NCCARF
National
Climate Change Adaptation
Research Facility

Synthesis and Integrative Research
Final report

Supporting evidence-based adaptation decision-making in Victoria: A synthesis of climate change adaptation research

AECOM

SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN VICTORIA

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.

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Shortened forms

ACT	Australian Capital Territory
AEP	Annual Exceedance Probability
ARCIP	Adaptation Research Centre Investment Panel
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
DEPI	Victoria Department of Environment and Primary Industries
DoHA	Australian Department of Health and Ageing
DPI	Victoria Department of Primary Industries
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 Organization for Standardization
NCCARF	National Climate Change Adaptation Research Facility
NDRRA	Natural Disaster Recovery Relief Arrangements
NGO	Non-Governmental Organisation
NT	Northern Territory
OEH	Office of Environment and Heritage
PCF	Policy Choice Framework
PICCC	Primary Industries Climate Challenges Centre
QLD	Queensland
QUT	Queensland University of Technology
SA	South Australia
SAFECOM	South Australian Fire and Emergency Services Commission
SME	Small or Medium Enterprise
VCAT	Victorian Civil and Administrative Tribunal
VCCCAR	Victorian Centre for Climate Change Adaptation Research
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.

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).

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 Victoria 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.

Current and future climate in Victoria

- Victoria's mild climate is already being impacted by increases in average and extreme temperatures and by changes in the intensity and frequency of extreme weather events.
- The state has experienced both severe drought and flooding in the last decade, both of which are expected to increase in frequency with further climate change.
- The 'Black Saturday' bushfires that occurred in February 2009 in Victoria caused devastation to the areas to the north of Melbourne. They were driven by low rainfall over a long period, record high temperatures, low humidity and high wind speeds.

Climate change impacts

- Health and wellbeing impacts include physical injury due to bushfire, extreme weather and heat-related illness. Impacts on the health services sector are expected to increase due to increased demand, resource constraints and damage to supporting infrastructure.
- Primary productivity is expected to be impacted by reduced rainfall, increased temperatures and physical damage to assets and infrastructure.
- The natural environment in Victoria is vulnerable to climate change impacts, particularly in coastal, alpine and forest areas, and where existing ecosystem fragmentation has occurred.
- Infrastructure and settlements will be impacted by increases in extreme weather including flooding, as well as sea level rise and bushfire activity.
- Tourism in alpine and coastal areas is likely to be impacted by climate change.

State government's role in adaptation

State government has an essential role to play in supporting adaptation to climate change. States have direct involvement in managing a range of assets and government services, and as a result have a significant role in direct adaptation actions. While the Victorian Government invests substantially in climate change research that is focused on particular portfolios, it also sponsors the Victorian Centre for Climate Change Adaptation Research, which addresses state-wide strategic knowledge.

States also play a role in creating an institutional, market and regulatory environment that supports and promotes adaptation to climate change. The Victorian *Climate Change Act 2010* requires preparation of a Climate Adaptation Plan every four years, and decisions across a variety of legislative areas to account for adaptation.

Research collected for synthesis

The project has drawn on a broad range of published research, including draft NCCARF research reports not yet publically 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 in addition to the NCCARF-funded research pool were selected and reviewed for synthesis on the basis of their relevance to state government policy.

The figure below maps the study locations and regions within Victoria examined in the research reviewed for this synthesis. It shows that research has covered the majority of the state and has been largely concentrated in and around Melbourne. Case study locations were often chosen because these communities had previously experienced extreme events, including heatwaves, drought, bushfires and floods.

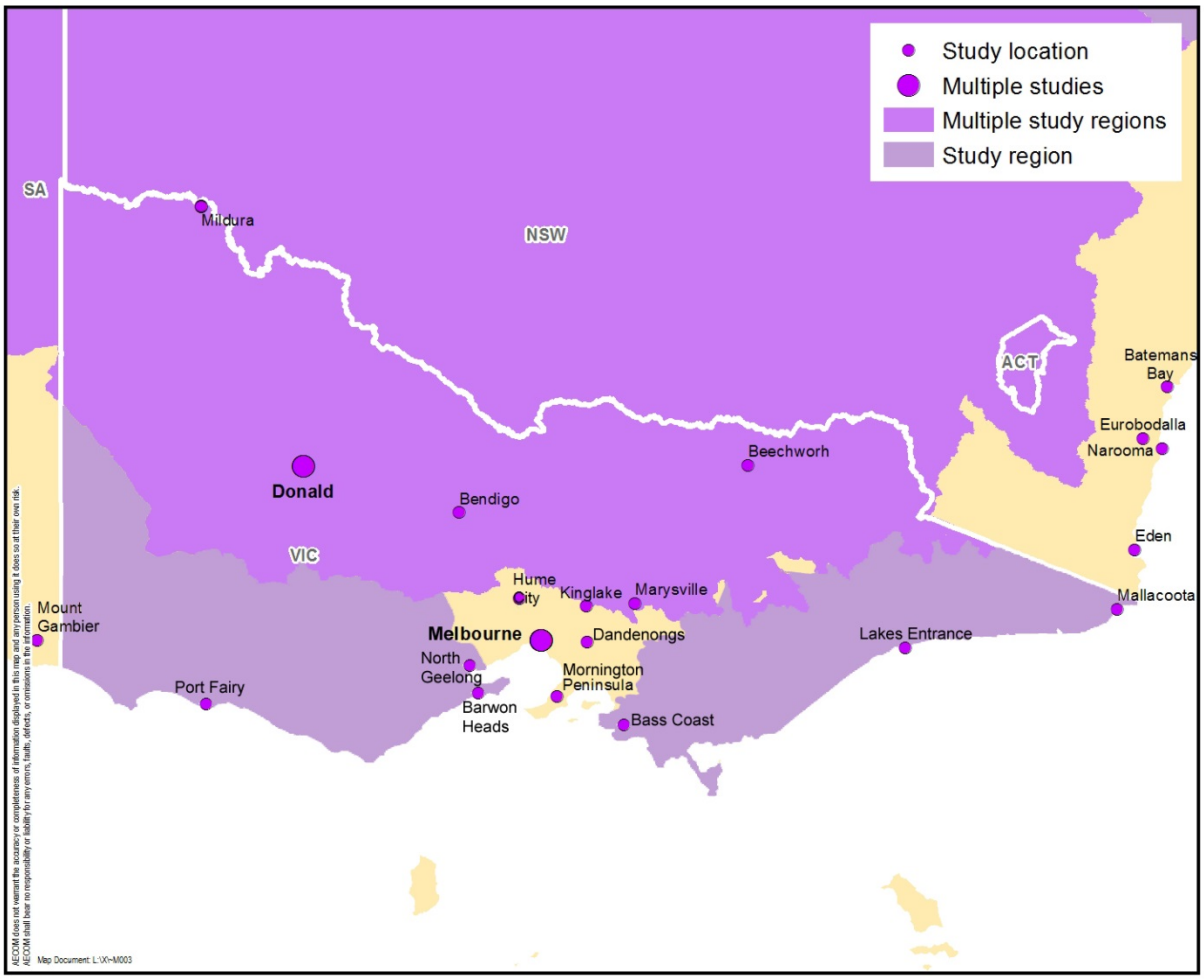


Figure ES1 Case study locations of synthesised adaptation research in Victoria

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, 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 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 that 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, such as water trading, needs to better consider broader social and economic impacts and the capacity of participants to engage in change.

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[1]). 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).

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

[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.

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 adaptation tool to help defer climate change risks, 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 that 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 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 (Mukheibir 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 who 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 of 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 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 (e.g. 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 need to be considered for extreme events as 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). This is typified by changes in drought policy responses in Australia over the past 20 years , which now see drought as part of normal climate, not as an extreme event. In light of this, disaster management arrangements need to be reviewed.

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 ongoing monitoring of climate change risks
- 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, and a list of the practical adaptation responses have been suggested from the research. Sectors covered under practical actions include coasts, land and water management, the built environment, emergency management, and communities. It is also important to note that in no way did the research reviewed comprehensively cover any individual sector.

A few of these findings are also specifically relevant to Victoria. The following table provides a summary of the key findings for each sector.

Table 1 Findings from the research for Victoria by sector

	Findings from the research 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 reconsidered in the context of longer term climate change. This is particularly relevant for initiatives such as the update of the regional catchment management plans. - 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 from the research related to agriculture, fisheries and forestry: - Diversification is the effective strategy for mitigating climate-induced variability. - Not all producers will be able to participate in water trading. Cost of water may affect the long-term viability of some sectors of Victoria's agricultural industry. - 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 from the research 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, bushfires and storm 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. This will be critical in the various rapid growth regions of Victoria.
	Findings from the research related to health and wellbeing: - State government should ensure adequate health services are available, both during and for the longer term after disaster events. - Targeted adaptation messages need to be developed for specific audiences.
	Findings from the research related to business and industry: - Adaptation action within small and medium businesses may be resource constrained. - Adaptation in some sectors of tourism, particularly in alpine regions, may require diversification – this may provide additional benefits and/or risk.

Conclusions

The complexity of climate change adaptation cannot be underestimated. A wide range of issues, including national and state 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 state 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 is also critical for continuous improvement, to build trust with stakeholders, and to effectively implement adaptive management.

Increase effort 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.

Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events. The research reviewed for this synthesis frequently reiterated the need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning which is essential for adaptive management.

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 which 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.

1.0 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 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 Victoria (Vic) and to 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 and national level. It also seeks to present findings and analysis in a way that will enhance adaptation understanding of decision-makers in state/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 key adaptation policy personnel.

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, such as 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 2 displays the main objectives and content of each section.

Table 2 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 state 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 Victoria's climate challenge	To describe the climatic challenge faced by Victoria and Victoria's existing adaptation priorities and actions.	Description of current and future climate conditions; key climate change impacts facing Victoria; discussion of Victoria's current adaptation priorities and activities.
3.0 Research relevant to Victoria	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 Victoria-specific case studies.
4.0 Research findings	To synthesise research reviewed based on common themes of learning for state-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 state 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 Victoria.	
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.

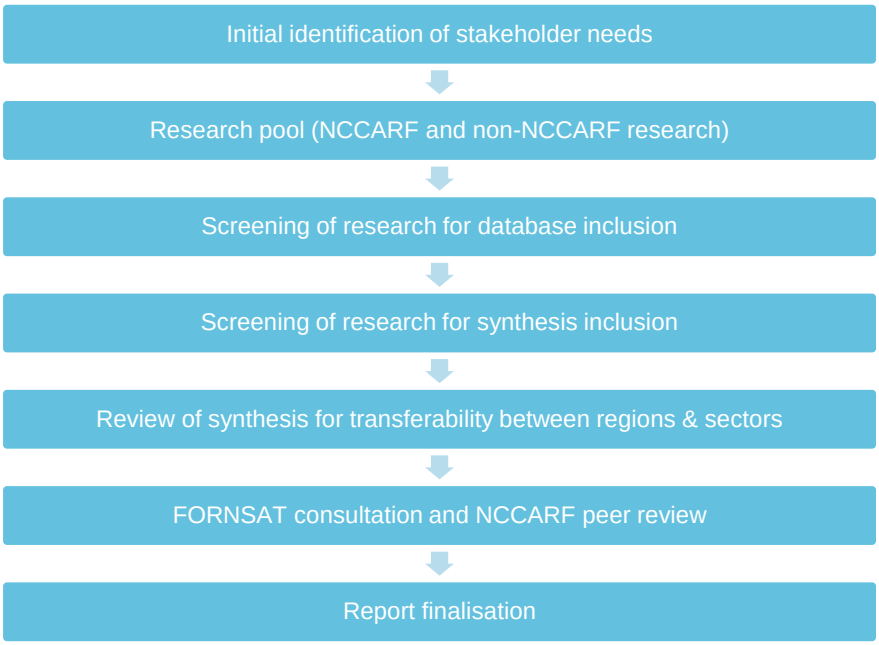
1.3 Scope and methodology

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-funded adaptation research, as well as research from other Australian sources.

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, such as how natural or human systems can adjust to unavoidable climate impacts and the effectiveness of these adjustments in reducing vulnerability and adverse effects. 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 Victoria. There is a growing body of international research which may also provide insights for adaptation planning and implementation in Victoria, 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 is 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 and Commonwealth websites for relevant research reports. Websites were scanned by entering the search terms into the search bar on State and Commonwealth department websites. The websites of Victoria departments searched included (list below are the names of the departments at the time of the search in 2012; some department names changed in 2013):
    - Department of Sustainability and Environment
    - Office of Water
    - Department of Health
    - Department of Primary Industries
    - Department of Transport
    - Department of Planning and Community Development
    - Department of Human Services
    - Environment Protection Authority Victoria
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
- publically 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 considering 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 government roles and responsibilities
- ability to influence state 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 that 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 that 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 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 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 government. As a result, the majority of research reports reviewed were determined to have elements of transferability between regions and/or sectors.

FORNSAT 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 NT who were not interested in a workshop at this time) to further discuss the project and gather feedback. All workshop attendees

were also encouraged to thoroughly review the draft report for their state/territory and provide written feedback during the month-long review period.

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 state/territory 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 NCCARF's program of research.

