft corals. [46]

Sea level rise presents particular risks to intertidal ecosystems such as saltmarshes and mangroves. If the land is uninhabited, there is an opportunity for landward migration as sea level rises. However, if there are built structures that prevent this migration landward (as in much of south-eastern Australia and parts of south-western Australia), these ecosystems are likely to be reduced by a process called 'coastal squeeze' as shown in Figure A1.4.[47]

Figure A1.4 Coastal squeeze

Human health

Good health is important for personal wellbeing, social cohesion and a productive economy.

Spending on health as a percentage of GDP has increased steadily over the last decade. In 2007–08 Australian health spending was almost $5000 per person, and governments funded almost 70 per cent of Australia's health expenditure.[48]

Current risks

Climate affects human health through a number of direct and indirect pathways, and the current climate presents many risks to health.

By one estimate, heatwaves have caused more deaths in Australia that any other natural hazard, with 4287 deaths directly attributable to heatwaves in the period 1803–1992.[49] More recently, 374 excess deaths were associated with the January 2009 heatwave in Melbourne.

46 Garnaut, *The Garnaut climate change review*, p. 271.
47 Australian Government Department of Climate Change, *Climate change risks to Australia's coast: a first pass national assessment*, Department of Climate Change, Canberra, 2009, p. 52.
48 Australian Institute of Health and Welfare, *Australia's health 2010*, AIHW, Canberra, 2010.
49 L Coates, 'An overview of fatalities from some natural hazards in Australia', in RL Heathcote, C Cuttler & J Koetz (eds), *Conference on Natural Disaster Reduction: conference proceedings*, Gold Coast, 29 September – 2 October, Institution of Engineers, Australia, Canberra, 1996, pp.49–54.

The incidence of mosquito-borne diseases such as Ross River virus infection and dengue fever is partly dependent on rainfall creating suitable conditions for mosquito breeding. An outbreak of dengue fever in 2008–09 infected more than 1000 people in the Cairns region. During 2011, there were 8314 notifications of vector-borne diseases in Australia.[50] Ross River virus infection (5151 notifications in 2011), Barmah Forest virus infection (1865) and dengue fever (812) were the most commonly reported.

Natural disasters such as floods, storms, cyclones and bushfires cause many injuries and deaths. Between 1967 and 1999 there were 223 deaths and 4185 injuries from bushfires, 154 deaths and 958 injuries from cyclones, 99 deaths and 1019 injuries from floods and 58 deaths and 942 injuries from storms.[51]

Storms can have a high cost on human health.

Mental health problems such as depression, suicide and loss of morale can follow in the wake of natural disasters, and accompany periods of drought (particularly in rural areas).[52]

Future risks

Further climate change will increase all the climate-related health risks discussed above.

More heat-related deaths in a warmer climate will be partly offset by a decrease in the number of cold-related deaths. In 1990, Australia had 5800 temperature-related deaths, but with unmitigated global warming this figure is projected to increase to 6400 by 2020, 7900 by 2050 and 17 200 by 2100. Reducing global greenhouse gases would lead to fewer temperature-related deaths later in the century but would make no difference in 2020 or 2050 (Figure A1.5).[53]

50 Australian Government Department of Health and Ageing, *National Notifiable Diseases Surveillance System*, DoHA, Canberra, 2012, viewed 29 January 2012, <www9.health.gov.au/cda/source/cda-index.cfm>.

51 Bureau of Transport Economics, *Economic costs of natural disasters in Australia*, report 103, Bureau of Transport Economics, Canberra, 2011, p. 52.

52 H Berry, BJ Kelly, IC Hanigan, JH Coates, AJ McMichael, JA Welsh & T Kjellstrom, *Rural mental health impacts of climate change*, paper prepared for the Garnaut Climate Change Review, Canberra, 2008.

53 H Bambrick, K Dear, R Woodruff, I Hanigan & A McMichael, *The impacts of climate change on three health outcomes: temperature-related mortality and hospitalisations, salmonellosis and other bacterial gastroenteritis, and population at risk from dengue*, paper prepared for the Garnaut Climate Change Review, Canberra, 2008, p. 14.

