NCCARF
National
Climate Change Adaptation
Research Facility

Synthesis and Integrative Research
Final report

Supporting evidence-based adaptation decision-making in the Northern Territory: a synthesis of climate change adaptation research

AECOM

SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN THE NORTHERN TERRITORY

A synthesis of climate change adaptation research

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The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

The project also had support from representative(s) from each state/territory government. For this report for Northern Territory, AECOM wishes to thank Bethune Carmichael for his involvement with this project and assistance with report review.

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Shortened forms

ACT	Australian Capital Territory
AEP	Annual Exceedance Probability
BCA	Building Code of Australia
BoM	Bureau of Meteorology
CALD	Culturally and Linguistically Diverse
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Community Service Organisation
DCCEE	Australian Department of Climate Change and Energy Efficiency
DECCW	New South Wales Department of Environment, Climate Change and Water
DEFRA	United Kingdom Department for Environment, Food and Rural Affairs
DoHA	Australian Department of Health and Ageing
DRR	Disaster Risk Reduction
FORNSAT	Forum for NCCARF interaction with states and territories
GIS	Geographical Information System
ILM	Integrated Land Management
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organiation for Standardization
NCCARF	National Climate Change Adaptation Research Facility
NDRRA	Natural Disaster Recovery Relief Arrangements
NGO	Non-governmental Organisation
NSW	New South Wales
NT	Northern Territory
OEH	Office of Environment and Heritage
PCF	Policy Choice Framework
Qld	Queensland
QUT	Queensland University of Technology
SA	South Australia
SAFECOM	South Australian Fire and Emergency Services Commission
SME	Small or Medium Enterprise
UNESCO	United Nations Educational, Scientific and Cultural Organization
VCAT	Victorian Civil and Administrative Tribunal
VIC	Victoria
WA	Western Australia

EXECUTIVE SUMMARY

Project background

A growing recognition of inevitable global climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes. As part of this, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making.

In 2012, NCCARF commissioned this project, a synthesis of the research for each Australian state and territory, to answer a fundamental question: "What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?"

This report for the Northern Territory is one of seven reports produced by AECOM for this project. A report was created for each state and territory with the exception of Tasmania. A Tasmanian report was produced separately by the University of Tasmania.

What is adaptation?

This project utilises the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC WG2 2007).

Current and future climate in the Northern Territory

- The Northern Territory's climate varies significantly spatially, with two distinct climate zones – the northern tropical climate and the central semi-arid climate. This means climate change impacts will vary significantly across the Territory.
- Temperature increases have been observed, particularly in southern areas and during the wet season, and this is predicted to continue in the future.
- Tropical cyclones and sea level rise pose significant threats to the Territory due to the proximity of its largest population centre to the northern coast. Cyclones are predicted to decrease in frequency and increase in intensity.

Climate change impacts

- Health and wellbeing impacts may include physical injury due to bushfire, extreme weather and heat-related illness. Impacts on the health services sector are expected due to increased demand, resource constraints and damage to supporting infrastructure. Rates of infectious and vector-borne diseases are also expected to increase. Existing health issues for Indigenous people are expected to be exacerbated.
- The drying trend underway in the southwest will have significant adverse impacts on primary production.
- Kakadu National Park and other internationally significant natural environments are expected to be significantly impacted by salt water intrusion due to sea level rise, as well as increases in bushfire activity and intensity.
- Infrastructure and settlements will be impacted by reduced rainfall and availability of water supply, flooding and higher temperatures. The potential for increased intensity of cyclones is also a significant risk.
- Mining, primary production and tourism are all likely to be significantly impacted by changes in rainfall, temperature and ocean temperatures. The reliance of the Territory's tourism industry on nature-based activities makes it particularly vulnerable to climate change impacts.

Territory government's role in adaptation

The purpose of this project is to synthesise adaptation lessons relevant to decision-makers in state and territory government. State and territory governments have an essential role to play in supporting adaptation to climate change. States and territories have direct involvement in managing a range of assets and government services, and as a result have a significant role in direct adaptation actions. Policy from the previous Northern Territory government noted the significant potential challenges of climate change on natural resource management, water demand and availability, and biosecurity risks.

States/territories also play a role in creating an institutional, market and regulatory environment that supports and promotes adaptation to climate change. This includes the establishment of responsive frameworks for urban development, agriculture, tourism and the protection of natural resources.

Research collected for synthesis

The project has drawn on a broad range of published research, including draft NCCARF research reports not yet publicly available. The majority of research utilised for the synthesis was funded by NCCARF. However, over 450 research reports were gathered in total from Australian journals and publications and included in the database that accompanies this project. Up to 15 pieces of research specific to each state/territory but not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. This research was selected based on its relevance to state/territory government policy.

The figure below maps the study locations and regions within the Northern Territory examined in the research. Research has been concentrated in the northern part of the territory, particularly in the capital Darwin and Kakadu National Park. The other region examined was Arnhem Land. Alice Springs was the only study location in the southern areas of the territory, though more than one study addressed this location.

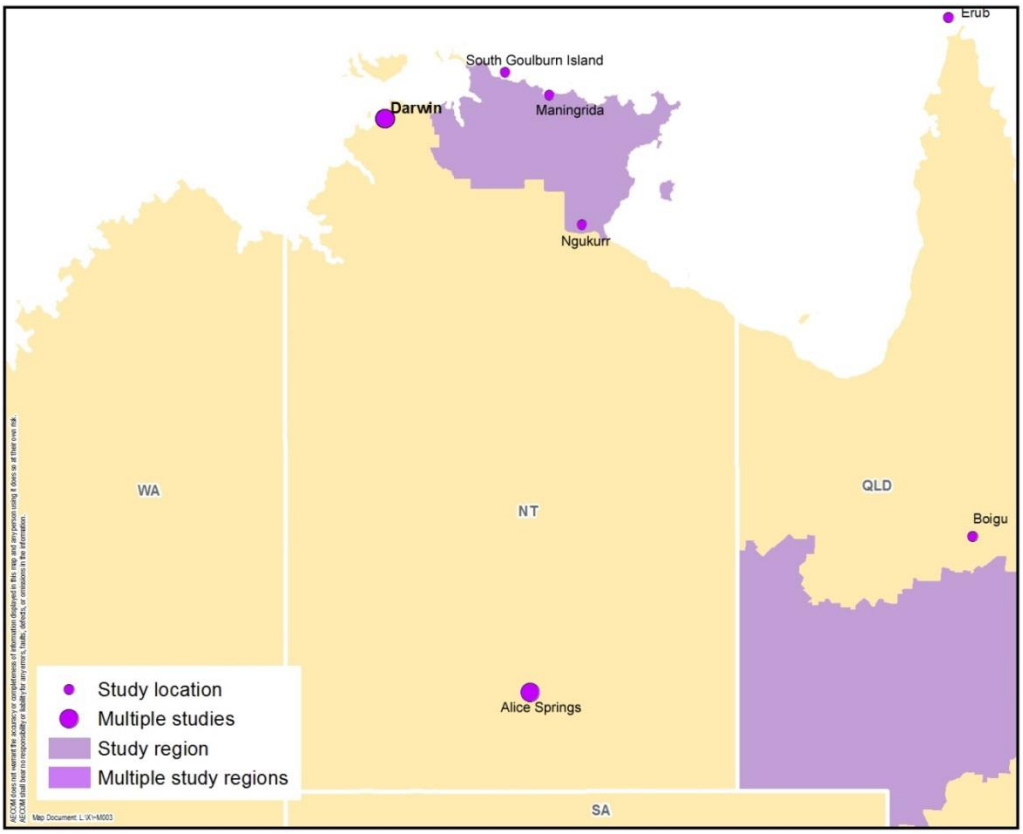


Figure ES1: Case study locations of synthesised adaptation research in the Northern Territory

Synthesis of findings by theme

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. The main themes utilised in this synthesis are: increasing resilience and adaptive capacity; learning from experience; costing, financing and funding adaptation; limits and barriers to adaptation; maladaptation; and the timing and scale of adaptation. It should also be noted that, due to the nature of the research reviewed, this synthesis largely presents broader findings rarely specific to an individual state/territory. The primary research findings are summarised below under these key themes.

Increasing resilience and adaptive capacity

Adaptation actions are largely centred on increasing a community or system's adaptive capacity and resilience and thereby reducing its vulnerability. However, as the research indicates, determining an effective method by which to increase resilience can be challenging.

Adaptation responses and emergency assistance need to take into account a community's short- and long-term challenges, including broader socio-economic issues, as well as ensure preparedness is holistic and tested for robustness (Kiem et al. 2010a, Boon et al. 2012D[1], Sherval and Askew 2012, Black et al. 2013D). At the community level, government disaster assistance can deter residents from securing insurance and can in some instances facilitate departure from a community post-disaster (Boon et al. 2012D). Limited assistance from government or insurers for pre-disaster preparation has been trialled. It is also important to remember that some communities are inherently more vulnerable than others and that community and system vulnerability may change over time (Kiem et al. 2010a, Hanson-Easey et al. 2013D, Boulter 2012).

Community connectedness and the presence of local networks were found to be strong contributors to community resilience and recovery (Boon et al. 2012D). State/territory government can help guide local efforts and initiatives and support local government and community service organisations in their efforts to assist communities (Boon et al. 2012D, Mallon et al. 2013D). A useful starting place for collaboration for adaptation is disaster risk management, as these arrangements are historically and currently formed around interagency and intergovernmental approaches (Howes et al. 2013D).

Building resilience and adaptive capacity also relies on the need to better consider messaging and communication. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, improve social cohesion, and can increase confidence in governance processes. Clearly articulating adaptation goals (together with options) and using shared terminology are seen as key to engaging the community (Kiem et al. 2010b, Hadwen et al. 2011, Howes et al. 2013D, Johnston et al. 2013D). In addition, it is important to use bespoke, tailored messaging to reach intended audiences and to distribute information through multiple, diverse channels (Boon et al. 2012D, Hanson-Easey et al. 2013D, Reser et al. 2012).

For natural systems, current efforts to improve habitat protection are considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations. However policy and management needs to transition to ecosystem-based approaches which seek to maintain function.

In primary production systems, adaptation will largely be driven by the private sector, however, government still has a key role to play in helping set the right policy conditions and through the provision of appropriate incentives. Implementation of market-based instruments needs to better consider the capacity of participants to engage in change and broader social and economic impacts.

Learning from experience

Adaptation planning will be informed by lessons learnt from past events. Recent events (drought, bushfire, floods and storms) have resulted in various policy responses across the country, enabling rapid mobilisation of resources across all levels of government (Howes et al. 2013D). However, prior experience with natural disasters can be unpredictable in its influence on community resilience. Communities with a collective memory of a crisis may be able to respond with adaptive change more easily than those with lack of experience; however, despite past experience, many communities still do not take steps to prepare for the next event (Kiem et al. 2010a, King et al. 2012D). Preparedness for one disaster, such as drought, can also make residents and agencies less concerned or prepared for other potential risks, such as floods (Bird et al. 2011, QUT 2010).

[1] Note that references ending in capital 'D' are draft NCCARF research reports; the date shows the year they were made available for incorporation into this synthesis report.

Basing decisions on past experiences will become increasingly risky. There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010). Furthermore, because of the urgency to re-build quickly, adaptation measures implemented after extreme events may not take adaptation opportunities into account or be fit for purpose with continued climate change and may increase vulnerability in the longer term (Kiem et al. 2010a; Albrecht et al. 2010).

Extreme events can also provide an impetus for overdue and unpopular adaptation actions (Kiem et al. 2010a) and can enable governments to mandate change, making implementation of actions progressively more affordable (Mason and Haynes 2010). However, the opposite can also be true. For some disasters, attitudinal barriers, such as the common belief that excessive heat is not a threat in a warm country, can prohibit planning and action. Public education campaigns are recommended (QUT 2010).

Costing, financing and funding adaptation

Adaptation options entail varying costs, both in terms of time and resources involved in their implementation and maintenance as well as with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors modify the impacts. The return on adaptation needs to be considered beyond the short-term and in relation to the distribution of costs and benefits to the broader community.

Disaster relief funding is considered by some to be over-generous and untargeted, and its ability to increase resilience to disaster under current arrangements is questioned (Wenger et al. 2012D). It also frequently does not provide assistance that takes into consideration a local government's capacity to commence emergency works or the longer term cost impacts of the extreme event (Verdon-Kidd et al. 2010).

Consideration of who pays for adaptation is also an ongoing issue for many decision-makers. Economic tools that estimate specific costs and potential benefits throughout the community can help inform sensible choices about which adaptations, or suite of adaptations, are likely to yield more benefits than they cost to implement (Fletcher et al. 2013D). Currently there is limited research testing how adaptation costs and benefits might be distributed through the community.

Insurance is generally considered an important tool to help defray the costs of climate change impacts, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters. There is also limited practice by insurers to promote or encourage actions which reduce or avoid future risks associated with climate change (Bird et al. 2011). Ultimately in the case of a disaster when people are not insured it is the government that bears the risk.

Apart from water trading, there are few tested market-based mechanisms for adaptation. Market-based approaches to adaptation are particularly important to encourage financing of physical assets and infrastructure.

Limits and barriers to adaptation

Understanding the limits and potential barriers to adaptation can help decision-makers determine more practical and legitimate responses to climate change and better engage with stakeholders (Morrison and Pickering 2011). The primary limitations identified in the research are as follows:

- *Lack of community support.* Public opposition and poor communication with stakeholders can derail adaptation implementation (Haynes et al. 2011, Poloczanska et al. 2012, Petheram et al. 2010). Varying perceptions of adaptation interventions among stakeholders can also be a major source of conflict (Gross et al. 2011, Evans et al. 2011).
- *Current institutional and legislative frameworks.* Practical management strategies at the local or state/territory level can be constrained by higher level government legislation, which may not take into account local conditions (Hadwen et al. 2011, Robson et al. 2013D). Institutional arrangements can also create barriers for effective collaboration, such as the relatively little transfer of expert personnel between the planning, building and insurance professions (King et al. 2012D).
- *Capacity and resource constraints.* Resource and capacity constraints can relate to financial or human capital limitations. Local governments, in particular, find long-term, large adaptation projects are beyond their capabilities (Mukheiber et al. 2012). There is also often an issue of split incentives, where the person able to fund an adaptation intervention is not the one that benefits in terms of avoided costs.

- *Lack of system understanding.* Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification effective adaptation options (Hadwen et al. 2011).
- *Lack of accessibility to up to date and relevant information.* There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities (Hadwen et al. 2011).

Maladaptation

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks from adaptation is often termed 'maladaptation'. Maladaptation can occur when the connections and interdependencies of systems are underestimated, particularly in the context of natural ecosystems (Hadwen et al. 2011). Therefore, it is critical to the success of adaptation activities that the connectivity between ecosystem and human systems is considered within the decision-making process. A number of climate change adaptation and mitigation policies also have the potential to negatively affect the most vulnerable sectors of society due to the inequitable distribution of economic impacts (Mallon et al. 2013D).

Timing and scale of adaptation

The timing for and scale at which adaptation is best delivered remain fundamental questions. Adaptation will continue to be a series of reactions to environmental and social changes – some quickly executed in response to emergencies, others more autonomously in response to slowly changing social and economic conditions (Gross et al. 2011).

Government and communities have tended to favour short-term and responsive approaches; this can make adaptation more difficult to initiate and more expensive (Stanley et al. 2013D). Adaptation actions need to take a long-term view to be effective (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward thinking approach.

At the same time, the windows for adaptation opportunity following extreme events are relatively short, largely due to current funding arrangements and community expectations. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (for examples revised building codes). However, there is a need to act quickly, while the issue remains within community memory and before complacency sets in (Helman et al. 2010).

Triggers for longer term adaptation need to be considered for extreme events. The increasing frequency of climate-related events is changing the perception of what is an extreme and what is 'normal climate' (Kiem et al. 2010a). In light of this, disaster management arrangements need to be reviewed. This is typified by changes in drought policy responses in Australia over the past 20 years.

Finally, it is important to recognise that doing nothing may be an appropriate adaptation response, if and only if (Garnett et al. 2012D):

- full consideration of the potential consequences has been given;
- there is on-going monitoring of climate change risks; and,
- there is flexibility to recognise and respond to changed circumstances in a timely manner.

Synthesis of findings by sector

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long-term. However, this report also contains lessons relevant to specific sectors, particularly for natural resource management, primary production and land use planning. A few of these findings are also specifically relevant to individual states or territorites. The table below provides a summary of the key findings by sector. It is also important to note that the findings captured below represent the lessons relevant to a sector but in no way did the research reviewed comprehensively cover any individual sector.

Table ES1: Findings for Northern Territory by sector

	Findings related to adaptation and natural resource management: • Existing management strategies will lessen the impacts on ecosystems, but the objectives of conservation and management plans will need to be re-considered in the context of longer term climate change. This is particularly relevant for inclusion in the Northern Territory Parks and Conservation Masterplan. • Habitat protection is currently considered the optimal action for assisting most species adapt to climate change within budgetary limitations. However, adaptation also needs to take an ecosystem-based approach where resources are directed towards a suite of actions. Effective adaptation requires adaptive management, meaning actively experimenting with actions and learning from past activities. • There are conflicting conclusions regarding whether water pricing reduces water demand.
	Findings related to agriculture, fisheries and forestry: • Diversification is the effective strategy for mitigating climate-induced variability. • Adaptation will be primarily driven by private sector responses, but government needs to play a supporting role to ensure the effectiveness of adaptation responses. • Individual farms have coped with periodic events through a range of management and behavioural changes. The effectiveness of these options in the long-term needs to be considered, as does how to transition agricultural production from areas of high vulnerability to low vulnerability to maintain food security and regional economic development.
	Findings related to infrastructure, communities and land use planning: • There are issues of continued expansion of populations into at-risk areas particularly with regard to coastal inundation and cyclone risks. • Regulatory instruments in land use planning need to have a precautionary approach, including greater flexibility to support adaptation. • Through development regulation, land use planning can play an essential role in reducing climate risks to populations and infrastructure. • Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response that focuses on empowering communities to identify and implement their own responses. • Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained. • Integrating local, Indigenous knowledge with climate change science is critical to adaptation.
	Findings related to health and wellbeing: • There is need for a consistent heatwave policy for the management of aged care facilities. This should be considered in the Northern Territory All Hazards Emergency Management Arrangements. • Targeted adaptation messages need to be developed for specific audiences, particularly for remote and indigenous communities.

Findings related to business and industry:

- Adaptation action within small and medium businesses may be resource constrained.
- Adaptation in some sectors of tourism may require diversification – this may provide additional benefits and/or risk.
- Aquaculture is a potential adaptation option for Goulburn Island residents but support would be needed to obtain the appropriate skills and resources.

Conclusions

The complexity of climate change adaptation cannot be underestimated. A wide range of issues, including national and state/territory policy contexts, local institutional constraints, short and long-term climate variability, local community needs and environmental conditions play a role. As pointed out by Gross et al. (2011) "adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances." (p. 77).

There are also clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Improvements in climate change science can only partially reduce this uncertainty and adaptation planning must accept this fact. These uncertainties highlight the need for flexibility, both as new information emerges and as society evolves.

Climate change uncertainties are not the only constraints however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain some of the greatest limits to effective adaptation. From these changes, values and priorities will also adjust and will need to be captured in adaptation objectives and actions.

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and drought. While it is critical that we learn from and address the many issues that arise from these events, the potential influence of further climate change has not been considered in order to identify where responses beyond 'business as usual' may be necessary. Further opportunities are lost by the rush to restore communities and meet shorter term needs. The question of whether experience with disaster events improves community resilience also remains inconclusive – it appears that the answer depends on a range of factors, unique to each location, each event and a point in time.

However experience from extreme events also brings hope. Stories of autonomous self- organisation and neighbourhood support highlight the need to continue efforts which strengthen a sense of community and ultimately improve adaptive capacity. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered in community and targeted by support programs.

Key lessons for Northern Territory government decision-makers

Monitor and evaluate existing adaptation practices for ongoing adaptation. Monitoring is essential to evaluate the effectiveness of current adaptation options, but it also critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management**.**

Increase effort in identifying adaptation opportunities and promoting positive change. While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, potential opportunities also need to be identified.

Clearly define specific adaptation objectives. Decision-making, implementation and evaluation require an understanding of the government's appetite for risk and what outcomes are expected. Objectives also need to be defined in consultation with stakeholders.

Adapting Indigenous communities to climate change requires a holistic, multi-sector, collaborative response. Adaptation programs should focus on empowering Indigenous communities to identify and implement their own responses. Furthermore, focus should be on the integration of local, Indigenous knowledge with climate change science.

Continue efforts to build community cohesion. Building a sense of community is important to increase adaptive capacity and resilience and will have a range of benefits beyond climate change adaptation.

Avoid calm weather planning. Taking a risk-based approach that factors in both experience from past extreme events and future potential climate change is a more robust approach for adaptation planning.

Create opportunities for greater engagement with researchers. To take advantage of research and to support better adaptation planning, government decision-makers need early and frequent engagement with the research community.

1. INTRODUCTION

1.1 Project background

Over the past two decades, climate change activities by governments around the world have largely focused on reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change. However, a growing recognition of the inevitable impacts of climate change has led to significant research investment aimed at understanding the impacts of climate change and how to best adapt to these changes.

In response to climate change, the Australian Government established the National Climate Change Adaptation Research Facility (NCCARF) in 2008 to harness Australian research capabilities to support adaptation decision-making. The NCCARF program, together with research outcomes from other Australian research institutions, constitute an important part of the growing body of climate change adaptation knowledge for Australia's states and territories. Emerging from nine research plans for key sectors of Australian society, more than 100 research projects have been funded to support decision-makers in climate change adaptation.

NCCARF has commissioned a synthesis of research outputs to date for each Australian state and territory. The intent of this report is to inform policymakers and other interested parties of relevant research for Northern Territory (Northern Territory) and identify what strategic implications and lessons can be learned from this research. At the same time, this synthesis is intended to identify transferable lessons between regions and sectors while also identifying emerging research gaps at both the state/territory and national level. It also seeks to present findings and analysis in a way that will enhance adaptation understanding of decision-makers in state and territory government.

This report draws together and presents key findings and lessons from individual NCCARF research reports, and a selection of other supporting studies identified through a literature review. This report has been shaped by the needs identified by state and territory government representatives participating on FORNSAT, NCCARF's forum for engagement with state and territory government.

Adapting to climate change

This project uses the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC WG2 2007). As such, the literature gathered and synthesised for this project is *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. It is focused on research that tests or discusses *responses* to climate change, that is, how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects.

1.2 Report structure

This report consists of seven sections and four Appendices. Table displays the main objectives and content of each section.

Table 1: The objectives and content of report sections

Report section	Objectives	Content
1.0 Introduction	To introduce the project background and purpose; to place the project in the context of the roles and challenges for territory government.	Project background; scope and methodology; description of the role of government in adaptation; discussion of the adaptation challenge for government and research.
2.0 The Northern Territory climate challenge	To describe the climatic challenge faced by the Northern Territory and the Northern Territory's existing adaptation priorities and actions.	Description of current and future climate conditions; key climate change impacts facing Northern Territory; discussion of the Northern Territory's current adaptation priorities and activities.
3.0 Research relevant to the Northern Territory	To provide an overview of the research collected for the synthesis and its geographical relevance.	Total number of research studies gathered; list and map of research reports with Northern Territory-specific case studies.
4.0 Research findings	To synthesise research reviewed based on common themes of learning for territory-government policy and decision-making.	Key findings and supporting research by identified themes and sectors. Also includes a list of practical adaptation options identified in the research.
5.0 Policy and research engagement	To capture lessons regarding how the intersection of and interactions between policy and research may be improved.	Key findings from the research regarding improving researcher and decision-maker engagement. Research gaps regarding the application of the research findings for specific end users.
6.0 Conclusions	To summarise the fundamental challenges facing territory government decision-makers and the key lessons.	Description of the adaptation challenges and potential policy implications; summary of identified lessons for decision-makers.
Appendix A	Appendix A provides an overview of early consultation with FORNSAT representatives about their needs for this project.	
Appendix B	Appendix B provides a list of the nationally relevant NCCARF research projects. This list of projects does not contain case studies specific to an Australian state or territory.	
Appendix C	Appendix C provides summaries of all NCCARF-funded research that contains a case study within the Northern Territory.	
Appendix D	Appendix D provides a list of all NCCARF-funded research reports excluded from the synthesis and reason for exclusion.	
Bibliography	To capture a full list of research reports reviewed for this project.	The bibliography includes all research reviewed for the synthesis, as well as cited research. Research reviewed but not cited also informed the thinking of this project.

Icon key	
	Natural environment
	Agriculture, fisheries and forestry
	Infrastructure and communities
	Health and wellbeing
	Business and industry
	Emergency management
	Government and governance
	Tools

Sector icons

Icons are presented throughout this document to represent the sectors, or themes, the information relates to or to indicate whether it provides a tool or framework to assist the end-user.

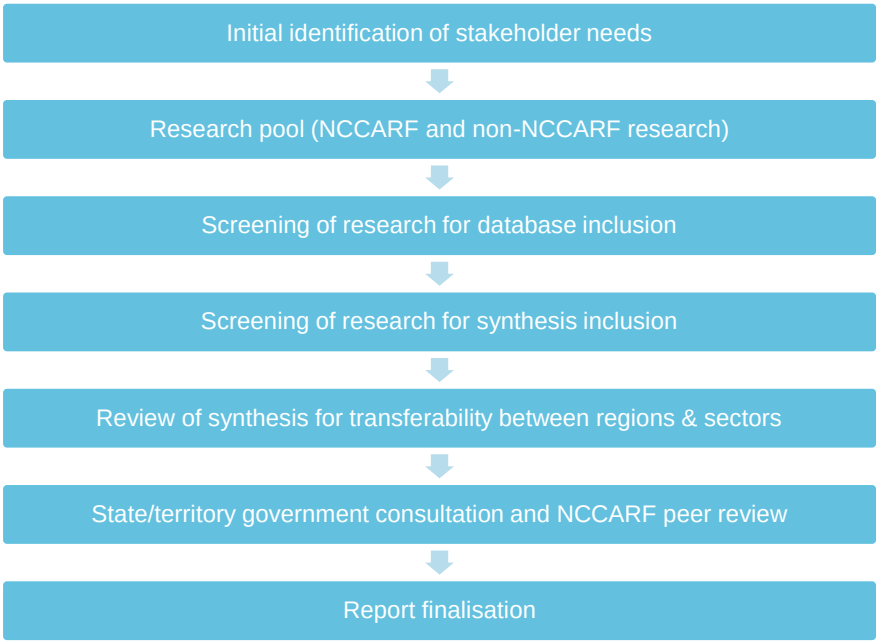
1.3 Scope and methodology

This project sought to identify relevant climate change adaptation research for each state and territory government while considering the transferability of research findings between jurisdictions. In addition to research commissioned by NCCARF, a scan of relevant scientific journals and Australian government websites was undertaken. The research reports collected during this scan are included in a database that accompanies this report, and a subset of this research is included in this synthesis report. The database is a searchable tool outlining NCCARF and non-NCCARF adaptation research in Australia.