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 targeted to a location are often very specific and at a level of detail not necessarily relevant to a synthesis approach
- 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 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 it could also be 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 probably not captured unless it directly mentioned climate change.
- neither NCCARF nor FORNSAT received a list of research that was determined not to 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 publically. Draft research incorporated into this synthesis is denoted as such in the reference (e.g. 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 asked specific questions about the relevance of the project to government decision-makers and about the project's likely policy implications, their answers used to populate the relevant database fields.

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 parts 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 government, the primary audience for this report, delivers a wide range of services, administers a significant body of legislation, and manages 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 Government of Victoria (2013) views its primary roles and responsibilities as:

- managing risks to the public assets and services it manages
- managing risks to the state's natural assets and natural resource-based industries through the development of policy
- building integrated emergency management and disaster resilience
- improving access to information and research in order to inform decision-making
- developing policy settings that support private sector adaptation through appropriate risk allocation, removing barriers and promoting innovation
- continuing to partner with local governments and communities.

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 vital to addressing the impacts to climate change, and the coordination between state and local government is especially important. Local government is best positioned to inform state 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). The State Government of Victoria (2013) views the responsibilities of local government as:

- managing the risks and impacts to the assets owned and managed by local government and to service delivery
- supporting activities that build adaptive capacity and climate resilience in local communities, including working in partnership with community, local organisations and other stakeholders to manage climate risks;
- collaborating across councils and with the state government to manage regional risks;
- implementing appropriate legislation to promote adaptation, such as ensuring local planning schemes appropriately incorporate climate change and are consistent with state government adaptation approaches;
- contributing to appropriate resources to prevent, prepare, respond and recover to adverse impacts of climate change.

Table 2 presents the key functions of the Victorian 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 state

government can play, or their sphere of influence, in adaptation planning and action. It is also important to note that there are a number of other organisations that work with state government departments, such as regional natural resource management (NRM) boards, not listed below that have an essential role in climate change adaptation.

Table 3 Key functions of the Victorian Government and potential climate change impacts[2]

Department of Premier and Cabinet	**Key functions**
	Leads the Victorian public service, advising government on emerging policy issues and reviewing the impact of government decisions Manages the issues that affect the government as a whole, including coordinating Victoria's response to major social, economic and environmental challenges and managing state-wide emergencies
	Potential climate change impacts
	Impacts of extreme climate events on government services, infrastructure, natural assets and community wellbeing
Department of Treasury and Finance	**Key functions**
	Supports the Government in budget and financial management Provides the Government with economic, financial and resource management policy advice Assists the Government with the implementation of major infrastructure projects
	Potential climate change impacts
	Negative impacts of climate change on local, state and national economies Increasing cost of providing and maintaining government assets and services
Department of Justice	**Key functions**
	Police and prosecution functions, administration of the court system, provision of the prison and community corrections services, administration of various tribunals and agencies established to protect citizens' rights, emergency management, provision of emergency services, policy on racing and gaming issues and the provision of legal advice to government
	Potential climate change impacts
	Sea level rise impacts on coastal planning (legal disputes) Increased demand for emergency services during extreme weather events
Department of Education and Early Childhood Development	**Key functions**
	Provides education and development services to children, young people and adults both directly through government schools and indirectly through the regulation and funding of early childhood services, non-government schools and training programs Implements Victorian Government policy on early childhood services, on school education for all school age students, and on training and higher education services. Provides policy advice to Ministers about education, early childhood development, children's services, higher education and training in general
	Potential climate change impacts
	Increasing need for climate change related science, education and knowledge Extreme event impacts to assets (e.g. schools and other property) Need to support communities vulnerable to the impacts of climate change
Department of Health	**Key functions**
	Planning, policy development, funding and regulation of health service providers and activities Health promotion and protection through emergency management, public health and related preventative services, education and regulation.
	Potential climate change impacts
	Increasing physical and mental impacts on health from extreme weather events Increasing prevalence of some vector-borne and respiratory diseases

[2] The potential climate change impacts included are indicative only and are not intended to represent all potential impacts. This analysis does not include interactions among various impacts nor the fact that for many issues, more than one department/agency will have a role. It is also recognised that adaptation options to reduce the risk of these or other impacts may already be in development.

Department of Transport, Planning and Local Infrastructure	**Key functions**
	Responsible for strategic transport planning, including ports, regional rail and public transport as well as land use planning, local government, and sport and recreation
	Potential climate change impacts
	Damage to infrastructure from extreme events as well as warmer and drier conditions Increased vulnerability and risks in specific locations, potentially changing the suitability of land for development, agriculture or other uses Changes to infrastructure and service demands
Department of State Development, Business and Innovation	**Key functions**
	To work with business and the community to boost productivity, exports, employment and investment through innovation technology, major projects, strategic infrastructure policy, regulatory reform and tourism. Engage with Victorian business and industry to help them become competitive, innovative and connected, and generate investment, jobs and exports.
	Potential climate change impacts
	Negative impacts of climate change on local, state and national economies Increased costs and risks to business Potential for new business development, particularly with regards to risk management services and products Increased investment and employment opportunities as local infrastructure is upgraded to take into account climate risks
Department of Environment and Primary Industries	**Key functions**
	Comprising the functions of the former Department of Sustainability and Environment and the Department of Primary Industries. The new Department of Environment and Primary Industries (DEPI) will focus on boosting productivity in Victoria's world-class food and fibre sector, managing natural resources, protecting the environment and responding to fire, flood and biosecurity emergencies
	Potential climate change impacts
	Increased drought, flooding and bushfire events, impacting emergency management, primary production, environmental values and water security. Changes in ecosystem management needs. Changes in the distribution of endemic flora and fauna, primary production, pests and diseases. Opportunities for new crops due to a warmer climate with longer growing seasons
Department of Human Services	**Key functions**
	Plans, funds and delivers community and housing services, directly and with community sector partners. Projects and initiatives focus on housing, community building, disability, children, youth and families, as well as assisting the community sector
	Potential climate change impacts
	Impacts on housing and service provision, including impacts on NGOs Impacts on vulnerable members of the community

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. However, due to the complexity of climate science, absolute certainty will likely never be achieved. 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; Morton et al. 2009).

According to the 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. Using this research effectively is challenged by a number of factors, including its discoverability, accessibility, direct relevance to the context (physical, socio-economic, ecological or geographical), clarity, internal processes and capacity of decision-makers (Preston and Stafford-Smith 2009; Morton et al. 2009). This synthesis aims to make a large portion of Australian adaptation research easily accessible to state and territory decision-makers.

2.0 VICTORIA'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 what challenges 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 Victoria. Recognising that considerable activity has already occurred in the state to address these climatic challenges, it also highlights Victoria's current adaptation priorities and current and past activities.

2.1 Current and future climate

A number of climatic events and associated impacts and risks have already affected Victoria. Between 1910 and 2010, average mean temperature in Victoria has increased by approximately 0.87ºC (Department of Sustainability and Environment 2012); even a small change to higher average temperatures leads to large increases in the incidence of extreme events (Steffen et al. 2012). Furthermore, between 2000 and 2010, the Victorian average minimum temperatures were at least 0.2ºC warmer than any other decade since 1910 (Department of Sustainability and Environment 2012).

The 'Black Saturday' bushfires that occurred in February 2009 in Victoria caused devastation to the area to the north of Melbourne. The combination of high temperatures, no rainfall for over a month, high wind speeds and low humidity created conditions ideal for a horrific and unprecedented natural disaster. This event affected 78 communities, claimed 173 lives and destroyed 2,000 properties (Steffen et al. 2012).

South-eastern Australia, including parts of Victoria, experienced a major drought beginning in the mid-1990s that lasted over fourteen years. This drought, referred to as the 'Big Dry' or the 'Millennium Drought' had major impacts on water availability, agriculture production and bushfire regimes (Sherval and Askew 2012). Stream-flow volumes in the state were 32 per cent of the long-term average in 2009, and by mid-2009, total water storage was 17 per cent (Department of Sustainability and Environment 2012).

More recently (in 2010 and 2011), Victoria experienced record breaking rainfall, resulting in extensive flooding over one-third of the state (Bird et al. 2011, Steffen et al. 2012). This record rainfall essentially brought the Big Dry to an end, and recharged Victoria's water storage levels from 17 to 71 per cent in June 2011 (Department of Sustainability and Environment 2012). However, rainfall averages in much of south-east Australia were still far below historical averages (Steffen et al. 2012).

Victoria's climate will continue to change as a result of both natural variability and increased global greenhouse gas emissions. Temperatures are expected to increase, relative to 1990, from 1ºC to 2.2ºC by 2070 under a low emissions scenario; or from 1.9 ºC to 4.2 ºC under a high emissions scenario (Department of Sustainability and Environment 2012). Increases in temperature will be accompanied by reductions in annual rainfall, although year to year variability and multi-year wet periods will persist (Department of Sustainability and Environment 2008, Department of Sustainability and Environment 2012). Combined changes in temperature and rainfall will exacerbate water stress and increase days conducive to bushfire (Buxton et al. 2011). Heavy rainfall events, such as the floods experienced in 2010 and 2011, could become more frequent as well, though the level of confidence of this prediction is low (Steffen et al. 2012).

As well as changes in average conditions, Victoria is also expected to experience a change in temperature extremes, including an increase in the frequency and intensity of days over 35ºC and a decrease in days with a minimum temperature below 2ºC (Patrick and Capetola 2011; Department of Sustainability and Environment 2008). Changes to temperature extremes are likely to be felt most severely in Victoria's inland regions (Department of Sustainability and Environment 2008). The extent and frequency of droughts may also more than double by 2050, and the frequency of very high fire danger days may also greatly increase (Department of Sustainability and Environment 2012).

Global sea level rise is predicted to have local impacts on Victoria's coast and around the state's waterways with storm surges and extreme wind and rain events aggravating impacts such as inundation, flash flooding and erosion (Department of Human Services 2007; Department of Sustainability and Environment 2008). Scientists predict that a global average sea level rise of 100 centimetres this century is a serious risk (Steffen et al. 2012), and average sea level rise along the Victorian coastline is consistent with global increases (Department of Sustainability and Environment 2012). A large portion of Victoria's population resides along the coast. The local government areas most at risk to sea level rise are Kingston, Hobsons Bay, Greater Geelong, Wellington and Port Phillip (Steffen et al. 2012).

2.2 Climate change impacts for Victoria

These expected changes in climate will have numerous and varied impacts across Victoria's population 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. Heatwaves can cause heatstroke and organ failure. Bushfires can cause injury, death and exacerbate respiratory issues, and heavy rainfall and flooding can contaminate drinking water supplies (Steffen et al. 2012). During the 2009 Melbourne heatwave, heat-related hospital admissions increased eight-fold, and there was a 62 per cent increase in mortality over what would normally be expected during the same period (Steffen et al. 2012).

Fisheries, forestry and agriculture

Climate change can impact livestock and crops in numerous ways, depending on their vulnerability to changes in temperature, moisture and water availability, exposure to pests and increased (or heightened) concentrations of carbon dioxide (State Government of Victoria 2012a). Flooding events, as were experienced in 2010 and 2011, can be particularly damaging to agriculture, resulting in the destruction of crops and increasing vulnerability to disease (Steffen et al. 2012).

The impacts of climate change on forest productivity are largely dependent on the balance of the benefits from increased carbon dioxide concentrations and the adverse consequences of increased temperatures and changes in rainfall (State Government of Victoria 2012a). A doubling of carbon dioxide combined with a warming of 3ºC but no changes in rainfall would result in increased tree growth; whereas higher temperatures and a reduced rainfall would have a negative effect on growth.

Victoria's south-eastern coastal waters are among the most vulnerable in Australia to climate change. Increased sea surface temperatures and changes in coastal processes could have significant impacts on the state's fisheries and aquaculture systems under climate change (State Government of Victoria 2012a).

Natural environment

The Victorian Alps are extremely vulnerable to climate change. With increasing temperature and lower precipitation, snow cover has been and will continue to decline, affecting already rare and threatened alpine species (Steffen et al. 2012). Some species are losing habitat while others, such as snow gums, are experiencing a declining habitat (shift) as higher altitudes become warmer. Warming is also affecting the timing of certain species' life cycles (Steffen et al. 2012).

The Murray Darling Basin will also be heavily impacted by climate change, with a 13 per cent reduction in average surface water availability predicted by 2030 in the south area of the basin (DCCEE 2012). The average long-term stream flow into Melbourne's water catchments could be reduced by up to 11 per cent by 2020 and 35 per cent by 2050 (Australian Government 2012). Water quality may also be affected due to changes in temperature, carbon dioxide concentrations, movement of sediment and chemicals, and organisms in the water (State Government of Victoria 2012a).

Community and infrastructure

Between 27,600 and 44,600 residential buildings and up to 2,000 commercial buildings in Victoria would be vulnerable to a 110 cm sea level rise and at risk of flooding due to sea level rise and a storm surge from a one-in-100 year storm (Steffen et al. 2012). A 110 cm sea level rise will also put up to 125 km of railways, 2,000 commercial buildings and 3,500 km of Victoria's roads at risk (DCCEE 2012).

During heat events, critical infrastructure, including roads, railways and power lines, is vulnerable to failure. For example, railways buckled from heat stress during the Melbourne's 2009 heatwave, cancelling over one-third of train services (Steffen et al. 2012). Flood events can also result in significant damage to bridges and roads, as well as power loss, water supply contamination and the loss of property.