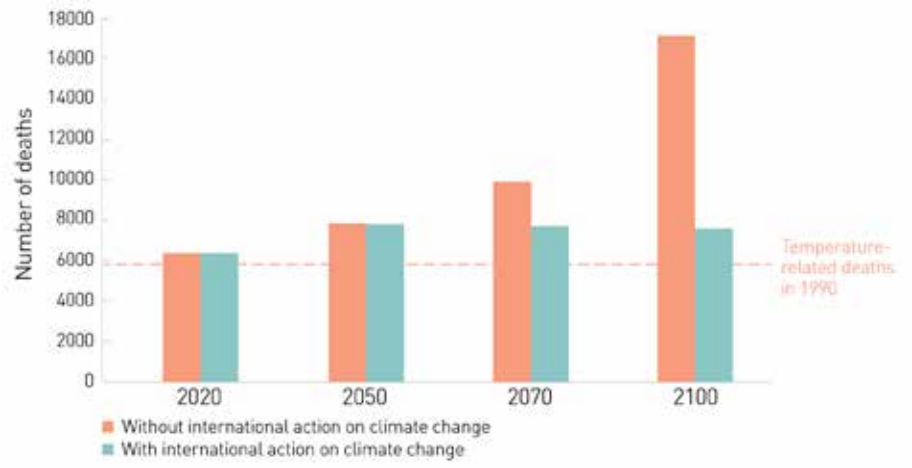

Figure A1.5 Projected temperature-related deaths in Australia with and without action on climate change

In Australia, dengue fever is currently confined to outbreaks in Northern Queensland. The dengue vector is sensitive to temperature and the availability of stagnant fresh water for breeding. A warmer climate could extend the range of the dengue vector southwards — as far as northern New South Wales in an extreme case (Figure A1.6).[54]

Figure A1.6 Projected spread of dengue fever by 2100

Coasts

The coast is of enormous economic, cultural, social and environmental importance for Australia. About 85 per cent of Australians live in coastal regions, which generate most of the country's economic activity including the ports through which most of our trade is conducted.[55] The sandy beaches of Australia's coasts are an integral aspect of the Australian

54 Climate Commission
55 Australian Government Department of Climate Change, C*limate change risks to Australia's coast: a first pass national assessment*, Department of Climate Change, Canberra, 2009.

identity, along with the coastal array of fragile ecosystems such as the Great Barrier Reef.

Current risks

Tropical cyclones, severe storms, floods and other hazards already cause loss of life and damage to private property and infrastructure in the coastal zone. Losses from coastal flooding and storms can be severe, as in the 2010–11 Queensland floods. There is evidence that climate change may already be contributing to the frequency or intensity of the extreme events that give rise to such damage. For example, evaporation resulting from record high sea-surface temperatures off northern Australia probably added around 25 per cent to the total rainfall associated with the 2010 Queensland floods.[56]

An estimated 30 000 buildings around Australia are exposed to coastal inundation given current sea levels.[57] While this represents just half a percent of building stocks, coastal erosion and inundation already causes problems in some areas. Recent major flooding in the Torres Strait islands affected roads, houses, cultural sites and wastewater treatment facilities for a community of 7000 people spread over 16 small islands.[58]

Global sea levels have risen by about 20 centimetres since the beginning of the 20th century, and the rate of sea level rise has accelerated over that period. Extreme sea level events at locations on the east and west coasts of Australia occurred three times more often in the second half of the 20th century than in the first half.[59] It is likely that higher sea levels have contributed to the increasing number of extreme high sea level events.[60]

Future risks

Climate change will exacerbate current climate risks in the coastal zone. Storms and cyclones are likely to become more intense, and rising sea levels will increase the impact of storm surge when it occurs.