The project has taken a broad view of published research – it has not been limited to peer-reviewed literature and it incorporates findings from NCCARF's draft research reports some of which may not yet be in the public domain. The literature gathered and synthesised for this project is also *not* focused on climate change science, climate change modelling, climate change risk or vulnerability assessments, although it is acknowledged that these often form a critical element of adaptation planning. The research scan instead focused on research that tests or discusses *responses* to climate change, i.e. how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects. In addition, the report focuses on research that can inform directed and planned adaptation, particularly in relation to the roles and responsibilities of state and territory governments.

A summary of the methodology is outlined in Figure 1. Broader adaptation research occurring at other Australian locations is considered where it has been deemed that this research is relevant to the Northern Territory. There is a growing body of international research which may also provide insights for adaptation planning and implementation in the Northern Territory, but this information was beyond the scope of this project.

Figure 1: Summary of project methodology



Initial identification of stakeholder needs

At the beginning of this project, all FORNSAT representatives and, when requested, additional state/territory government employees were interviewed by phone to:

- better understand what they would most like to get out of this synthesis
- discuss identified or articulated priority climate change risks or adaptation priorities
- clarify where research has been used so far to inform policy and program development.

A summary of the interview results are included in Appendix A.

Research pool (NCCARF and non-NCCARF research)

This synthesis draws upon climate change adaptation research commissioned by NCCARF and research gathered through Australian sources. The primary sources for research gathered were:

1. Published and peer reviewed literature using relevant databases and key search terms:
    a. The databases utilised for the scan were Science Direct, APAIS, SciVerse Scopus, ANR index, ANR research, EVA, FAMILY, and CSIRO Publishing.
    b. Search terms included adaptation, adaptive capacity, climate change, climate impact, climate proofing, climate risk, climate variability, future proofing, resilience, and vulnerability.
2. Scan of state/territory and Commonwealth websites for relevant research reports. Websites were scanned by entering the search terms into the search bar on state/territory and Commonwealth department websites. The websites of the Northern Territory departments searched include:
    - Department of Resources Minerals and Energy
    - Department of Fisheries
    - Department of Construction and Infrastructure
    - Department of Environment
    - Department of Natural Resources, Environment, The Arts and Sport
    - Department of Lands and Planning
    - Environment Protection Authority
3. Engagement with FORNSAT representatives to nominate research. After the database search and website scan was complete, a full list of over 610 pieces of research was sent to each FORNSAT

representative. FORNSAT representatives were then given two weeks to review the research relevant to their state/territory and provide feedback on inclusion or exclusion.

Screening of research for database inclusion

Prior to submitting the research list to FORNSAT representatives, AECOM assessed the research for inclusion in the project database that accompanies this report based on criteria agreed upon by FORNSAT representatives and NCCARF. This criteria list was also to be used by FORNSAT representatives to guide their research nomination process:

- primary research reports (mainstream media reports and peripheral research outputs were included)
- research published since 2001
- publicly available (confidential government reports or reports pending government approval were not included. An exception to this is NCCARF research.)
- consistency with the IPCC definition of adaptation
- of relevance/significant to the responsibilities and interests of Australian states and territories
- specifically consider responses to future climate change.

Screening of research for synthesis inclusion

All research reports included in the database were then considered for inclusion in the synthesis using the following criteria:

- relevance to state/territory government roles and responsibilities
- ability to influence state/territory government policy and decision-making
- robustness of research methodology to 'scale up' findings and lessons to sectors and regions
- provision of policy analysis or policy recommendations relevant to state and territory government roles and responsibilities.

The purpose of these criteria was to have the synthesis informed by research which is the most appropriate and relevant to a state and territory government audience.

The second purpose of these criteria and the inclusion/exclusion process was to allow AECOM capacity to review non-NCCARF research. Our initial scope of work allowed for a total of 150 reports to be reviewed for the synthesis. This was based on the synthesis being informed by NCCARF research only.

AECOM identified 454 non-NCCARF funded adaptation research articles which met the above four criteria. To consider all of these for the synthesis report in addition to the identified NCCARF research was beyond the scope of the project.

To resolve this issue, AECOM proposed that:

- all research which meets the above four criteria were included in the database
- the synthesis was based predominately on findings from the identified NCCARF research but supplemented by the inclusion of up to 15 of the most relevant research papers for each state/territory as identified by AECOM. NCCARF and FORNSAT were also invited to nominate research that they identified as being most relevant and influential.

Any NCCARF research reports provided to AECOM after close of business on the 14 January 2013 were also unable to be included in the synthesis due to project time constraints.

Review of synthesis for transferability between regions and sectors

The research identified for each state/territory was initially reviewed and captured separately in order to draw out state/territory-specific lessons. However, as a stated interest from FORNSAT was identifying transferable lessons and comparisons across regions, states/territories and sectors, the full body of research reviewed was considered for each synthesis report. As discussed under 1.3.1 Project limitations, there turned out to be limited consideration of geographical distinctions within the research examined, as only a limited number of research pieces considered the current policy frameworks for state/territory government. As a result, the majority of research reports reviewed were determined to have elements of transferability between regions and/or sectors.

State/territory government consultation and NCCARF peer review

Draft reports were submitted to FORNSAT representatives and NCCARF in March 2013 for review. In March and April, AECOM also conducted a workshop in each state/territory, with the exception of the Northern Territory whose representative was not interested in a workshop at this time, to further discuss the project and gather feedback. The Northern Territory representative provided written feedback on the draft report.

Draft reports were also submitted for a peer review by a qualified science reviewer identified by NCCARF.

Report finalisation

Feedback provided during consultation workshops along with written comments provided by FORNSAT representatives and NCCARF science reviewers were incorporated as feasible into the final versions of the reports. Each FORNSAT representative was also sent a draft version of their report with changes incorporated for a final review prior to submission to NCCARF for publishing.

1.3.1 Project limitations

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. Within this approach, bias is inherent and the authors of this report acknowledge that bias. This bias was also inevitably further compounded by the interests and experiences of the individual authors of this report.

In compiling this synthesis, an interpretative approach was used and the research was approached subjectively – first to identify research findings relevant specifically to the responsibilities of state and territory, secondly to focus on research findings developed or currently being developed under the program of research undertaken by the National Climate Change Adaptation Research Facility (NCCARF).

While this synthesis was also initially intended to draw out themes of learning specific to each individual state and territory, review of the literature indicated that:

- there is limited consideration of geographical distinctions within the research examined – largely as a result of only a limited number of research pieces giving consideration to current policy frameworks for this particular level of government;
- research findings that targeted to a location are often very specific and at a level of detail not necessarily relevant to a synthesis approach; and
- research findings were generally based on a specific climate hazard (such as flooding, heatwaves, bushfires etc.), which are largely common risks faced by all states and territories but with different levels of likelihood and underlying vulnerability.

As a result, the roles and objectives of state/territory government (when defined) are discussed to place the research in the context of each state/territory's needs and activities. However, this synthesis largely presents broader themes and findings occasionally specific to a sector but rarely specific to an individual state/territory. This can be considered an advantage as it creates a larger pool of potential knowledge but also a disadvantage as it presents few distinct and specific directions to further the adaptation policy creation and implementation at a geographical scale.

The synthesis and project database are also not intended to be comprehensive collections of all research on adaptation relevant to states/territories in Australia. As a result, the following limitations should also be noted:

- international adaptation research was not included unless it was specific to Australia.
- journal articles relating to climate change impact studies were not been included unless they specifically mentioned adaptation in the abstract.
- some modelling articles (such as those discussing the pros and cons of various models on impacts) have not been included, despite possibly falling within the adaptation spectrum.
- research connected to adaptation (disaster management, planning, etc.) was likely not captured unless it directly mentioned climate change.
- neither NCCARF nor FORNSAT received a list of research that was determined to not meet the criteria. As a result, there is a risk that eliminated research was considered relevant by NCCARF or FORNSAT representatives. This risk was mitigated by asking FORNSAT representatives to nominate additional research.

A final limitation of this work is project timing. Literature was gathered between August and October 2012; research completed after October and research not publicly available during this time was not included unless nominated by NCCARF or FORNSAT. However, in order to incorporate the majority of NCCARF research, draft reports commissioned by NCCARF were considered. Many of these reports are still undergoing peer review and are not yet available publicly. Draft research incorporated into this synthesis is denoted as such in the reference (for example, Smith, 2013D).

Completed first drafts of some NCCARF commissioned research were also not yet available for inclusion in the synthesis. In order to include these projects in the database, the researchers were surveyed to gather the database attributes and were asked specific questions about the relevance of the project to government decision-makers and about the project's likely policy implications.

AECOM recognises that the inclusion of incomplete NCCARF research but not research in progress from other agencies, universities, government bodies and institutions (e.g. CSIRO) is an inconsistency and a limitation of this project.

1.4 The role of government in adaptation

Government and private parties both have essential roles to play in supporting adaptation to climate change. Government is responsible for managing risks to public goods and assets (including the natural environment) and to government service delivery. Businesses and individuals are best placed to manage the risks to their own private assets and income. However, government is also responsible for creating an institutional, market and regulatory environment that supports and promotes private adaptation to climate change (DCCEE 2012).

The three levels of government in Australia have different roles to play in climate change adaptation. In some cases, adaptation will be best managed by an individual state or territory, whereas in other cases it will require collaboration across tiers of government and jurisdictions (DCCEE 2012). The Commonwealth will need to take a leadership role in climate change adaptation, driving and coordinating national reform efforts while managing the key assets under its control (DCCEE 2012).

State and territory governments, the primary audience for this report, deliver a wide range of services, administer a significant body of legislation, and manage important assets and infrastructure – all of which are likely to be directed impacted by climate change (DCCEE 2012). To assist with adaptation and encourage climate resilience and adaptive capacity, state and territory government's primary roles are to (DCCEE 2012):

- collaborate with Commonwealth and other states/territories to provide local and regional science and information
- manage risks and impacts to public assets, infrastructure and services
- through planning, policy and legislation, encourage effective adaptation by asset and infrastructure owners and managers (both public and private)
- collaborate with other jurisdictions when necessary to manage risks and provide emergency services
- work with the Commonwealth and other jurisdictions to establish and implement national adaptation priorities and to improve adaptive capacity and strengthen climate resilience in vulnerable communities, establish a consistent approach to regulation and education, and implement monitoring and evaluation of adaptation response
- promote risk management response by government and the private sector through appropriate forums and communication channels
- ensure regulatory frameworks promote effective adaptation by private parties, utilising market mechanisms when most likely to be effective
- support local government in efforts to build resilience and adaptive capacity in the local community and in creating and implementing policies and regulations consistent with state/territory government adaptation approaches.

Adaptive responses to climate change are often localised, meaning responses and their benefits depend on location and local circumstances. A decentralised approach that strongly emphasises local or regional action is often most effective and efficient (Cimato and Mullan 2010). For this reason, local governments are essential to addressing the impacts to climate change, and the coordination between state/territory and local government is especially important. Local government is best positioned to inform state/territory government and the Commonwealth of local and regional needs, to communicate with their communities directly, and to respond to local changes in an appropriate and timely manner (DCCEE 2012).

Table 2 presents the key functions of the Northern Territory government and the potential climate change impacts that are likely to affect each department's areas of responsibility. An understanding of the duties of different departments and how climate change will affect them and their constituents can help determine the role each part of territory government can play, or their sphere of influence, in adaptation planning and action.

Table 2: Key functions of the Northern Territory government and potential climate change impacts

Department of Children and Families	**Key functions**
	Develops and oversees the implementation of strategic plans, policies and programs for childhood care and family services
	Sets governance standard and policies improve the lives of vulnerable children, families and individuals.
	Potential climate change impacts
	Need to support communities vulnerable to the impacts of climate change
Department of Attorney-General and Justice	**Key functions**
	Provide advice to government on justice related issues
	Manage programs and projects that develop, support and protect the community
	Develop, coordinate, implement and evaluate government policy
	Potential climate change impacts
	Sea level rise impacts on coastal planning
	Impacts on sustainable land use and protection of natural assets
Department of Business	**Key functions**
	Deliver business and industry development services, defence support, and employment and training
	Stimulate business innovation, research and knowledge development
	Regulate workplace health and safety, dangerous goods, electrical safety, and rehabilitation and workers' compensation through NT WorkSafe
	Provision of strategic programs and activities to support business and industry development
	Potential climate change impacts
	Increased costs and risks to business
	Increased need for climate change related science and knowledge
	Need to support innovation and to assist in the development of new technologies
	Realignment of training and development programs to support emerging industries
Department of Chief Minister	**Key functions**
	Services the needs of the Chief Minister and Cabinet as well as the Leader of the Opposition
	Coordinates and implements government policies
	Potential climate change impacts
	Impacts of extreme climate events on government services, infrastructure, natural assets and community well-being
	Broader transitional impacts on the territory economy
Department of Education and Children's Services	**Key functions**
	Provides educational and training options for Territorians from the early years to adulthood
	Potential climate change impacts
	Increasing need for climate change related science, education and knowledge
	Need to support communities vulnerable to the impacts of climate change
Department of Primary Industries and Fisheries	**Key functions**
	Delivers strategic services that support profitable and sustainable primary production
	Promotes industry growth and ensure access to markets for animals, plants, and animal and plant products
	Potential climate change impacts
	Reduced cropping yields and reduction in viticulture quality and suitability
	Increased forest vulnerability to fire and lack of water
	Increased heat stress and water allocation for livestock
	Increased exposure to pests and disease
	Damage to agricultural infrastructure (e.g. fencing, water reticulation) resulting from increased fire frequency and intensity

Department of Health	**Key functions**
	Management and delivery of public health services and programs for child, youth and family. These also include ambulance services, drug and alcohol withdrawal, disability services, family support services and other community-related services
	Potential climate change impacts
	Increasing physical and mental impacts on health from extreme weather events and heat
	Impacts on vulnerable members of the community
	Increasing prevalence of some vector-borne and respiratory diseases
	Increased incidence of bacterial contamination of water resources, particularly in remote communities with existing potable water supply challenges
Department of Housing	**Key functions**
	Deliver social housing programs through public housing, supported accommodation, and home ownership.
	Potential climate change impacts
	Impacts on housing and service provision, including impacts on NGOs
	Impacts on vulnerable members of the community
Department of Infrastructure	**Key functions**
	Provides strategic advice and policy on a whole-of-government basis for infrastructure planning, building sustainability issues, energy management and capital works
	Provides project management services for the design, procurement and supervision of the NT Government's infrastructure program
	Potential climate change impacts
	Disruption and damage to assets and infrastructure during extreme events
	Increasing cost and demand for electricity and water
	Water availability and allocation
	Impacts on sustainable resource use and management
	Increased vulnerability and risks for certain regions, potentially changing the suitability of land for development, agriculture or other uses
	Increased maintenance requirements
	Changes to infrastructure and service demands
	Disruption to transport networks
Department of Lands, Planning and the Environment	**Key functions**
	Develop effective and sustainable land use plans
	Control and enforce standards for land development and buildings to ensure that they can withstand the local climate
	Conserve and promote the Territory's natural and cultural heritage
	Potential climate change impacts
	Negative impacts of climate change and more frequent extreme events on natural and cultural heritage
	Changes in ecosystem and land use management needs.
Department of Land Resource Management	**Key functions**
	Management of bushfire prevention, water resources, flora and fauna, and land use
	Potential climate change impacts
	Negative impacts of climate change and more frequent extreme events on ecosystems and water resources.
	Changes in ecosystem and land use management needs.
	Decline in rainfall and reduction in both run-off to surface water storages and recharge to aquifers
	Increase in evaporation rates driving demand
	Loss of biodiversity in arid-land wetlands (i.e., Central Australian water holes and river catchments)

Department of the Legislative Assembly	**Key functions**
	Responsible for parliamentary matters and operations covering infrastructure, education, and human resources.
	Comprise of the following units: Office of the Speaker, Office of the Clerk , Chamber Support Services, Hansard Services, Committee Office, Strategic and Business Support Services, Building and Property Management Services, Parliamentary Education Services, and the Security Services Unit.
	Potential climate change impacts
	Increased costs and risks to business
	Negative impacts of climate change on local, territory and national economies
Department of Local Government	**Key functions**
	Strengthen local government capacity
	Management and maintenance of local infrastructure
	Support animal welfare education and ensure legislative compliance across the Territory
	Potential climate change impacts
	Negative impacts of climate change on local, territory and national economies
	Increasing cost of maintaining local government assets and services
Department of Mines and Energy	**Key functions**
	Attracts capital investment to the Territory
	Assistance and advice in indigenous liaison and land access issues
	Promote opportunities in energy related areas, including oil, gas, petroleum, geothermal and alternative energy
	Grant and license support for companies
	Potential climate change impacts
	Negative impacts of climate change on local, territory and national economies
	Changes to energy demands and increased energy costs
	Increased costs and risks to business
	Increase in heat stress experienced by outdoor workers
	Increase in dust intensity and resultant issues
	Potential for new business development
Department of Regional Development and Indigenous Advancement	**Key functions**
	coordinate whole-of-government Indigenous policy
	Provide interpreting and translating services to improve access to services for all Territorians
	build regional economies through enterprise development, job creation and infrastructure investment
	Potential climate change impacts
	Increasing vulnerability and structural adjustment for regional economies
Department of Sport and Recreation	**Key functions**
	Construct, maintain and manage key sporting facilities
	Deliver an Indigenous Sport Program targeted at remote communities
	Deliver water safety programs, including administering the Swimming Pool Safety Act
	Potential climate change impacts
	Negative impacts of climate change and more frequent extreme events on sporting facilities
	Impacts of extreme weather events on community well- being
Department of Transport	**Key functions**
	Provides public transport and road services, including compliance audits and education and safety awareness programs
	Manages public transport assets and infrastructure
	Potential climate change impacts
	Damage to transport infrastructure from extreme events as well as warmer and drier conditions
	Increased vulnerability and risks for certain regions, potentially changing the suitability of land for development, agriculture or other uses
	Increased maintenance requirements
	Changes to infrastructure and service demands
	Disruption to transport networks, including those servicing remote indigenous communities

Department of Treasury and Finance	**Key functions**
	Providing advice on and management of the Territory's whole of government budgeting and financial matters, including superannuation
	Manages collection of taxes, mineral and petroleum royalties.
	Administers home owner incentive schemes
	Advises the Treasurer and the Government on economic issues affecting the Territory
	Potential climate change impacts
	Negative impacts of climate change on local, territory and national economies
	Increasing cost of providing and maintaining government assets and services
Tourism NT	**Key functions**
	Markets the Territory as a desirable visitor destination
	Facilitates the sustainable growth of the tourism industry in the Northern Territory
	Potential climate change impacts
	Change to length and timing of preferred tourist season, due to extreme heat
	Disruption and damage to supporting infrastructure and services due to extreme weather events

1.5 The adaptation challenge for government and the role of research

Climate change is one of the most pressing issues of our time and one of the most challenging to address. It exceeds the capacity of any one actor – be that government or the private sector – to understand and respond to. In fact, the motivation and actions of all individuals and all levels of government are critical and interactive components of the solution. Mitigation efforts to reduce greenhouse gas emissions are important, but some level of climate change has occurred and further change is inevitable. There is considerable uncertainty related to future climate change, but sufficient evidence exists to start planning adaptation action. Increasingly frequent and extreme weather events combined with continued economic growth suggest that action to adapt to climate change is increasingly urgent. Pre-emptive adaptation action is also likely to be the most efficient, effective, equitable and sustainable approach to managing the risks associated with climate change (Department for Environment, Food and Rural Affairs 2010).

Adaptation to climate change clearly presents new challenges and opportunities for decision-makers. While decision-makers may aim to make sensible decisions that take into account current and future climate change, they frequently lack a clear understanding of their own vulnerability to climate variability (Preston and Stafford-Smith, 2009). Furthermore, as climate change and adaptation are complex topics, policymakers may feel the need to wait for science to provide clear answers before taking action. This creates a fundamental challenge, as there are a number of areas of public policy and management directly related to climate change that still have critical unanswered questions (Morton et al. 2009). Decision-makers are being asked to use their partial knowledge and the current state of scientific knowledge to implement specific policies and measures; they are finding this a difficult undertaking (Preston and Stafford-Smith 2009 and Morton et al. 2009).

According to the Australian DCCEE (2011), governments face numerous barriers to adaptation-related decisions, including:

- limits to the availability of, or access to, information as well as the understanding, funds, expertise and other capacity necessary to make appropriate decisions and implement the actions that flow from these decisions
- a misunderstanding of the nature and timing of climate change, especially the perception that it will occur in a slow and linear manner
- emerging awareness of a range of institutional, regulatory and other factors which act to constrain action to prepare for the impacts of climate change.

To address some of these challenges, Australian state and territory governments frequently fund or undertake research activities to support their direct needs. However, state and territory government decision-makers are also reliant on independent research. Utilising this research effectively is challenged by a number of factors, including its discoverability, accessibility, direct relevance to the context (physical, socioeconomic, ecological or geographical), clarity, internal processes and capacity of decision-makers (Preston and Stafford-Smith 2009 and Morton et al. 2009). In its attempt to make a large portion of Australian adaptation research easily accessible to state and territory decision-makers, this synthesis aims to help reduce this barrier.

2. THE NORTHERN TERRITORY'S CLIMATE CHALLENGE

In order to plan for climate change and prioritise adaptation activities, it is important to understand what climatic challenges are occurring now and will be faced in the future. This section of the report highlights the current state of the climate, the climatic changes anticipated, and how these changes are expected to affect the Northern Territory. Recognising that considerable activity has already occurred in the territory to address these climatic challenges, it also highlights Northern Territory's current adaptation priorities and current and past activities.

2.1 Current and future climate

The Northern Territory's climate varies significantly spatially, with two distinct climate zones. The northernmost section of the territory–or the Top End – which includes Darwin, experiences a highly humid tropical climate with a wet season lasting from November to April and a dry season between May and October. The centre and south of the Territory, including Alice Springs and the Uluru national park, experiences a semi-arid climate (DCCEE 2012). Maximum temperatures are higher in the south of the territory during the wet season and in the north during the dry season, with minimum temperatures higher in the north than the south for both seasons (AECOM 2010a). The wet season in the Top End is influenced by the summer monsoon with summer thunderstorms and cyclones, which are somewhat limited or supressed by El Niño events and intensified by La Niña events (AECOM 2010a).

The historic average rainfall for the entire Territory is 540.2 mm, the long-term average maximum temperature is 31.9^{o}C, and the long-term average minimum temperature is 18.5^{o}C (Australian Bureau of Meteorology 2013a).

The wet season has tended to become warmer over the past three decades, with more hot days over 35^{o}C, and an increase in rainfall (though the relative humidity has showed little change). The dry season has also tended to become warmer with more hot days over 35^{o}C, though decreased rainfall has been recorded (AECOM 2010a). Dry season bushfires are a frequent and prevalent feature of the tropical savannahs of Northern Territory, and are considerably more numerous and sizeable than any other region in Australia (Bryant 2008; Eldridge 2012). Weather influences the incidence of bushfires both during the event by providing favourable atmospheric conditions, and in previous seasons and years though establishing vegetation growth, and drying biomass that acts as fuel for the fires (Bryant 2008).

Sea level rise of has been recorded in the Northern Territory coastal zone, and is occurring at an approximate rate of 7.5 mm a year – double the global average of around 3.1 mm per year estimated for the 1993 – 2003 period (AECOM 2010a).

Due to the vicinity of the Northern Territory coastline to the equator, tropical cyclones pose a serious threat to communities and business, with an average of 7.7 cyclone days per season for the Northern Region (Australian Bureau of Meteorology 2013b). Darwin, the coastal capital of the Territory, was the site of Australia's most significant cyclone event – Cyclone Tracy. This was responsible for the loss of 71 lives, displacement of the majority of the population and major destruction of infrastructure and homes (DCCEE 2009). The direct and indirect costs of Cyclone Tracy were in the billions of dollars. Overall, cyclones have accounted for more than 90 per cent of natural disaster costs since 1967 (DCCEE 2009).

Temperature increases are predicted to continue in the Northern Territory, particularly in the south west of the territory and in the Wet Season. Temperatures during the day time and the number of hot days are predicted to increase in the Top End during both the wet and dry seasons, with worst case A1F1 emissions scenarios returning a 3.5^{o}C increase in the wet season and a 3.4^{o}C in the dry season by 2070. The majority of models also predict a reduction in rainfall for both the wet and dry seasons, accompanied by a slight decrease in humidity across both seasons (AECOM 2010a). The Northern Territory is also expected to experience a change in temperature extremities including up to a sixfold increase in the frequency of days over 35^{o}C in Darwin by 2030, and up to twenty-eight fold by 2070; and double the frequency of days over 35^{o}C in Alice Springs by 2070 (DCCEE 2012).

With continued climate change, there is a predicted reduction in total cyclones for the territory, with an increase in the intensity and proportion of higher category tropical cyclones (DCCEE 2012), and more intense storms overall. Sea level rise in synergy with more intense storms will increase storm surges which are expected to lead to sea water inundation and riverine flooding in the Northern Territory (DCCEE 2012).

2.2 Climate change impacts for the Northern Territory

The expected changes in climate will have a range of impacts across Northern Territory's population, economy and environment. The following summarises a selection of expected impacts by sector.

Health and wellbeing

Increasing temperatures and extreme weather events pose a serious risk to human health, with the potential to cause injury, illness and death. Temperature related health impacts include heat rashes, heat exhaustion and heat stroke, which are likely to increase with projected changes to temperature, including the intensity, frequency, length of hot periods and the temperature rate of change (McMichael et al. 2003 in Green 2006).

Up to an extra 346 temperature related deaths due to climate change are predicted by 2100 for the Northern Territory (DCCEE 2012), though there is also likely to be a decrease in winter respiratory infections and deaths in parts of the Northern Territory because of increases in temperatures (Green 2006). People most vulnerable to heat related health impacts include people with cardiovascular disease and the elderly (McMichael et al. 2003 in Green 2006).

Asthma and respiratory diseases are likely to increase due to increased particulate matter in the atmosphere including higher dust from dryer, less vegetated landscapes and from bushfires (McMichael et al. 2003 in Green 2006). An increase in vector born disease from mosquitos is possible in some areas due to changes in water storage practices (such as increased water tank usage to adapt to drought) and a moderately warm and wetter climate (DCCEE 2012). Food, waterborne and communicable diseases also have the potential to increase without control measures (DCCEE 2012, Green 2006).