Business and industry

The impacts to Victoria's agriculture and wine regions, natural resource areas, and coasts previously discussed may also decrease the attractiveness of Victoria for tourism. For example, reduced snow cover in the Australian Alps is affecting alpine tourism. By 2020, a reduced snow cover of 10 to 40 per cent (compared to 1990 levels) is expected (DCCEE 2012). Many ski resorts currently make artificial snow to compensate; however, this may become increasingly difficult due to lack of water availability and increased costs (Steffen et al. 2012).

Due to climate change, the manufacturing and services businesses of Victoria may experience increased business costs associated with energy and water supplies and rising insurance premiums. Extreme weather events and climate change in general may lead to disruptions in energy, water supplies, transport, and supply chain inputs (such as agricultural produce), as well as cause damage to business assets.

2.3 Victoria's adaptation research priorities and activities

The Victorian government has taken numerous actions to address the impacts of climate change since the release of the *Victorian Greenhouse Strategy* in 2002. In 2010, the *Climate Change Act* was introduced to create a climate change decision-making framework, including specific requirements for government decision-makers to have regard to climate change impacts in relation to specific decisions under the C*atchment and Land Protection Act 1994, Coastal Management Act 1995, Environment Protection Act 1970, Flora and Fauna Guarantee Act 1988, Public Health and Wellbeing Act 2008 and Water Act 1989*. The Act also requires the Minister for Environment and Climate Change to prepare a *Climate Change Adaptation Plan* every four years to assess the potential impacts and risks arising from climate change at both a state and regional level, clarify the government's role and responsibilities in managing risks and articulating strategic adaptation priorities as well outline what adaptation actions are being taken. The first plan was released in 2013 and is focused on increasing government preparedness through improved risk management for assets and services, as well as disaster resilience strategies and the development of government policies and programs to facilitate community resilience and adaptive capacity.

The *Victorian Climate Change Adaptation Plan* identifies six key framework strategies to build Victoria's climate resilience (State Government of Victoria 2013):

1. managing risks to public assets and services
2. managing risks to natural assets and natural resource-based industries
3. building disaster resilience and integrated emergency management
4. improving access to research and information for decision-making
5. supporting private sector adaptation
6. strengthening partnerships with local government and communities.

The plan also builds on a platform of action being undertaken across a number of government departments and agencies, including but not limited to:

- establishment of the Victorian Centre for Climate Change Adaptation Research (VCCCAR). While the Victorian Government has over many years continued to invest in research aimed at addressing the impacts of climate change for specific departments and portfolios, in 2009 the government established this partnership, operating between La Trobe, Melbourne, Monash, RMIT and Deakin universities, to address strategic research gaps in adaptation knowledge with broad applicability across a range of portfolios
- a *Coastal Planning Program* to help local councils plan for sea level rise based on Victorian coastal inundation dataset and Coastal Hazard Guidelines (Department of Planning and Community Development 2010)
- the *Victorian Public Health and Wellbeing Plan 2011–15*, which identified the need to consider climate-related impacts on health and the requirement for local government to consider climate change in preparing Municipal Public Health and Wellbeing Plans (Department of Health 2011)

- a climate change risk assessment for existing transport assets and the identification of potential adaptation responses that can be integrated into business planning, maintenance and emergency response planning (State Government of Victoria 2013)
- a formal review of Victoria's emergency management arrangements to increase community resilience to disasters (State Government of Victoria 2012b)
- the Primary Industries Climate Challenges Centre (PICCC) research partnership between the former Department of Primary Industries and the University of Melbourne. Research is focused on supporting capacity within primary industries to manage climate change risks and take advantage of opportunities to build the capacity of primary industries to manage risks and opportunities from climate change (PICCC n.d.)

  the *Victorian Floods Review* (2011) which identified the need for more resilient design of new developments and infrastructure to reduce flood risks (State Government of Victoria 2011)
- diverse research activity on specific sectoral priorities including water supply, rail infrastructure, heatwaves and health care as well as individual agricultural outputs and native species (State Government of Victoria 2013).

Finally, the *Victorian Climate Change Adaptation Plan* also articulates the government's overarching climate change adaptation research needs; these include (State Government of Victoria 2013):

- regionally-specific climate change adaptation information, which considers system level interactions in relation to land use, ecological and biophysical processes
- climate risks to specific sectors, in relation to vulnerabilities and risks as well as potential opportunities, and the interactions between sectors to avoid maladaptive responses
- tools to facilitate private risk management by businesses and communities through better understanding
- improved disaster resilience and managing risks to public assets and service delivery by building capacity within Victorian Government agencies and local government to make effective investment decisions.

3.0 Research relevant to Victoria

This project primarily draws upon NCCARF research. However, the synthesis findings (Section 4) 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 Victoria.

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.**2 displays the number of research reports collected by state/territory to which they are relevant (meaning that state/territory was stated as the study area). A large portion of the research collected had national relevance and did not contain case studies specific to a state/territory. For the research that contained case studies, Queensland and Victoria were most commonly studied, followed by New South Wales.

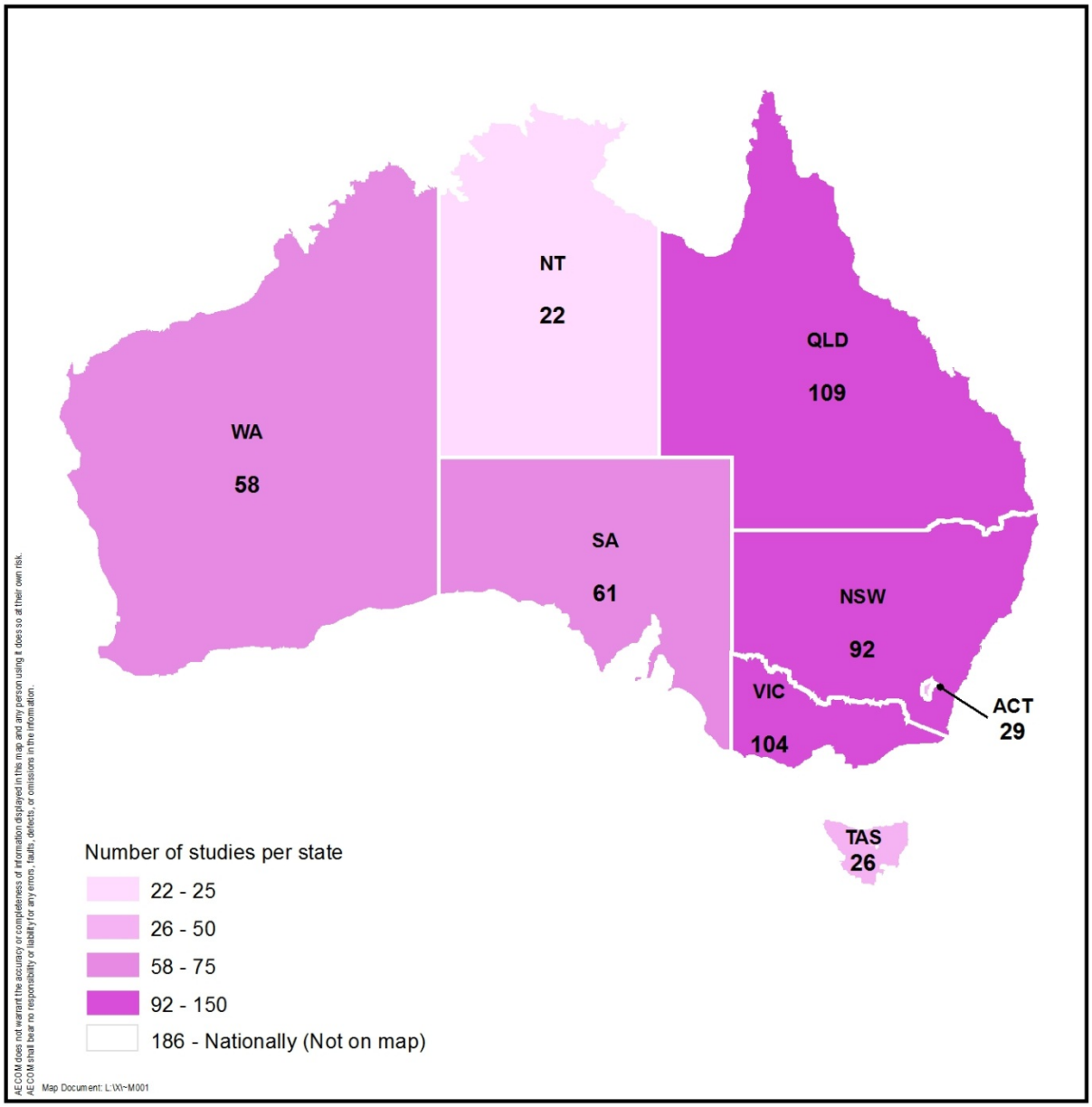


Figure 2 NCCARF and non-NCCARF research by state/territory

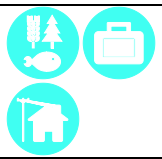
A selection of the research gathered for the database was included in the synthesis (Section 4). Some NCCARF reports were unable to be included as research drafts were not available at the time of synthesis drafting. Others were excluded as their content was not directly relevant to state government 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. A number of these non-NCCARF reports were VCCCAR projects. The research was selected based on its relevance to state government policy.

3.2 Research included in the synthesis occurring in Victoria

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, multiple research projects used as the foundation for this synthesis consider adaptation specifically within Victoria and are listed in Table 3. Projects were chosen on the basis that their research included at least one Victoria-specific location or case study, although not all projects were delivered by Victoria-based research organisations. The purpose of this table is to assist readers locate a particular report in Victoria 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 Victoria government activities and priorities, referenced in Section 2.0. These reports are listed in the bibliography.

Table 4 Victoria-specific research

Lead author	Status	Year	Title	Sectors
A. Aldous	Final	2011	Droughts, floods and freshwater ecosystems: evaluating climate change impacts and developing adaptation strategies	
J. M. Balston	Draft	2012	Development of tools that allow local governments to translate climate change impacts on assets into strategic and operational financial and asset management plans	
J. Barnett	Draft	2013	Barriers to Adaptation to Sea Level Rise	
T. D. A. Bennett	Final	2012	Integrated landscape management for a changing climate	
C. Biggs	Final	2011	Assessing resilient urban systems to support long-term adaptation to climate change	
D. Bird	Final	2011	Impact of the 2010–11 floods and the factors that inhibit and enable household adaptation strategies	
H. Boon	Draft	2012	Recovery from disaster experience: its effect on perceptions of climate change risk and on adaptive behaviours to prevent, prepare, and respond to future climate contingencies	

Lead author	Status	Year	Title	Sectors
M. Buxton	Final	2011	Vulnerability to bushfire risk at Melbourne's urban fringe: the failure of regulatory land use planning	
D.L. Choy	Draft	2013	Understanding coastal urban and peri-urban indigenous people's vulnerability and adaptive capacity to climate change	
D. Dutta	Final	2011	Synthetic impact response functions for flood vulnerability analysis and adaptation measures in coastal zones under changing climatic conditions: a case study in Gippsland coastal region, Australia	
J. Fritze	Final	2009	Community engagement and climate change: benefits, challenges and strategies	
D. Griggs	Draft	2013	Indigenous voices in climate change adaptation: Addressing the challenges of diverse knowledge systems in the Barmah-Millewa	
A. Hansen	Draft	2012	Extreme heat and climate change: adaptation in culturally and linguistically diverse (CALD) communities	
A. Hurlimann	Final	2011	Voluntary relocation – An exploration of Australian attitudes in the context of drought, recycled and desalinated water	
K. Hussey	Draft	2013	An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice?	
J. M. Kandulu	Final	2012	Mitigating economic risk from climate variability in rain-fed agriculture through enterprise mix diversification	
A. S. Kiem	Final	2010b	Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia.	
A. S. Kiem	Final	2012	Limits and barriers to climate change adaptation for small inland communities affected by drought	
A. S. Kiem	Final	2010a	Learning from experience: historical case studies and climate change adaptation	

Lead author	Status	Year	Title	Sectors
N. Kuruppu	Draft	2013	Understanding the adaptive capacity of small-to- medium enterprises (SMEs) to climate change and variability	
A. Loch	Draft	2012	The role of water markets in climate change adaptation	
M.E. Loughnan	Final	2013	A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities	
A. Lukasiewicz	Final	2013	Identifying low risk climate change adaptation in catchment management while avoiding unintended consequences	
M. Mason	Draft	2012	Damage to buildings during the 2010–11 Eastern Australia flooding events	
D. McEvoy	Final	2013	VCCCAR project: framing adaptation in the Victorian context – synthesis report	
C. Morrison	Final	2011	Climate change adaptation in the Australian Alps: impacts, strategies, limits and management	
B. Norman	Draft	2012	Coastal urban climate futures in South East Australia: Wollongong to Lakes Entrance	
J-A Paschen	Final	2012	Exploring local narratives of environmental change and adaptation	
R. Patrick	Final	2011	It's here! Are we ready? Five case studies of health promotion practices that address climate change from within Victorian health care settings	
C. Pettit	Final	2011	Building an ecoinformatics platform to support climate change adaptation in Victoria	
C.M. Pickering	Draft	2013	Determining high risk vegetation communities and plants species in relation to climate change in the Australian alpine region.	
Queensland University of Technology	Final	2010	Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009.	
B.J. Robson	Draft	2013	Novel methods for managing freshwater refuges against climate change in southern Australia.	
M. Sherval	Final	2012	Experiencing ‘drought and more’: local responses from rural Victoria, Australia	

Lead author	Status	Year	Title	Sectors
W. Steele	Draft	2013	Learning from cross-border mechanisms to support climate change adaptation in Australia: Every state for themselves? Learning from cross-border regulatory instruments to support and promote climate change adaptation in Australia	
N. Tostovrsnik	Final	2011	Climate change impacts and adaptation responses for South West Victoria's primary industries	
H. Van Rees	Final	2011	Farming during a period of extreme climate variability: consequences and lessons. Final report	
C. Wenger	Draft	2012	Living with floods: key lessons from Australia and abroad	
J. Wiseman	Final	2011	Scenarios for climate adaptation	

3.3 Victoria's synthesis research locations

Figure 3 maps the study locations and study regions within Victoria examined in the synthesised research. The purpose of this map is to highlight the cities, towns and regions where research has occurred, as this information may be relevant to the Victorian Government's work with regions and local councils and emphasises locations where additional research may need to occur.