Rising sea levels will also create new risks. Sea level rise will continue for many centuries and global average sea level rise may exceed 1 metre,[61] even if warming is limited to 2 °C.[62] Warming of 3–4 °C is likely

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56 J Evans & I Boyer-Sauchet, 'Local sea surface temperatures add to extreme precipitation in northeast Australia during La Nina', *Geophysical Research Letters*, 39, 2012, LXXXXX, doi:10.1029/2012GL052014.

57 T Baynes, A Herr, A Langston & H Schandl, 'Coastal 2012 climate risk project milestone 1 final report', Australian Government Department of Climate Change and Energy Efficiency, Canberra, 2012.

58 D Green, *How might climate change affect island culture in the Torres Strait?*, CSIRO Marine and Atmospheric Research Paper 11, CSIRO, 2006; D Green, L Alexander, K McInnes, J Church, N Nicholls & N White, 'An assessment of climate change impacts and adaptation for the Torres Strait Islands, Australia', *Climatic Change*, vol. 102, 2008, pp. 405–33.

59 JA Church, JR Hunter, K McInnes, & NJ White, 'Sea-level rise around the Australian coastline and the changing frequency of extreme sea-level events', *Australian Meteorological Magazine*, vol. 55, 2006, p. 257.

60 IPCC, *w*, special report of Working Groups I and II of the Intergovernmental Panel on Climate Change, CB Field, V Barros, TF Stocker, D Qin, DJ Dokken, KL Ebi, MD Mastrandrea, KJ Mach, G-K Plattner, SK Allen, M Tignor & PM Midgley (eds.), Cambridge University Press, Cambridge, UK, & New York, USA, 2012, pp. 178–80.

61 Local sea level rise will vary from place to place but this variation is not important for the broad discussion of climate risks in this chapter.

62 GA Meehl, WM Washington, JM Arblaster, A Hu, H Teng, C Tebaldi, BN Sanderson, J-L Lamarque, A Conley, WG Strand & JB White III, 'Climate system response to external forcings and climate change projections in CCSM4', *Journal of Climate*, vol. 25, 2012, pp. 3661–83.

to trigger irreversible melting of the Greenland ice sheet, leading to sea level rise of several metres, although this will take hundreds of years.[63]

Discussions of sea level rise usually focus on likely changes by the end of the century. This timescale is relevant because areas that are currently settled or used for industry are likely to continue to be used for those purposes in 2100, even if residential buildings and infrastructure are gradually rebuilt over the intervening years.

One measure of the magnitude of risks is to consider current assets in locations that would be affected by coastal inundation or erosion as sea levels rise. A 2011 study of current assets in locations vulnerable to 1.1 metres of sea level rise found that assets at risk included:

- 5800–8600 commercial buildings, with a value of $58–81 billion (2008 replacement value)
- 3700–6200 light industrial buildings, with a value of $4.2–6.7 billion (2008 replacement value)
- 27 000–35 000 kilometres of roads and rail, with a value of $51–67 billion (2008 replacement value).[64]

The 2011 study underestimates the risk to coastal settlements from sea level rise because it does not take new developments into account.

Sea level rise will be experienced mainly as an increase in the frequency or likelihood of flooding events, rather than simply as a steady increase in an otherwise constant level.

Sea level rise exacerbates current climate risks in the coastal zone.

63 GA Meehl, WD Stocker, P Collins, P Friedlingstein, AT Gaye, JM Gregory, A Kitoh, R Knutti, JM Murphy, A Noda, SCB Raper, IG Watterson, AJ Weaver & Z-C Zhao, 'Global climate projections', in S Solomon, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, M Tignor & HL Miller (eds), *Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom, and New York, USA, 2007, pp. 830–1.

64 Australian Government Department of Climate Change and Energy Efficiency, *Climate change risks to coastal buildings and infrastructure: a supplement to the first pass national assessment*, DCCEE, Canberra, 2011, p. 3.

Figure A1.7[65] shows how much more frequent extreme tidal events will become with a 0.5-metre rise in mean sea level. On average, Australia will experience a roughly 300-fold increase in extreme tidal events, meaning that infrastructure that is presently affected once in 100 years will be affected several times per year after a sea level rise of 0.5 metres.