Extreme weather events can have flow on consequences to health by causing disruption to services and social systems such as hospitals, emergency services and community service/ welfare organisations (Green 2006).

Some socioeconomic and culturally and linguistically diverse (CALD) communities also have increased health vulnerabilities. This is particularly true for indigenous communities in Northern Territory, with a high incidence of existing health problems such as heart, kidney and respiratory conditions, infectious diseases, diabetes and mental health issues, all which have the potential to be exacerbated by climate change (Green 2006).

Fisheries, forestry and agriculture

Agricultural activities, including cattle farming, cropping and vegetable production, remain an important part of the Northern Territory economy. Climate change impacts on average rainfall, intensity and timing of rainfall events, average temperatures and intensity of storm events are predicted to have a major impact on these activities. In particular, climate change is likely to significantly reduce beef production in the Northern Territory. Increases in temperature and heat stress can reduce appetite and slow growth rates, as well as exacerbate vector related problems, with potential reductions of 19.5 per cent of cattle population by 2030 and by 33.2 per cent by 2050 (DCCEE 2012).

Natural environment

Climate change is likely to have significant impacts on iconic natural heritage sites such as Kakadu. Salt water intrusion from projected sea level rise is likely to result in fundamental change in ecosystem function, placing extreme pressure on various plant and animal species. The impacts of this change have already been observed, with salt water inflows over the past 50 years reducing Melaleuca forest by up to two thirds (DCCEE 2012).

An increase in the frequency and intensity of fires is expected, impacting on habitat, food sources and the structure of ecosystems (AECOM 2010a).

Predicted changes to species distribution, habitat and food sources will also impact on the availability of bush tucker. Items such as turtle eggs, sugar bag and yams form an important part of the diet of Indigenous people in some areas of the Territory (AECOM 2010a).

Community and infrastructure

Climate change will have direct and indirect impacts for the Northern Territory's built environment as a consequence of increasing temperatures, changing rainfall patterns, and rising sea. A sea level rise of 1.1 m is likely to impact on an estimated 260 to 370 residential buildings (currently worth $100 million - $134 million) and 24 commercial buildings (up to $500 million) in the

Northern Territory, as well as 2,045 km of roads ($1.8 billion) and 32 km of rail ($100 million) (DCCEE 2012). There is the additional risk of loss of water distribution and storage capacity due to salt water intrusion into groundwater from sea level rise.

The predicted increase in the intensity of cyclones will impact on buildings and infrastructure, particularly those built prior to changes to minimum design and construction standards. While critical infrastructure including power stations, water treatment plants, sewage treatment plants and hospitals are required to be designed to survive a 1-in-2,000 year event, only a small percentage of Darwin's total buildings are guaranteed to conform to post-2001 strengthened building code requirements (DCCEE 2009). The increase in number and intensity of storm events is also predicted to impact on energy transmission and distribution infrastructure, ferry and barge landings, airstrips, wastewater treatment infrastructure and communications infrastructure (AECOM 2010a – f).

Business and industry

Tourism is a major contributor to the Northern Territory economy making up approximately ten per cent of the Territory's economy (DCCEE 2012). A reliance on nature-based tourism, promoting unique natural environments, outdoor attractions and activities, makes the Northern Territory tourism industry particularly vulnerable to climate change impacts. Existing visitation patterns indicate a lower preference for the Northern Territory as a tourist destination during the hotter months of the year, and with climate change predicted to make these periods longer and hotter, this could result in a significant drop in tourism levels for the Territory (AEC Group 2007). Iconic sites, such as Kakadu National Park, are also directly threatened by the impacts of climate change and could be irreparably damaged by sea level rises (DCCEE 2012).

Manufacturing, mining, healthcare and professional services industries all have the potential to be significantly impacted by extreme weather events, increasing temperatures and sea level rise. In particular, the impact on transport, utilities and communications infrastructure could result in severe disruptions to businesses (AECOM 2010a – f).

2.3 The Northern Territory's adaptation priorities and activities

The Northern Territory Government has not released a formal set of climate change adaptation and adaptation priorities. The previous Territory Government's *Climate Change Policy 2009* was principally concerned with actions to mitigate climate change and 'greening' the Territory. This noted, the policy does identify adaptation challenges for the Territory that include increased water demands and reduced availability, natural resource management challenges relating to sea level rise and salt water inundation, increased bushfire and biosecurity risks. The policy also identifies potential responses to these challenges, including barrage upgrades on the Mary River and the establishment and extension of conservation corridors to improve biodiversity resilience (Northern Territory Government 2009).

The Greater Darwin Region Land Use Plan Towards 2030 Consultation Paper (Department of Lands and Planning 2011) identifies the need for climate change impacts to be considered in urban development. It specifically notes a need for vulnerability mapping to identify high risk areas, and for this to be considered in decision-making regarding urban development.

The Kakadu National Park Management Plan 2007-2014 identifies the loss of biodiversity, increases in water extremes (drought and flood), extreme weather events, altered fire regimes and the need to relocate infrastructure from high risk areas as possible management implications related to climate change (Hadwen et al. 2011). The Kakadu National Park Climate Change Strategy 2010 – 2015 also identifies a number of managed adaptation options that relate to biosecurity, fire management, refugia identification, and protection of freshwater habitats from saltwater intrusion (Hadwen et al. 2011).

3. RESEARCH RELEVANT TO THE NORTHERN TERRITORY

This project primarily draws upon NCCARF-funded research. However, the synthesis findings (Section 4.0) also utilise a selection of policy-relevant research gathered through Australian sources. This section of the report provides further information on the research collected and synthesised for this project and, in particular, highlights which research studies occurred in the Northern Territory.

3.1 Identified adaptation research

Over 450 research reports (including NCCARF-funded research) were gathered in total and included in the database that accompanies this project. **Error! Reference source not found.**Figure 2 displays the number of research reports collected by the state/territory in which the research occurred (meaning that state/territory was stated as the study area). A large portion of the research collected had national relevance as they did not contain case studies specific to a state/territory. For the location-specific research, Queensland and Victoria were most commonly studied, followed by New South Wales.

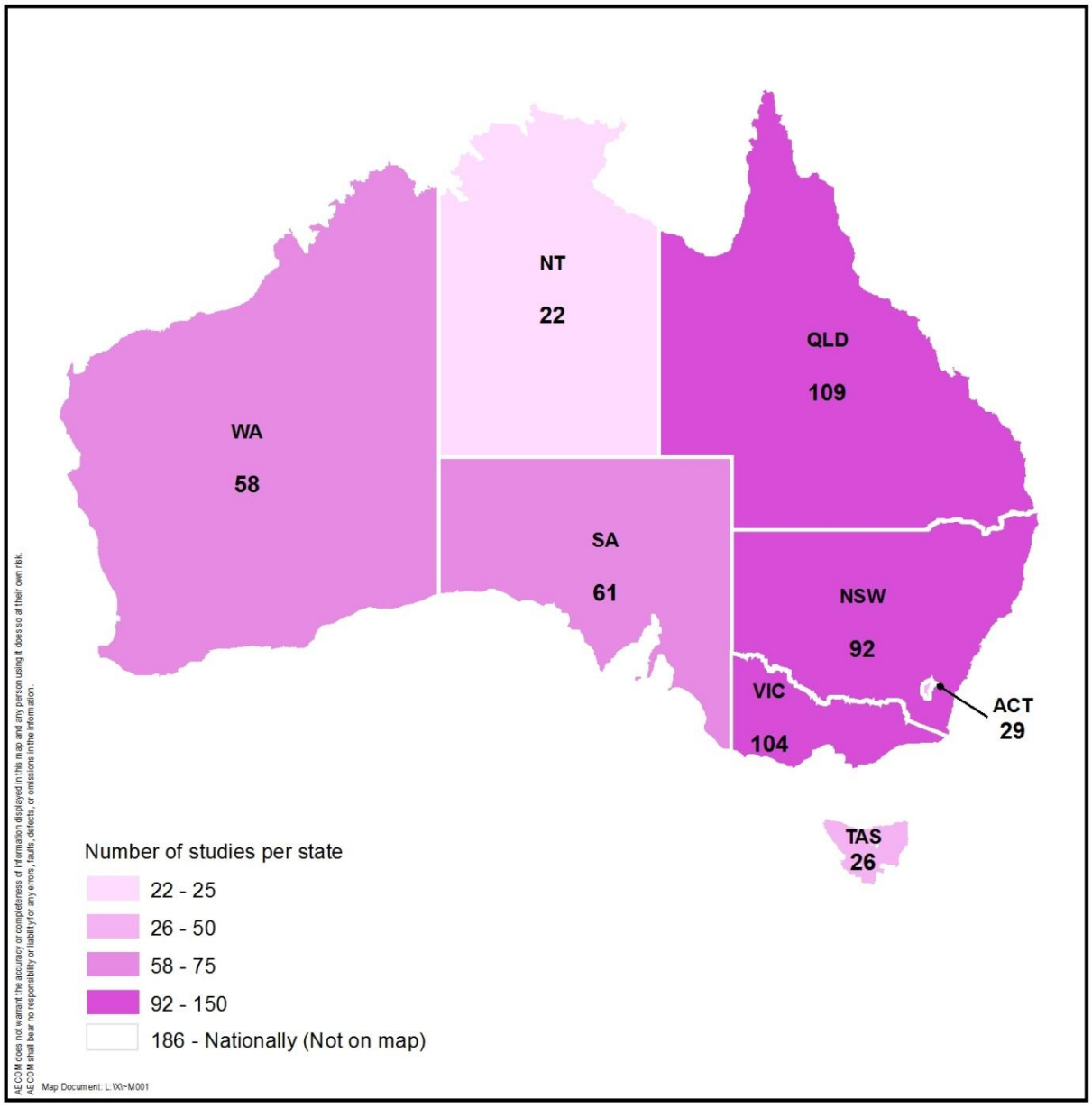


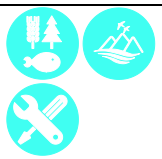
Figure 2: NCCARF and non-NCCARF research by state/territory

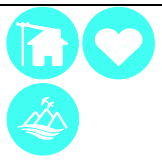
A selection of the research gathered for the database was included in the synthesis (Section 4). Some NCCARF reports were unable to be included as research drafts were not available at the time of synthesis drafting. Others were excluded as their content was not directly relevant to state/territory government policy- and decision-makers. A full list of excluded projects is included in Appendix D. Up to 15 pieces of research specific to each state/territory but not part of the NCCARF-funded research pool were selected and reviewed for synthesis in addition to the NCCARF reports. The research was selected based on its relevance to adaptation response and territory government policy.

3.2 Northern Territory-specific research

Research projects used to inform and shape this synthesis occurred across Australia, as many lessons were transferrable to multiple geographies. The bibliography lists all research projects reviewed for this report. However, some research projects used as the foundation for this synthesis consider adaptation specifically within the Northern Territory and are listed in Table **.** These projects were chosen on the basis that their research included at least one Northern Territory-specific location or case study, although not all projects were delivered by Northern Territory-based research organisations. The purpose of Table 4 is to assist readers locate a particular report relevant to the Northern Territory that they may wish to find and read further. Note that Table 4 does not include the research reports reviewed that only covered climate change impacts and the Northern Territory government activities, referenced in Section 2.0.

Table 3: Northern Territory-specific research

Lead Author	Status	Year	Title	Sectors
D. Bird	Draft	2013	Future change in ancient worlds: Indigenous adaptation in northern Australia	
W.L. Hadwen	Final	2011	Climate change responses and adaptation pathways in Australian coastal ecosystems: synthesis report	
R. Horne	Draft	2013	Living change: Adaptive housing responses to climate change in the town camps of Alice Springs	
K. Haynes	Final	2011	Institutional response and Indigenous experiences of Cyclone Tracy	
BMT WBM Pty Ltd	Final	2010	Kakadu – Vulnerability to climate change impacts	
A. S. Kiem	Final	2010b	Learning from experience: historical case studies and climate change adaptation	

Lead Author	Status	Year	Title	Sectors
M. Mason	Final	2010	Adaptation lessons from Cyclone Tracy	
D. Green	Final	2006	Climate change and health: impacts on remote Indigenous communities in northern Australia	
A. Hurlimann	Final	2011	Voluntary relocation – An exploration of Australian attitudes in the context of drought, recycled and desalinated water	
L. Petheram	Final	2010	'Strange changes': Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia)	
L. Petheram	Draft	2013	For-sea-ing change: Indigenous women's preference for adaptation to climate change	

3.3 Northern Territory locations of research

Figure 3**Error! Reference source not found.** maps the study locations and study regions for the research reviewed for the synthesis within the Northern Territory. This map demonstrates that research has been concentrated in the northern part of the territory, particularly in the capital Darwin and Kakadu National Park. The other region examined was Arnhem Land. Due to their proximity to the coast, these areas are more likely to experience impacts of climate change including sea level rise and increases in the intensity of tropical cyclones. The focus on Kakadu National Park can also be attributed to its unique ecological and cultural significance and status as a UNESCO World Heritage Site. Alice Springs was the only study location in the southern areas of the territory, though more than one study addressed this location.

Appendix C includes summaries of the NCCARF-funded research that occurred in the Northern Territory.

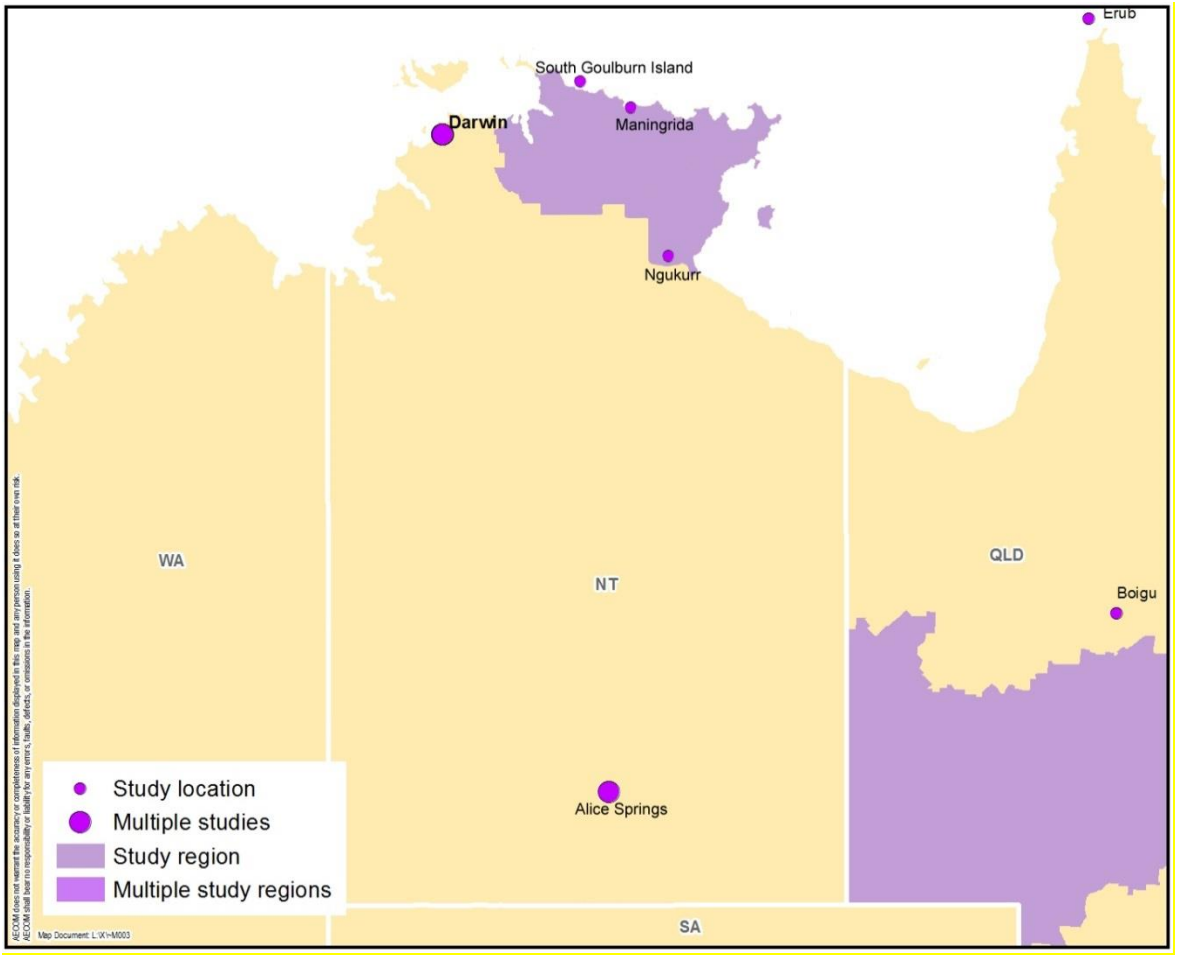


Figure 3: Case study locations of synthesised adaptation research in Northern Territory

4. RESEARCH FINDINGS

The role of a synthesis is to value add to existing research by breaking down individual research reports and aggregating findings to form a new whole based on common threads or themes of learning. A synthesis of research is also usually formulated in an attempt to find answers to a specific question or a series of questions. For this synthesis, that question was: “What are the common emerging adaptation research lessons that can be used by state and territory decision-makers, particularly with regards to policy-setting?”

This section of the report presents the main findings of the synthesis by the identified themes. It is important to note, however, that though findings have been categorised into one theme, there are overlapping and cross-theme relationships between the lessons described.

The findings described are the opinions and conclusions of the researchers and are not necessarily the professional opinion of AECOM. It is also important to recognise that, despite best efforts to aggregate findings across multiple research reports, the distinct focus of some of the research has not enabled some findings to be supported by more than one research study.

4.1 Increasing resilience and adaptive capacity

Vulnerability (be that biophysical or socioeconomic) is intrinsically linked with adaptation through the consideration of resiliency and adaptive capacity. The IPCC WG2 (2007) defines vulnerability as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity” (p. 883). This concept is important as many adaptation actions focus on increasing a community or system’s ability to handle exposure to climate change, i.e. increasing its adaptive capacity, and thereby reducing its vulnerability. Increasing adaptive capacity can relate to changes in resources (e.g. financial or human capital) and institutional or governance arrangements.

Resilience is a related term that can create confusion as it could be interpreted to mean returning to a prior state after a disturbance while adaptation usually refers to a fundamental shift or transformation in state (Preston and Stafford-Smith 2009). However, often resilience simply refers to a community or system’s robustness or its ability to undergo change while maintaining its integrity. This confusion in terminology is discussed further in Section 4.1.3.

This section outlines the emerging themes identified in the research which are relevant to increasing the resilience and adaptive capacity of communities, systems or individuals. It includes a discussion of pre/-post-extreme event support, lessons regarding building and maintaining community resilience, messaging and communication about climate change and adaptation, and community expectations for government.

4.1.1 Pre- and post-extreme event support

The findings in this section are particularly relevant for emergency management.

Many of the findings presented below and in Section 4.2, Learning from Experience, deal with disaster risk reduction (DRR); DRR is the practice of reducing the disaster risks from extreme events through the reduction of underlying factors that contribute to vulnerability. While technically separate practices, DRR and climate change adaptation converge on the common goals of risk and vulnerability reduction. They differ in multiple ways: two key distinctions are that DRR addresses broader risks, beyond climate, including volcanic eruptions and earthquakes, which adaptation does not; and that adaptation considers longer-term changes to climate while DRR is mainly interested in extremes. However, at the local level, many communities also do not see a separation between the two (Gero et al. 2010). Therefore, the historical experiences of DRR can contribute greatly to climate change adaptation, and the integration of the two is often recommended (Gero et al. 2010).

Key findings for increasing resilience and adaptive capacity pre- and post-extreme events:

- Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience.
- Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and well-being.
- Adaptation and emergency assistance needs to take into account a community's short- and long-term challenges, including broader socio-economic issues.
- Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness.

Government financial support post-disaster is complex and could lead to moral hazard and reduced resilience. Provision of government assistance post-disaster is a complicated issue given the complexity and cost of insurance arrangements and limited capacity of the uninsured to make changes to their homes due to lack of funds (Bird et al. 2011). Nonetheless, some research suggests there is a real risk that this type of financial support could deter some residents from covering their own risk and instil expectations that may be detrimental to a community's long term resilience (Bird et al. 2011). As stated by Macintosh et al. (2013D):

> If there is an expectation that governments will manage the risks, and cover private losses when risks materialise, the incentive to avoid at-risk areas, and to take appropriate preventative action, will be reduced. In a liberal democracy like Australia, where there is a significant social safety net and governments provide extensive emergency assistance, eliminating this expectation would be difficult and could involve considerable political cost (p. 28).

This may be particularly problematic if people are reluctant to donate to the sources of these funds, such as the Premiers Flood Appeal, as the frequency of extreme events increases, and governments are unable to afford continued assistance (Bird et al. 2011). In addition, Boon et al. (2012D) found that, in some cases, providing financial support from state or federal agencies and NGOs to residents faced with the adverse impacts of floods, bushfires and cyclones does not support resilience and can facilitate a departure from the community, thereby potentially reducing the resilience of the community as a whole.

Targeted preparation investment, including subsidising community emergency supplies and SME support, is critical to community economy and wellbeing. Being financially able to prepare for a disaster is critical for resilience. Boon et al. (2012D) suggest that emergency supplies, preparation kits and other items encouraging a proactive response to extreme weather events should be subsidised. Similar issues for small to medium sized enterprises (SMEs) were also noted in Victorian bushfire and flooding case studies by Kuruppu et al. (2013D). Historical disaster response initiatives supporting the economic recovery of SMEs were found to be generally reactive and to fail to specifically address underlying vulnerabilities, such as limited access to financial and human resources, under-insurance and operational location challenges. The effectiveness of these assistance measures was perceived by SMEs to be further limited as a result of:

- the short-term duration of business recovery programs (generally only up to three years following an event).
- the limited support available to SMEs indirectly impacted by climate hazards and in preparing disaster response and recovery. This sentiment has also been raised as an issue between farmers and non-farmers in relation to drought assistance in Victoria (Sherval and Askew 2012).
- lack of consideration of the psychological impacts for SMEs.
- difficulties in accessing recovery funds.

These identified shortfalls suggested the importance of ensuring that business continuity for SMEs under climate change is integrated into existing processes and networks (Kuruppu et al. 2013D). This type of approach was undertaken with SMEs in Western Australia in response to drought where counsellors were assigned to support local businesses with more strategic business planning processes to improve resilience. Given the importance of SMEs to local economies and to community resilience, further consideration needs to be given to more proactive adaptation support to this sector.

Adaptation and emergency assistance needs to take into account a community's short- and long-term challenges, including broader socio-economic issues. Adaptation and response to extreme events cannot be considered in isolation. As noted by Kiem et al. (2010b), the social and economic issues facing many

communities (inland, rural) are not just the product of a climate hazard and to understand them as such underestimates the extent of the problem and reduces the effectiveness of intervention. While the type of disaster, its intensity and length of its impact will influence resilience, responses need to take into account short- and long-term issues affecting both individuals and the community as a whole.

Planning for multiple levels of preparedness is needed for catastrophic and less severe events and for the onset of rapid and slow events (Boon et al. 2012D). The first step towards enhancing community resilience requires an understanding of the community's strengths and vulnerabilities, its physical characteristics (e.g. local infrastructure), local governance (e.g. disaster policies and plans) and social characteristics (e.g. level of community cohesion) (Boon et al. 2012D). For example, lack of provision within funding contracts (particularly within government contracts) for community service organisations to act in response and recovery from extreme events, as well as lack of government adaptation policy and guidelines were identified as barriers for these organisations to adapt and act as adaptation enablers for the disadvantaged (Mallon et al. 2013D).

Many adaptation lessons can be learned from decades of drought policy which help illustrate how other external factors, such as the introduction of water trading, commodity prices and aging communities, affect the effectiveness and the equity of interventions. According to Sherval and Askew (2012), local experiences of Victoria's recent drought, particularly in rural towns whose local economies rely on agriculture, are not well understood as a result of the combination of rapidly evolving changes in water market reforms, the drought itself and non-climate related simultaneous changes (in this case, the changes to the Australian Wheat Board). While many of these challenges have been financial, health impacts have also resulted due to the important social and emotional connections with water for the community. The ongoing resilience and adaptive capacity of these towns is severely challenged by multiple drivers of changes, not just a changing climate (Sherval and Askew 2012; Kiem et al. 2010b). Therefore, support needs to take into account underlying vulnerability and support for longer term adaptation within the broader community. For example Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b).

Finally, post-event assistance needs to consider projected future events and the resilience of the community as a whole. This includes changes in frequency and intensity of the same hazard, as well as others where adaptation measures against one risk may introduce new risks from other events – for example buildings built with lighter, more comfortable materials to handle hot, tropical weather can be maladaptive during a cyclone, increasing the risk of damage from flying debris.

Planning for extreme events is important, yet preparedness also needs to be holistic and tested for robustness. In some Australian states, heatwave plans for aged care facilities are directed by the government. For example, heatwave planning is a major focus of health and safety departments in South Australia. Ninety-three per cent of aged care facilities surveyed by Black et al. (2013D) in South Australia had heatwave plans. In Queensland, 41 per cent of facilities had a dedicated heatwave plan, while dedicated plans were uncommon among New South Wales aged care facilities.

Only about half of the facilities in South Australia surveyed had back-up generators, though this was more than the aged care facilities in both New South Wales and Queensland. Many facilities in South Australia also suggested back-up cooling methods that rely on electricity. This indicates that many aged care facilities have not considered the risk of increased power outages during periods of extreme heat, a necessary consideration for planning to be considered robust and holistic. A number of adaptation options are available to reduce risk which could be incorporated into asset renewal and maintenance plans. These include provision of water coolers, tinted windows, window awnings and shutters, reflective roof paint, and air conditioning upgrades (Black et al. 2013D).

Black et al. (2013D) also found variable and inconsistent results across the states/territories regarding staff knowledge of the health effects of extreme heat and the best ways to care for the elderly during very hot weather. Clinical care staff need to be aware of the importance of caring for the elderly in periods of extreme heat, even if air conditioning is available and functioning.

4.1.2 Building and maintaining community resilience

Key findings for building and maintaining community resilience:

- Community connectedness and local networks are strong contributors to community resilience and recovery.
- Resilience of community and individuals will be reduced by people leaving a community following an extreme event.
- Inherent levels of vulnerability and how they may change over time will help prioritise adaptation.
- Community service organisations are important in building resilience and addressing community vulnerability.
- Communities will be more likely to accept adaptation solutions as climatic conditions become more severe.