This map demonstrates that research has covered nearly the entire state but has been concentrated around Melbourne. In particular, case study locations were often chosen because they had previously experienced extreme events, including heatwaves, drought, bushfires and floods. Regions examined include the Murray–Darling Basin, the Australian Alps, Goulburn Broken Catchment, Mallee and Wimmera regions, Gippsland, Glenelg Hopkins and Corangamite catchment management regions, and Greater Bendigo. A few locations were studied in more than one project, particularly Melbourne and Donald.

Appendix C includes summaries the NCCARF-funded research that occurred in Victoria.

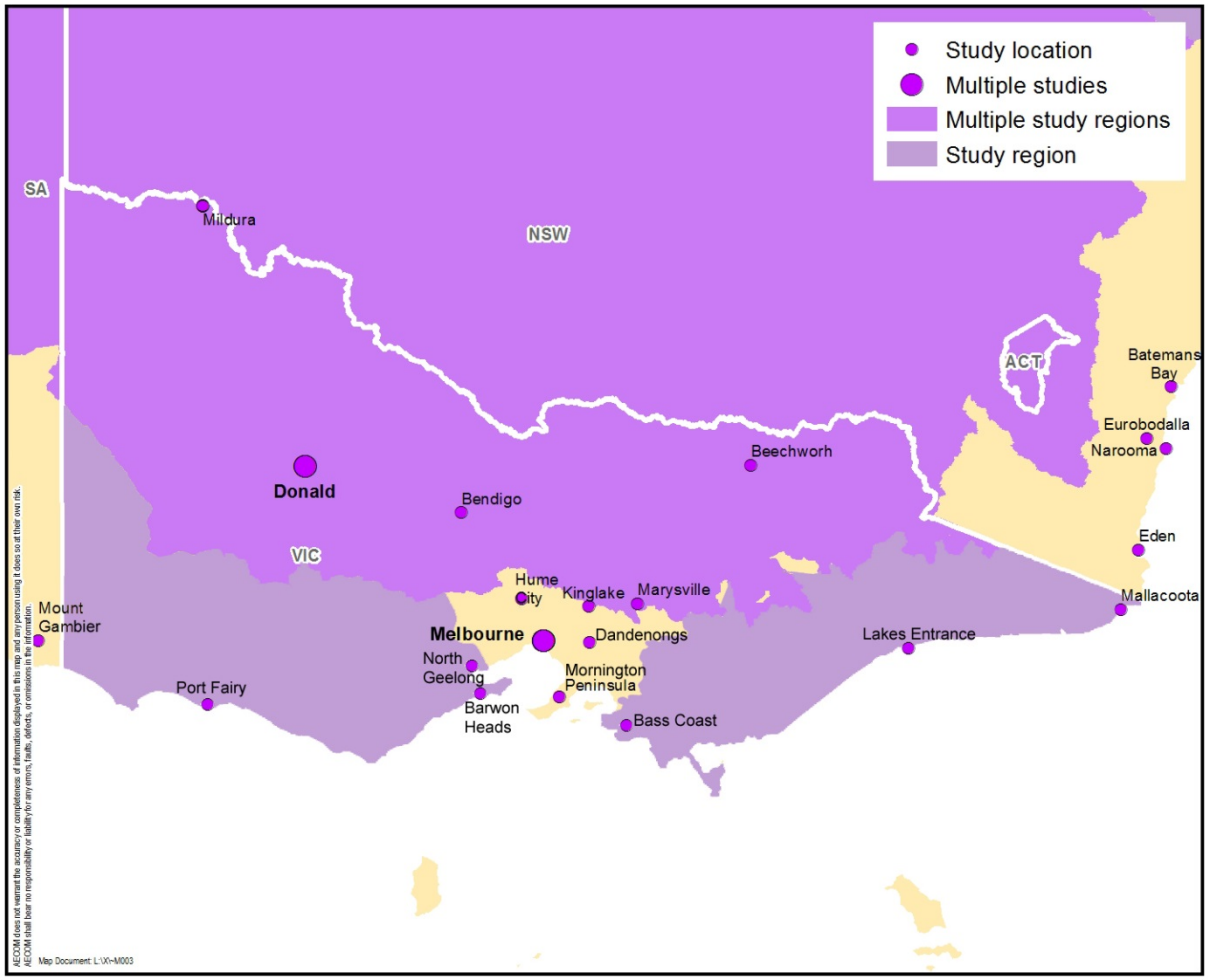


Figure 3 Case study locations synthesised adaptation research in Victoria

4.0 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 socio-economic) 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, that is, 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 (4.1) 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 wellbeing.
- 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 which 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 increase, 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 were 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 whole.

Planning for multiple levels of preparedness is needed for both 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 learnt from decades of drought policy which help illustrate how other external factors, such as the introduction of water trading, commodity prices and ageing 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 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, ongoing 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 likely 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; this decision was 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 related to 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.

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 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 (Mallon et al. 2013D). 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 small to medium sized organisations – 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 (Mallon et al. 2013D). 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 attachments to place. Participants stated that they would not move if recycled or desalinated water was added to the drinking water supply; they might be opposed to drinking recycled water but would ultimately have to accept it due to lack of alternatives. Due to the social, economic and public infrastructure costs associated with decisions to move, relocation would be the very last option considered. This indicates that despite the high level of public resistance to drinking potable quality recycled water; people would prefer this solution over 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). Other terms were found to be more appealing to community members than others. To residents in Port Fairy, Victoria, "scientific labels such as 'sensitivity' and 'vulnerability' were considered far less appealing and articulate to the community than other wording with more positive connotations such as 'strength' and 'resilience'" (McEvoy and Funfgeld 2013 p. 19). Furthermore, exclusive language (i.e. the language of experts) was found to be a key barrier to a community's understanding of and willingness to adapt to climate change (McEvoy and Funfgeld 2013; Paschen and Ison 2012).

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 use 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 (Boon et al. 2012D). This will have resilience repercussions but can also be seen as individuals managing their own risk. It is important that engagement around disaster preparedness strategies do not focus on climate change messages that may induce further scepticism, apathy or fear; messages regarding climate change need to be constructive and positive, focusing on what can be done and addressing individual interests (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, likely due to their strong sense of place about their community (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.'s (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 socio-economic disadvantage, linguistic barriers, poor housing conditions, and cultural practices (such as heavy clothing or not drinking water). For local and state 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 the identification of vulnerability based on factors that make a group distinct or different to the broader population can be divisive. The response to vulnerability and how it is communicated should be sensitive to this, and ensure that actions do not reinforce perceptions of difference.

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. The 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 information and imbalances in influence
- using existing policies and strategies as a basis for developing common objectives
- 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 communication 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 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 bearing 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. Community tension can increase when residents feel that government is not listening and when they feel like practices and arrangements do not allow them the agency to take action (Paschen and Ison 2012). 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:

- identifying 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 before 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; scenario planning can assist.
- We have already begun adapting; however, climate change creates additional complexity and may not be the primary driver.
- For some disasters, attitudinal barriers can prohibit planning and public discourse is needed to change views.
- Extreme climatic events can provide impetus for overdue or unpopular adaptation options.
- Local policy that is enacted after an extreme event can become a model for new national policy.

Prior experience is unpredictable in its influence upon disaster resilience, a finding important for emergency managers to note when preparing communities for future natural hazards (Boon et al. 2012D). 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. Of note was the finding that homeowners in Innisfail and Ingham did not report having building insurance despite past experience.

Victoria's drought prior to the floods had caused many residents to become apathetic towards flooding as they had not previously experienced flooding in their area. 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.

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 preparedness 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 2010–11 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 during the heatwave (QUT 2010). Bushfire risk planning had taken precedence over planning for extreme heat.

On the Gold Coast, significant coastal protection works and legislation was 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; scenario planning can assist. 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 also recommended to analyse the impact of hotter and more prolonged heatwave events on Victoria's infrastructure (QUT 2010).

Scenario planning is particularly useful and suited to situations of high uncertainty and limited control (Wiseman et al. 2011). It also provides a key opportunity to examine assumptions about ideas for the future and how problems and solutions are framed. However, in order for scenario planning to be effective, the following principles should be followed (Wiseman et al. 2011):

- develop a clear, shared understanding of climate change adaptation aims and challenges
- develop a clear, shared understanding of the strengths, limitations and goals of scenario planning
- gain early, high-level support for the scenario planning process from key stakeholders and champions
- ensure the appropriate time, resources, and skills are allocated to the scenario planning process
- involve a broad range of experience, expertise and evidence in the process and encourage consideration of a full range of drivers and pathways
- ensure scenarios can be defined and effectively communicated to key audiences
- consider ways in which the outcomes of scenario planning can be integrated into strategic planning and decision-making.

We have already begun adapting; however, climate change creates additional complexity and may not have been the primary driver. 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 governments are unable to claim reimbursement for a percentage of certain response and recovery costs.

Extreme climatic events can provide impetus for overdue or unpopular adaptation options. Kiem et al. (2010b) 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).

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).

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 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 existing policy mechanisms can create barriers to effective adaptation decisions, particularly in the private sector.
- Real options analysis is emerging as a technique to incorporate uncertainties and value decision-making flexibility.
- 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 costs and benefits throughout the community are useful to inform practical choices about which adaptations, or suite of adaptations, are likely to result in 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, can potentially result in a balanced 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 additional 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 taxpayers 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) identified that because the payments were not means tested, this could be seen as having a disincentive for people to cover their own exposure.

Traditional economic approaches and existing policy mechanisms can create barriers to effective 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 protection of long-term 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.

Real options analysis is emerging as a technique to incorporate uncertainties and value decision-making flexibility. A real options approach includes the option of either ending the project or changing the use of a long-

term asset in the case that either results in a greater present value than the proposed plan; one of the main messages of real options is that there may be gains in deferring decisions when uncertainty is present (Davis and Jenkinson 2013). This technique is currently more popular with researchers than industry circles (West and Brereton 2013D). The State Government of Victoria (2013) is currently testing real options analysis for application within government.

Current insurance products and practices need improvement to be an effective adaptation tool in the longer term. 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. As noted in one report, 26 per cent of all New South Wales households do not have any form of home and contents insurance (Giles 2007 in Verdon-Kidd et al. 2010, p. 44).

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 from and preparation for 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).

Many residents in Donald, Victoria post the 2010–11 floods were confused about their insurance coverage; many, particularly those who had no prior flood experience, thought they were covered for all types of floods but discovered after the fact they were not covered (Bird et al. 2011). Some residents also found renewing or modifying their policy challenging; many companies were refusing to accept people that had just been flooded (Bird et al. 2011).

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 and national government to actively support the uptake of insurance, including subsidies for lower socio-economic 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). The State Government of Victoria (2012c) has stated in *Environmental Partnerships* that it will "clarify legal liabilities for state and local government and insurance arrangements for climate-related risks" in order facilitate adaptation to a changing climate (p. 25).

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 policymakers 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, Bates 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.

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 (Mukheibir 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 frameworks 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 affecting 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. This lack of interaction is compounded by the governance of these issues by the government departments, statutory bodies and boards that have responsibility for current guidelines, codes and legislation (King et al. 2012D).

The timing required to amend legislative frameworks can also create barriers to adaptation. This was explored by Hussey et al. (2013D) for the integration of revised flood data and climate change information into planning schemes. Barriers identified include "a ten-year interval before some planning instruments become due for revision, the complexity of approval processes, cost, compensation liabilities and competing pressures" (Hussey et al. 2013D p. 63).

Norman et al. (2012D) found decision-makers to be concerned about potential shifts of responsibility for sea level rise planning from state government to the local level, but without supportive policies or resources. Climate change policy was seen to lack coordination between state government and local councils.

Finally, McEvoy and Funfgeld (2013) emphasise that adaptation will require the breakdown of traditional management barriers, as adaptation does not fall neatly into a single area of responsibility. Therefore, "adaptation requires a whole-of-organisation coordinated approach that relies on active collaboration to be effective and efficient" (McEvoy and Funfgeld 2013 p. 2).

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.

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 government planning agencies can be excessively risk averse out of fear of having to compensate those 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 which 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 if not handed sensitively, 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 that 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 that stayed 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 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.
- The scale of both the impact and the potential adaptation response need to align.

