

NCCARF

National
Climate Change Adaptation
Research Facility

National Climate Change Adaptation Research Plan: Settlements and Infrastructure

Consultation Draft

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1 **Executive Summary**

2
3 Climate change poses significant threats to the social fabric of our towns and cities and to our
4 urban and strategic infrastructure. Climate change is likely to result in increased damage to
5 buildings, energy, telecommunications, transport and water infrastructure and the services they
6 provide. Coastal settlements and infrastructure will be especially vulnerable to the combined
7 effects of climate change including sea level rise, increased air and sea surface temperature,
8 increased storm intensity and frequency, ocean acidification, and changes to rainfall and run-off.
9 Sea level rise will cause greater coastal inundation, erosion, loss of wetlands and salt-water
10 intrusion into freshwater sources, with impacts on infrastructure, coastal resources and existing
11 coastal management programmes.

12
13 Developing effective adaptation responses will be critical in reducing the impacts of climate
14 change on settlements and infrastructure. A variety of adaptations have already been identified,
15 including revising building codes to take account of changing climatic conditions, introducing
16 climate responsive planning measures (e.g. planned retreat, dune management, building
17 designs, and regulation of new structures), and managing urban development in climate
18 sensitive areas through zoning and regulation. However, many more adaptation responses
19 need to be developed and implemented, including shifts in the behaviour and expectations of
20 urban, regional and remote area populations.

21
22 The National Adaptation Research Plan for Settlements and Infrastructure identifies critical gaps
23 in the information needed to address the full range of issues arising from potential impacts of
24 climate change on settlements and infrastructure. The primary purpose of this research plan is
25 to set out the priority research agenda for the next 5-7 years to inform a better understanding of
26 climate change risks and impacts on the built environment and how these risks can be managed
27 and impacts reduced through planned adaptation interventions. This plan will support adaptation
28 efforts by identifying research priorities that are most relevant to the needs of stakeholders.

29
30 This research plan is structured around four themes, which relate to both the issues and
31 structures that are under threat from the impacts of climate change. While there are overlaps in
32 the research questions for each of the themes, they individually enable development of research
33 priorities across different sectoral interests, time scales, and, especially, different spatial scales.
34 The themes are:

- 35 • Urban and regional planning and management
- 36 • Built environment
- 37 • Vulnerable coastal communities
- 38 • Infrastructure

39
40 A number of critical information needs and research gaps are identified under each theme.
41 Ranking research areas into higher and lower priorities is difficult, given that many aspects of
42 research are not directly comparable and timeframes for research vary, but questions were
43 prioritised using six criteria that have also been applied in the other sectoral National Adaptation
44 Research Plans:

45 **Essential**

- 46 • Severity of potential impact to be avoided or degree of potential benefit to be derived
- 47 • Immediacy of required intervention or response
- 48 • Need to change current intervention and practicality of alternative intervention

49 **Desirable**

- 50 • Potential for co-benefit
- 51 • Cross-sectoral relevance

- 1 • Equity considerations
2

3 The following questions to guide research were identified as high priorities through applying
4 these criteria.
5

6 **Urban and regional planning and management**

- 7 • How can existing urban planning principles accommodate climate change and the
8 uncertainty of climate change impacts? How should these principles differ based on the
9 location and spatial scale of the settlement? What can we learn about the adaptive capacity
10 of settlements from responses to stresses in the past?
11
12 • How can the governance of urban planning in Australia, including formal and informal rules,
13 nationally consistent approaches and guidelines and locally driven standards and outcomes,
14 and the institutions responsible for decision-making, be improved to facilitate planning
15 processes and outcomes which incorporate adaptation to climate change?
16
17 • What are the particular planning needs of remote and Indigenous settlements under a
18 changing climate?
19
20

21 **Built environment**

- 22 • What are the design options and principles for adapting new buildings to climate change in
23 different locations and how can these be implemented? What are the full life-cycle costs of
24 different parts of the built environment and their critical inter-dependencies during extreme
25 events?
26
27 • What are the design options and principles for adapting existing buildings to climate change
28 in different locations and how can these be implemented?
29
30

31 **Vulnerable coastal communities**

- 32 • How will demographic pressures and changes in different Australian coastal settlement
33 types affect (1) potential impacts of extreme and gradual climate change, and (2) current
34 policy and regulatory settings which govern the decision-making by government agencies,
35 businesses and individuals? How will planning for coastal climate change impacts respond
36 to local circumstances?
37
38 • How well do we understand the relationship between climate and coastal processes? How
39 can methods currently used to determine the physical risk on a regional basis of extreme
40 inundation and coastal erosion from climatic and oceanic processes, either singularly or in
41 combination, be improved and new methods developed and applied?
42
43

44 **Infrastructure**

- 45 • What is the vulnerability of infrastructure (individual and interlinked critical sectors) to
46 existing and predicted climate change conditions at various spatial scales, considering
47 average and extreme weather conditions?
48
49 • What key infrastructure may have concatenating or cascading impacts during extreme
50 climate events, and how might these impacts be avoided?
51
52 • What design standards (ARI or AEP) and planning periods for the various infrastructure
53 components should be adopted for particular locations and over what time frames?
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Cross-cutting

- What would a climate-adapted Australian settlement look like?
- What sectors of society are most vulnerable to climate change in urban and regional settlements? What is the nature of those vulnerabilities? At what spatial and temporal scales should adaptation responses for vulnerable communities be developed?
- To what extent can geologic/geomorphic/historical/traditional/local knowledge be best applied to assessing vulnerability of existing settlements under different climate change conditions?