Community connectedness and local networks are strong contributors to community resilience and recovery. Assistance from friends, neighbours and family during a disaster builds a sense of place, which then supports community resilience. Being connected to neighbours and having friends strongly enhances individuals' resilience, even independently of the length of time of residence in the community (Boon et al. 2012D). Apan et al. (2010) also found that in areas vulnerable to flooding, communities with greater connections displayed more resilience. Furthermore, Boon et al. (2012D) noted that "state government services should not dominate or overshadow local government or volunteer roles, but should support and guide local efforts and initiatives" (p. 264).

Stanley et al. (2013D) identified three ingredients for a community to be successfully adapted: community strength; adequate, secure, on-going financial support to enable the community to do this work; and a climate change and adaptation governance structure that coordinates, enables, promotes and finances a significant part of the adaptation process. Other identified factors of community resilience include:

- capacity to self-organise
- access to social networks, including family
- collective learning from past experiences
- diversification of markets and employment (Boon et al. 2012D).

Resilience of community and individuals will be reduced by people leaving a community following an extreme event. The departure of individuals may further decrease the resilience of both the community and the individuals leaving as they will unlikely be unfamiliar with local conditions and access to support networks in their new location. The desire to leave was predicted following the 2010/11 Queensland floods, which suggests that decisions are influenced by factors relating to reduced adaptability (including ill health, a poor sense of place, low financial capacity) and experience with infrastructure problems. Community members who had received financial support by government or charity groups were also more likely to leave the community, which was consistent with being more financially or emotionally vulnerable, or having sustained extensive damage by the hazard event (Boon et al. 2012D). However, it is also noted that relocation can be considered a form of adaptation, particularly where future climate risks for the location being left are seen as sufficiently high that other adaptive actions may not be perceived as adequate.

The evacuation of the Warruwi community prior to Cyclone Monica, which made landfall in the Northern Territory during April 2006, highlights the importance of effective engagement. Strong community leadership and planning led to indigenous protocols being followed and successful evacuation of the island (Haynes et al. 2011).

Inherent levels of vulnerability and how they may change over time will help prioritise adaptation. Some communities are inherently more vulnerable than others because of their geographical, social, cultural and/or economic situation (Kiem et al. 2010a). Social stratification, particularly wealth inequality, plays a key role in constraining the adaptive capacity of certain communities and individuals, increasing vulnerability (Hanson-Easey et al. 2013D). What has not been well considered in the exploration of adaptation options is how these vulnerabilities may also change over time –

particularly with regards to non-climate drivers and factors.

This theory applies to natural systems and human community systems alike. A community that is degraded in habitat and survival options is more inherently vulnerable to changing climatic conditions. For example, adaptation of Australia's natural systems to climate change will be constrained by:

- rates of evolutionary change versus rates of climate change
- reductions of suitable habitat
- limited capacity to migrate due to habitat fragmentation
- extreme events that reduce the capacity of a forest to recover (Boulter 2012).

Community service organisations are important in building resilience and addressing community vulnerability. However, many community service organisations (CSOs) are highly vulnerable to extreme weather events and would face temporary or permanent closure as a result of major damage to physical infrastructure and disruptions to critical services. This closure is likely to occur over periods when there is a critical need for their services to assist clients to respond to and recover from crisis, with many of the smaller to medium-sized CSOs – and in particular those that provide direct services from an office or building -- facing the risk of permanent closure. The follow-on impacts for those already most vulnerable to climate risks, some of whom rely on CSOs to help overcome everyday adversity, is likely to be severe. Despite these vulnerabilities and the opportunities for CSOs to improve community resilience, they are mostly overlooked in policy and climate adaptation studies.

Communities will be more likely to accept adaptation solutions as climatic conditions become more severe. Hurlimann and Dolnicar (2011) noted that past experience with drought may make people more resilient and less willing to relocate, a response that is discussed further in section 4.2. Participants stated they would explore many options before choosing to relocate and would delay relocation for multiple reasons, including social, financial and attachment to place. For example, people prefer the solution of introducing recycled or desalinated water to the drinking water supply – a move that has a high level of public resistance – to being forced to move due to a water shortage.

4.1.3 Messaging and communication

Key findings related to messaging and communication in order to increase resilience and adaptive capacity:

- Climate change adaptation terms are often misunderstood or understood differently by different stakeholders.
- Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism.
- Communication and education about climate change needs to be targeted to vulnerable and hard to reach populations (older people, low income groups, people with disabilities, newly-arrived migrants and Indigenous communities).
- Collaboration and effective sharing of information is critical.
- The messenger is just as important as the message.

Climate change adaptation terms are often misunderstood or understood differently by different stakeholders. Concepts such as 'resilience' tend to be oversimplified by policymaking and planning processes. Resilience should not be mistaken for stoicism or 'bouncing back' (i.e. returning to a pre-disaster state), as this understanding can actually be a barrier to increasing adaptive capacity by supporting a reluctance to change (Kiem et al. 2010b). Lack of consistent adaptation terminology between organisations will also create issues for cross-jurisdictional communication and cooperation (Hadwen et al. 2011). For example, confusion between 'mitigation' and 'adaptation' was identified within the private sector (Johnston et al. 2013D). At the same time, Howes et al. (2013D) suggest that use and definition of key terms need to better account for socio-economic diversity and allow for more tailored, context-specific responses. As some organisations and departments utilise terms differently, this suggests that terms need to be clearly defined and discussed at the outset of planning processes to ensure all participants have the same understanding.

Climate change messaging needs to be bespoke to its intended audience and should take care not to induce fear, apathy or scepticism. While much of the research recommended the need for more communication with communities, this is not without risks. Awareness of climate change can result in a sense of helplessness, thereby reducing adaptive capacity. Climate change knowledge can generate fear and a lack of

confidence, as evidenced by residents in Victoria and Queensland concerned about climate change being more inclined to leave a potential climate impacted area. This will have resilience repercussions but can also be seen as individuals managing their own risk. It is important to keep climate change messages and disaster preparedness strategies separate. Engage people in disaster preparedness strategies without focussing on climate change messages that may induce further scepticism, apathy or fear (Boon et al. 2012D). People can be adaptable without believing that climate change is a concern. This was highlighted in the Ingham, Queensland case study where residents who were least concerned about climate change showed a high level of resilience to floods (Boon et al. 2012D).

Promoting the implementation of adaptation strategies may also give a sense of false security. Therefore, communication of adaptation responses needs to be upfront about its objectives and known limitations. This was particularly noted in response to flood control schemes which were felt to encourage development in high risk areas (Wenger et al. 2012D). The community response to the failure of the Wivenhoe Dam to protect downstream communities during the 2011/12 Queensland floods is a recent example of this phenomenon. The role of the dam for opposing purposes (drought and flood protection) was not well understood (Kiem and Austin 2012). Drought and flooding strategies need to coexist and need to be carefully communicated to surrounding communities, particularly as climate change projections predict that droughts and intense short-lived rainfall events are likely to occur with increased frequency in the future (Sherval and Askew 2012).

Climate change messaging is particularly complex because, as Hanson-Easey et al. (2013D) note, perceptions of climate change do not exist in an isolated vacuum; they are linked with political views, media representations, personal values, lifestyle imperatives and other concerns, such as financial or cost of living issues (Hanson-Easey et al. 2013D). Because of this and climate change's inherent nature as a complex topic with some degree of uncertainty, climate change frequently struggles to hold public attention when competing with other everyday challenges. For climate change to be perceived as a risk that demands a response from individuals and the local community, it must be presented as a serious, present danger to an asset valued by and relevant to the community (Hanson-Easey et al. 2013D). This needs to be carefully balanced with Boon et al. (2012D) suggestion to avoid generating fear.

Public engagement on climate change, therefore, cannot simply be improved through educating the 'misinformed' with more accurate information (Hanson-Easey et al. 2013D). Instead, the design and implementation of bespoke, tailored climate change communication and visual narratives are needed that align with a community's interests, concerns, and general worldview. This will also help to avoid audience responses being ineffective or eliciting the opposite reaction from those intended (Hine et al. 2013D). 'Climate change will always mean different things to different people, and the opportunities it engenders for social dialogue on what is valuable, who is most vulnerable, and what type of future we want for future generations' (Hanson-Easey et al. 2013D p. 53).

***Communication and education about climate change needs to be targeted to vulnerable and hard to reach populations (older people, low income groups, people with disabilities, newly-arrived migrants and Indigenous communities*).** Related to the point above, targeting needs to take into account local and cultural considerations. Research by Reser et al. (2012) show that people from more closely settled areas with higher levels of education, women and younger generations are more likely to be concerned about climate change although the gap may be narrowing between rural and urban people (Reser et al. 2012). Boon et al. (2012D) also noted that younger generations are more likely to be concerned about climate change; therefore a focus on disaster education for this age group will help this cohort to adapt to longer term changes in climate. Older groups, and those less educated have been found to be the least concerned and informed about climate change.

People from culturally and linguistically diverse (CALD) backgrounds can face greater challenges during extreme heatwaves due to socioeconomic disadvantage, linguistic barriers, poor housing conditions, and cultural practices (such as heavy clothing or not drinking water). For local and state/territory government, creating refuges (such as community houses), providing sheltered bus stops with drinking water, increasing cultural awareness in health services and other agencies, and building stronger partnerships are additional actions that should also be considered (Hansen et al. 2012D).

Fritze et al. (2009) also note that, regarding climate change, hard to reach communities may also include wealthy, high consumption communities, and people who are sceptical about climate change or the proposed actions to address it. Principles for engaging hard to reach communities include devoting time and resources to develop trust, using existing networks and trusted sources of information, and going to places where people feel comfortable.

Carefully designed, well implemented and effective community engagement strategies are important components of effective and inclusive climate change adaptation measures. Citizen engagement in decisions and actions can have multiple benefits including but not limited to securing local ownership and support; creating heightened trust, transparency and credibility for decision-making processes; making policies more practical and relevant; and

achieving cost savings (Fritze et al. 2009). However, Hansen et al. (2012D) also point out that vulnerability is a sensitive subject; the concept can be divisive and should be avoided as much as possible Adaptation to climate change should take a 'whole of population' approach while reducing inequalities that increase vulnerability.

Collaboration and effective sharing of information is critical. Information sharing within agencies, between levels of government and with the community was routinely identified in much of the research as critical to collaboration. Information sharing needs to be planned and strategic, particularly for emergency management which needs to consider operational, tactical and strategic issues.

How to effectively engage stakeholders on adaptation, particularly when change is required, remains a key challenge. QUT (2010) notes that:

> The standard approach of making relatively small adjustments to existing management processes is unlikely to be successful. Fundamental shifts in thinking are needed that explicitly acknowledge the new and uncertain risks a changing climate is likely to bring. Processes for bringing together stakeholders and key decision-makers with the scientific community could help promote new forms of dialogue and consensus-building (p. 9).

Integrated land management (ILM) is one approach being trialled as a technique for stakeholder engagement to enhance the resilience of socio-ecological systems between stakeholders and across multiple scales through major changes in land use. As a process of greater collaboration, this 'involves facilitating interactions, sharing knowledge and joint decision-making between different levels of government and between public and private land managers' (Bennett et al. 2012 p. 5). Bennett et al. (2012) have identified numerous enablers for good collaboration, including building on existing formal and informal networks, creating informal links across governance levels to reduce problems associated with imbalances in information and influence, using existing policies and strategies as a basis for developing common objectives, and carefully considering the nature of change, particularly climatic change. Collaborative approaches can increase costs in the short term due to the greater time requirements. Collaboration can also be hindered by unequal power relations, fragmentation and lack of leadership in interactions and decision-making.

The messenger is just as important as the message. The perceived importance of each source of communication was found to vary between and within communities (Boon et al. 2012D). This re-enforces the need for communications to occur across multiple modes and by different sources, including emerging social media. Research by Boon et al. at (2012D) at locations in Queensland and Victoria found compelling evidence that the community does not trust the government or media with information about climate change but were more inclined to believe scientists. This result parallels the findings of Reser et al. (2012) on public trust in these sources.

4.1.4 Community expectations for government

Key findings for community expectations for government in relation to efforts to increase resilience and adaptive capacity:

- Community expectations about the role of government for climate change adaptation may not align with government responsibilities and capacity.
- Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation.

Community expectations about the role of government for climate change adaptation may not align with government responsibilities and capacity. Residents in New South Wales and Victoria see a significant role for government in coastal adaptation including creating knowledge, sharing information, managing risk to public and private assets, local planning and paying for adaptation action (Barnett and Waters 2013D). Participants distinguished adaptation functions by different levels of government, with state/territory government seen as the best entity to coordinate local governments and provide funding support. Federal government was seen as needing to focus on providing risk information and bear adaptation costs. Local government was viewed as more appropriate for managing public assets, regulating decision-making related to private adaptation and coordinating local planning. However, community members were not interested in one level of government or sector to have sole responsibility for coastal adaptation. This may also apply to other areas of adaptation action.

Deliberative processes between government and communities can have a positive effect on perceptions of and engagement with climate change adaptation. Hobson and Niemeyer (2011) tested the efficacy of employing the deliberative process to foster adaptive capacity for individuals from the ACT region, compared to just providing climate change information. It was found that the discourse increased motivation, fostered a greater

desire for action and willingness to act, and reduced scepticism. Being exposed to different opinions and ideas allowed participants to re-evaluate their own positions and form more coherent positions on the climate issues being discussed (Hobson and Niemeyer 2011). The authors noted that this change in attitude does not necessarily translate to adaptive action and suggest that "strong governance signals and leadership are still essential for fostering a positive public response to the challenges of climate change" (Hobson and Niemeyer 2011, p. 957).

Research by McNamara et al. (2011) in two Torres Strait Island communities also indicated that confidence in decision-making or governance process is critical in the assessment of limits to adaptation. Confidence in the process underpins perceptions of risk, especially as to if, how and when barriers may be addressed, and provides context in which limits to adaptation can be assessed or determined by a community rather than imposed by external circumstances (McNamara et al. 2011).

4.2 Learning from experience

The findings in this section are particularly relevant for emergency management.

'Vows made in storms are forgotten in calm.' (Thomas Fuller in Verdon-Kidd et al. 2010)

Natural disasters are generally considered by governments as one-off events, as evidenced in early drought policy (Sherval and Askew 2012). However, the perception of some climate-related events has been shifting over time. For example, drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005 in Kiem and Austin 2012). However, today the view of drought as a "one-off, unpredictable and unmanageable natural disaster" is questioned in science and policy (Kiem and Austin 2012, p. 5).

Regardless, adaptation planning will be informed by lessons learnt from past events. They are a valuable source of information with regard to:

- identification of unknown vulnerabilities or those that have yet to be addressed, including different levels of vulnerability within a single community
- adaptation measures put in place as a result of the knowledge gained from the experience from and immediately after the event
- adaptation measures put in place following subsequent reflection or formal enquiry on ways to better prepare for future events
- understanding community, institutional and governance responses to climate events, and their interactions that may determine the success or failure of climate change adaptation strategies (Kiem et al. 2010a).

Recent events (drought, bushfire, floods and storms) have resulted in various policy responses to disaster risk management across the country that has enabled rapid mobilisation of resources which can assist with adaptation planning (Howes et al. 2013D). The lessons below have been informed by research reviewing these events to help inform adaptation decision-making. Broader emergency management responses have not been considered as part of the methodology of this project.

Learning from experience has tended to focus more on these extreme events rather than more gradual changes. There is a risk that adaptation lessons are skewed by only understanding the impacts and responses to extreme events and opportunities to learn from more gradual changes are missed.

Key findings regarding how past experience with extreme events can inform future adaptation action:

- Prior experience is unpredictable in its influence upon disaster resilience.
- Short-term adaptation responses may create a false sense of security in the longer term.
- Disaster management is a useful starting point to consider renewed institutional arrangements for adaptation.
- Basing decisions on past experiences will become increasingly risky.
- We are already adapting – even if climate change is not explicitly considered.
- For some disasters, attitudinal barriers can prohibit planning and public discourse is needed to change views.
- Local policy that is enacted after an extreme event can become a model for new national policy.
- Extreme climatic events can provide impetus for overdue or unpopular adaptation options.

Prior experience is unpredictable in its influence upon disaster resilience. Research in Innisfail (post-cyclone) and Ingham (post-flood) found that preparedness was highly predicted by prior disaster experiences, as well as financial capacity and communications (Boon et al. 2012D).. Of note was the finding that homeowners in Innisfail and Ingham did not report having building insurance despite past experience.

Kiem et al. (2010b) noted that lack of system stresses, such as water scarcity, is likely to make communities unprepared for system failures. Communities with a collective memory of a water supply crisis may be capable of responding to water insecurity with adaptive change more easily than those that lack experience

AECOM (2010) identified that there was a high level of awareness of bushfire in the ACT due to relatively recent and historical bushfire events. This level of awareness can be observed through bushfire adaptation strategies being implemented (including gutter and garden design in some new developments), and is supported and driven by the high quality and highly accessible data on bushfire in the region (AECOM 2010).

However preparedness for one disaster can make residents and agencies less concerned or prepared for other potential risks. For example, Victoria's drought prior to the floods had caused many residents to become apathetic towards flooding. Residents were more concerned about drought-proofing their homes and some were seeking permits to build on properties covered by flood overlays (Bird et al. 2011). A few residents also thought they were safe because their home was built above 1909 flood levels. Similarly, Victoria's Department of Health had made progress in pre-planning prior to the 2009 heatwave; however, the department was still challenged by service demands and escalating fatalities (QUT 2010). Bushfire risk planning had taken precedent over planning for extreme heat.

On the Gold Coast, significant coastal protection works were carried out and legislation enacted following repeated storm surge events during the 1960s and 1970s. However, an extended period of relative calm (or limited storm surge events) followed, causing lessons to be forgotten and governments to be less proactive. At the same time, significant development has occurred. While the management and protection responses undertaken have been effective to date, many of its elements have yet to be tested under extreme conditions. Proactive responses are also facing increasing community objections during calm weather (Helman et al. 2010).

Short-term adaptation responses may create a false sense of security in the longer term. The building of resilience, such as diversifying water supply systems, needs to consider long-term viability and sustainability. Current actions may create a false sense of security within individuals and communities and thereby reduce long-term resilience (Albrecht et al. 2010). For example, Kalgoorlie, with the provision of the Golden Pipeline to supplement local water supply with that from Perth, have much greater confidence that their water supply will persist into the future due to technology and government support than communities such as Broken Hill (New South Wales) that have had to endure repeated failure of their water supply. However, Kalgoorlie's water supply is potentially at risk due to climate change and residents may find themselves unprepared for a future of price increases and interruption of supply (Albrecht et al. 2010).

Disaster management is a useful starting point to consider renewed institutional arrangements for adaptation. In Australia, disaster risk management arrangements are formed around interagency and intergovernmental approaches spanning all three levels of government, working together closely with volunteers, NGOs, businesses and the community. Importantly, issues around key definitions have been largely overcome. (Howes et al. 2013D).

Basing decisions on past experiences will become increasingly risky. There is a tendency to stay within known parameters and uncertainties, yet there is a growing need to understand system-wide properties at scales and within timeframes beyond the normal comfort zone of most decision-makers (Albrecht et al. 2010).

Small changes in the sequencing, timing or location of impacts from specific events should be used to hypothesise a number of 'what if' scenarios to consider potentially different or more significant impacts (Verdon-Kidd et al. 2010). Impacts on overall capacity of core services, such as health care and social services, should also be included (for example longer term disasters, multiple disasters across a region or multiple events over short periods of time). The 2009 extreme heatwave and bushfires had major impacts for Victoria's infrastructure, emergency service providers and health care system. The electricity system has been identified as being particularly vulnerable; as it operates with little spare capacity, it lacks resilience to unexpected events such as a heatwave. Scenario testing is recommended to analyse the impact of hotter and more prolonged heatwave events on Victoria's infrastructure (QUT 2010).

We are already adapting – even if climate change is not explicitly considered. Major events such as cyclones, bushfires and floods, have been a major impetus to undertake adaptation measures (Kiem et al. 2010a). These events have resulted in various changes including:

- introduction of building and infrastructure design standards
- emergency management protocols
- revised coastal policy
- land buy backs and exit grants
- changes in water policy, including the introduction of water trading
- technological and engineering based solutions (such as desalination and flood protection works)
- community awareness programs (including warning systems and pre-event preparation)
- operational changes to coordination, operation and maintenance of essential infrastructure (for example drainage networks and load shedding).

However, measures implemented after these events may not be fit for purpose with continued climate change. For example, flood protection was put in place to address risk in Charleville (Qld) from the Warrego River but failed to take into account flooding from Bradley's Gully; this left the town exposed to flooding as evidenced in 2008 (Kiem et al. 2010a). In New South Wales, the residents of Broken Hill have faced numerous water crises and have implemented various engineering strategies to improve the water catchment and supply systems. However, a hotter climate and harsh cost-recovery economic conditions puts the security of Broken Hill's future at risk (Albrecht et al. 2010).

For some disasters, attitudinal barriers can prohibit planning and public discourse is needed to change views. During Victoria's 2009 heatwave, there was a general attitude among certain agencies that heatwaves do not require a specific planned response or that a generic disaster response is adequate (QUT 2010). Furthermore, there is a collective attitude among the public that, as Australia is a country where warm temperatures are common, excessive heat is not a threat. Public education campaigns are recommended (QUT 2010). However, the issue of response is compounded by the fact that the heatwaves are not a recognised emergency by the Federal Government; therefore, state/territory governments are unable to claim reimbursement for a percentage of certain response and recovery costs.

Local policy that is enacted after an extreme event can become a model for new national policy. Cyclone Tracy's high intensity and low movement speed caused widespread devastation due to Darwin's inadequate structural engineering design, including the complete destruction of around 60 per cent of housing which led to the evacuation of around 80 per cent of Darwin residents (Mason and Haynes 2010). Following the disaster, design recommendations were produced in response to the failures of building practices by incorporating integrated engineering design into residential buildings (Mason and Haynes 2010). These wind engineering recommendations and design standards have since been refined and incorporated into national building codes for other cyclone prone areas of Australia. The practice of using structural engineering design in housing is now standard in Australia (Mason and Haynes 2010).

Extreme climatic events can provide impetus for overdue or unpopular adaptation options. Kiem et al. (2010a) note the ability of natural disasters to provide drive for governments, communities and industry to implement adaptation measures that may not be popular or deemed worthwhile during periods of average climate. Engineering-based design requirements for residential buildings in tropical cyclone regions were

implemented in response to Cyclone Tracy. Because these changes were mandated, the process of incorporating these requirements became progressively more affordable (Mason and Haynes 2010).

4.3 Costing, financing and funding adaptation

There are considerable challenges associated with costing, financing and funding adaptation actions. Adaptation options entail varying costs, in terms of time and resources involved in their implementation and maintenance, and with respect to the risks involved (Hadwen et al. 2011). Robust costing must take into account a wide range of direct and indirect impacts of both climate change itself and the responses put in place. The effectiveness of some options may decrease as climate change continues or as other factors which modify the impact change. Consideration of who pays for adaptation is also an ongoing issue for many decision-makers.

Key findings regarding how to cost, finance and fund adaptation action:

- The return on adaptation needs to be considered beyond the short-term.
- Adaptation options can have distinctly different thresholds of or criteria for appraisal.
- There is limited research testing how adaptation costs and benefits might be distributed through the community and over time.
- Disaster relief is not currently an effective tool for financing adaptation.
- Traditional economic approaches and mechanisms will only have limited value in informing and driving adaptation decisions, particularly in the private sector.
- Current insurance products and practices need improvement to be an effective adaptation tool in the longer term.

The return on adaptation needs to be considered beyond the short-term. Planned retreat along the coast is likely to have the highest upfront cost, but there can be a high return on investment due to the potential for greatly reduced costs associated with future extreme events and inundation, at least in regional or rural areas (Hadwen et al. 2011). In higher density urban coastal areas, retreat is often not viable due to the high value of coastal assets and areas compared to the costs of increased flooding from sea level, storm surge and extreme rainfall flooding. Retreat pathways require parallel legal and social frameworks to cover future retreat and associated transitions (Helman et al. 2010).

Adaptation options can have distinctly different thresholds of or criteria for appraisal. In working with three local governments in Queensland, Fletcher et al. (2013D) found that different coastal adaptation options (protect, accommodate and retreat) have distinctive acceptance thresholds with decision-makers. Intensification of defensive structures is primarily based on economic or cost-effectiveness thresholds, whereas retreat is predicted more on political or social thresholds conditioned by the local perceptions of acceptable risk by residents in vulnerable locations.

There is limited research testing how adaptation costs and benefits might be distributed through the community and over time. The costs per property of implementing community-level adaptation options are likely to be reduced as requirements are introduced and homes are increasingly being built from standardised plans (Mason and Haynes 2010). Some situations will require alternative adaptation options, either at the property level or alternative funding from scales of governance beyond the community; regardless, benefits may not be shared equally across the community (Fletcher et al. 2013D). Economic tools that estimate specific costs and potential benefits throughout the community can help inform sensible choices about which adaptations, or suites of adaptations, are likely to yield more benefits than they cost to implement (Fletcher et al. 2013D). Such information will be essential to engage communities on adaptation. Community-level coastal adaptation options, such as seawalls, have the potential to yield a good mix of total benefits and high benefit to cost ratios; they also require coordination and funding from the entire community for both reasons of equity and affordability. Going beyond traditional local and regional scale cost-benefit analyses, to investigate the distributions of costs and benefits within the community, will be vital for ensuring the most efficient adaptation options which are equitable, affordable and economic (Fletcher et al. 2013D).

Draft research by Dobes et al. (2012D) examined the Cairns community's willingness to pay for post cyclone emergency services. This work identified that the community was generally willing to pay for a faster resupply of fresh food and a reconnection of utilities but not for addition services (policing and emergency accommodation for animals).Despite a willingness to pay, faster provision of services may not be feasible due to post-cyclone logistical challenges. The value of these services may need further consideration, especially given that these

issues are already being addressed by competition in the private sector. It also would be difficult to restrict faster utility connections only to those willing to pay; all residents in a re-connection area would benefit, incentivising many to free-ride.

Disaster relief is not currently an effective tool for financing adaptation. Combined underinvestment in protection prior to a catastrophic event and taxpayer financing recovery following the event has been critiqued on both efficiency and equity grounds (Crompton et al. 2012D). Disaster relief in response to the 2010/11 flood in Victoria and Queensland was felt by many to be over-generous and untargeted, and under current arrangements would not increase resilience to disaster and adaptation in the longer term (Wenger et al. 2012D). Regardless, with continued climate change, the long-term viability and suitability of existing relief arrangements for natural disasters is questionable. Existing funding mechanisms, such as funding arrangements for Natural Disaster Recovery Relief Arrangements (NDRRA), provide for the repair of public infrastructure within a short period of time (e.g. 21 days) from the date of declaration of the natural disaster. Councils may not be able to commence emergency works and clean up within this time frame. While extensions have been granted (e.g. Newcastle floods of 2007), this is by exception (Verdon-Kidd et al. 2010).