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, the following is essential:

- consider fully the potential consequences of doing nothing
- monitor climate change risks on an ongoing basis
- recognise and respond to changed circumstances in a flexible and 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 cited 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 a relatively short window (Helman et al. 2010). Delay of implementation of adaptation strategies, particularly after an extreme event, can be detrimental to success (Kiem et al. 2010a).

*Governments, hospitals, emergency response organisations and the community were under-prepared for Victoria's 2009 heatwave (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).*

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.

The scale of both the impact and the potential adaptation response need to align. 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).

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 adaptation planning for ports has been focused on the seaward side of operations (access, mooring, loading and unloading of ships); however it is more

likely that disruptions to supply chains and supporting infrastructure will have greater impacts and implications (McEvoy and Mullett 2013).

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 reconsidered 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.
- 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 *reconsider***ed 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 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 which seek to restore environments to pre-European states or similar aspirational benchmarks will need to be reconsidered 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. Rethinking 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 reconsidered in order to accommodate climate change threats. Whilst there is scope for improvement

and targeted adaptation actions, a major rethink of legislative objectives is required to ensure that actions are sustainable 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 (Steffan 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, need to be considered from a variety of approaches – 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:

- maintain well-functioning ecosystems (terrestrial, aquatic and marine)
- protect a representative array of ecosystems (underpinned by a National Reserve System)
- remove or minimise of existing stressors
- build appropriate landscape and seascape connectivity
- identify and protect 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. Integration involves the systematic consideration of the benefits, effectiveness, potential maladaptation, implementation constraints and failure risks of the actions as a whole rather than individually (Lukasiewicz et al. 2013D). 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 to undertaking climate change adaptation strategies for catchment management areas that need to be overcome for effective engagement. 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, north-west Western Australia, and southern South Australia and Victoria, with the focus of the restoration efforts in south-eastern Australia.

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.
- Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty.
- Adaptation in primary production is primarily driven by private sector responses but Government needs to play a supporting role to ensure the effectiveness of adaptation responses through the provision of information and other resources.
- 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.
- 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). Sheep, as the least water intensive activity, are preferred in these areas. As wheat has the highest net returns per tonne compared to lupin or sheep, wheat cultivation is preferred to diversification in wet areas (Kandulu et al. 2012).

Water trading can be an effective adaptation tool, but not all users will be able to participate and effectively manage associated uncertainty. Water trading can be complex and fraught with limitations. It appears to succeed in meeting its intent to reallocate water resources to high value users (e.g. mining, manufacturing, electricity production) but often at the expense of users such as agriculture, the supply of drinking water and the provision of water to protected ecosystems (Kiem and Austin 2012). In particular, Kiem et al. (2010a) report that water trading and allocations have been challenging for farmers in Mildura. The rapidity and volatility of the market have resulted in the loss of considerable amounts of money for some farmers and some have exited farming entirely.

However, water trading also helped other businesses manage the impacts of the most recent drought, faring much better than they would have otherwise (Kiem et al. 2010b). Loch et al. (2012D) also suggest that, on the

whole, water markets have been of net benefit for Australian irrigators and will be of increasing importance to adaptation to climate change. Concerns about social implications are discussed by Loch et al. (2012D), and the possibility of transformational change (conversion to dryland farming, relocation, farm exit etc.) for marginal farms are identified, though it is suggested that there is little evidence of negative social impacts, and that some impacts suggested as relating to water trading are a continuation of ongoing structural change of rural communities that predate water markets.

Key to avoiding or reducing maladaptive water trading and water reform is the need for more complete baseline information on water availability, water quality and current uses (Newton 2009). However, rainfall and streamflow are highly uncertain due to the variability of the climate; this means that defining a sustainable water allocation is extremely difficult (Kiem and Austin 2012). To address this limitation, more research is needed to differentiate which part of the changes in water use (or limitations of water policy) are due to inadequate policy and which parts are due to variable hydroclimatic conditions (Kiem and Verdon-Kidd 2011 cited in Kiem and Austin 2012). Sherval and Askew (2012) note that stakeholders in their study expressed a need for a stable and secure water allocation and buy-back system that is planned and negotiated with farmers.

Loch et al. (2012D) identified a number of behavioural barriers related to water trading, including unwillingness by some farmers to commit to change given climate uncertainty and variability, the lack of adequate market mechanisms and signals to deal with climate change, economical barriers including debt levels and access to finance, disincentives for preparedness including exceptional circumstances support programs, and scepticism.

Finally, Loch et al. (2012D) state that water policies should be designed to address both incremental adaptation decisions (a relatively common decision) and transformative decisions (a rarer decision as it results in a major change in location, livelihood identity). Furthermore, it was suggested that water policy:

- be focused on adaptive change for farmers as they adjust to new levels of water scarcity and land management needs. In particular, policy should help educate irrigators on how planning for water shortages can improve farm viability and profitability
- recognise that change is not possible for all farmers; some parts of irrigated districts perhaps should no longer be supported in the future due to soil conditions, costs, environmental conditions or other factors.

Adaptation in primary production is primarily driven by private sector responses. 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 p. 7).

Individual farms have coped with periodic events through a range 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. Primary production in the north-west of Victoria has been identified as being more vulnerable to drought than other regions as a result of already low rainfall totals. Farms in these regions have made management changes in order to cope with temporary rainfall deficiencies including de-stocking, crop intensification and adopting no till practices (Rees et al. 2011). However, some of these responses can result in additional cost to the farmer (for example new machinery, additional fertiliser, etc.) during periods of reduced incomes. These adaptation responses may therefore increase risk or reduce resilience if operations are reduced to a single income source.

Agriculture is already a major industry in most parts of south-west Victoria, and climate change is expected to be less damaging to this region than in other parts of the state. Thus, this region is likely to be even more attractive to agriculture producers over time (Tostovrsnik et al. 2011). However, climate change will still affect agriculture in this region as a result of changes to both temperature and rainfall. Similar to the modifications discussed by Rees et al. (2011), on-farm adaptations suggested by Tostovrsnik et al. (2011) include conversion from perennial to annual fodder, changes in crop management practices, increased use of reduced tillage techniques, altered rotations of crops, changing feed systems, changing livestock milking times and water management.

As Victorian grain growers may find it difficult to anticipate which crop management systems would work best under unpredictable weather patterns, Birchip Cropping Group, CSIRO and the Agricultural Production Systems Research Unit have collaboratively developed an online, subscription-based software package, Yield Prophet, in

order to help grain growers forecast crop yields, manage the risks of a variable climate and maximise returns (State Government of Victoria 2013).

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 in adaptation is extremely important but can be contentious.
- There are issues of continued expansion of populations into at-risk areas.
- Through development regulation, land use planning can play an essential role in reducing climate risks to populations and infrastructure. However there are limits.
- 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.
- Regional-scale approaches and land use policy will be needed to address shrinking land availability for certain uses, such as high quality apple production.
- 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)
- 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. 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. 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).

Regulatory instruments in land use planning need to have greater flexibility to support adaptation. More flexible regulatory instruments at the level of state 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.

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).

Through development regulation, land use planning can play an essential role in reducing climate risks to populations and infrastructure. However there are limits. 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). However, Buxton et al. (2011) found the Victorian planning system, in light of the 2009 bushfires that devastated the peri-urban region to the north of metropolitan Melbourne, to be inadequate to reduce this risk. The current Victorian planning system, which uses a suite of standard planning provisions (the Victoria Planning Provisions), “has led to a proliferation of rural residential development in the peri-urban area, where biodiversity values are significant, agriculture may be practised and the bushfire risks are at their greatest” (Buxton et al. 2011 p. 6). More specifically, Buxton et al. (2011) criticise the prevalence of dispersed, small lot development; the inadequacy of policy and planning provisions to preserve remnant native vegetation; the inability of the Wildfire Management Overlays (WMO) to regulate the suitability of land for development; and the inconsistent application of WMO among municipalities.

The State Government of Victoria has instituted a number of reforms to planning requirements since the 2009 bushfires. The new Bushfire Management Overlay provisions, for example, “ensure that development in areas subject to a significant bushfire hazard only occurs after full consideration of bushfire issues. If risk to life and property from bushfire cannot be reduced to an acceptable level, the development must not proceed” (State Government of Victoria 2013 p. 35).

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 vs. 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). Furthermore, Norman et al. (2012D) 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.

As stated above, after the 2009 Black Saturday bushfires in Victoria, new requirements were introduced to improve risk assessment processes in planning systems. These requirements now include the provision that the precautionary principle be applied when assessing the risk from bushfire to life, property and community infrastructure (State Government of Victoria 2013).

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 have 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.'s (2013D) research in South Goulburn Island, NT, 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).

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 building trust are important parts 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, NT; 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:

- Heatwave-related deaths are largely avoidable; spatially identifying high risk areas is important to reduce unnecessary mortality and illness.
- State government should ensure adequate health services are available, both during and for the longer term after disaster events.

[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.]

Heatwave-related deaths are largely avoidable; spatially identifying high risk areas is important to reduce unnecessary mortality and illness. Loughnan et al. (2013) found that four variables were important in assessing adverse, heat-related health outcomes: age, disability, ethnicity and urban heat island. Generally, higher risk areas are clustered outside of the centre city; in Melbourne, the highest vulnerability surrounded but did not include the inner city area, with some areas of higher vulnerability extending to the western and south-eastern bayside suburbs (Loughnan et al. 2013). Understanding the spatial distribution of vulnerability can help emergency services plan for increased demand and identifies where adaptation and heatwave planning is needed.

State 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 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.

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.
- Adaptation will likely require the promotion of flexibility and spare capacity in systems, an approach often in contrast with business efficiency.

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.

Adaptation will likely require the promotion of flexibility and spare capacity in systems, an approach often in contrast with business efficiency. For seaports, impacts from extreme events has been greatest regarding supply chain issues (e.g. flooding affecting coal supply through the flooding of mines and damaging railway lines) (McEvoy and Mullett 2013). Therefore, adaptation needs to look beyond immediate business environs, as well as consider non-climate drivers. This will require the promotion of flexibility and spare capacity in systems. Port authorities also will need to undertake assessments in collaboration with logistics providers and local/state/national governments in order to ensure supply chain routes and a long-term approach to land use planning for ports are taken into account (McEvoy and Mullett 2013).

4.8 Potential policy options and practical adaptation actions

The following potential policy options and 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, and the options have not been critiqued. However, where possible, AECOM has added reference to state policy or activity that supports the action or where the action could add further value to a particular policy.

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).
- Establish water trading mechanisms to manage water between tidal estuaries and upstream habitats. (Hadwen et al. 2011).
- 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). In Victoria, catchment management authorities are working with local government to improve flood hazard mapping to better aid actions to reduce flooding impacts on regional communities; this mapping will be important to support improved land use planning and emergency response (State Government of Victoria 2013).
- 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). Under the requirements of Clause 56.07 of the Victoria Planning Provisions, developers must use water sensitive urban design techniques, such as rain gardens and rainwater tanks, in new subdivisions (Melbourne Water n.d.). Amendments to the Victoria Planning Provisions are being considered to apply these performance requirements to other types of urban development (State Government of Victoria 2013). Melbourne Water also produces recycled water from two sewage treatment plants to supply water for agricultural irrigation, industrial processes and non-potable municipal and domestic uses.
- 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).
- Reconsider land use to maintain connectivity at landscape, ecological and evolutionary scales to allow species the opportunity for autonomous adaptation (Hadwen et al. 2011).
- Remove trade restrictions to allow for more efficient transfers of water allocations inter-regionally to facilitate more fluid farm adjustment to water scarcity or climate change; better groundwater regulation to avoid over-allocation of the resource; expand water trade products (and cross-sector interaction); improve assessment and approvals procedures to better provide readily available information on processing, remove assessment factors, address handling process complaints, and other critical requirements to reduce water trade transaction costs; and provide greater transparency where potential conflicts of interest may arise (Loch et al. 2012D).
- Develop more robust and detailed market price information signals for water; improve seasonal water allocation announcements through substantial up-front and periodic review to make allocation determinations more transparent; and improve knowledge of potential adaptive responses and their effectiveness across different industries and regions (Loch et al. 2012D).

4.8.2 Infrastructure, communities and land use planning

- Require major infrastructure owners to conduct climate risk assessments (McEvoy and Mullett 2013). The Victorian Department of Transport is in the final stages of finishing a climate change risk assessment of all existing transport assets (State Government of Victoria 2013). Furthermore, the Victorian Government is currently developing a *Strategy for Critical Infrastructure Resilience* and has already published *A Roadmap for Critical Infrastructure Resilience* (State Government of Victoria 2013). This Roadmap outlines directions to reform the state's emergency management arrangements for critical infrastructure, including movement to an all hazards resilience framework.
- Localise building design requirements beyond current regional zoning in the Building Code of Australia (Hadwen et al. 2011). The State Government of Victoria (2013) has created new building construction standards in order to ensure new buildings in designated Bushfire Prone Areas are built to achieve minimum construction standards designed to protect buildings from bushfires.
- 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). Nationally consistent guidance would require collaboration with the Commonwealth government and other states/territories. Victoria does have the aim to "integrate consideration of climate risk into existing policy and planning frameworks and into the development of national building standards" (State Government of Victoria 2013 p. 34).