Figure A1.7 Rate of increase in flooding events with a 0.5-metre rise in sea level

Rising sea levels will magnify flood risks from more intense cyclones and extreme rainfall events. Where coastal flooding coincides with extreme sea level events, flood waters are blocked from draining to the sea and floods persist longer and are more severe.[66]

65 J Hunter, I Allison & T Jakszewicz, *Report card: sea-level rise 2012*, Antarctic Climate & Ecosystems Cooperative Research Centre, Hobart, 2012.

66 Australian Government Department of Climate Change, *Climate change risks to Australia's coast: a first pass national assessment*.

A2 Appendix 2 Three examples of climate risk allocation

	Rural water resources management	Natural disaster management	Local government liability
Risks are clearly allocated	The Council of Australian Governments (COAG) agreed to the National Water Initiative (NWI), which is Australia's blueprint for water reform. Through it, governments across Australia have agreed on actions to achieve a more cohesive national approach to the way Australia manages, plans for, measures, prices and trades water. Key reforms for water management were enacted through the *Water Act 2007*, which included the specific requirement to prepare a plan for the Murray–Darling Basin. Both the NWI and the Basin Plan set out provisions that assign risks in relation to changes in water availability, which includes climate change risks.[a]	The National Strategy for Disaster Resilience set out the roles of different levels of government, businesses, individuals and non-government organisations. The Australian, state and territory governments agreed to the National Disaster Resilience Statement in 2009, followed by the strategy in 2011. However, recent reviews of natural disasters have identified that inadequately defined roles and responsibilities across emergency management agencies reduced the effectiveness of emergency services.[b]	Legal liability has been identified as a key issue for local governments. Many local governments are concerned about potential liability if they approve a development that is likely to be exposed to climate risks in the future (such as inundation from sea level rise). Councils are concerned about liability both when they take action to address climate change and when they fail to take action. Lack of certainty about liability means that decisions are being tested in the courts. This can impose a significant burden on local government budgets.

continued

Opposite page: A farmer assesses the soil on his drought-stricken property.

	Rural water resources management	Natural disaster management	Local government liability
Risks are well understood	Undertaking effective water reform requires a good understanding of the climate change risks and expected water availability patterns. In March 2008, COAG agreed to assess water yields in all major water systems across Australia. The objective was to achieve a comprehensive scientific assessment of water yields in most major water systems. The resulting assessments include analysis of current and future climate scenarios and provide a framework for national water policy decisions.[c]	Understanding risk is critical to building disaster resilience. It has been a priority area of work in the early stages of implementing the strategy, and will continue to be a primary driver in the future. Since COAG endorsed the strategy, significant progress has been made in building a greater understanding of risk across Australia, in particular through endorsement of the National Emergency Risk Assessment Guidelines (NERAG) in November 2011. The use of the NERAG, a nationally consistent methodology for risk assessments, will contribute to improved consistency, comparability and quality of future risk assessments in Australia. However, there are some challenges related to understanding the risks of climate change on natural disasters that remain. For example, while we know that climate change is expected to increase the frequency and/or severity of some extreme weather events, how that translates to localised risks is not well understood. A good understanding of the current and future risks would help inform decisions to divide resources between prevention, preparedness, response and recovery options. For example, there needs to be a stronger recognition of climate change impacts and adaptation in hazard mapping and modelling, to ensure future risks can be addressed.[d] Making decisions is challenging when it is hard to quantify exact impacts.	Local governments have many competing priorities, and often do not have dedicated resources for understanding climate risks. There is great diversity of understanding among local governments.