Reducing reliance on government emergency relief may help defer the costs of subsidies while promoting more strategic adaptive behaviours (Boon et al. 2012D). The Darwin Cyclone Damage Compensation Act was passed in May 1975, which allowed uninsured owners and occupants to claim up to half of the value of their home and contents (capped) from the government. Mason and Haynes (2010) identify that, because the payments were not means tested, this can be seen as having a disincentive for people to cover their own exposure.

Traditional economic approaches and mechanisms will only have limited value in informing and driving adaptation decisions, particularly in the private sector. Communities may not have the capacity to invest in adaptation due to financial constraints or because of lack of consensus (Fletcher et al. 2013D). The level of government and community support will guide adaptation decision-making as much as the cost of the options themselves (King et al. 2012D). The types of adaptation will also be bound by the scale at which adaptation options are governed which may further constrain funding or financing opportunities (Fletcher et al. 2013D).

Hussey et al. (2013D) note that there are currently no market-based mechanisms to encourage financing adaptation in physical assets and infrastructure. There are also institutional and policy barriers, including a lack of policy incentives to replace or upgrade existing assets to increase climate resilience (Hussey et al. 2013D). For the private sector, Johnston et al. (2013D) identify uncertainty in policy and information, as well as insufficient commercial incentives as a problem for engagement with this sector in general. A combination of information provision, non-coercive adaptation financing policy such as co-financing and market based mechanisms (tax-credits, grants, tariffs, climate bond etc.), coercive regulation by requiring adaptation, and the introduction of specific taxations are recommended by Hussey et al. (2013D) to facilitate private sector adaptation action.

The long-term protection of the physical and financial assets of Australia will also require significantly more capital than is available through normal funding options. It is suggested that further adaptation policy and reform include business cases for private investment and financing (Hussey et al. 2013D). Kiem et al. (2010a) note that "power utilities and transport (especially rail) companies find it difficult to invest in adaptation because of regulatory barriers (they are unable to recoup their investments through pricing, for example) – limiting their potential to enhance their adaptive capacity" (p. 34).

Risk information is also needed to trigger private adaptation responses. Johnston et al. (2013D) identify that there is a paradigm in many governments, including those in Australia, that adaptation in the private sector will be predominantly led by market signals; however, it is suggested that without direct policy guiding adaptation, this is a high risk strategy which is untested.

Current insurance products and practices need improvement to be an effective adaptation tool in the longer term. Insurance is generally considered an important adaptation to help defray the costs of climate change impacts, particularly in the private sector. However, there are limitations associated with insurance arrangements, individual behaviours and government responses to natural disasters.

Insurance plays a key role in sending price signals that reflect risk and contributes to resilience by supporting recovery from extreme events. While there is growing scientific confidence that many natural hazards will increase in both frequency and intensity, regional and local implications of a warming climate on extreme weather remain uncertain. As a result there is no clear climate change signal in the increasing cost of disasters (Crompton et al. 2012D). The 2013 flooding in Queensland may be the start of such a signal as insurance providers are in the process of withdrawing from high risk areas or significantly increasing premium prices.

Insurance coverage can be linked to prior experience but is more likely associated with financial capacity. The provision of government or charitable assistance has been found to be negatively associated with insurance

cover in some flood and fire impacted communities (Boon et al. 2012D). Limited or patchy uptake of insurance by individuals will limit the effectiveness of insurance as an adaptation response. Consumers are reluctant to pay for insurance to cover natural hazards with low probabilities of occurrence, as evidenced through surveys with 2011 Australian flood victims (Crompton et al. 2012D). Furthermore, post-disaster inflation, a surge in demand and shortage of materials and labour, can leave fully insured asset owners with significant costs. Many Darwin residents found that after Cyclone Tracy, they were left with significant out of pocket expenses for their fully insured houses due to post-disaster inflation, which was compounded by Darwin's relative isolation (Mason and Haynes 2010).

Limited investment in protection and preparation to natural disasters combined with government financing of part of the recovery following can be critiqued on both efficiency and equity grounds (Crompton et al. 2012D). There are critical issues of equity when examining preparedness for disaster, since those with limited means are likely to be more vulnerable to impacts and hence will be subject to those influences which have led to leaving a community. In addition, they are more likely to be subject to greater psychological distress, poor coping and adaptive capacity as a result, bringing an additional burden upon community service organisations, including government agencies (Boon et al. 2012D).

Government has a key role to play in better supporting uptake of insurance by residents and businesses and by seeking to minimise future losses through land use planning and building regulations (Crompton et al. 2012D). Greater consideration by state/territory and national government to actively support the uptake of insurance, including subsidies for lower socioeconomic groups needs should also be considered. Government should also consider how to work with industry to promote awareness about standard insurance arrangements regarding coverage. For example, although insurance companies cover the cost of repairs to property damage associated with landslip, they do not generally cover restoration works associated with the landslip itself. Similarly, the cost of removing a fallen tree is also not covered by insurance unless it has fallen on a fence or other insured object (Verdon-Kidd et al. 2010).

Significant amounts of property (approximately 40 per cent of the houses, 20 per cent of the apartments and 5 per cent of commercial and industrial buildings) in Darwin were owned by the government and self-insured prior to Cyclone Tracy. As well as the cost to government to re-build these assets, additional financial support was provided to occupants to assist with re-establishment. This level of government ownership has greatly decreased, increasing the importance of private insurance (Mason and Haynes 2010). This change could be seen as decreasing the direct risk for the government.

4.4 Limits and barriers to adaptation

There are many challenges associated with adaptation. Understanding the limits and potential barriers to adaptation is important for decision-making for a number of reasons, including:

- determining which responses to climate change are both practicable and legitimate, and the timescales over which adaption may be needed and considered effective
- engaging with stakeholders to identify issues and values
- prioritising adaptation strategies and refining their objectives (Morrison and Pickering 2011).

Social and economic limits to adaptation are largely subjective. These limits are rarely absolute or insurmountable, while physiological limits of individuals remain largely unknown. The factors which create limits and barriers are also strongly interrelated and complex – making it difficult to isolate a particular ecological, economic or institutional system as the key factor limiting adaptation (Evans et al. 2011).

Key findings regarding the limits and barriers to adaptation:

- Lack of community support can be a significant barrier to climate change adaptation.
- Local governments face capacity and resource constraints to effectively support local adaptation.
- Top-down, state-driven policy practices may inhibit local policy makers from being able to push forward local policy initiatives.
- Current institutional arrangements can create barriers for effective collaboration.
- Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict.
- Lack of system understanding remains a key barrier to adaptation.
- Lack of accessibility to the most up to date and relevant information can be a limitation for decision makers.
- Key tools to support adaptation are constrained by potential issues of liability.
- Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning.

Lack of community support can be a significant barrier to climate change adaptation. As evidenced by multiple failed efforts to introduce potable wastewater reuse to supplement failing water supplies, community support for adaptation options is critical (Poloczanska et al. 2012). Similarly, relocation from areas at higher risk from storm surge in Darwin was proposed by the Commonwealth Government after Cyclone Tracy. This strategy was met with public opposition and eventually abandoned, despite the likely risk of future storm surges (Haynes et al. 2011).

In some instances, effective communication has been identified as key to ensuring community engagement for implementing waste and recycled water use for a case study in Queensland. (Freeman et al. 2008 in Poloczanska et al. 2012). Alternatively, poor communication, combined with top-down management approaches can lead to a disconnection between policy and the communities affected by adaptation strategies. This was found to be a key issue when engaging Indigenous communities. Petheram et al. (2010) explored this with remote Yolngu communities in north east Arnhem Land, who preferred adaptation strategies which supported independence and self-sufficiency.

Local governments face capacity and resource constraints to effectively support local adaptation. Local governments in all states and territories face competing priorities and limited resources when addressing adaptation (Mukheiber et al. 2012). However, long-term, large adaptation projects are likely to be beyond the capabilities of most local governments and need federal funding on a priority basis. The complexity and cross-cutting nature of climate change risks, particularly of coastal areas, requires inter-jurisdictional reform supported by a national coastal policy that clearly articulates roles and responsibilities (Helman et al. 2010).

Top-down, state-driven policy practices may inhibit local policymakers from being able to push forward local policy initiatives. Kellett et al. (2011) have considered the use of climate analogues to help identify potential policies for a region under a new climate. Using this approach in three states (Queensland, Western Australia and South Australia), no discernibly clear pattern for the use of analogues at the policy level was found. This is largely because many relevant policies, particularly those related to planning and health, are driven at the state level. Many local councils, especially in South Australia, expressed frustration that state-wide framework and directives did not take into account local circumstances (Kellett et al. 2011). In New South Wales, coastal planning local adaptation strategies have been seen as being constrained by state and federal legislation (Hadwen et al. 2011). The lack of articulation and clarity about the roles and responsibilities of various levels of government and other entities were also identified as a limiting factor, particularly for existing development and infrastructure (Verdon-Kidd et al. 2010). This was noted with regards to flooding but also more generally by the mining and resources sector (Sharma et al. 2013).

Examples were also identified where local policies, regulations and operating rules imposed adaptation barriers. For example, cold water releases are specifically avoided in some rules of operation for reservoirs, and planning regulations may restrict the creation of new urban water bodies, such as wetlands, in areas where current wetlands have management issues effecting local amenity (such as mosquitos and algal blooms) (Robson et al. 2013D).

Current institutional arrangements can create barriers for effective collaboration. Planning, building and insuring are co-dependent elements of the built environment, however there is relatively little transfer of expert personnel between professions. Separateness is compounded by the professional bodies and governance of these issues between government departments, statutory bodies and boards that have responsibility for current guidelines, codes and legislation (King et al. 2012D).

Perceptions of adaptation interventions will vary between stakeholders and may be a source of conflict. Adaptation interventions will be viewed in different ways by different stakeholders and may affect stakeholders differently. “A benefit to one part of the system (such as maintenance of water level) results in a negative impact to another part of the system, with the emergence of winners and losers being one outcome” (Gross et al. 2011 p. 77). This can divide communities, erode trust, and reduce capacity for stakeholders to work together.

Research by Morrison and Pickering (2011) on limits to adaptation in the Australian Alps worked with tourism operators and conservation managers to identify the value of better consideration of social and governance issues in adaptation planning. This approach identified that conflict may arise between stakeholders as a result of different adaptation actions where objectives are not shared. Perceptions of limits were also identified – for example stakeholders other than tourism operators identified technological and resource limits for ski operators, however, these were not identified by the operators themselves.

Limits for one stakeholder can be viewed as opportunities by a different stakeholder. Evans et al. (2011) sought to identify potential limits to adaptation for the tourism and fisheries sector in the Great Barrier Reef Marine Park Heritage Area. In the Great Barrier Reef region, there are many examples where addressing limits to adaptation could benefit multiple industries simultaneously, particularly with regard to catchment management and coastal development, although there may be trade-offs for individual land owners (Evans et al. 2011).

Lack of system understanding remains a key barrier to adaptation. Unknown thresholds of ecological resilience and lack of understanding about the interconnectivity within ecosystems limit the identification of effective of adaptation options. Similarly, better understanding of how climatic and non-climatic changes over time will influence vulnerability and adaptive capacity (Hadwen et al. 2011).

Hadwen et al. (2011) identify that the separation of the terrestrial and marine zones in coastal ecosystems limits the understanding of the system’s interconnectedness, affects the accuracy of data produced, and influences policy – often encouraging the zones to be addressed as discrete elements.

Trade-offs between different adaptive management approaches also need to be considered in the short and long-term. For example water managers need to consider a range of short and longer term solutions, including diversification of supply and storage options, increasing storage capacity and improving water management through changes behaviours. Some of these responses have the potential to push systems to unstable states with limited predictive capacity, meaning that further adaptive responses will be difficult (Albrecht et al. 2010).

As the greatest need for adaptation may not relate to direct impact or a core function, systems level thinking from a local perspective should also be considered. For example, initial operational concerns for ports have been focused on the seaward side of operations (access, mooring, loading and unloading of ships), which are expected to be particularly vulnerable to climate variability; however, disruptions to wider supply chains and supporting infrastructure have experienced the greatest impacts during recent extreme events, suggesting that planning also needs to be look beyond the port (McEvoy and Mullett 2013).

Lack of accessibility to the most up to date and relevant information can be a limitation for decision-makers. The need for increased sharing of information and data is identified as necessary for effective decision-making, including specific and general data relating to climate projections, natural, constructed and social systems, and bio- or geo-physical parameters (Hadwen et al. 2011). There is a distinct lack of coordination of existing databases and data-sharing arrangements between relevant authorities. This was recognised by the Northern Australia Land and Water Taskforce (2009) as a significant issue, with the need for increased data collection and analysis particularly important for improved land and water use planning.

Key tools to support adaptation are constrained by potential issues of liability. While the need for information relating to the location of possible risks to support adaptation planning is clear, there is a reluctance to provide this information because of the potential adverse impacts on property values (Wenger et al. 2012D). Furthermore, local and state/territory government planning agencies can be excessively risk averse out of fear of having to compensate people affected by climate hazards (Macintosh et al. 2013D). Formal enquiries following flood events, such as Royal Commissions, are similarly cautious about recommendations for structural measures and were limited to considering options that only protect current development (Wenger et al. 2012D).

Liability shield instruments are one mechanism to reduce this constraint; they provide partial or full exemption from legal liability for action, or lack of action, regarding climate hazards (Macintosh et al. 2013D). Another

approach is the use of statutory exemptions, which can provide councils with exemption from liability provided they can demonstrate compliance with applicable codes, guidelines, manuals or demonstrate good faith (Macintosh et al. 2013D).

Failure to consider the potential consequences of climate change in formal reviews of natural disasters is constraining adaptation learning. A review of four recent enquiries on flooding were found to all but ignore the issue of enhanced flooding as a result of climate change and therefore have likely underestimated future risks and adaptation needs. In addition, failure to consider other relevant changes, such as future population pressures and movements, compound this underestimation (Wenger et al. 2012D).

4.5 Maladaptation

Adaptation-related decisions intended to reduce climate change impacts may instead increase vulnerability. This problem of increasing risks as a result of adaptation is often termed 'maladaptation'. Actions that (relative to alternatives) increase greenhouse gas emissions, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, or establish mechanisms that limit the choices available to future generations are maladaptive (Barnett and O'Neill, 2010). Adaptation planning decisions should be screened for these possible adverse effects.

Key findings regarding maladaptation:

- Underestimating connections and interdependencies in systems can lead to maladaptation through unintended consequences.
- The management of evacuation due to extreme weather events can be maladaptive, leading to inequities and additional problems after the event.

Underestimating connections and interdependencies in systems can lead to maladaptation through unintended consequences. This is explored by Hadwen et al. (2011) in the context of coastal ecosystem adaptation strategies, which mostly contain no overt consideration of flow on effects in neighbouring habitats. It is critical to the success of adaptation activities that the connectivity between ecosystem and human systems is considered within the decision-making process to make certain non-target habitats are not adversely affected. It was also noted that most coastal adaptation strategies partially take an interdependency approach as they rely on removing or reducing non-climate risks, such as invasive species; these actions can be perceived as adaptation strategies as they address ecosystem resilience (Hadwen et al. 2011).

The management of evacuation due to extreme weather events can be maladaptive if not handed sensitively, leading to inequities and additional problems after the event. The evacuation of Darwin under Cyclone Tracy was enacted under a protocol which prioritised the evacuation of women, children and elderly couples; this split families in some instances, creating disconnected families and communities (Haynes et al. 2011). The negative impacts of the cyclone on mental, physical and social recovery were also observed to be more severe for people who were evacuated (especially non-returned evacuees) than those that stayed. This is explored in Haynes et al. (2011) through the lens of being part of the 'therapeutic community', with those who stayed being able to contribute to the clean-up, rebuilding and reinvigoration efforts. However, it is not known whether evacuees' recovery was hindered by evacuation itself or by the degree of loss experienced by this group; it is also possible that this group may have experienced even greater trauma had they remained in Darwin (Haynes et al. 2011).

4.6 Timing and scale of adaptation

The timing for and scale at which adaptation is best delivered remain two fundamental questions. Adaptation will continue to be a series of reactions to environmental and social changes – some quickly executed in response to emergency, others more autonomously in response to slowly changing social and economic conditions (Gross et al. 2011). Government and communities have tended to favour short-term and responsive approaches – this can make adaptation more difficult to initiate (Stanley et al. 2013D).

Key findings regarding the timing and scale of adaptation:

- Timing of stakeholder engagement needs to be carefully considered.
- Timing and scale of implementation is complex and may not align with financial capacity.
- Adaptation actions need to take a long-term view to be effective.
- Doing nothing may be an appropriate adaptation response.
- Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate.
- Government needs to consider the time and steps it takes to effectively implement adaptation actions.
- Windows of adaptation opportunity following extreme events are short.
- Scale needs to consider both the impact and the potential adaptation response to best manage risk.

Timing of stakeholder engagement needs to be carefully considered. Engaging with stakeholders on adaptation to longer term changes in climate should be considered independently of extreme events when public emotions and political considerations are heightened. Conversely, there is value in capturing learning from extreme events before collective memory fades. Firsthand exposure to climate change related-risks can create an emotional connection to climate change and make it a more meaningful, pressing issue (Hanson-Easey et al. 2013D). However, previous experience with a climate hazard does not necessarily increase ability to respond or adapt.

Timing and scale of implementation is complex and may not align with financial capacity. Understanding when to respond to adaptation and the scale of this response is a critical and challenging question for policymakers. When the answer of when and how to respond is clear from an economic perspective (based on a cost-benefit analysis), the distribution of risk and the distribution of cost may complicate the issue (Fletcher et al. 2013D). Furthermore, communities may not have the financial capacity to fund the recommended adaptation option, such as a seawall, in the short or medium term even if economically justifiable and providing broad, equitable benefit to the community. This will put the onus of adaptation in the short-term on alternative options, such as individual adaptations funded by the property owner, often at a smaller scale (Fletcher et al. 2013D).

Adaptation actions need to take a long-term view to be effective. Although adaptation decisions need to be made now and adaptation measures need to start being implemented, the timeframe that these options need to take into account is long-term to ensure they are effective and do not decrease long-term adaptive capacity (Hadwen et al. 2011). Having more flexible and dynamic policy and planning that looks beyond political cycles is needed for this forward thinking approach.

Doing nothing may be an appropriate adaptation response. Garnett et al. (2012D) state that a do nothing approach can be considered an appropriate response to climate change risks. However, in order to select this approach, a following are essential:

- full consideration of the potential consequences has been given
- on-going monitoring of climate change risks
- flexibility to recognise and respond to changed circumstances in a timely manner.

Triggers need to be established for extreme events, as do thresholds for when extreme events move from a natural disaster to normal climate. Governments, hospitals, emergency response organisations and the community were under-prepared for the 2009 heatwave experienced in Victoria (Kiem et al. 2010a; QUT 2010); coping was said to be “the result of reactive competence and capacity rather than proactive planning” (Kiem et al. 2010a, p. 33). Part of the reason for this was that, as the event developed over a number of days, there was no clear threshold to trigger the management as a disaster (Kiem et al. 2010a).

The increasing frequency of climate-related events is also changing the perception of what is an extreme and what is ‘normal climate’ (Kiem et al. 2010a). In light of this, disaster management arrangements may need to be further reviewed. This is typified by changes in drought policy responses in Australia over the past 20 years. The perception of drought has been shifting over time. Drought was viewed until the late-1980s as a climatic abnormality and therefore was treated with disaster relief policies in a similar way to earthquakes or floods (Botterill and Wilhite 2005, in Kiem and Austin 2012). However, today the view of drought as a “one-off,

unpredictable and unmanageable natural disaster" is questioned in science and policy (Kiem and Austin 2012, p. 5). Drought measures are moving from a crisis management approach to risk management.

Government needs to consider the time and steps it takes to effectively implement adaptation actions. A sequence of action necessary to enable adaptation needs to occur. First, there needs to be a focus on governance in order to define roles and responsibilities among levels of government and between sectors. Next, statements of purpose and other institutional preconditions are needed in order for government and sectoral players to take action. Finally, after this statutory support is in place, uncertainty about risks and responses as well as an assessment of resources can be addressed. To support this, government initially needs to play an active role in adaptation rather than leaving action up to individuals and sectors (Barnett and Waters 2013D).

Windows of adaptation opportunity following extreme events are short. Recovery from extreme events and other reactive responses create windows of adaptation opportunities with the goal of reducing the impact. Rapid recovery may hinder adaptation, as new knowledge can take time to incorporate into existing regulations and guidelines (for examples revised building codes). However, there is a need to act quickly, not just for community recovery, but also while the issue is relevant within the community memory and before complacency sets in which is relatively short (Helman et al. 2010). Delay of implementation of adaptation strategies, particularly after an extreme event, can be detrimental to success (Kiem et al. 2010a).

Conflict can arise when the timing of adaptation objectives differ between stakeholders. Morrison and Pickering (2011) note that effective long-term conservation management goals (usually 10+ years) often can conflict with the short-term decision-making by the tourism industry and political decision-makers (usually less than 5 years). Rapid recovery responses may over-ride longer term goals and reduce opportunities for stakeholder engagement.

Other temporal factors will also influence adaptation timing needs. For example environmental goals of adaptation strategies for natural resource management will vary depending on the climate conditions each year (Lukasiewicz et al. 2013D). During dry years, habitat and ecosystem protection will likely be the primary goals whereas in wet years the focus would be biodiversity enhancement and restoration.

Scale needs to consider both the impact and the potential adaptation response to best manage risk. Climate change adaptation actions should be implemented at local or regional scales, as these scales will determine which adaptation approaches are appropriate in order to address adaptation objectives given the physical, ecological, social, economic and cultural features of the area of concern. However, larger scales require consideration since adaptation actions may have consequences for connectivity with ecological and human systems beyond this area (Hadwen et al. 2011).

4.7 Sector-specific findings

A primary purpose of this synthesis was to look across sectors and to integrate and aggregate findings into common threads or themes of learning. This is particularly important in adaptation as responding to climate change largely requires a holistic, systems approach to avoid maladaptation and to manage risks (including non-climatic threats) over the long-term. Sector-related messages are relayed, for this reason, throughout this report under broader, interconnected themes. However, as summarised in this section, quite often the research did directly address the adaptation objectives of a specific sector, particularly for natural resource management, primary production and land use planning. It is also important to note that the findings captured below represent the lessons relevant to a sector but in no way did the research reviewed comprehensively cover any individual sector.

4.7.1 Natural environment

Key findings related to adaptation and natural resource management:

- Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be re-considered in the context of longer-term climate change.
- Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity.
- Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities.
- Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making.
- Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations.
- Many potential land management strategies have the potential to reduce vulnerability to climate change impacts but are not always transferrable.
- There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand.

Existing management strategies will lessen the impacts on ecosystems, but the objectives and approaches of conservation and management plans may need to be re-considered in the context of longer-term climate change. Many adaptation options already occur in response to stresses other than climate change, including protecting and maintaining habitats, landscape connectivity, species management and population genetics (Lukasiewicz et al. 2013D; Garnett et al. 2012D; Hadwen et al. 2011). These options are also likely to have less potential for maladaptation, offer multiple ecosystem service benefits and have lower risk levels. More interventionist approaches need to be considered for maladaptation potential, ecosystem service benefits and effectiveness (Lukasiewicz et al. 2013D).

A review by Hadwen et al. (2011) of existing management actions in Kakadu National Park found that they were considered to be reasonably robust to threats posed by climate change as a consequence of their focus on sustainability and building resilience to a range of stressors. Many of the identified approaches also need to be considered as complementary strategies where the level of management intensity will have to increase over time (Garnett et al. 2012D).

Policy objectives that seek to restore environments to pre-European states or similar aspirational benchmarks will need to be re-considered as their value in a changing climate will become increasing obsolete. Broader spatial and temporal perspectives about conservation benchmarks will need to be employed. To facilitate regeneration, protection of some species at specific locales may have to be abandoned to avoid further exposure and vulnerability in the longer term or to the system as a whole (Garnett et al. 2012D).

The goal of adaptation also needs to be much more explicit and consider limits posed by climate change. Re-thinking of current objectives for natural resource management may be required as many of those currently set will be both expensive and unsuccessful. Existing goals, targets and thresholds of these management actions need to be re-considered in order to accommodate climate change threats. While there is scope for improvement and targeted adaptation actions, a major re-think of legislative objectives is required to ensure that actions are sustainable and not maladaptive in other habitats and/or detrimental to existing economic and social values within a given area (Hadwen et al. 2011).

To provide holistic resilience in natural systems, a change in focus from maintaining all species in their current locations to preserving ecosystem service delivery through a range of diverse and robust ecosystems is suggested (Steffen et al. 2009, in Newton 2009). Garnett et al. (2012D) also support an emphasis on ecosystem processes and function in which individual species are indicators rather than the endpoint of conservation. Maintaining areas that will be crucial for species persistence, such as habitats and refugia, needs to be considered from a variety of perspectives – not just climate change. Improving connectivity between these areas may not serve all species (Garnett et al. 2012D).

Frameworks for decision-making in the face of both uncertainty and value-based judgements need to be developed, tested and monitored over time. Currently prioritisation of activities is based more on financial efficiency (Garnett et al. 2012D).

Adaptation needs to take an ecosystem-based approach where resources are considered and directed towards a suite of actions; however, this approach is constrained by institutional complexity. Adaptation pathways for the natural environment identified in Newton (2009) include:

- maintenance of well-functioning ecosystems (terrestrial, aquatic and marine)
- protection of a representative array of ecosystems (underpinned by a National Reserve System)
- removal or minimisation of existing stressors
- building appropriate landscape and seascape connectivity
- identification and protection of refugia
- effective monitoring networks
- flexible policy and management approaches.

The combination of actions will help form the basis of an ecosystem-based approach to adaptation. These options have often been implemented in parallel but have yet to be carried out as an integrated climate adaptation package. Institutional complexity (i.e. rules and funding relationships between and within levels of government) can constrain ecosystem approaches. Increasing the scale and speed of measure implementation is needed in addition to an integrated approach (Lukasiewicz et al. 2013D).

Taking an ecosystem-based approach to adaptation for natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities. As some experiments may fail, community expectation must allow for learning through implementation, change of practices, and offer understanding of undesirable results. Ongoing monitoring is also needed to measure the effectiveness of actions Lukasiewicz et al. 2013D).

Due to competing demands and pressures on environmental assets, adaptation needs to ensure diverse stakeholder engagement and collaboration to allow value-based decision-making. Morrison and Pickering (2011) recommended that government "formally identify, promote and fund collaborative stakeholder partnerships" (p. 6). Their study identified conservation managers and the tourism industry as key stakeholders with potential for collaboration but likely to have conflicting adaptation agendas and approaches. Identifying opportunities of mutual benefit (for example removal of invasive species) can help build trust and encourage networks for further collaboration.