- 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. As stated in the *Victorian Climate Change Adaptation Plan*, flexibility is already a key approach taken by the Victorian Government in order to manage climate risks.
- 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).

4.8.2.1 Emergency management

- Consider a policy that subsidises insurance purchase for lower socio-economic groups as an alternative to charity donations by government (Boon et al. 2012D). The State of Victoria (2013) also recognises the need to have an effective private insurance market and states "lower take-up rates of insurance and under-insurance could be improved by appropriate policy and regulatory settings and, where appropriate, addressing affordability issues for vulnerable groups" (p. 37).
- 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. For heatwaves, the State Government of Victoria (2013) has developed a heat health alert system that notifies state and local government, hospitals, and health and community service providers of extreme heat conditions. The temperature thresholds established differ by region.
- 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). The Victorian Government gave over $600,000 to ten councils in the southwest through the Victorian Local Sustainability Accord to assess climate risks and identify adaptation measures (State Government of Victoria 2013).
- Establish or enhance formal and informal local support networks (Boon et al. 2012D). Strengthening partnerships with communities and local government is a main objective of the Victorian Government in regard to adaptation. To support this, the government is renewing its commitment of partnership with local government through the Victorian Adaptation and Sustainability Partnership.

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). The Victorian Government's *Residential aged care services heatwave ready resource* provides some educational information for what can be done to assist residents (Department of Health 2010). However, further information and educational programs may be developed to ensure staff and volunteers are trained to effectively respond to the needs of residents during heatwaves.

- 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). The Victorian Department of Health has developed a health alert system to notify local governments, hospitals and other community service providers of heatwave conditions (State Government of Victoria 2013); however, it is not explicitly stated whether these alerts are provided in multiple languages.

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).
- Create a web-based resource which showcases best practice for ports; knowledge exchange between ports is important for enhancing resilience (McEvoy and Mullett 2013).

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 and local government (Mukheibir et al. 2012).
- Increase clarification and differentiation between local and state 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). The State Government of Victoria (2013) also recognises this need in its *Victorian Climate Change Adaptation Plan* as one of the primary roles of the plan is to "provide guidance on roles and responsibilities of government – in particular, state and local government – and the private sector, on the basis that climate risks are best managed by those closest to the risk" (p. 3). Furthermore, the Victorian Adaptation and Sustainability Partnership has been developed to strengthen cooperation between local and state government; all 79 Victorian councils have joined the partnership (State Government of Victoria 2013).
- Create consistent methodologies and data frameworks to enable information sharing between and within government agencies – particularly important for remote communities (Bird et al. 2013D).

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 return 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.*

5.0 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 also 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 data and 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 for this synthesis 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 an 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. (2010a) 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 further increase discord between end users and researchers (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 Centre for Climate Change Adaptation Research (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 research 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, 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 of uncertainty so that decisions can be reviewed and changed as needed over time (Verdon-Kidd 2012).

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).

6.0 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 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). 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 common themes, outlined in Table 5. These challenges include potential implications for policy development, programs and management undertaken by state and territory governments.

Table 5 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 has 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.
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.
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 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.

Fundamental challenge	Issue	Policy implications	Example
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.
Financing adaptation	Issues around who pays for adaptation are largely still unresolved. Linked to this issue is also the concerns of government in relation to legal liability.	Private sector investment in adaptation will be guided by government responses and support. Use of traditional tools such as cost benefit analysis, are emerging but there is limited knowledge on how to best consider distributional issues.	Investment by the government in coastal protection is proving a direct benefit to individual property owners. Government subsidy post-disaster can disincentivise households to cover their own exposure through insurance.
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, 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).

Climate change uncertainty

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. The 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 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. Fortunately, government policy is reviewed and updated regularly as new information emerges and communities change. The complexity of changes to consider, however, may require policy and management objectives – particularly in relation to natural resource management, disaster recovery and land use planning – to be reconsidered 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.

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. The range of areas potentially impacted will also require an unprecedented level of collaboration and agreement between government departments, different levels of government and other organisations. This can be a considerable challenge, particularly when responsibilities are not clearly defined.

Communication and engagement

While government engages with community stakeholders on a frequent basis, engagement around climate change can be particularly challenging. 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, a 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. 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).

Articulation and implementation of adaptation objectives

Clearly articulating adaptation goals (together with options) is seen as a key to engaging the community. Well-defined objectives can also help coordinate the integration of climate adaptation into existing policies, strategies and operational activities at state government departmental and agency portfolio level. While the articulation of objectives seems relatively easy, actually ensuring action is often more difficult.

Underlying this challenge, and many of the challenges discussed so far, is political will and the changing political landscape. Clearly articulated objectives can be watered down due to political sensitivity or can be hard to implement. Uncertainty can be an excuse not to act when an action is challenged or seems unpopular. Other change drivers can take political precedent over climate drivers, crowding out adaptation considerations. Overcoming this barrier with political leadership will be essential for adaptation success.

Monitoring and review of both risks and adaptation responses

Monitoring of both risks and adaptation responses is needed to support flexible decision-making over time. Monitoring can also provide evidence of how natural and human systems are changing as a result of climate and the need for change, as well as provide support for the continuous implementation of effective policy interventions. Unfortunately, there is currently little knowledge or experience in evaluating adaptation options. There also can be a lack of understanding of what needs to be monitored or a lack of feeling of urgency to establish appropriate systems. Even when it is known what to monitor, monitoring can be difficult to implement as it frequently requires a long-term commitment of time and resources. This is likely a larger issue for some sectors

than others; some form of monitoring may be typical for business and industry but likely requires significantly more investment for natural resource management.

Financing adaptation

Issues around who pays for adaptation are largely still unresolved. This is perhaps the greatest challenge for state government policymakers, as it can be unclear how much the private sector will engage and take action. Related to the other actions discussed, institutional barriers, political will and uncertainty can reduce the willingness of government to dedicate limited financial resources to a problem, particularly when responsibility is unclear. It can also be challenging to accurately quantify the costs and benefits of some actions, increasing the uncertainty of economic decision-making.

Learning from recent extreme weather events

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 longer 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. While extreme events can provide key opportunities to act, opportunities can also be lost by the rush to restore communities and meet shorter term needs in lieu of considering the needs due to a gradual shift in climate.

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.

However, despite the challenges, it is also important to recognise that the experience from extreme events can bring 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.

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.

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, 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. As stated in the *Victorian Climate Change Adaptation Plan,* climate change could stimulate new opportunities for businesses and communities, including the growth of new crops, increased habitat for some fish, further development of the carbon market, and new innovations such as the development of new climate resilient building products (State Government of Victoria 2013).

Monitor and evaluate existing adaptation practices for ongoing adaptation. One of the strategies identified in the *Victorian Climate Change Adaptation Plan* is to implement a monitoring, evaluation and reporting framework to keep track of changes to the natural environment. The Victorian Government also currently monitors the ecological impacts of planning burning through the Hawk Eye monitoring project (State Government of Victoria 2013). 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.

Ensure structures and institutions are flexible and can react to emerging issues and unforeseen events. From land use planning to natural resource management to primary production, the research reviewed for this synthesis frequently reiterated the need to ensure governance systems are flexible in order to respond to unforeseen events as well as incremental changes. Flexibility will also allow for continuous learning which is essential for adaptive management. The Victorian Government also recognises the value of flexibility and adaptability for improving resilience; this is a key approach discussed in the *Victorian Climate Change Adaptation Plan* (State Government of Victoria 2013).

Clearly define specific 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.

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. Strengthening partnerships with communities and local government is a main objective of the Victorian Government in regard to adaptation. To support this, the government is renewing its commitment of partnership with local government through the Victorian Adaptation and Sustainability Partnership.

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. 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. Scenario planning can be useful in order to address future needs and options, particularly in situations of high uncertainty. It also provides an opportunity to examine assumptions about how experiences with past events may apply to future conditions. Research undertaken by VCCCAR has explored the role and importance of scenario planning to address future needs and options, including 33 projects where this approach has been used effectively in a number of government departments (State Government of Victoria 2013).

Continue to 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. The State Government of Victoria (2013) also recognises the need to further development a body of knowledge to support effective climate risk management. National research by institutions and initiatives such as CSIRO, BoM, NCCARF and the Australian Research Council Discovery and Linkage Projects, provide a foundation of research for Victoria. The Victorian Centre for Climate Change Adaptation Research (VCCCAR) also supports a multi-disciplinary research program to address adaptation priorities identified by the state government.

Appendix A: FORNSAT Interviews

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 July 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's adaptation program?

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

- Identifying and aggregating policy-focused and practical, 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-based adaptation research investment.

2. Has your state 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 had 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. In these cases, states 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 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 and 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 (the 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.

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.

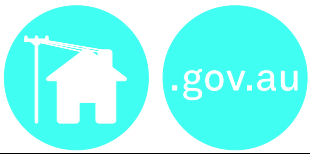
Appendix Table 3: Nationally relevant NCCARF research projects

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	
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.	

ID	Lead Author	Year	Title	Sectors
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	.gov.au
P2IMLR	E.S. Poloczanska	2012	iClimate Project	gov.au
S3AUN2	A. Randall	2012	Understanding end-user decisions and the value of climate information under the risks and uncertainties of future climate	gov.au
EM1101	J.P. Reser	2012	Public risk perceptions, understandings, and responses to climate change and natural disasters in Australia, 2010 and 2011	.gov.au
P1ACP1	T.F. Smith	2010	The nature and utility of adaptive capacity research	.gov.au
EM1103	S. Trueck	2013	Developing an Excel spread sheet tool for local governments to compare and prioritise investment in climate adaptation	.gov.au
S3AUN1	D. Verdon-Kidd	2012	Bridging the gap between end-user needs and science capability: dealing with uncertainty in future scenarios	.gov.au
SI1005	C. Woodroffe	2012	A model framework for assessing risk and adaptation to climate change on Australian coasts	.gov.au

Appendix C: NCCARF research summary – Victoria

Development of tools that allow local governments to translate climate change impacts on assets into strategic and operational financial and asset management plans	
Authors (Year)	J. M. Balston, J. Kellett, G. Wells, S. Li, A. Gray, I. Iankov (2012)
Status	Draft final report
Summary	This study developed a financial modelling tool which estimates climate change impact costs associated with road maintenance and management for local governments. The financial tool incorporates existing mathematical models which estimate climate change impacts on road deterioration and maximum service life of three major road asset classes (hot-mix sealed, spray-sealed and unsealed roads) based on changes to temperature and rainfall. This financial tool is intended for integration with the current Institute of Public Works and Engineering Australia (IPWEA), National Asset Management Strategy NAMS.PLUS program - part of a suite of models and tools within the International Infrastructure Management Manual (IIMM) framework widely used to guide management of infrastructure assets. The tool was developed in collaboration with 10 local governments in southern Australia (Victoria, South Australia, Western Australia and Tasmania), and tested by 8 of the collaborating councils which had sufficient data to run the models. Results for the modelling show a slight cost reduction and improvement of maximum service life for spray sealed and unsealed roads; with more significant results for hot-mix sealed roads. The researchers note that these results are based on a general increase in temperatures and decrease in rainfall projected for the case study councils; that the tool does not take into account the effects of extreme events – though identify it as an important factor to be considered outside of theoretically-driven variables.
Methodology	This study was guided by stakeholder meetings, interviews with collaborating councils, and used information provided by these councils and desktop review to create the modelling tool.
Output	Knowledge, Testing of methodology or approach, Tools or guidelines
States (specific location)	South Australia (Port Adelaide Enfield, Barossa, Wattle Range, Onkaparinga, Tumby Bay, Campbelltown), Victoria (Hume City, Bass Coast), Western Australia (Esperance), Tasmania (Brighton).
Sector Relevance	

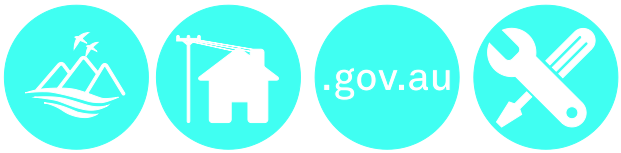
Barriers to adaptation to sea level rise	
Authors (Year)	J. Barnett; E. Waters (2013)
Status	Draft report
Summary	This report investigated the institutional, legal and cultural barriers that exist for adaptation to climate change – and in particular sea level rise in Australia. The study reviewed over 800 submissions to the Australian Productivity Commission's inquiry into barriers to adaptation provided by government, non-government organisations and institutions, and the private sector, to develop a typology of barriers to adaptation which exist. A round of 80 semi-structured interviews was also conducted with residents of two coastal communities to investigate opinions on sea level rise, with a focus on distribution of responsibility for adaptation. The review of submissions to the Australian Productivity Commission's inquiry identified five recurring barriers, relating to: governance (uncertainty about roles and responsibilities), policy, uncertainty, resources, and psychosocial factors. The interviews with coastal community members uncovered a view that the local government were best placed to regulate and manage local assets, and provide a platform for local input into planning, the Federal government was considered best placed to provide information on impacts and funding for adaptation actions, and state government were identified as having a key role to play in co-ordinating actions across local government boundaries.
Methodology	This study employed desktop research and interviews.
Output	Knowledge
States (specific location)	New South Wales (Eurobodalla), Victoria (Mornington Peninsula)
Sector Relevance	