continued

	Rural water resources management	Natural disaster management	Local government liability
The people managing the risk are those who are best placed to do so	Managing the risks associated with reductions in water reliability as a result of climate change is the responsibility of governments and water access entitlement holders. The NWI clarifies the assignment of risk arising from future changes in the availability or reliability of water. For example, water access holders may invest in upgrading irrigation delivery systems, alter crop types, utilise water markets to buy and sell water or improve on farm irrigation management to enable a higher level of resilience against reductions in water availability. Governments may seek to improve information systems and knowledge surrounding future water availability patterns or review and amend water management policies.	While the strategy focuses on priority areas to build disaster-resilient communities across Australia, it also recognises that disaster resilience is a shared responsibility[e] for individuals, households, businesses and communities, as well as for governments. The strategy supports a new focus on shared responsibility, where political leaders, government, businesses, community leaders and the not-for-profit sector all adopt increased or improved emergency management advisory roles, and contribute to achieving integrated and coordinated disaster resilience. In turn, communities, individuals and households need to take greater responsibility for their own safety and act on information, advice and other cues provided before, during and after a disaster.	It is unclear how risks are allocated between private (property and land owners) and public (local governments) interests. There are also potential externalities, whereby the actions of an individual affect others. For example, building a seawall in front of one property might make flooding worse for another property.

continued

	Rural water resources management	Natural disaster management	Local government liability
Those who benefit from risk management pay for the costs	Identification of the risks and agreement on how the risks will be managed is an important element of who bears the costs under reduced water availability scenarios. Water reforms under the NWI and the *Water Act 2007* have improved the security and commercial certainty of water access entitlements. This has allowed water access entitlement holders to value their assets according to their business needs. Businesses can choose how to adjust to change under reduced water availability conditions as a result of climate change.	The Natural Disaster Relief and Recovery Arrangements (NDRRA) are the Australian Government's main funding mechanism for assisting with the social and economic impacts of natural disasters on individuals and communities. Since the NDRRA provides partial reimbursements to states and territories for disasters, incentives for states and territories to reduce risks are potentially dampened. For example, in Queensland, most state recovery expenditure after the flooding and cyclone of 2011[f] (that is eligible under NDRRA) has been used to replace state roads and local government assets. Many of these assets were built in locations of known vulnerability to flood events, thus maintaining previous vulnerabilities. Some observers have identified potential barriers to the use of betterment provisions within the NDRRA (replacing damaged infrastructure to a more resilient standard).[g]	Given that risks are not yet clearly allocated, those who benefit from risk management may not be bearing the costs. There are also community concerns about short-term losses (e.g. loss of property values) versus long-term gains (reduction in future exposure).

a www.environment.gov.au/water/australia/nwi/guidelines.html
b Productivity Commission, *Barriers to effective climate change adaptation*, report 59, Final Inquiry Report, Productivity Commission, Canberra, pp. 245–50.
c www.environment.gov.au/water/policy-programs/sustainable-yields/index.html
d www.climatechange.gov.au/climate-change/adapting-climate-change/australias-coasts-and-climate-change/xxxx-adapting-coastal--1
e 'Shared responsibility' means an increased responsibility for all, rather than equal responsibility (as there are some areas in which the state for example should assume greater responsibility than the community, (e.g. state fire authorities will usually be better placed than individuals to identify risks associated with bushfire). (Victorian Bushfires Royal Commission Final Report 2010, cited in National Strategy for Disaster Resilience 2011)
f Productivity Commission, p. 265.
g Productivity Commission, p. 267.

Image credits

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	Builders construct the timber frame of a house	DIICCSRTE
	Two young men stand at the water's edge as flooding encroaches on Brisbane's CBD in 2011	iStockphoto
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Page 60	Coastal erosion is a significant challenge for south-east Queensland	DIICCSRTE
Page 63	Coasts are important for culture and recreation in south east Queensland	DIICCSRTE
Page 64	Milton Road is inundated during the 2011 floods in Brisbane	© Glenn Walker
Page 66	Flood waters inundate Suncorp Stadium in Brisbane in 2011	© Suncorp Stadium
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Page 88	Bushfire risk increases as temperatures rise	iStockphoto
Page 99	Storms can have a high cost on human health	iStockphoto
Page 102	Sea level rise exacerbates current climate risks in the coastal zone	DIICCSRTE
Page 104	A farmer assesses the soil on his drought-stricken property	iStockphoto