However, when landowner participation is needed, Lukasiewicz et al. (2013D) also identified numerous constraints that need to be overcome for effective engagement when undertaking climate change adaptation strategies for catchment management areas. These include:

- physical constraints in the form of both natural and infrastructure features, particularly where dams restrict freshwater habitat connectivity
- financial constraints limiting the ability to establish long-term monitoring programs
- social constraints, such as community attitudes towards overbank flows possibly flooding private land
- lack of community concern or aversion to government interventions
- institutional constraints arising from inadequate knowledge of some management options (or lack of adequate funding to acquire expertise).

Habitat protection is considered the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations. Maggini et al. (2013D) explored a process for allocating resources to promote optimal habitat protection and restoration responses to a changing climate. Habitat protection was identified as the optimal action for assisting the majority of species adapt to climate change within the budgetary limitations and was more spatially dominant as the suggested action for 1.8 million km^2 of Australia, as opposed to 3000 km^2 where passive or active restoration was considered necessary. Maggini et al. (2013D) suggest the optimal focus areas for the allocation of protection and restoration resources (taking into account the cost of implementation, probability of success and benefits across threatened species) are the woodlands and rangelands of eastern Australia, Northern Territory, northwest Western Australia, and southern South Australia and Victoria, with the focus of the restoration efforts in south-eastern Australia.

Many potential land management strategies have the potential to reduce vulnerability to climate change impacts but are not always transferrable. Strategies relating to wetland rehabilitation, Ramsar protective management, and flood gate management will help reduce the potential impacts of climate change, as noted by research undertaken in the Hunter Estuary (Hadwen et al. 2011). However, existing strategies of relevance to adaptation for Australian coastal ecosystems offer relatively few practical options and tend to concentrate on enhancing ecosystem resilience via the management of existing threats (Hadwen et al. 2011).

There are conflicting research conclusions regarding whether water pricing is effective in curbing water demand. Poloczanska et al. (2012) suggest that pricing is commonly considered an effective strategy, though point out that not all research supports this contention. Grafton and Kompas (2007) (in Poloczanska et al. 2012) suggested pricing amongst a range of fundamental changes in water policy to stave off critical water shortages in Sydney; however, a study by Hoffmann et al. (2006 in Poloczanska et al. 2012) on water usage in Brisbane from 1998 to 2003 suggests that water demand is independent of price.

4.7.2 Agriculture, fisheries and forestry

Key findings related to agriculture, fisheries and forestry:

- Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture.
- Adaptation in primary production is primarily driven by private sector responses. However, government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources.
- Clear management goals for adaptation under climate change are needed for forest management.

Agricultural enterprises respond differently to variations in climate; therefore, diversification (meaning cultivating several different crops and livestock) is the most common and effective strategy for mitigating climate-induced variability in net returns from rain-fed agriculture. However, the greatest benefit for this approach is in moderate rainfall areas where trade-offs between the reduced expected net returns and the benefit of reduced variability can be maximised. There is the least benefit in dry regions, as diversification introduces water-intensive and rainfall sensitive crops (Kandulu et al. 2012).

Adaptation in primary production is primarily driven by private sector responses. However, government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources. The Victorian Department of Primary Industries has recognised that farmers' adaptation responses can also have flow-on effects and negative consequences. It has developed a Policy Choice Framework (PCF) to examine the nature of the flow-on effects, suggest policy responses to assist (such as education, regulation, research and incentives), and also farmers' likely responses to potential policy interventions. The framework can be used to examine when government investment may be required and whether industry needs could be more effectively met by private service providers or by government agencies (Tostovrsnik et al. 2011).

Clear management goals for adaptation under climate change are needed for forest management. The adaptive capacity of forest management in Australia is supported by several systems, including a well-developed economy; extensive scientific knowledge and technical capabilities; sustainable forest management practices; disaster mitigation strategies and plans; existing policies; and well developed biosecurity procedures (Boulter 2012). However, previously established principles (such as the principle of setting the composition and biogeography of forests to pre-European settlement conditions as the benchmark) may no longer be appropriate under climate change. Under climate change, it is highly likely that rates of growth and species compositions will change; forests are also likely to shift or change the areas in which they occupy. These impacts will be compounded by other stressors, such invasive species, disease, habitat fragmentation and economic conditions (Boulter 2012).

Significant financial investment is needed for the adoption of some forest adaptation measures (Boulter 2012). For example, shifting plantation production locations as an adaptation measure for plantations would require significant investment in new infrastructure.

4.7.3 Infrastructure, communities and land use planning

Key findings related to infrastructure, communities and land use planning:

- The role of land use planning is adaptation is extremely important but can be contentious.
- There are issues of continued expansion of populations into at-risk areas.
- Regulatory instruments in land use planning need to have greater flexibility to support adaptation.
- A precautionary approach to land use planning is recommended to address risks.
- Making adaptation-related home and property changes can be hindered by a number of factors post-disaster events.

Key findings for indigenous communities are also discussed in this section, under their own sub-heading (sub-section 4.7.3.1).

The role of land use planning in adaptation is extremely important but can be contentious. Owing to its role in guiding economic, social and environmental activities, spatial planning is viewed by many as an indispensable tool for facilitating efficient and equitable adaptation to climate change. However, the use of land use planning systems to address adaptation issues can be particularly contentious due to uncertainty, the politicisation of the issue of climate change and other factors, raising three particularly prickly issues:

- whether governments should second-guess individual choices and intervene to stop people from putting themselves in harm's way;
- the role of government in compensating or assisting individuals who are adversely affected if climate risks materialise (i.e. to share risks and losses); and
- to what extent governments should respect the 'property rights' of landholders in designing and implementing land-use policies (Macintosh et al. 2013D).

Regardless, the location and configuration of settlements and infrastructure can influence the vulnerability and resilience of communities to climatic events. By shaping the nature and location of land use and development, spatial adaptation planning can help reduce the adverse impacts of climate change. Urban growth management should consider land for potential abandonment and resettlement as well plan for more compact communities in areas of reduced risk of inundation, erosion and bushfire (Norman et al. 2012D). Planning processes can also be used as a medium for the dissemination of information about potential climate change impacts, thereby promoting private adaptation initiatives (Macintosh et al. 2013D).

There are issues of continued expansion of populations into at-risk areas. In many coastal and riverine areas, existing development has expanded and populations have increased without taking into consideration climate change impacts. Planned retreat or relocation is a confronting option to communities, individuals and governments and is likely to only be considered when all other options are exhausted (Hadwen et al. 2011; Hurlimann and Dolnicar 2011).

Over the past two decades, a planning setback policy in Byron Shire have helped serve as a 'managed relocation' strategy in response to historical storm surges. Despite this policy, the ethical, moral, legal, and management issues of relocating beachfront residents have not been addressed. It has also not been successful in preventing further development of the coastal areas or in protecting the beach, the natural function of the surf zone, the surrounding biodiversity corridors or the public reserves. In the absence of more recent extreme storm surges, the policy is also becoming increasingly difficult to maintain as both Council and residents forget the reasons for its genesis (Helman et al. 2010).

In the years since Cyclone Tracy, an increased number of people have moved into the well characterised storm surge zone of Darwin, and more assets have been constructed in these areas (Haynes et al. 2011). There has also been high population growth within the indigenous populations in the Northern coastal and floodplain regions of the territory. This has increased the exposure of a group already disproportionally vulnerable to climate risks (due to close connections to the land, lack of elementary infrastructure, lower socio-economic status and existing chronic health problems) (Green 2006). Relocation of the northern suburbs of Darwin out of the storm surge area (towards the southern parts of the city) was proposed during rebuilding efforts after Cyclone Tracy; however this was met with enough public opposition that the suburbs were rebuilt on the original site, thereby continuing to expose residents to a perceived significant future threat (Haynes et al. 2011).

The Darwin Harbour Strategy recognises this risk, and notes that relevant climate change projections should be taken into account through all phases of urban development including design, construction and operation (Darwin Harbour Advisory Committee 2009).

Regulatory instruments in land use planning need to have greater flexibility to support adaptation. More flexible regulatory instruments at the level of state/territory planning policy and in some local planning schemes need to be considered. Macintosh et al. (2013D) suggest that these instruments should include explicit provision for the use of time-limited and contingent approvals in the context of new development. Norman et al. (2012D) suggest that, at least when assisting coastal communities with adaptation, a risk management approach should be adopted that includes progressive learning from experience in order to ensure strategic and statutory planning controls can adapt to a changing environment.

Following Cyclone Tracy, design recommendations were produced in an attempt to respond to the failures of building practices that contributed to the devastation caused. This included an increased focus on engineering-based design in residential buildings, something that had previously been considered unnecessary and too expensive (Mason and Haynes 2010).

The key advantage of using contingent and time-limited approvals is that they allow current use and enjoyment of land until such time as the hazard materialises (Macintosh et al. 2013D). They are most appropriate in areas where the hazards are likely to develop incrementally over an extended period of time and the changes are likely to be largely irreversible. As such, they are more applicable to coastal areas, which are prone to erosion and permanent inundation, than a bushfire planning context. There is however considerable concern among decision-makers that it will be difficult for future governments to exercise options to require houses and other buildings to be removed without facing claims for compensation or demands for coastal protection measures. There is also concern among utility providers that contingent development approval will make planning and provision of reticulated services (particularly sewerage) very difficult (Macintosh et al. 2013D).

A precautionary approach to land use planning is recommended to address risks. The use of highly detailed flood modelling and mapping, consistent application of overlays and controls throughout Victoria, and a more prescriptive response or precautionary approach to planning are all lessons from robust flood regulations recommended to address bushfires. Related to a precautionary planning approach, Buxton et al. (2011) also highlighted the need to look to VCAT's decision regarding Gippsland Coastal Board v South Gippsland Shire Council, which emphasised the "need to invoke the precautionary principle and introduced the option for responsible authorities to require coastal vulnerability assessments when considering planning applications. The analysis of risk in this judgement applies also to other risks associated with climate change, including from bushfires" (p. 11). Norman et al. (2012D) also support the use of an adaptive decision-making process that incorporates the precautionary principle to ensure the risks of locating future development in the context of climate change is understood.

Making adaptation-related home and property changes can be hindered by a number of factors post-disaster events. After a flood, residents do and are likely to make changes to their home and property, including improving their garden drainage or building a permanent barrier. Land use or development controls, however, can restrict or delay changes. For example, permits are required in Donald to build a flood levee and restrictions apply. Furthermore, constructing a flood levee is expensive, and perhaps not worth the investment if residents do not think another similar event will occur during their lifetime (Bird et al. 2011). Other residents can be restricted by the structure or material of their homes; brick and slab-on-ground constructions are unable to be modified to reduce future risk. This type of construction should be eliminated if development on floodplains continues (Bird et al. 2011).

4.7.3.1 Indigenous communities

Climate change will have tangible and spiritual impacts on Australia's Indigenous people and their culture as a result of underlying vulnerability, the potential damage to cultural sites and the disappearance of spiritually important species and plants and animals (Griggs et al. 2013D). For example, in Nursey-Bray et al. (2013D)'s study of the Arabana people of South Australia, the study demonstrates that the Arabana consider climate change to be a risk and are particularly concerned about availability, access and quality of water, especially in relation to their culturally significant mound springs. They are also concerned about the destruction and erosion of cultural sites due to wind and flooding. In addition, Choy et al. (2013D) reference opportunities for wild harvesting by traditional owners will decrease as a result of climate change.

The following findings are based on draft NCCARF-funded research. It is also important to note that the research utilised for this section was received after the draft synthesis reports were issued for peer review and state/territory review. Therefore, the findings discussed below should be used with caution, as both the research utilised and the synthesis has not been independently peer-reviewed.

Key findings related to Indigenous communities:

- Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses.
- Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained.
- Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response.
- Integrating local, Indigenous knowledge with climate change science is critical to adaptation.

Climate change adaptation programs targeted to Indigenous communities should focus on empowering communities to identify and implement their own responses. As only the communities are able to best determine their needs, interests and circumstances, climate change responses need to come from within the community itself; externally imposed or determined solutions are unlikely to be effective or sustainable (Griggs et al. 2013D). As part of Petheram et al.(2013D)'s research in South Goulburn Island, Northern Territory, many participants of workshops and interviews expressed a strong interest in being involved in government decision-making around adaptation. They preferred adaptation options that were community driven and allowed greater self-sufficiency and independence (Petheram et al.2013D). Bird et al.(2013D) likewise note that the concerns of the younger Indigenous population regarding migration are more in relation to the level of control they will have over movement rather than movement itself.

The desire for control is also referenced by Memmot et al.(2013D), noting Aboriginal concern for greater collaboration and local control of their living environment regarding housing and infrastructure. Indigenous people in the Upper Georgina River Basin area of Queensland and Northern Territory have negligible control or representation in either the administration or provision of infrastructure with the exception of Myuma. Greater participation in decision-making and the supply of infrastructure would improve adaptive capacity. This is particularly important and challenging for housing which must be more climate and culturally responsive (Memmot et al.2013D).

In order to identify adaptation options, communities need support in the form of:

- culturally-relevant climate change information and research, as well as the development of the necessary skills to understand how climate change may affect them and how to determine the most appropriate adaptation options
- meaningful access to regional and national policy and decision-making processes affecting their lands, as well as assistance implementing their selected adaptation options within their community. In particular, governments need to move away from top-down prescriptive approaches to shared decision-making and joint management.
- assistance developing opportunities to share knowledge between Australia's First Nations communities and Indigenous people in other countries (Griggs et al. 2013D).

Related to the second point above, Nursey-Bray et al. (2013D)'s research suggests that the Arabana may wish to explore co-management or power sharing as it offers a conceptual frame within which to build the partnerships (such as with mining and government) in order to help progress their adaptation and other plans, while ensuring sovereignty is not lost. Power sharing will also need to include a shift in understanding what local and cultural knowledge is and how it affects decision-making. This will also require flexible mechanisms that enable cultural perspectives to be negotiated (Nursey-Bray et al. 2013D).

Griggs et al. (2013D) also note that academia can support communities with information and research but long-term partnerships between communities and academics are needed, which is challenging due to the current institutional structures of research funding. Establishing long-term relationships and the building of trust are important part of Indigenous culture. Face-to-face interactions are particularly important (Griggs et al. 2013D). Currently, distrust and bitterness exists between the many Indigenous communities, government, academia and others due to a long history of disrespect, marginalisation, exclusion and betrayal.

Indigenous communities, particularly in remote areas, are often the most vulnerable to climate change. However, remoteness can also increase resilience and adaptive capacity, particularly when a strong connection to country is maintained. Specific Indigenous populations will differ in terms of vulnerability and adaptive capacity for a range of reasons related to their history, their environment and exposure to hazards, relationships with stakeholders, their understanding and expectations of climate change (Bird et al.2013D). Many of the Indigenous communities of Australia, such as the Aboriginal communities in Broome, WA; Maningrida and Ngukurr, Northern Territory; and Wujal Wujal, Qld, are highly vulnerable to shocks and stresses and are located in hazard prone places (Bird et al.2013D). Furthermore, factors such as the centralisation of services for remote areas, loss of culture and connection to country, dependence on government funding, lack of monitoring, ad hoc development and land use planning and the multi-faceted issue of poverty are also found to contribute to vulnerability (Bird et al.2013D). Lower socio-economic members of Indigenous communities are more vulnerable to climate change compared to the general Australian population (Choy et al.2013D). Nursey-Bray et al.(2013D) note that the Arabana people demonstrate adaptive capacity to respond to climate change and have demonstrated this ability to remain culturally strong in the face of change for millennia. However, "livelihood security, welfare dependency and the disadvantages of race in contemporary Australia remains a point of vulnerability for a significant number of Arabana" (Nursey-Bray et al. 2013D p. 63).

While Indigenous communities are typically considered the most vulnerable to climate change, they are also less likely to re-locate/migrate as the climate changes (Memmot et al.2013D). This underscores the importance of appropriate planning and preparedness at the local community level to best build adaptive capacity in remote locations (Memmot et al.2013D). In these locations, self-reliance will be critical to reduce vulnerability. For extreme weather events, specific and unique evacuation protocols will need to be considered (Bird et al.2013D). At the same time, remoteness can also increase resilience and adaptive capacity when it is accepted by the community (Bird et al.2013D). This is largely due to the strong connection to country in remote areas with limited human distractions and development, giving a close connection to land and family (Bird et al.2013D). It is also important to note that moving away was not seen as option for the older generations, whereas younger community members, who may not have as strong of a connection to country, view migration as an adaptive response (Bird et al.2013D).

Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response. Climate change risks and manifestations are salient to the Indigenous population, but more immediate life and livelihood concerns are more specific, salient and articulated (Memmott et al. 2013D). Nursey-Bray et al. (2013D, citing AIPP 2011, pp. 7–8) describe how Indigenous people see links between climate change and other equally pressing impacts or change agents:

> [M]any Indigenous peoples … do not dichotomize between the effects of onslaughts of climate change and the onslaughts of human development. A storm upsurge has as much the same effect as large-scale open pit mining: massive soil erosions and community displacement. A drought has as much the same effect as large-scale logging: destruction of forests, drying of rivers and loss of source of food, among others. Indigenous people's adaptations to these forces have the same objectives – to effectively defend life.

As a result, management approaches need to take into account multiple dimensions and how to manage them beyond climate change adaptation. Adaptation responses can and should occur in parallel with other initiatives to best address long-standing socio-economic and capacity issues (Choy et al. 2013D).

Collaboration and cross-sectoral linkages will also be required. Nursey-Bray et al. (2013D) state that the Arabana people will need to engage and perhaps collaborate with the mining and pastoral communities in order to build collective strategies for managing issues and resources, such as water availability and access. Bird et al. (2013D) note that greater importance needs to be given to linking land use planning, emergency management and disaster management strategies to ensure knowledge is shared. However, the issue of governance and working with differing systems is also important to consider in order to support collaboration and to avoid conflict; governance systems for adaptation planning can be both formal and informal, as well as occur across state, local government and sectoral scales (Brooks et al. 2005 and Richards et al. 2006, in Nursey-Bray et al. 2013D).

Integrating local, Indigenous knowledge with climate change science is critical to adaptation. This includes the recording of Indigenous knowledge, as well as the education and training of skilled environmental managers who can combine Indigenous knowledge with science and actively engage in environmental management (Memmot et al.2013D). Indigenous knowledge and tools, such as seasonal calendars, can also aid in tracking climate change impacts on the environment beyond records established during European settlement (Choy et al.2013D).

The integration of Indigenous knowledge with science will ensure that adaptation plans are understandable by all readers and users;

Knowledge is not an accepted 'truth' but is in fact constituted differently in different cultural contexts. Western knowledge systems tend to be linear, sequential, and follow scientific principles, whereas Indigenous people's knowledge systems are more circular and different knowledge systems operate concurrently and feedback within a community in various ways (Sillitoe et al. 2002, Croal and Darou 2002, in Nursey-Bray et al. 2013D p. 119).

4.7.4 Health and wellbeing

Key findings related to health and wellbeing:

- There is need for a consistent heatwave policy for the management of aged care facilities.
- State/territory government should ensure adequate health services are available, both during and for the longer term after disaster events.

There is need for a consistent heatwave policy for the management of aged care facilities. Each state/territory in Australia varies in its creation of heatwave plans. For example, South Australia has a clearly defined Heatwave Plan administered by SA Health and SAFECOM whereas Queensland has incorporated the state heatwave plan into the State Emergency Plan. Black et al. (2013D) suggest that, where applicable, a consistent heatwave policy for the management of aged care facilities is needed in addition to the broad State-wide Emergency Management Plan. This policy should be created in collaboration with aged care service providers, the Department of Health and Ageing (DoHA) and the Aged Care Association of Australia. Continuous monitoring and response to extreme heat should also be a component of a regular continuous improvement strategy, and disaster/emergency planning (including heatwave response) should be part of Aged Care Facility Accreditation Standards (Black et al. 2013D).

State/territory government should ensure adequate health services are available, both during and for the longer term after disaster events. Boon et al. (2012D) recommend that state/territory government agencies and NGOs provide counselling and health support services for up to five years after a disaster. As a result of the 2010/11 flood events in Victoria, many residents discussed fears of another flood and being forced to re-live the experience (Bird et al. 2011). Those residents whose wellbeing suffered after the flood felt that they were less able to make changes to reduce their flood risk than others in the community (Bird et al. 2011). Ongoing support to rebuild mental and physical health, will increase individual resilience and capacity and contribute to greater community resilience.

[Note: Health and wellbeing is also closely tied to and important for increasing resilience and adaptive capacity. Therefore, there are also multiple health and wellbeing-related findings within Section 4.1.]

4.7.5 Business and industry

Key findings related to business and industry:

- Adaptation action within small and medium businesses may be resource constrained.
- Adaptation in some sectors of tourism may require diversification – this may provide additional benefits and/or risk.
- Aquaculture is a potential adaptation option for Goulburn Island residents but support would be needed to obtain the appropriate skills and resources.

Adaptation action within small and medium businesses may be resource constrained. West and Brereton (2013D) have developed a consolidated framework to enable boards and executive managers of the Australian business community to develop an approach to climate change adaptation governance, climate change risk assessment and financial disclosure that leads to increased reporting and disclosure without the need for additional and explicit regulations. However, it is noted that this framework is designed to assist mainly large companies; small and medium businesses do not have the resources to implement this framework. Therefore, more needs to be done to assist this sector undertake climate change adaptation assessment activities.

Adaptation in some sectors of tourism may require diversification – this may provide additional benefits and/or risk. Tourism in the Australian Alps, particularly snow-tourism, is expected to be especially impacted by climate change due to loss of snow cover and decreased winter visitors. Adaptation strategies identified by the tourism industry included snow-making, water recycling for snow-making, and the promotion of year-round tourism (Morrison and Pickering 2011). Lack of knowledge of climate change impacts and concerns about decreases in visitor satisfaction were viewed as limits to their climate change adaptation strategies. To correct these limits, the industry identified information on the social perceptions of climate change and skiing, as well as accurate information on climate change predictions on a relevant time scale, as research needs. While not identified by the tourism industry itself, other stakeholders interviewed in Morrison and Pickering's study (2011) also reported technological and economic thresholds involved with snow-making and/or manipulation and the social and economic costs of diversifying to year-round tourism as other limits to adaptation for this sector. Pickering and Venn (2013D) identify increased risks to alpine biodiversity through augmented summer tourism, including hiking and biking spreading weed and introduced plants as well as physical damage to flora. While snow-tourism is not available in the Northern Territory, other tourism activities in the territory may need to consider diversification under climate change, which may introduce new risks.

Tourism in the Northern Territory relies heavily on unique natural environments, including Kakadu National Park. The ecological deterioration that is likely to occur has potential to lead to a serious decline in the number of tourists and money available to these areas and the economies that rely on them (BMT WBM 2010).

Aquaculture is a potential adaptation option for Goulburn Island residents but support would be needed to obtain the appropriate skills and resources. Aquaculture could help increase the availability of food supply within the community and provide an extra source of income (Petheram et al. 2013D). However, the viability of such as enterprise is uncertain under climate change. The remote location of the community and the poor diversification of markets also add to an uncertain future (Petheram et al. 2013D).

Despite interest in aquaculture, there was little knowledge among Goulburn Island residents of the resources and capacity needed in order for aquaculture to be a viable enterprise (Petheram et al. 2013D). However, the community was very keen for an aquaculture enterprise to be an Indigenous run business. They felt that the fisheries agency could provide them with support to obtain the skills and resources needed. They also indicated their newly established community governance organisation, Yagbani Aboriginal Corporation, should be responsible for decision-making for an aquaculture enterprise; there was a lot of faith and confidence in this board among the community. However, there were many differences in opinion by participants over handling any profit from an aquaculture initiative (Petheram et al.2013D).

4.8 Practical adaptation actions

The following practical adaptation responses have been suggested from the research. Note that this is not an exhaustive list of actions; there are many additional actions that also could be pursued.

4.8.1 Natural environment and Agriculture, fisheries and forestry

4.8.1.1 Coasts

- Establish buffers and rolling easements around coastal reserves and wetlands to allow migration and displacement of habitats (Hadwen et al. 2011; Norman et al. 2012D).
- Develop coastal adaptation plans which identify where the existing coastal buffer is of sufficient width to accommodate future impacts, where immediate protection or retreat is required, and how adaptation actions can be undertaken (Helman et al. 2010).

4.8.1.2 Land and water management

- Develop model flood planning controls for local government (Wenger et al. 2012D).
- Utilise stormwater harvesting to reduce flood risk during extreme events and compliment water supply for open space and street trees while also reducing urban heat island effects (SGS 2010).
- Clarify the responsibilities and regulatory powers of responsible parties for the establishment, maintenance, and enhancement, and planning controls on developments adjacent to and on storm water systems. (Verdon-Kidd et al. 2010).
- Develop an integrative climate change model to incorporate terrestrial, marine and sea-level models which can consider interactions to allow greater understanding and improved projections for coastal zones (Hadwen et al. 2011).
- Re-consider land use to maintain connectivity at landscape, ecological and evolutionary scales to allow species the opportunity for autonomous adaptation (Hadwen et al. 2011).

4.8.2 Infrastructure, communities and land use planning

- Localise building design requirements beyond current regional zoning in the Building Code of Australia (Hadwen et al. 2011).
- Create building retrofit codes for existing buildings in high risk (flood, bushfire, cyclone) areas. Continue to evolve the draft Flood Standard in the Building Code of Australia (BCA) into a technical standard for commercial and industrial buildings (currently limited to housing). This should also include performance requirements for construction in areas prone to coastal inundation (Mason et al. 2012D).
- Create clear and nationally consistent guidance on public and private obligations in responding to and preparing for climate change, both in terms of managing changes with existing developments and new developments (Helman et al. 2010).
- Undertake property buy-backs, compulsory land acquisition and land swapping in high risk areas (Hadwen et al. 2011). However, property buy backs need to be complete and not piecemeal if they are to provide an effective adaptation strategy to hazards such as flooding and bushfire (Helmen et al. 2010).
- Increase flexibility in legislative and planning frameworks to accommodate future change (Hadwen et al. 2011). Adaptation actions taken today may not represent the best solution fifty years from now; therefore flexible responses into the future need to be considered in current decision-making processes and frameworks.
- Require major infrastructure owners to conduct climate risk assessments (McEvoy and Mullett 2013).