Impact of the 2010-11 floods and the factors that inhibit and enable household adaptation strategies	
Authors (Year)	D. Bird, D. King, K. Haynes, P. Box, T. Okada, K. Nairn (2011)
Status	Final report
Summary	This report assessed factors that impede and assist adaptation strategies in flood impacted areas. The report focussed on what can be learnt from case study communities in Queensland and Victoria affected by the 2010/ 2011 floods. Barriers to adaptation that were identified in the report include financial constraints, pre-existing building construction and lack of skills and guidance on response and adaptation. The lack of awareness, preparedness and education for flooding events and the aftermath (as opposed to some other extreme weather events such as cyclones) was identified as a key inhibitor. Overall the study found that there were more factors that impeded adaptation than enabled it (though it notes possible interviewee bias), and recommends government and external agencies invest in fostering resilience and adaptive behaviour in flood prone communities.
Methodology	This study undertook literature review, then interviews and questionnaires for the case study locations.
Output	Knowledge
States (specific location)	Queensland (Chelmer, Graceville, Tennyson, Rocklea, Brisbane, Emerald), Victoria (Donald)
Sector Relevance	

Recovery from disaster: resilience, adaptability and perceptions of climate change	
Authors (Year)	H.J.Boon, J. Millar, J. Lake, A. Cottrell, D. King (2012)
Status	Final report
Summary	This report assessed the resilience of people who remained in disaster affected communities; and the beliefs, behaviours and policies that encourage greater community resilience. Specifically, individuals from the bushfire impacted Beechworth community, drought impacted Bendigo community, flood impacted Ingham community and cyclone impacted Innisfail community were interviewed and surveyed to assess their resilience, with an analysis of commonalities between responses undertaken. It was found that the safety and wellbeing of individuals through support from neighbours, friends and family and other local support networks (formal and informal) contribute to resilience, as does physical and emotional preparedness through advance warnings. The research uncovered a need for increased and more flexible support, recovery and health services for longer periods after a disaster event.
Methodology	The study team undertook literature review, interviews and surveys.
Output	Knowledge, Testing of methodology or approach, Tools or guidelines
States (specific location)	Victoria (Beechworth, Bendigo), Queensland (Ingham, Innisfail)
Sector Relevance	

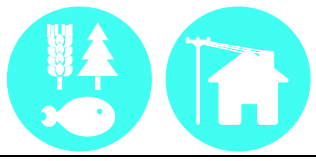
Development of tools that allow local governments to translate climate change impacts on assets into strategic and operational financial and asset management plans	
Authors (Year)	J. M. Balston; J. Kellett; G. Wells; S. Li; A. Gray; I. Iankov (2012)
Status	Draft final report
Summary	This study developed a financial modelling tool which estimates climate change impact costs associated with road maintenance and management for local governments. The financial tool incorporates existing mathematical models which estimate climate change impacts on road deterioration and maximum service life of three major road asset classes (hot-mix sealed, spray-sealed and unsealed roads) based on changes to temperature and rainfall. This financial tool is intended for integration with the current Institute of Public Works and Engineering Australia (IPWEA), National Asset Management Strategy NAMS.PLUS program - part of a suite of models and tools within the International Infrastructure Management Manual (IIMM) framework widely used to guide management of infrastructure assets. The tool was developed in collaboration with 10 local governments in southern Australia (Victoria, South Australia, Western Australia and Tasmania), and tested by 8 of the collaborating councils which had sufficient data to run the models. Results for the modelling show a slight cost reduction and improvement of maximum service life for spray sealed and unsealed roads; with more significant results for hot-mix sealed roads. The researchers note that these results are based on a general increase in temperatures and decrease in rainfall projected for the case study councils; that the tool does not take into account the effects of extreme events – though identify it as an important factor to be considered outside of theoretically-driven variables.
Methodology	This study was guided by stakeholder meetings, interviews with collaborating councils, and used information provided by these councils and desktop review to create the modelling tool.
Output	Knowledge, Testing of methodology or approach, Tools or guidelines
States (specific location)	South Australia (Port Adelaide Enfield, Barossa, Wattle Range, Onkaparinga, Tumby Bay, Campbelltown), Victoria (Hume City, Bass Coast), Western Australia (Esperance), Tasmania (Brighton).
Sector Relevance	

Understanding coastal urban and peri-urban indigenous people's vulnerability and adaptive capacity to climate change	
Authors (Year)	D.L. Choy, P. Clarke, D. Jones, S. Serrao-Neumann, R. Hales, O. Koschade (2013)
Status	Draft report
Summary	This report examined the impacts of climate change on peri-urban and urban indigenous communities and their capacity to adapt. By considering the impacts of climate change on five communities the following priority areas of concern were identified for individuals, households , business and institutions: • Opportunities and capacity to represent indigenous knowledge and values in state and federal government processes relating to environmental management and land use; • Flexibility to move or modify housing to better adapt to climate change • Strategic consideration of climate change on employment opportunities and risk, particularly in natural resource based industries • Use of environmental and cultural assets to inform climate change monitoring, communicate indigenous perspectives on environmental issues and built environmental awareness. • Impacts on and opportunities for the wild food network. The report includes recommendations for on-going engagement with indigenous communities through increased collaboration and inclusiveness to improve indigenous land use agreements. A proposed research framework to build a more comprehensive research agenda has also been included. This incorporates specific research needs which have been prioritised by indigenous representatives on the project reference group.
Methodology	This study undertook a literature review. Data was collected through workshops in five case study areas and through selected interviews with Elders and other knowledgeable people.
Output	Knowledge
States (specific location)	Victoria (North Geelong, Mornington Peninsula) South Australia (Adelaide Plains) Queensland (Stradbroke Island, Moreton Bay, Brisbane-Ipswich)
Sector Relevance	

Indigenous voices in climate change adaptation: Addressing the challenges of diverse knowledge systems in the Barmah-Millewa	
Authors (Year)	D. Griggs, A. Lynch, L. Joachim, X. Zhu, C. Adler, Z. Bischoff-Mattson, P. Wang, T. Kestin (2013)
Status	Draft report
Summary	This project examined how the knowledge of the Yorta Yorta people can be utilised to increase their participation and influence in the national and regional processes that determine how their traditional land is managed for adaptation. Yorta Yorta youth were trained to gather data for the creation of a GIS database that captures climate, hydrology, biodiversity, administrative, imagery, socioeconomic and cultural data. The purpose of this database is to create a tool that incorporates both traditional and Indigenous knowledge in order to enable informed decision-making.
Methodology	This project involved data collection, volunteer training, interviews and a two-day workshop (National Workshop on Indigenous Knowledge for Climate Change Adaptation).
Output	Knowledge, Testing of methodology or approach, Tool
States (specific location)	New South Wales and Victoria (Yorta Yorta and Barmah-Millewa areas)
Sector Relevance	

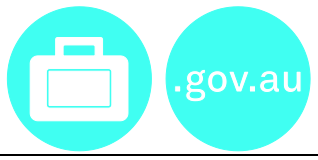
Extreme heat and climate change: adaptation in culturally and linguistically diverse (CALD) communities	
Authors (Year)	A. Hansen, P. Bi, A. Saniotis, M. Nitschke, J. Benson, Y. Tan, V. Smyth, L. Wilson, G.-S. Han (2012)
Status	Draft report
Summary	This report investigated the cultural, socioeconomic and linguistic elements which can influence culturally and linguistically diverse (CALD) communities' vulnerability to climate change focussing on extreme heat, and looked at options to increase adaptive capacity in these communities. Non climatic factors which affect some segments of CALD communities, such as socioeconomic disadvantage, linguistic barriers, cultural factors and poor housing conditions can increase vulnerability to extreme heat, prohibiting adaptation actions due to cost, lack of knowledge of local conditions and facilities, and limiting access to information. Vulnerability is particularly high for some segments of these communities including elderly migrants, new arrivals, people living in new or emerging communities, and people with low English proficiency. The report suggests programs to communicate information on health impacts and ways to minimise risks be promoted to be delivered in a culturally appropriate and accessible way to people from non-English speaking backgrounds.
Methodology	Interviews, focus groups and a workshop were undertaken with CALD communities, and other government and community stakeholders.
Output	Knowledge
States (specific location)	Victoria (Melbourne), New South Wales (Sydney), South Australia (Adelaide)
Sector Relevance	

An assessment of Australia's existing statutory frameworks, associated institutions, and policy processes: do they support or impede national adaptation planning and practice?	
Authors (Year)	K. Hussey, R. Price, J. Pittock, J. Livingstone, S. Dovers, D. Fisher, S. Hetfield Dodds (2013)
Status	Draft report
Summary	This report assessed the extent that institutional arrangements support or impede adaptation, where there is a need for revisions to these processes or new institutions, and whether a strategic national policy framework has the potential to deliver these changes. The report explores this through seven policy and framework case studies that cover factors including the potential of national and inter-governmental frameworks (including those that relate to the primary industries sector) and planning regimes to address climate adaptation, the role of the financial market in climate adaptation, informational availability, accessibility and the need for connectivity between information providers and users, and interactions between policy mechanisms. The research suggests that although it is evident that all levels of Australian government are aware of climate risk, and that the regulatory and institutional landscapes generally support adaptation planning by being dynamic and flexible; a number of policy concerns and major barriers to effective implementation still exist. The report suggests general measures to address these barriers which include designing clear overarching national (or nationally consistent) frameworks and guidelines, developing incentives to encourage and facilitate private sector investment in adaptation; investing in 'no regrets' adaptation options – options that are beneficial under all climate scenarios; coordinating efforts between councils to minimise administrative burden on State and Commonwealth agencies and reduce overall financial burdens; and provision of high quality and relevant climate-relevant data and information that is accessible and able to be understood by decision makers.
Methodology	This study reviewed literature relating to seven case study framework and policy areas.
Output	Knowledge
States (specific location)	National, Victoria (Melbourne), Queensland
Sector Relevance	

Drought and the future of rural communities: drought impacts and adaptation in regional Victoria, Australia	
Authors (Year)	A. S. Kiem, E. K. Austin, L.E. Askew, M. Sherval, D.C. Verdon-Kidd, C. Clifton, P.M. McGuirk, H. Berry (2010)
Status	Final report
Summary	This project assessed the impacts of drought on two agricultural communities in Victoria. The report explored the context of drought in Australia and on inland rural communities; focussing on historical and projected impacts for the case study locations of Mildura and Donald; exploring community attitudes, and identifying responses to climate change and adaptation pathways. Despite the very real difficulties and distress experienced by many people in both agricultural centres, the project found that there is evidence of resilience and optimism within the wider community due to robust social capital and forward thinking attitudes. Problems were identified with the current research and policy paradigm of 'drought as crisis' in Victoria, which needs to be shifted to 'ongoing drying', and the disconnect between urban populations and the sources of their food. The extensive research on climate change and drought adaptation was recognised, though the problem of understanding language used in them, and problems of implementation was raised.
Methodology	This study undertook literature review, data analysis of climate history for the two towns, and undertook stakeholder interviews and workshops.
Output	Knowledge
States (specific location)	Victoria (Mildura,Donald)
Sector Relevance	

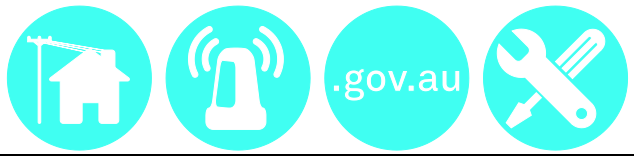
Learning from experience: historical case studies and climate change adaptation	
Authors (Year)	A. S. Kiem, D. C. Verdon-Kidd, S. Boulter, J. Palutikof (2010)
Status	Final report
Summary	This report is a summary of the historical case studies developed via the NCCARF consortium in 2010, and synthesis 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	

Limits and barriers to climate change adaptation for small inland communities affected by drought	
Authors (Year)	A.S. Kiem, E.K. Austin (2012)
Status	Final report
Summary	This report assessed the implications of using 'market-based' instruments (MBIs) on adaptation. Specifically, it focused on the barriers and limitations to climate change adaptation in small inland communities using water trading. The project found that water trading has potential to deliver beneficial adaptation outcomes, although for some people and industries there may be negative impacts. Water trading will allow those with the financial capacity to purchase water greater flexibility in making decisions about their priorities for water use. However, water trading can also have adverse consequences on local communities (such as smaller agriculture operations and drinking water supply), particularly as residents may sell their water entitlements and exit the community.
Methodology	This study took a case study approach, examining water trading in the Murray-Darling Basin as a MBI for climate change adaptation.
Output	Knowledge, Testing of methodology or approach
States (specific location)	Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia (Murray-Darling Basin)
Sector Relevance	