4.8.2.1 Emergency Management

- Consider a policy that subsidises insurance purchase for lower socioeconomic groups as an alternative to charity donations by government (Boon et al. 2012D).
- Reconsider conventional and standard levels of risk. Although the 1 per cent AEP flood extent is almost universal nationally as an area requiring some level of planning or building intervention, there is no clear reason why this level of risk has been chosen. In many ways, it is out of line with construction practice

for other natural hazards in Australia (e.g. ultimate limit design for wind and earthquake is 0.2 per cent of AEP) (Mason et al. 2012D).

- Establish clear but dynamic thresholds for recognising and responding to a disaster or climate event (Kiem et al. 2010a). The distinction between an event and disaster can be important, as there are often significant changes in strategy and management that follow the declaration of a disaster.
- Embed researchers within emergency management organisations in order to help emergency management staff better understand climate risks and direct research into needed areas (Howes et al. 2013D).

4.8.2.2 Communities

- Include greater local engagement and involvement in planning adaptation at the community level to identify the most effective strategies for building community resilience and adaptive capacity (Petheram et al. 2010).
- Establish collaborative funding mechanisms to manage risks and encourage agencies to form consortiums across all levels of government and the private and community sectors to work together to solve problems, such as finding ways to build building resilience to a range of natural disasters (such as floods and bushfires) and climate change (Howes et al. 2013D).
- Support local community resilience grants with local government to encourage communities to undertake simple projects to increase resilience (Howes et al. 2013D).
- Establish or enhance formal and informal local support networks (Boon et al. 2012D).
- Tenancy and property management strategies need to consider adaptive responses to climate change, including assigning responsibility for adaptation planning and resourcing (Horne et al. 2013D).
- Future public housing design guidelines should enable and promote adaptive climate practices (Horne et al. 2013D).
- Create consistent methodologies and data frameworks to enable information sharing between and within government agencies – particularly important for remote communities in the tropical north (Bird et al.2013D).

4.8.3 Health and wellbeing

- An education resource on maintaining wellness under extreme heat should be developed for aged care staff and service providers (Black et al. 2013D).
- Specific programs for CALD communities to increase awareness about the health risks of heat exposure and to behaviours to reduce the risk that do not rely on home air-conditioning. Provide information and warnings in multiple languages and through multiple, diverse channels, including religious leaders and school children (Hansen et al. 2012D).

4.8.4 Business and industry

- Explore market-based instruments to encourage homeowners to undertake upgrades to their houses, similar to the Florida Comprehensive Hurricane Damage Mitigation Program/My Safe Florida Home program (King et al. 2012D).

4.8.5 General

- Establish adequate monitoring and review of adaptation policy, including assessment and review frameworks (Lukasiewicz et al. 2013D; Aldous et al. 2011; Saintilan et al. 2011; Robson et al. 2013D).
- Develop a shared information system for data on risks, uncertainties and other climate related information for each jurisdiction (Hadwen et al. 2011).
- Develop a standardised approach for evaluating costs and benefits of adaptation investments, particularly for state/territory and local government (Mukheiber et al. 2012).
- Increase clarification and differentiation between local and state/territory government responsibilities, and explore the potential for greater involvement of local government in regional decision-making due to local government's greater connection with local priorities, capacities, barriers and aspirations (Sharma et al. 2013).

Tools for decision-making

While there are many uncertainties associated with climate change, decisions must continue to be made which need to be robust across a range of possible futures (Dessai et al. 2009 in Mortazavi et al. 2013D). Many research projects have included the development of tools to assist climate change adaptation decision-making through:

- risk identification, including costing;
- communication of hazards;
- identification, comparison, optimisation and prioritisation of adaptation options;
- stakeholder engagement and collaboration (Bennett et al. 2012).

Limitations or challenges associated with tools are formulating objectives, constraints and decisions. Tools, such as optimisation (i.e. a methodology that identifies optimal and robust planning and operational decisions in the face of uncertain knowledge about future climate change), will not produce a single answer – but may help identify a range of 'good' solutions that can form the basis for adaptation (Mortazavi et al. 2013D).

The interpretation of climate projections and integration into adaptation tools remains problematic. A majority of the research reports included recommendations for improved climate change information particularly for highly localised information, average returns periods and event intensities. However, specific needs and issues were largely not identified. Many of the tools discussed in the research are also specific to or have only been tested within the context of a single sector or at discrete locations. It was beyond the scope of this project to further test these tools. However, most of these tools need broader testing and evaluation beyond the initial development phase to better consider broader applicability. Similarly, consideration also needs to be given to promote tools and how to provide adequate support to the range of stakeholders targeted. This is generally beyond scope of initial research funding or beyond the skillset of the researchers.

Look for this icon for tool-related reports. This icon identifies research reports where a tool or framework is discussed.

5. POLICY AND RESEARCH ENGAGEMENT

The primary purpose of this synthesis was to identify the common emerging adaptation research lessons that can be used by state and territory decision-makers in their efforts to set policy. Viewing the research through this lens highlighted a number of lessons regarding how the interactions between policy and research may be improved for researchers to better generate knowledge for adaptation policy and for practitioners to better specify what knowledge is needed for action. This section highlights these findings.

Adaptation policies and strategies need to articulate the adaptation goal in terms of the end point to be attained. Often adaptation policies and strategies do not directly state the goal of adaptation action in terms of the end point to be achieved. Instead, objectives are vaguely stated with a focus on increasing resilience, reducing risk and maximising opportunities (Hadwen et al. 2011). This creates a number of tensions, including the need to have flexibility in order to manage uncertainty. It also leads to a lack of clear measurable objectives to test through research.

Participatory approaches can benefit both researchers and policymakers. A participatory approach to research is important to:

- ensure that existing knowledge and current research is being built upon
- promote access to, and interpretation of information necessary for risk assessment and adaptation planning
- allow for iterative feedback to ensure that deliverables are fit for purpose/practical action (McEvoy and Mullett 2013).

A large portion of the research examined public engagement and stakeholder collaboration strategies. As supported by the research, engagement with a diverse group of stakeholders is essential and much can be gained through cross-sectoral collaboration. However, the principles and frameworks that emerge from such collaboration can be difficult to incorporate into research reports, as the lessons are best gleaned through the engagement process itself. Furthermore, formal studies evaluating the effectiveness of engagement techniques for climate change initiatives are limited in quality and quantity (Fritze et al. 2009). This is a key barrier to sharing knowledge about successes, failures and possible improvements.

Improvements could be made to increase the value of research for policymakers. Often few distinct lessons emerged from the research that would enable decision-makers to take clear actions. More often, the research identified gaps in knowledge, limitations, barriers, and research gaps. While this is extremely important function for research, it is unlikely to be the type of specific information government decision-makers need to develop and implement identified adaptation-related priorities. A few researchers noted this issue in their work. For example, Kiem and Austin (2012) state that a fundamental barrier exists between the information that climate science can provide and the information that is practically useful for end users and decision-makers. The source of this disconnect is unclear; it may be “a communication issue, an education issue, a technological issue, or a fundamental philosophical issue (i.e. that scientists think about things differently than practitioners, decision-makers and/or end-users do)” (Kiem and Austin 2012, p. 22).

Kiem et al. (2010b) also identify a barrier that exists between scientists and researchers providing climate change data and adaptation information, and policymakers, resource managers, emergency response personnel, farmers etc. that use the data. This disconnect exist on both sides of the exchange. Information providers do not always understand the needs of end-users and the format that the end-users need data and information in for it to be useful. At the same time, end-users can have unrealistic expectations of what science can currently provide or may not understand the limitations and uncertainties of the data outputs provided (Kiem et al. 2010b). Conflicting time constraints can cause further issues (Hadwen et al. 2011). As a result of this disconnect, the priorities of policymakers and other end users do not align with the priorities of climate science researchers, constraining both progression of practical climate knowledge and adaptation action (Kiem et al. 2010a).

An example of a strategy that has worked to bridge this gap in the disconnect between researcher and decision-makers is the strong relationship that exists between the City of Melbourne and the Victorian Climate Change Adaptation Research Facility Institute (Hussey et al. 2013D). This is noted as allowing information providers to gain insights into the decision-making process and what is needed by the organisations, as well as encouraging “a legacy within organisations to identify and assess adaptation options” (p. 68). This relationship is promoted by Hussey et al. (2013D) as something that should be further explored and encouraged within other organisations (government, NGO and private) and research institutions due to the mutual benefits it provides.

Care needs to be taken in research to avoid stakeholder fatigue and disenfranchisement. Kiem et al. (2010b) report stakeholder fatigue in many rural areas, meaning people are becoming tired and sceptical of

climate change research projects because they have been involved in so many but have seen few positive outcomes. “Further efforts are needed to coordinate ‘outcome-based’ or applied research activities – a practice that not only provides the benefits of interdisciplinary and interagency knowledge, but also respects those we are working with by not overburdening them with separate and disconnected research interventions” (Kiem et al. 2010b p. 17).

There is a need for consistent climate change terminology use across research bodies, government departments, relevant industry and organisations to allow greater understanding between research providers and end users. There are current disparities between terms used including adaptation, prediction, projection and scenario in documents relating to climate change and adaptation (Hadwen et al. 2011 and Verdon-Kidd 2012). Some of these are due to different sectors or organisations adopting different meanings, others due to misuse through lack of knowledge of accepted meanings. It is noted in that there are current lists of terminology widely adopted by researchers, predominantly the IPCC definitions; however there is a need to adopt and educate on standard definitions (Verdon-Kidd 2012). This lack of consistent terminology use also leads to an increase in misunderstanding between the information providers and information users, as identified by Kiem et al. (2010b).

5.1 Strategic cross-sectoral research gaps

A common outcome of the literature reviewed was to identify research gaps and new questions. Many of these recommendations were focused on areas where further research is required. While it is important that these issues are captured, it is equally important that gaps are identified in relation to application of the research findings themselves for specific end users, in this case state and territory decision-makers.

Understanding of autonomous adaptation. Although autonomous climate adaptation has been observed in some systems, it is not known whether or how long this will be able to match the rate of climate change. Similarly, thresholds of ecological, social and economic resilience are unidentified for many systems and communities. For example, there are significant knowledge gaps regarding which species are capable of shifting their habitat range (including pests). Without this knowledge, the role of protected area conservation as an adaptation option is likely to be limited (Hadwen et al. 2011).

Adaptation effectiveness. Research to assess the efficacy potential and unintended consequences of different potential adaptation actions is limited. This research needs to be done at a regional scale as it is likely that consequences will vary according to local settings and in response to interactions with each other and regional non-climatic stressors (Hadwen et al. 2011). It is acknowledged that the number of on-ground human climate change adaptation practices remains limited (or optimistically, are difficult to identify due to integration). Measuring the success of adaptation actions needs to be undertaken in the short, medium and long-term and will need to be informed by careful monitoring.

Understanding of the limits of uncertainty. For effective and robust adaptation-related decisions to be made, realistic and practically useful information on climate change impacts is needed (Verdon-Kidd 2012). For example, a lack of understanding of climate change impacts has been identified as a major barrier to adaptation interventions for freshwater ecosystems (Robson et al. 2013D). However, it appears that this information is not as critical for interventions to improve community resilience. Uncertainty is also unlikely to be reduced for many sectors in the near future (if at all), so effective decisions will need to be made under uncertain conditions (Verdon-Kidd 2012). Understanding for which sectors the uncertainty of climate change impacts limit adaptation action and where a reduced uncertainty is largely unnecessary would facilitate implementation. It is also important to understand the causes and structure.

Non-physical and compounding vulnerability. Research and interest remains focused on adaptation associated with physical vulnerabilities that can be incorporated into policymaking. However, non-physical vulnerabilities, such as social and economic vulnerabilities, and how different factors interact and may compound vulnerability remain poorly understood. This information would be useful to inform approaches such as scenario planning. Examples of where this has been identified in the literature include:

- the interaction between heatwaves, air quality and urban form, establishing a better understanding of sub-groups vulnerable to temperature extremes and characteristics that increase vulnerability (QUT 2010)
- the risks of multi-city extreme events and their effects on emergency services, insurance and disaster relief (QUT 2010)
- mental health and nutrition issues in indigenous communities where climate change impacts affect ceremonial hunting and food gathering practices (Green 2006).

6. CONCLUSIONS

6.1 Fundamental adaptation challenges relevant to state and territory government decision-makers

The complexity of climate change adaptation cannot be underestimated. A wide range of issues, including national and state/territory policy contexts, local institutional constraints, short and long-term climate variability, local community development strategies and local environmental conditions, play a role. As pointed out by Gross et al. (2011), “adaptation to climate change should be considered as one aspect in a complex, ever changing set of environmental, social and economic circumstances” (p. 77).

There are clear challenges associated with the scale of adaptation required, the timing of when to introduce interventions and how interventions are best delivered. Humans tend to be relatively short-term thinkers, and Australia’s variable climate and relative short history of European settlement may further discourage consideration of long-term changes in climate. In particular, climate change projections for extreme events have significant levels of uncertainty – both in terms of timing and frequency. The reality that improvements in climate change science can only partially reduce this uncertainty requires that adaptation planning accepts these uncertainties. These uncertainties also highlight the need for flexibility, both as new information emerges and as society evolves. What flexibility actually looks like is only just starting to emerge – particularly in relation to the balance between water management for both floods and drought.

Climate change uncertainties are not the only constraints however. Changes within society and the environment – both in response to climate change and other forces and their influence on adaptive capacity and vulnerability – remain one the greatest limits to effective adaptation. Use of a ‘business as usual’ baseline to compare impacts and vulnerability over time is overly simplistic at best and misleading at worst. Changes in global and regional economies, demographic shifts and technological advancements will fundamentally shift underlying vulnerability and adaptive capacity. From these, changes in values and priorities will also emerge. As a result, policy and management objectives, particularly in relation to natural resource management, disaster recovery and land use planning need to be re-considered at a fundamental level. Objectives must be considered from a non-stationary baseline and in light of longer term risks, multiple scales and in the context of potentially diverse values.

Some members of the community are unwilling to link climate change to observed phenomena. At the opposite end of the spectrum, there are portions of communities overwhelmed by the picture of unstoppable and pervasive climate change. As such, communication regarding disaster preparedness and climate change often need to be separate and offer bespoke, tailored messaging depending on a community’s world-view, interests and needs. In fact, significant proportion of the research reviewed for this synthesis recommends the need to better consider messaging and communication on climate change adaptation. The need to engage both stakeholders and the broader community to get behind adaptation actions is crucial. Engagement can help increase community preparedness, create ownership of and buy-in for adaptation options, and improve social cohesion. Clearly articulating adaptation goals (together with options) and using shared terminology are seen as key to engaging the community. By engaging the community, local and historical knowledge can be also be accessed to help identify risks, opportunities and maladaptive options. In the Northern Territory and South Australia, for example, the engagement of indigenous communities is considered beneficial for a range of adaptation activities including emergency management and natural resource management (Hadwen et al. 2011; Bardsley and Wiseman 2012; Haynes et al. 2011).

Responses to recent extreme events have been examined to identify potential adaptation lessons, particularly with regards to floods, bushfires and droughts. Unfortunately, the findings for long-term adaptation are not as clear. While it is critical that we learn from and address the many issues that arise from these events, we may still be missing key adaptation lessons. Of the formal reviews of these events studied by different pieces of research, the potential influence of further climate change was not considered to gauge or identify where responses beyond ‘business as usual’ may be necessary or to test recommendations made. Further opportunities are lost by the rush to restore communities and meet shorter term needs.

Using these experiences as the basis for adaptation planning may also introduce risks and bias. As noted by Kiem et al. (2010b) strategies to deal with extreme events can be irrelevant under climate change as evidenced by ‘exceptional circumstances’ payments, which were originally enacted as an emergency response, in reality worked against rural communities adapting to drought and drier conditions in the long-term.

The question of whether experience with disaster events improves community resilience also remains inconclusive – it appears that the answer depends on a range of factors, unique to each location, each event and

a point in time. No research has challenged the validity of the question for policy – which is particularly important when considering the long-term nature of climate change.

While adaptation is a growing challenge for state/territory government decision-makers, there is an expanding body of adaptation knowledge to assist. Through recognition of the emerging fundamental challenges, adaptation approaches can be identified (specific options will be highly contextualised and therefore beyond the scope of this synthesis approach). The breadth of research reviewed, both in terms of location and sector, highlight the complexity of these challenges and these common themes, outlined in Table 2. These challenges include potential implications for policy development, programs and management undertaken by state and territory governments.

However, despite the challenges, it is also important to recognise that the experience from extreme events can brings hope. Stories of autonomous self-organisation and neighbourhood support highlight the need to continue efforts which strengthen a sense of community and ultimately improve adaptive capacity. Examples such as Queensland 'Mud Army' and 'Bake Relief' demonstrate the potential role of social media along with the capacity of the human spirit. Other local or autonomous' responses to recent and current climatic stressors have also been identified, including how some farmers have shown innovation and flexibility in adapting livelihood systems to changeable and marginal environments through crop diversity and water management in response to climate variability. Local knowledge provides considerable assets in the form of social capital and natural capital, demonstrating innovation in the face of adversity. Recognition and promotion of these behaviours needs to be considered in community and targeted by support programs.

Table 2: Summary of the fundamental challenges

Fundamental challenge	Issue	Policy implications	Example
Climate change uncertainty	Assessing the impacts of climate change is uncertain due to inherent uncertainty in climate change and numerical modelling but also because impacts will vary over time and space and will be synergistic. Adaptation planning needs to consider the possibility that most uncertainties are unlikely to be resolved by the time decisions need to be made.	Because of uncertainty, it will be difficult to prioritise adaptation planning and when decisions are made, they are likely to be contested. Failure to accept uncertainty is resulting in inertia and stifling the development of flexibility. Issues of uncertainty should be considered a limiting factor to adaptation.	Use of a range of decision support tools such as scenario planning and sensitivity analysis can help identify adaptation options which are robust under a range of conditions or identify trigger points for new adaptation options.
Working with a changing baseline	Climate change represents only one of many drivers of change. Taking into account other drivers is essential to help inform long-term adaptation planning.	There is significant economic, institutional, ecological risk in planning adaptation responses without considering all pressures. Adaptation needs and effectiveness will change over time in response to diverse factors. By not considering these shifts, investment may be ineffective in the longer term and new risks may arise.	The early introduction of flood barriers has encouraged the concentration of development in high risk floodplains. However, the effectiveness of these barriers have not been reviewed against future increases in rainfall.

Fundamental challenge	Issue	Policy implications	Example
System approaches	Climate change is complex, and vulnerability will be driven by ecological, social and economic responses, interactions between sub-systems and interactions across scales. To maximise adaptation effectiveness, create opportunities for change and avoid maladaptation, a holistic approach to adaptation needs to be considered.	Mechanisms for collaboration between and within government need to be facilitated. Collaboration with stakeholders will also be essential. Processes by which to consider trade-offs and the distribution of costs and benefits at local and regional scales will need to inform decision-making.	Water trading/pricing impacts multiple systems and sectors, including natural resource management, agriculture, industry, infrastructure and community resilience.
Articulation and implementation of adaptation objectives	Historical policy objectives may no longer be appropriate in the face of climate change and may limit opportunities for transformational change. Failure to explicitly state adaptation objectives may create unrealistic community expectations and fail to trigger autonomous adaptation responses by individuals.	Natural resource management, biodiversity conservation and land use planning objectives will be particularly affected. By working with stakeholders to articulate adaptation objectives, conflict can also be avoided and barriers addressed. This will also assist to coordinate the integration of climate adaptation into existing policies, strategies and operational activities at state/territory government departmental and agency portfolio level.	Biodiversity conservation may need to consider adaptation options to maintain ecosystem function rather than the conservation of individual species. The establishment of habitat corridors may need to focus on the needs of a different range of species than what might currently be expected.
Limits to adaptation	Limits to adaptation may be artificially imposed and will vary over time. Limits may be imposed by societal values, physical or resource constraints or institutional constraints.	If limits to adaptation are temporary or artificial constructs, effective stakeholder engagement, flexible policy and clear articulation of short and long-term adaptation objectives will be critical.	Community acceptance of adaptation options may change in response to conditions – for example, the use of recycled water as described by Hurlimann and Dolnicar (2011).

Fundamental challenge	Issue	Policy implications	Example
Learning from recent extreme weather events	Action on the ground to date tends to focus on responses to past severe weather effects. Reviews of these events do not generally consider the implications for the future under a new climate. . Substantial long term long-term, continuous changes may require different responses than limited, temporary events such as floods, bushfires and droughts.	While it is important for government to take a continuous improvement approach following extreme events, current recovery support may be compounding risk and reducing the resilience of communities. Opportunities for significant change are lost due to need to support recovery efforts in the short-term and as communities discount the impacts of past events.	Consideration of climate change in reviewing extreme events. Exceptional Circumstances payments for farmers can work against communities trying to adapt and transition (Kiem et al. 2010b).
Monitoring and review of both risks and adaptation responses	Monitoring is needed to support flexible decision-making over time. Monitoring can also help define triggers for action including different or intensified adaptation responses. There is currently little knowledge or experience in evaluating adaptation options.	Consideration of how climate change can be taken into account when reviewing and updating existing policies	Natural resource management requires adaptive management, meaning actively experimenting with actions and learning from past activities. Monitoring is essential to evaluate actions.
Communication and engagement	There is no value in a 'one size fits all' approach to engaging stakeholders on climate change adaptation. Specific, targeted engagement is required.	Greater consideration of the interests, needs and concerns of specific stakeholders is needed to build community support for adaptation.	Information and warnings need to be provided in multiple languages and through multiple, diverse channels.

6.2 Key lessons for state and territory government decision-makers

While a key focus on the research reviewed has been issues associated with research constraints, gaps and limitations, a number of lessons for decision-makers have been identified.

Greater effort is needed in identifying adaptation opportunities and promoting positive change. While there is a need to continue to prioritise adaptation aimed at reducing the risk of harm and in evaluating the limits and barriers of adaptation, there are benefits in seeking to identify potential opportunities, including incentives and regulation. Careful messaging will be required, but this approach may help to positively engage stakeholders, especially those that may feel overwhelmed by climate change. Clear opportunities already exist. For example, on average 35,000 new buildings are built each year in Australia offering numerous opportunities to improve the climate resilience of Australia's future built environment.

Monitoring and evaluation of existing adaptation practices will be critical for on-going adaptation. As well as being necessary to monitor the effectiveness of current adaptation options, including those intended to increase adaptive capacity, an evaluation process is critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

Define adaptation objectives. Understanding what the government's appetite for risk is and what outcomes are expected for an adaptation approach are critical for decision-making, implementation and evaluation. Developing these objectives in consultation with stakeholders will help build support and send appropriate messages to trigger private adaptation. Defining adaptation objectives need to go beyond 'motherhood statements' (for example, 'a community that is resilient to climate change') and actually articulate what that may look like.

Climate change adaptation with Indigenous communities requires a holistic, multi-sector, collaborative response. Adaptation programs should focus on empowering Indigenous communities to identify and implement their own responses; co-management or power sharing arrangements are also recommended to build partnerships while ensuring sovereignty is not lost. Furthermore, the integration of local, Indigenous knowledge with climate change science is important to aid in tracking climate change impacts on the environment and to ensure that adaptation plans are understandable by all readers and users.

Continue efforts to build community cohesion. Building a sense of community is important to increase adaptive capacity and resilience but will have a range of benefits beyond climate change adaptation. Communities with a strong sense of place and greater social networks tend to have greater adaptive capacity than communities without these characteristics. The topic of climate change does not need to be the focus of community building programs in order to be advantageous for adaptation. This will require continued close engagement with local government and community organisations.

Avoid calm weather planning. Taking a risk-based approach, which factors in both experience from past extreme events and future potential climate change, is a more robust approach for adaptation planning than just relying on experiences with past extremes. This approach will also help focus on the co-existence of adaptation needs for diverse events, such as water management planning which considers both floods and droughts.

Create opportunities for greater engagement between researchers and end users. To take advantage of research and to support better adaptation planning, government decision-makers need early and frequent engagement with the research community. There also needs to be a greater focus on end user focused research, which supports policy development and implementation.

Appendix A: FORNSAT Interviews—summary of issues and directions

Report compiled 6 August 2012

NCCARF appointed AECOM to prepare a synthesis of adaptation research relevant to each state and territory. The starting research questions for this research are:

- What useful and practical analysis for state and territory policymakers can be provided from the adaptation research now available?
- What are the implications of that analysis for sectors in individual states and territories?

The synthesis reports are to be targeted specifically to the needs of state and territory governments. Therefore, a critical success factor for this project is the extent that the synthesis meets these needs.

To commence this work, AECOM sought input from individual states and territories with regards to:

- the scope and focus of the synthesis
- the inputs into the synthesis
- broader stakeholder engagement
- the outputs of the synthesis.

This input was gathered through interviews with FORNSAT representatives and other invited guests from each state and territory (excluding Tasmania) between 26 and 6 August. Appendix Table 1 provides a full list of interviewees by state or territory.

Appendix Table 1: Interviewees by state/territory

State/territory	Representatives interviewed
New South Wales	Christopher Lee
Victoria	John Houlihan
Western Australia	James Duggie
South Australia	Stephanie Ziersch
Queensland	Lynn Whitfield, John Locke, Nancy Esler, Craig Walton, Kirsten Lovejoy and Daniel Rodriguez
Northern Territory	Bethune Carmichael
Australian Capital Territory	Kathy Tracy and Tim Wong

Summary of findings

Interviewees were asked the same seven interview questions. Feedback received has been qualitatively summarised by question, highlighting key themes, similarities and differences between responses.

1. What do you most want out of this synthesis of adaptation research? What would be of greatest value to the state/territory's adaptation program?

FORNSAT representatives expressed the following needs or interests in this project:

- Identifying and aggregating policy-focused and practically applicable research relevant to each state and territory.
- Providing a clear picture of what research has occurred and where (including types of research). Also, identifying research gaps and research opportunities.
- Supporting the strategic positioning of adaptation efforts and investment by demonstrating the need for adaptation research and benefit of action.
- Drawing out conclusions that can help decision-makers (ensure the synthesis is pragmatic and demonstrates how research can clearly inform actions).

- Identifying transferable lessons from and comparisons with other regions.
- Demonstrating how NCCARF research is complementary to other state/territory-based adaptation research investment.

2. Has your state/territory defined or articulated its priority climate change risks or adaptation priorities?

Few states and territories have formally or publicly defined their priority climate change risks or adaptation priorities. However, where risks have been identified in internal documents, there was a willingness to share this information with AECOM on a confidential basis where feasible.

A regional approach to adaptation planning is being used by a number of states/territories. In these cases, states/territories are working with regions to define their priorities.

Some interviewees suggested specific plans or stated policy objectives that should be used to organise findings. It should be noted that tailoring a state or territory synthesis report to a specific plan's actions is likely to be beyond the scope for this project. AECOM will use existing plans and policy objectives to understand government needs and to guide the creation of the project's synthesis framework. A consistent synthesis framework and approach will be used for all states and territories.