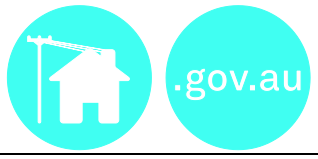
Understanding the adaptive capacity of small-to- medium enterprises (SMEs) to climate change and variability	
Authors (Year)	N. Kuruppu, J. Murta, P. Mukheibir, J. Chong, T. Brennan (2013)
Status	Draft report
Summary	This report investigated the adaptive capacity of small to medium enterprises (SMEs) around Australia, including the underlying factors and processes that influence SME engagement with climate adaptation, barriers and opportunities for particular sectors, and strategies for the future. The study focused on ways that SMEs have considered and incorporated adaptation into business planning, determinants that hinder or guide adaptive capacity, and support mechanisms needed for SMEs to be viable with continued climate change. The study observed a higher likelihood of incorporating short term climate extremes into business planning, rather than medium to long term climate change. Government regulations, and access to relevant climate change information and knowledge were identified as general external determinants which underpin adaptive capacity; with climate change the climate change beliefs and values of the organisation (or owner), the size of the business and its network, and extent of forward planning identified as internal determinants. Provision of access to support mechanisms, including educational and training initiatives, case-workers and business advisors were identified as being able to be provided through modifications to current processes and networks
Methodology	Empirical data was collected through online surveys, semi-structured interviews were conducted, five case study businesses were analysed and stakeholder workshops were undertaken.
Output	Knowledge
States (specific location)	Queensland, (Cassowary) New South Wales (Parramatta), Victoria (Marysville, Kinglake), Western Australia (Southwest Western Australia).
Sector Relevance	

The role of water markets in climate change adaptation	
Authors (Year)	A. Loch, S. Wheeler, S. Beecham, J. Edwards, H. Bjornlund, H. Shanahan (2012)
Status	Final Draft
Summary	This report investigates the relationship between the southern Murray-Darling Basin water markets and how these may be affected by anticipated future climate change impacts. Specifically, the report investigated how water markets have been implemented in the Murray-Darling Basin, investigated the expected climate change impacts for the southern Murray-Darling Basin and for the agricultural industry. The report then examined the financial, social and ecological impacts of market based water reallocation; and opportunities for future development to encourage positive outcomes in these areas. The report identified predominantly positive financial and ecological outcomes from water markets, and little evidence of negative social impacts as a whole.
Methodology	This study took a literature review approach.
Output	Knowledge
States (specific location)	Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia
Sector Relevance	

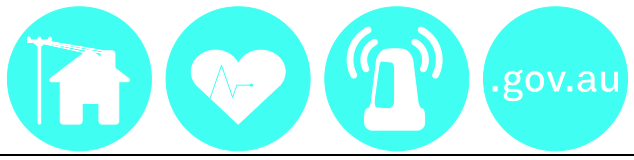
Identifying low risk climate change adaptation	
Authors (Year)	A. Lukasiewicz, C.M. Finlayson, J. Pittock (2013)
Status	Final report
Summary	This report investigated climate change adaptation and mitigation actions for catchment management, using New South Wales and Victorian catchments of the Murray-Darling Basin as a focus. The report assessed the risks, costs, benefits and maladaptive potential associated with various climate catchment management strategies, and developed a framework for implementation. Amongst the project's findings were that implementing an ecosystem based approach for adaptation, and adopting a suite of complimentary measures was more effective than focussing on a small number of 'best' actions; though policy restrictions and institutional complexity may restrict the ability to implement this approach.
Methodology	Desktop review, stakeholder workshops and semi-structured interviews were undertaken as part of this study.
Output	Knowledge
States (specific location)	New South Wales, Victoria (Murray, Lachlan, Goulburn Broken catchments)
Sector Relevance	

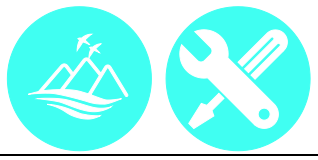
Analysis of damage to buildings following the 201-11 East Australian floods	
Authors (Year)	M. Mason, E. Phillips, T. Okada, J. O'Brien (2012)
Status	Final report
Summary	This report analysed the extent and mechanisms of damage that occurred during the Eastern Australia floods in late 2010 and early 2011, and what can be learnt from this event. The study explores the conditions that occurred during the events in Queensland, New South Wales, Victoria and Tasmania; how buildings can be damaged during a flood event; methods of protecting from flood damage; analysis of damage data from case study areas affected during the Queensland floods; creation of a model from this data to predict flood loss and displacement; and the role of controls on planning, building design and guidance to adapt for future flooding events. The project found that Queensland and Victoria were the most severely affected states of the Eastern Australia floods, with significant loss of life and serious financial impacts through inundation of properties. A high percentage of the properties affected in Queensland predate floodplain controls for planning or building contributing to damage – though a significant number had experienced flooding in the past. Models that were created have been proposed as useful for risk assessments for flood prone areas and rapid assessment of impacts following a flooding event; though further validation and refinement is also recommended. A number of development controls were identified for Queensland and Victoria that currently apply to floods, as well as those being developed at the moment including the introduction of a Flood Standard to the Building Code of Australia, and the related Flood Handbook that will provide guidance and regulation on design.
Methodology	This study used a literature review and synthesis approach.
Output	Knowledge, Testing of methodology or approach, Tools or guidelines
States (specific location)	Queensland, Victoria, New South Wales, Tasmania
Sector Relevance	

Climate change adaptation in the Australian Alps: impacts, strategies, limits and management	
Authors (Year)	C. Morrison, C. M. Pickering (2011)
Status	Final report
Summary	This report assessed potential impacts of climate change on the Australian Alps examining the existing and prospective adaptation strategies, limits to adaptation, and possible partnerships and conflicts between sectors and stakeholder groups. Possible collaborative and conflicting adaptation strategy areas between sectors and stakeholders were identified in the literature, with the focus primarily on the local and regional level. These include accord in endangered species protection strategies between conservation managers and resort operators, and conflict in the strategy of diversification of the tourism season by resort operators – with the possibility of tourists disturbing natural systems at the times that conservation managers may be trying to restore habitats and restrict access. Adaptation limits were identified that include social acceptance, technical restrictions and financial sustainability of artificial snow making (the tourism industry's principal adaptation strategy), and ecological and economic limits for invasive species management when considering changing ecosystems. The research team identify a lack of recognition of the Alps' water resources and knock on importance to the wider Australian economy by the stakeholders interviewed.
Methodology	Literature review was undertaken followed by interviews with stakeholders from conservation managers, the tourism industry, local council, and other researchers.
Output	Knowledge
States (specific location)	New South Wales, Victoria, Australian Capital Territory (Australian Alps)
Sector Relevance	

Coastal urban climate futures in South East Australia: Wollongong to Lakes Entrance	
Authors (Year)	B. Norman, W. Steffen, W. Maher, C. Woodroffe, A. Capon, R. Webb, K. Rogers, J. Lavis, H. Sinclair, B. Weir (2012)
Status	Draft
Summary	This report identified desired future scenarios for towns along Victoria and New South Wales' coastline from Lakes Entrance to Wollongong in 2030 and beyond under a range of climate and other potential social, environmental and economic changes. Case study towns with diverse demographics, economies, environments and social circumstances were investigated, in order to gain understanding of commonalities and differences between coastal settlements, and how this will impact on adaptive capacity and adaptation strategies. The project found that the region already experiences extreme weather events, and other climate extremes that may increase in the future, and that a number of vulnerabilities exist which affect parts of the region, which include an aging population, physical isolation, and a level of relatively high unemployment in some areas.
Methodology	This study reviewed journals, government reports, and employed local case studies, targeted focus groups and fieldwork.
Output	Knowledge
States (specific location)	New South Wales (Wollongong, Sussex Inlet, Batemans Bay, Narooma, Eden), Victoria (Mallacoota, Lakes Entrance)
Sector Relevance	

Determining high-risk vegetation communities and plant species in relation to climate change in the Australian alpine region using functional traits	
Authors (Year)	C.M. Pickering, S.E Venn (2013)
Status	Final report
Summary	This report assessed potential impacts of climate change on the Australian Alps and adaptation strategy priorities. Specifically, the likely biophysical climate change impacts were presented, the functional traits (height, size, shape, reproduction etc.) were collected and analysed to assess species composition change in relation to climate and non-climate impacts; and this was examined in relation to functional diversity. The project found no short term impacts on functional diversity due to climate change, though long term climate change was indicated to lead to distinct differences in flora traits and composition. Adaptation priorities were identified around fire management, invasive flora control, grazing of larger hooved mammal and summer tourism controls.
Methodology	Literature review, collection of new functional trait data and analysis of existing data was undertaken.
Output	Knowledge
States (specific location)	New South Wales, Victoria, Australian Capital Territory (Australian Alps)
Sector Relevance	

Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009	
Authors (Year)	Queensland University of Technology (2010)
Status	Final report
Summary	This study examined the impacts of the southern Australian heatwave of 2009, the adaptive capacity of areas affected, and the response at state and sub-regional/ local government levels. Specifically, it focused on impacts to primary infrastructure and services in South Australia and Victoria, the preparedness of government agencies, emergency services and the community. It was found that the extent of disruption during the event was exacerbated by dependencies that exist between a number of key services with little resilience - such as public transport being reliant on electricity supply networks; and that communications, coordination and services lagged behind demand in both state's government and emergency services (despite some level of preparation in Victoria). Recommendations of the study include scenario testing for future conditions, public education campaigns, and the need to factor in the cost of climate change adaptation and more frequent heatwaves into capital programs. It is identified that community vulnerability, societal expectations, and overreliance on technology need to be further addressed; and non-climate risks as well as parallel climate hazards need to be addressed in heatwave policy (and other climate hazard policy) for the policy to be effective.
Methodology	This study utilised literature review, data review and analysis, interviews and workshops with key stakeholders.
Output	Knowledge
States (specific location)	Victoria (Melbourne), South Australia (Adelaide)
Sector Relevance	

Novel methods for managing freshwater refuges against climate change in southern Australia	
Authors (Year)	B.J. Robson, E.T. Chester, M. Allen, S. Beatty, P. Close, B. Cook, C.R. Cummings, P.M. Davies, R. Lester, A. Lymbery, T.G. Matthews, D. Morgan, M. Stock (2013)
Status	Draft report
Summary	This report summarised the application and potential of four potential measures for protecting freshwater refuges from climate change in South Australia. The potential for cool water release or 'shandying' measures to control water temperature was evaluated using literature from overseas; a decision support tool was developed to assist in selecting riparian re-vegetation locations to ensure maximum benefit, the potential for artificial wetlands to act as refuges was assessed using literature, sampling of existing wetlands and laboratory experiments; and a method for prioritising the removal of redundant artificial river barriers and structures was developed, based on whether they have positive impacts (act as an artificial refuge) or negative impacts (prevent access to upstream to refuges).
Methodology	Literature review, sampling and experiments were undertaken as part of this study.
Output	Knowledge, Tools or guidelines
States (specific location)	Western Australia, Victoria, South Australia, New South Wales
Sector Relevance	

Learning from cross-border regulatory instruments to support and promote climate change adaptation in Australia	
Authors (Year)	W. Steele, L. Eslami-Andargoli, F. Crick, S. Serrao-Neumann, L. Singh-Peterson, P. Dale, D. Low Choy, I. Sporne, S. Shearer, A. Lotti (2013)
Status	Draft report
Summary	This report considered lessons that can be learnt from current cross- border regulatory mechanisms in Australia, to enhance the efficacy of cross-border climate change adaptation practices. Specifically, the study developed a conceptual framework to investigate cross-border arrangements between jurisdictions, using a number of case study regions (which have potential climate change issues that do not adhere to administrative boundaries) and implemented agreements, with a focus on the challenges and opportunities of these arrangements. The project found that there are significant legal, institutional, cultural and historical based challenges hindering cross-border collaboration, particularly at the state level; though local level arrangements often exist, as do an increasing number of National drivers.
Methodology	Desktop review, workshops and semi structured interviews were employed in this study.
Output	Knowledge, Tools or guidelines
States (specific location)	Queensland (Gold Coast), New South Wales (Tweed Heads), Victoria, Australian Capital Territory; (Australian Alps, Murray Darling Basin)
Sector Relevance	

Living with floods: key lessons from Australia and abroad	
Authors (Year)	C. Wenger, K. Hussey, J. Pittock (2012)
Status	Draft report
Summary	This report analysed inquiries and reviews into recent Australian flooding events, to find common messages and key lessons. Specifically the report focussed on the findings of the Brisbane City Council's Flood Review Board Report (Brisbane Review), Queensland Floods Commission of Inquiry (QLD Inquiry), Victorian Review of the 2010-11 Flood Warning and Response (VIC Review), Parliament of Victoria's Environment and Natural Resource Committee Inquiry into Flood Mitigation Infrastructure in Victoria (ENRC Inquiry); synthesized the outcomes, and compared the methods and findings to similar inquiries overseas. In addition a number of experts from sectors relating to flooding were interviewed to validate and expand on the knowledge collected. It was found that in contrast with the overseas reviews, flood reviews either mostly or totally ignored climate change impacts on flooding. Information from the reviews and interviewees pointed towards socio-institutional measures (such as education and legislation) over engineered solutions (such as use of levees) as most effective for adaptation.
Methodology	This study undertook literature review and conducted interviews with key stakeholders (mainly to validate findings).
Output	Knowledge
States (specific location)	Victoria, Queensland
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	Socioeconomic 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 were 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, 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 were 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 were 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 were 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	01/10/12
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–Feb 2013)
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	Unknown
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 31/05/130 (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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[3] *In order to incorporate the majority of NCCARF research, draft reports were considered. Many of these reports are still undergoing peer review and are not yet available publically. Draft research incorporated into this synthesis is denoted as such in the reference (for example, Smith, 2013D).*

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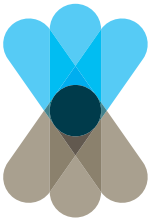

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