3. Have any literature reviews or broader vulnerability assessments been undertaken that could help inform this project?

Sector-specific and regional vulnerability assessments and climate change impact assessments have been completed or are underway by most states and territories. Many have also internally identified adaptation research needs or have conducted internal literature reviews. AECOM has asked representatives to share this internal information if feasible and relevant.

4. Where you have used research to inform policy and program development, what have been some of the key factors that have ensured the research is useful/applicable?

Many states and territories conduct research for policy and program development in-house or in close partnership with universities. Research undertaken or directly commissioned by individual government agencies is preferred as these agencies are best placed to consider issues pertinent to their sector or department. Similarly, research with active end-user engagement tends to have greater levels of confidence, increased potential for application, and fewer barriers for uptake.

Utilising uncommissioned academic research can be challenging for governments as it tends to be less directly relevant to state or territory needs and/or less practically focused. Some states/territories view this project as an important first pass to identify relevant literature, indicating to states and territories which researchers to engage with further.

The language used in research can also be important for uptake, particularly for less scientific- or academic-focused government staff and policy officers. Language needs to be accessible to a range of users and clearly articulate lessons.

5. What elements of this project would be most useful for you?

FORNSAT representatives had differing views of the utility of project elements, particularly related to the length and detail of the reports.

Appendix Table 2 displays a qualitative assessment of the level of state and territory interest in project outputs.

Appendix Table 2: Project outputs and level of interest

Project element	Level of state/territory interest
A searchable database of NCCARF research	*High*. Considered the most useful project element by one representative. However, representatives frequently requested that the database include more than just NCCARF research.
A scan of adaptation research relevant to your state/territory	*High*. Considered useful by all representatives. Some also expressed the importance of including transferable learnings from other locations within Australia.
A scan of adaptation research relevant to targeted government priorities or critical sectors	*Low*. Considered the most useful project element by two representatives. However, very few states/territories were able to provide clear direction on their key priority sectors.
A stand-alone short report of the synthesis findings (e.g. a document of 6-10 pages for non-technical audiences)	*High*. Considered useful by the majority of representatives; deemed valuable for engaging with ministers and senior management but less valuable for adaptation practitioners. Many representatives stressed the importance of not over-synthesising the research and warned about the potential risks of editorialising. Others stated the need for the synthesis to include analysis and clear direction to end users.
A detailed technical report outlining the project methodology and findings	*Medium*. Considered highly useful for representatives who felt the short synthesis would not provide practitioners with enough technical detail. However, multiple representatives had little interest in this report.

Representatives occasionally suggested additional project elements not listed above. Suggestions included:

- providing useful guidance on how to reach/engage communities (general public) to build resilience
- creating outreach materials to communicate project progress and share the outputs of this project to a broader audience (communities, stakeholder groups, etc.)
- providing guidance on how to use, maintain and adapt the database.

Representatives also provided input on how best to benchmark research within the database. Suggestions included:

- including a variety of categories and key words to search the database, such as type of methodology used, outputs, geography, knowledge transfer mechanisms, completion date
- considering how the database can mesh information between states/territories.

6. Who do you see in state/territory government being the key audience?

Interviewees generally saw two audiences for this work:

- high level decision-makers, where a short, sharp synthesis can help demonstrate the need for adaptation
- policy officers, practitioners, sectoral experts, existing adaptation/climate change working groups, who will want detail that is specifically relevant to them. A searchable database and technical summary is likely to be of greatest interest to this group.

A few states and territories also highlighted the importance of local governments in adaptation planning and emphasised their place as a key audience.

7. How can the value of this project to other end users in your jurisdiction best be communicated?

FORNSAT representatives intend to directly engage with existing interdepartmental working groups throughout this project. Where existing working groups do not exist, representatives intend to utilise existing databases of government stakeholders to distribute information.

Working groups and stakeholders will be asked to provide any relevant adaptation research, review the list of adaptation research to be synthesised, and attend the workshops in November / December to provide feedback

on the draft synthesis. In order to ensure end users are responsive and engaged, some representatives emphasised the need for the synthesis to be linked to each government's policy priorities.

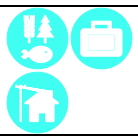
At the end of the project, FORNSAT representatives plan to distribute project end products to a broad audience of government stakeholders using their existing information channels.

Interviewees requested that AECOM provide short, sharp project updates to assist with outreach. It will also be important to consider the timing of communication and outreach (especially in relation to combined run-up to Christmas and potentially bushfire season).

Appendix B: Nationally relevant NCCARF projects

A total of 23 NCCARF research projects included in the synthesis have been determined to be national projects – projects that are not limited to specific locations, have either no geographical case study region or cover common issues for Australia.

Appendix Table 3: Nationally relevant NCCARF research projects

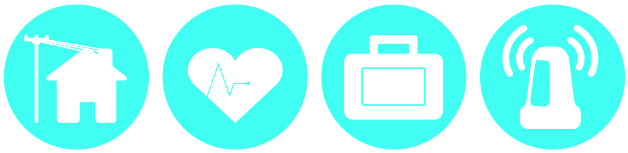
ID	Lead Author	Year	Title	Sectors
SI1004	G. Barnett	2012	Pathways to climate adapted and healthy low income housing	
P1FVA5	S. Boulter	2012	A preliminary assessment of the vulnerability of Australian forests to the impacts of climate change synthesis	
SD1117	R. Crompton	2012	Market-based mechanisms for climate change adaptation: Assessing the potential for and limits to insurance and market-based mechanisms for encouraging climate change adaptation	
FW1109	M. Dunlop	2013	Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems	
S3BCM1	D. Hine	2013	Enhancing climate change communication: strategies for profiling and targeting Australian interpretive communities	
EM1102	M. Howes	2012	The right tool for the job: achieving climate change adaptation outcomes through improved disaster management policies, planning and risk management strategies	
TB1105	L. Hughes	2013	Determining future invasive plant threats under climate change: an interactive decision tool for managers	
SD1109	K. Hussey	2013	An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice?	
S3BCM2	G.S. Johnston	2013	Climate change adaptation in the boardroom	
P2LTA6	A.S. Kiem	2012	Limits and barriers to climate change adaptation for small inland communities affected by drought	

ID	Lead Author	Year	Title	Sectors
EM0901	M.E. Loughnan	2012	A spatial vulnerability analysis of urban populations to extreme heat events in Australian capital cities	
SI11 01	A. Macintosh	2013	Limp, leap or learn?: Developing a legal framework for adaptation planning in Australia	
TB1102	R. Maggini	2013	Optimal habitat protection and restoration for climate adaptation.	
SI1106	K. Mallon	2013	Climate change and the welfare sector – risk and adaptation of Australia's vulnerable and marginalised	
S3BIB1	L. Mason	2012	Leading practice guidelines: planning and preparing for extreme weather events	
S3AFS1	D. Michael	2012	Food security, risk management and climate change	
S3ABA1	P. Mukheibir	2012	Cross-scale barriers to climate change adaptation in local government, Australia	
P2IMLR	E.S. Poloczanska	2012	iClimate Project	
S3AUN2	A. Randall	2012	Understanding end-user decisions and the value of climate information under the risks and uncertainties of future climate	
EM1101	J.P. Reser	2012	Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011	
P1ACP1	T.F. Smith	2010	The nature and utility of adaptive capacity research	
EM1103	S. Trueck	2013	Developing an Excel spread sheet tool for local governments to compare and prioritise investment in climate adaptation	
S3AUN1	D. Verdon-Kidd	2012	Bridging the gap between end-user needs and science capability: dealing with uncertainty in future scenarios	
SI1005	C. Woodroffe	2012	A model framework for assessing risk and adaptation to climate change on Australian coasts	

Appendix C: NCCARF research summaries – NT

Future change in ancient worlds: Indigenous adaptation in northern Australia	
Authors (Year)	D. Bird, , J. Govan, H. Murphy, S. Hardwood, K. Haynes, D. Carson, S. Russell, D. King, E. Wensing, N. Tsakissiris, S. Larkin (2013)
Status	Draft
Summary	This report examines underlying vulnerabilities, adaptive capacity and population movements of indigenous people within four remote northern Australian communities already exposed to extreme weather events and climate variability. Through a literature review, demographic analysis and interviews with different elements of the indigenous communities, a unique set of circumstances emerge which influence directly and indirectly each community's vulnerability and adaptive capacity as a result of their history, their environment and exposure to hazards, relationships with stakeholders, their understanding and expectations of climate change Factors such as the centralisation of services in remote areas, loss of culture and connection to country, dependence on government funding, lack of monitoring, ad hoc development and land use planning and the multi-faceted issue of poverty were all found to contribute to vulnerability. However, the remoteness of these communities can also enhance adaptive capacity by creating greater levels of self-reliance. As such, emergency management and other adaptation strategies for remote communities need to be considered separately from other communities.
Methodology	This study utilised literature reviews, census data, spatial network analysis and case studies involving stakeholders at the three locations.
Output	Knowledge
States (specific location)	Broome, WA Maningrida and Ngukurr, NT Wujal Wujal, QLD
Sector relevance	

Climate change responses and adaptation pathways in Australian coastal ecosystems: synthesis report	
Authors (Year)	W.L. Hadwen, S.J. Capon, E. Poloczanska, W. Rochester, T. Martin, Bay L, Pratchett M., Green J., Cook B., Berry A. and Lalonde A. and Fahey S. (2011).
Status	Final report
Summary	This report is a synthesis of research on coastal ecosystems, climate impacts and risks, and management strategies; with a focus on how anthropic and ecological adaption pathways can minimise the impacts of climate change and allow coastal ecosystems to recover. The study undertakes a broad-scale exploration of Australian coastal processes and ecosystems, possible climate changes in the differing coastal zones, and resultant climate change impacts and hazards for the ecosystems that reside in these zones. Autonomous and managed adaptation pathways are explored, as well as possible unintended impacts on humans and ecosystems of adaptation options. The study finds that immediate action on climate change should be taken, with the need to engage stakeholders and the community to get behind adaptation actions as key. It is suggested this is done by clearly articulating probable impacts and the goals of the adaptation plan (together with alternate options), underlining the benefits of early and effective actions, and by highlighting maladaptive options and actions.
Methodology	The project team reviewed an extensive list of literature and synthesized this into end-user products.
Output	Knowledge, Tools or guidelines
States (specific location)	Northern Territory (Hunter Estuary), New South Wales (Newcastle), Queensland (Cairns Region, Kakadu National Park).
Sector relevance	

Institutional response and Indigenous experiences of Cyclone Tracy	
Authors (Year)	K. Haynes, D. K. Bird, D. Carson, S. Larkin, M. Mason (2011)
Status	Final report
Summary	This report assessed how government and NGOs responded to Cyclone Tracy, and how the event affected indigenous people and communities in the region. The study focused on the actions of the newly formed Federal Natural Disasters Organisation (NDO) in response to the event; an overview on how these actions and the cyclone affected locals – and whether there was disparity between the indigenous and non-indigenous experience. Findings include that although some nomadic indigenous people may have been more vulnerable due to lack of shelter; many indigenous people interviewed identified resilience within the community due to a lifestyle generally less reliant on material possessions and a strong connection to extended family and community. A key finding was that indigenous people interviewed considered that their experience was very similar to that of the broader population in terms of services, response procedures and treatment.
Methodology	The study team undertook literature review, data collection and analysis, oral history transcript analysis and interviews with key stakeholders.
Output	Knowledge
States (specific location)	Northern Territory (Darwin)
Sector relevance	

Living change: Adaptive housing responses to climate change in the town camps of Alice Springs	
Authors (Year)	R. Horne, A. Martel, P. Arcari, D. Foster, A. McCormack (2013)
Status	Draft report
Summary	This project had three objectives: - To identify adaptive practices of residents in new or recently refurbished houses regarding comfort and healthy living, as well as to determine resident vulnerabilities to climate change - To identify management practices that affect climate change vulnerabilities and to examine the integration of tenant initiated sustainable living practices into tenancy management and future public housing design guidelines - To increase the research capacity of the Tangentyere Research Hub in energy, water use and sustainable design, as well as to increase the experience of the RMIT researchers in conducting interview based surveys of Indigenous households. The research found that Alice Springs town camp residents currently have fairly good adaptive capacity as they are dealing with the heat and cold in diverse ways. They also have a clear understanding of and experience with dealing with extreme weather events. However, adaptive practices need to actively monitored and nurtured as there is a current imbalance between town camp resident incomes and the number of household dependents, which places stress on the community. Tenancy management partially supports tenant initiated sustainable living, and there is further work needed in this area.
Methodology	This project involved interviews with town camp residents, tenancy and property managers from CAAHC, and management from Territory Housing.
Output	Knowledge
States (specific location)	Northern Territory (Alice Springs)
Sector relevance	

Learning from experience: historical case studies and climate change adaptation	
Authors (Year)	A. S. Kiem, D. C. Verdon-Kidd, S. Boulter, J. Palutikof (2010)
Status	Final report
Summary	This report is a summary of the historical case studies developed via the NCCARF consortium in 2010, and synthesis of the climate variability and adaptation lessons that can be learnt from them. The summary included case studies on Cyclone Tracy, which struck Darwin on Christmas Day 1974; drought in rural communities, looking at the agricultural communities of Donald and Mildura, and the mining communities of broken Hill and Kalgoorlie; heatwaves that occurred in Melbourne and Adelaide in early 2009; the Queensland floods of early 2008; severe storm tides along the southern Queensland and northern New South Wales coast; and the Pasha Bulker storm that affected Newcastle in June 2007. The summary found broad lessons from across the case studies. These included a need for all levels of government to provide frameworks of regulation and incentives to enable adaptation; recognition that solutions which address extreme, short-term events are not necessarily suitable under long-term climate change; that successful adaptation relies on establishing a clear threshold for emergency and recognising a new type of disaster; a need for communities to know how to respond appropriately to a disaster and not necessarily rely on communication capacity during the event; that transformational change (substantial alteration from existing practices) may be needed in the long-term in some communities; and that the geographical, social, cultural or economic characteristics of some communities simply make them more vulnerable to a changing climate.
Methodology	This project involved literature review and summary of case studies.
Output	Knowledge
States (specific location)	Northern Territory (Darwin), Victoria (Donald, Mildura, Melbourne), New South Wales (Broken Hill, Newcastle), South Australia (Adelaide), Queensland (Charleville, Mackay), Western Australia (Kalgoorlie)
Sector relevance	

Adaptation lessons from Cyclone Tracy	
Authors (Year)	M. Mason, L. Haynes (2010)
Status	Final report
Summary	This project assessed the impacts of Cyclone Tracy on the city of Darwin and its people, and lessons that can be learnt from this event. Specifically the study focussed on the physical damage, the financial costs, underlying reasons it was so disastrous, responses to the event and adaptations that occurred afterwards. The impacts of another Cyclone Tracy sized event in modern Darwin is also briefly looked at, as is the increased risk through climate change for the future. The project found that the majority of devastation was due to inadequate structural engineering design of infrastructure, especially in residential buildings. Responses after the cyclone include stricter building codes, regulations and practices; which the researchers identify as the most effective adaptation response (and that with the greatest potential). Despite the largely uncertain nature of climate change's influence on the range and intensity of cyclones, the authors note that increased losses from extreme weather events have been well documented in recent history, and recommend focussing on the locations of future population expansion; and on building design as safeguard measures for future events.
Methodology	Desktop study and literature review was undertaken including data collection and collation for weather variables, as well as interviews with key stakeholders.
Output	Knowledge
States (specific location)	Northern Territory (Darwin)
Sector relevance	

For-sea-ing change: Indigenous women's preference for adaptation to climate change	
Authors (Year)	L Petheram, A Fleming, N Stacey, and A Perry (2013)
Status	Draft report
Summary	This project investigated the Indigenous people of South Goulburn Island's dependency on marine resources and their perspectives on climate change and adaptation for aquaculture. The research found that the worldview of the Island's people was strongly dominated by social and cultural links to the past and present but with weaker links to the concept of 'the future.' The preferences of workshop and interview participants regarding adaptation concerned building general community capacity, drawing on customary knowledge, having increased involvement in government decision-making, and learning more about western scientific knowledge. The Indigenous people of South Goulburn Island also expressed interest in aquaculture in order to help minimise reliance of purchased food and to diversify food sources. Supporting aquaculture development on the island would require improved communication and learning among all stakeholders as well as an adaptive management approach involving all stakeholders, but it may help adaptation by expanding economic options and enhancing the consumption of local foods.
Methodology	This project involved workshops and interviews with an emphasis on using participatory and visual techniques to support discussion and visioning of the future.
Output	Knowledge
States (specific location)	Northern Territory (South Goulburn Island)
Sector relevance	

Appendix D: Excluded research (NCCARF)

Appendix Table 4: Reports excluded due to content

Lead author	Title	Reason for exclusion	Geographic Relevance
Barmuta	Joining the dots: integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity	The report is focused on Tasmania, which is outside the geographical scope of this synthesis.	Tasmania
Byrne	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	This research focused on two species of eucalypt in a limited number of regions (two).The application of results to other species or locations was deemed not appropriate, and there is little to no policy relevance.	Western Australia, Victoria
Cockfield	Socio-economic implications of climate change with regard to forests and forest management. Contribution of Work Package 3 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Davis	Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management	The focus of this report was on technical findings related to factors influencing connectivity (population genetics, dispersal traits), so there is little policy relevance.	Queensland, South Australia, Northern Territory, Western Australia
Dyer	Predicting water quality and ecological responses to a changing climate: informing adaptation initiatives	The focus of this report was on technical findings, based on Bayesian network models using data from a single location, and so was not considered robust enough for synthesis.	Australian Capital Territory
Guilding	Strata title in a world of climate change: managing greater uncertainty in forecasting and funding common property capital expenditure	The report was deemed not policy-relevant, as its focus is on private investment risk, and it is written more as a technical report for a fund manager audience.	National
Medlyn	Biophysical impacts of climate change on Australia's forests. Contribution of Work Package 2 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Moir	Developing management strategies to mitigate increased co-extinction rates of plant-dwelling insects through global climate change	This project focused on species level assessments and the management of invertebrates under climate change, which does not appear to be a current policy priority for state governments.	Western Australia

Lead author	Title	Reason for exclusion	Geographic Relevance
Padgham	Agent-based simulation framework for improved understanding and enhancement of community and organisational resilience to extreme events	This report was based on the application of agent based modelling (based on the author's main project) at one Victorian location. As there was limited testing, the report was not considered robust enough for synthesis.	Victoria
Padgham	Exploring the adaptive capacity of emergency management using agent-based modelling	This research was deemed more relevant to operational decision-making; although the tool may be useful to assess policies; this has not been part of the research.	Victoria
Reser	Public risk perceptions understandings and responses to climate change and natural disasters in Australia and Great Britain	The follow-on research has been included (EM1101 [Reser]), which has more up-to-date results.	National
Sanò	Adapt between the flags – enhancing the capacity of Surf Life Saving Australia to cope with climate change and to leverage adaptation within coastal communities	The focus of this report is on asset management, lifesaving operations and the role of local clubs in increasing community resilience. There is mention of the role of state funding, and adaptation options have state relevance (such as retreat); however, the discussion (which is in an early stage) does not currently draw enough conclusions relevant to state/territory policy and decision-making.	Queensland, New South Wales, Tasmania
Foster	Analysis of institutional adaptability to redress electricity infrastructure vulnerability due to climate change	Few lessons relevant to state government policy.	National
Thompson	Impacts of elevated temperature and CO_2 on the critical processes underpinning resilience of aquatic ecosystems	The focus of this report is on technical findings related to laboratory testing and modelled future conditions. The report focuses on management options at specific locations rather than on policy.	Victoria
Unsworth	What about me? Factors affecting individual adaptive coping capacity across different population groups	Only 1 of the 4 identified research streams is likely to be relevant to state government adaptation policy (Stream 1 focuses on responses to carbon emissions while Streams 3 and 4 focus on specific population groups defined by employment (resource sector and hospital employees)).	National
Wardell-Johnson	Creating a climate for food security: the businesses, people and landscapes in food production	The report was deemed to lack policy relevance.	Queensland, Western Australia
Willetts	Understanding the Pacific's adaptive capacity to emergencies in the context of climate change	This report covers a topic not relevant to state and territory responsibilities.	National

Lead author	Title	Reason for exclusion	Geographic Relevance
Wilson	Climate change adaptation options, tools and vulnerability. Contribution of Work Package 4 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National
Wood	Establishing the need and consultation with key stakeholders in forest policy and management under climate change. Contribution of Work Package 1 to the Forest Vulnerability Assessment	The component reports I to IV was not reviewed for the synthesis, which has been informed by Synthesis and Final Report only.	National

Appendix Table 5: Reports excluded due to deadline

NCCARF research reports provided to AECOM after close of business on 14 January 2013 were also unable to be included in the synthesis due to project time constraints. In some cases, the report due date was before 14 January 2013, but the report was delayed.

Lead author	Title	Geographical relevance	Report due date
Abadi	EverFarm® – Design of climate-adapted perennial-based farming systems for dryland agriculture in southern Australia	New South Wales, Victoria, Western Australia	25/01/13
Barrett	Adaptive management of temperate reefs to minimise effects of climate change: developing effective approaches for ecological monitoring and predictive modelling	Tasmania	Draft 1/04/14; Final Report 30/04/14 (March-April)
Bax	Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species	Tasmania	Draft 28/02/13; Final report 30/03/13 (March-April)
Beer	Australia's country towns 2050: What will a climate-adapted settlement pattern look like?	National	Draft: 31/12/12
Burton	Urban food security, urban resilience and climate change	National	0/10/12
Caputi	Management implications of climate change effects on fisheries in Western Australia	Western Australia	Draft 30/11/13; Final report 31/12/13 (Nov–Dec)
Correa-Velez	Displaced twice? Investigating the impact of Queensland floods on the wellbeing and settlement of a cohort of men from refugee backgrounds living in Brisbane and Toowoomba	Queensland	Unknown
Crase	Leading gifted horses to water: the economics of climate adaptation in government-sponsored irrigation in Victoria	Victoria	15/01/13 (draft)
Davis	Ensuring that the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge action and informed adaptation frameworks	National, New South Wales	Draft 10/12/12; Final report 24/12/12 (Jan–Feb13)
Dear	Changing heat: direct impacts of temperature on health and productivity – current risks and climate change projections	National	Unknown
Dobes	The economics of government as insurer of last resort for climate change adaptation	National	3/03/13 (draft)
Doerr	The architecture of resilient landscapes: scenario modelling to reveal best-practice design principles for climate adaptation	Victoria, Queensland, New South Wales, Australian Capital Territory	3/02/13 (draft)
Frusher	A climate change adaptation blueprint for coastal regional communities	National	Draft: 01/06/13; Final report 30/06/13
Fry	Reforming planning processes trial: Rockhampton 2050	Queensland	28/02/13

Lead author	Title	Geographical relevance	Report due date
Gledhill	Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data-rich case	Tasmania, Victoria, New South Wales, Queensland	(May–June)
Green	Health impacts of climate change on Indigenous Australians: identifying climate thresholds to enable the development of informed adaptation strategies	Western Australia, Northern Territory, Queensland	Unknown
Hanna	Climate change impacts on workplace heat extremes: health risk estimates and adaptive options	National	Unknown
Harley	Dengue transmission under climate change in Northern Australia: linking ecological and population-based models to develop adaptive strategies	Queensland	Unknown
Hertzler	Will primary producers continue to adjust practices and technologies, change production systems or transform their industry – an application of real options	Western Australia, South Australia, New South Wales	31/12/12 draft
Hobday	Growth opportunities and critical elements in the value chain for wild fisheries and aquaculture in a changing climate	National, Western Australia, New South Wales, Victoria, Queensland, Tasmania, South Australia	Draft 30/03/13; Final report 31/05/13 (May–June)
Hobday	Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change	National	Draft 30/12/12; Final report 30/01/13 (Jan–Feb 13)
Hugo	Impact of climate change on disadvantaged groups: issues and interventions	South Australia	3/02/13 (draft)
Jerry	Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia	Queensland, Northern Territory	Draft 31/10/13; Final report 31/12/13 (Nov–Dec)
Jones	Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation	National	3/02/13 (draft)
Lockwood	Changing currents in marine biodiversity governance and management responding to climate change	Queensland, New South Wales, Tasmania	Draft: 14/09/13; Final report 27/09/13 (Sept–Oct)
Maani	Overcoming challenges for decision-making about climate change adaptation	National	31/10/12
McMichael	Climate change and rural communities: integrated study of physical and social impacts, health risks and adaptive options	National	Unknown
Parsons	Learning from the past, adapting in the future: identifying pathways to successful adaptation in Indigenous communities	Western Australia	30/04/13
Pecl	Preparing fisheries for climate change: identifying adaptation options for four key fisheries in south-eastern Australia	New South Wales, Victoria, Tasmania, South Australia	Draft 1/09/13; Final report 2/01/14

Lead author	Title	Geographical relevance	Report due date
Pratchett	Effects of climate change on reproduction, larval development and population growth of coral trout	Queensland	Draft 1/03/13; Final report 30/06/13 (Mar–April)
Raybould	Beach and surf tourism and recreation in Australia: vulnerability and adaptation	New South Wales, Queensland	Draft 28/02/13; Final report 30/04/13 (Mar–April)
Saman	A framework for adaptation of Australian households to heat waves	New South Wales, South Australia, Queensland	Draft 11/01/13
Shaw	Climate change adaptation – building community and industry knowledge	Tasmania, Western Australia, Queensland	Draft 1/02/13; Final report 1/04/13
Sheaves	Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems	National	Draft 15/12/13; Final report 30/12/13 (Nov–Dec)
Thresher	Adapting to the effects of climate change on Australia's deep marine reserves	Tasmania, Victoria, South Australia, New South Wales	Draft: 1/06/13; Final report 1/12/13
Tong	Projection of the impact of climate change on the transmission of Ross River virus disease	Queensland	Unknown
VanDerWal	Identification and characterisation of freshwater refugia in the face of climate change	National	30/04/13
Webb	Web-based tools for adaptation in Australia – an international and Australian review	National	30/11/12
Weir	Changes to country and culture, changes to climate: strengthening institutions for Indigenous resilience and adaptation	Queensland, Western Australia	Draft 31/12/12
Welch	Management implications of climate change impacts on fisheries resources of tropical Australia	Western Australia, Northern Territory, Queensland	Draft 31/12/13; Final report 14/03/14
West	Climate change adaptation: a framework for best practice in financial risk assessment; governance and disclosure	National	31/12/12 (draft)
Williams	The role of refugia in ecosystem resilience and maintenance of terrestrial biodiversity in the face of global climate change	National	30/04/13

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The following is a full list of research examined for this report. Some references included may not be cited in the report text.

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