A fundamental input to achieving the research activities described in this research plan are sound climate projections pertaining to parameters and scales that are relevant to the risks and vulnerabilities of the sectors and interests on which this plan is focused. This input will require ongoing research to better understand climate change and its impacts at a regional level. In particular, better information is required about what extreme events are likely to be experienced at regional and local levels, and what their frequency, intensity and scale are likely to be.

Implementation Plan

An implementation plan is being prepared in parallel to the development of this research plan and will include consideration of possible projects, research capacity and resource issues, and funding opportunities. The National Adaptation Research Network for Settlements and Infrastructure will play an essential role in implementing the research plan, and will contribute greatly to building collaboration, information sharing and research capacity across the Australian research community.

1. Context and objectives

1.1 Background

There is now widespread acceptance that human activities are contributing significantly to climate change and that this change is producing significant physical effects. Since 1950 Australia has experienced a warming of 0.4 to 0.7°C, with more heatwaves, more rain in the north-west and less rain in the southern and eastern regions and an increase in the intensity of droughts. It is generally acknowledged that some of the effects from climate change are now either present or inevitable and that they will become more severe if we do not modify our behaviour. Australia is already experiencing impacts from recent climate change with increasing stresses on water supply and agriculture, and is expected to face more severe extreme events with more intense and frequent heatwaves, droughts, floods and storm surges (Hennessy *et al.*, 2007).

Human responses to climate change generally fall into two broad categories: mitigation and adaptation. Both mitigation and adaptation help to reduce the risks of climate change. *Mitigation* involves actions that are intended to reduce the magnitude of our contribution to climate change (e.g., reducing greenhouse gas emissions) or offset or reverse its effects. *Adaptation* consists of actions to reduce the adverse consequences of changes that are inevitable, or at least likely, as well as to harness any beneficial opportunities. Adaptation actions aim to reduce the impacts of climate stresses on human and natural systems.

Our focus in this National Adaptation Research Plan (NARP) for Settlements and infrastructure is on adaptation. Specifically, this NARP identifies research required to help Australian governments, organisations and communities prepare and respond to likely or inevitable effects of climate change on settlements and infrastructure. It provides a framework to guide research funding decisions and key directions for the country's settlements and infrastructure research community. It is recognised that climate change will be only one of several drivers of change for settlements and infrastructure. Nevertheless, this NARP focuses on identifying research that is likely to inform adaptation to climate change and guide funding priorities within that broader context.

The aims of this NARP are to:

1. Identify important gaps in the information needed by decision-makers to reduce the vulnerability of settlements and infrastructure to climate change impacts; and
2. Set adaptation research priorities based on these information gaps.

1.2 National policy context for this National Adaptation Research Plan

The National Climate Change Adaptation Framework (the Framework) was endorsed by the Council of Australian Governments (COAG) in April 2007 as the basis for government action on adaptation over five to seven years. The Framework identifies possible actions to assist vulnerable sectors and regions, such as water resources, human health, settlements and infrastructure, and coasts, to adapt to the impacts of climate change. It also identifies actions to enhance the knowledge base underpinning climate change adaptation and improve national coordination of climate change adaptation research. In 2007 the Australian Government provided \$126 million over five years towards implementing the Framework.

In addition to work at the national level, state and territory governments as well as local government authorities are beginning to consider the impacts of climate change on settlements and infrastructure and the communities they support. Increasingly, industry groups, such as the

1 Institute of Engineers, Infrastructure Partnerships Australia, and the Planning Institute of
2 Australia are also taking into account climate change impacts in their ongoing operations.

3
4 The Australian Government established the National Climate Change Adaptation Research
5 Facility (NCCARF), hosted by Griffith University, to coordinate and lead the Australian research
6 community in generating the biophysical, social and economic information and tools needed to
7 facilitate adaptation to climate change. Research outputs will be focused on the needs of
8 decision-makers in government, vulnerable industries and communities as they respond to the
9 range of potential climate change impacts. A key role of the Facility is to coordinate
10 development of National Adaptation Research Plans (NARPs) across NCCARF's eight priority
11 areas:

- 12 • Emergency Management
- 13 • Human health
- 14 • Marine biodiversity and resources
- 15 • Primary industries
- 16 • Settlements and infrastructure
- 17 • Social, economic and institutional dimensions of adaptation
- 18 • Terrestrial biodiversity
- 19 • Water resources and freshwater biodiversity

20
21 NARPs identify critical gaps in the information needed by sectoral decision-makers and set
22 national priorities for research to assist adaptation to expected impacts of climate change. Up to
23 \$30 million will be invested in priority research for key sectors as identified in these NARPs.
24 These research plans are being developed in partnership with governments, stakeholders and
25 researchers.

28 **1.3 Development of this National Adaptation Research Plan**

29 The development of the NARP for Settlements and Infrastructure was led by the following
30 drafting team: Professor Bruce Thom (Chair), Ms. Jennifer Cane (DSE, Victoria), Professor Ron
31 Cox (UNSW), Ms. Catherine Farrell (DCC), Professor Peter Hayes (RMIT), Dr. Robert Kay
32 (Coastal Zone Management Pty Ltd), Mr. Allen Kearns (CSIRO), Associate Professor Darryl
33 Low Choy (Griffith University), Professor John McAneney (Macquarie University), Professor Jan
34 McDonald (Griffith University), Mr. Michael Nolan (Maunsell AECOM), Professor Barbara
35 Norman (University of Canberra), Professor Jonathan Nott (JCU) and Professor Tim Smith
36 (USC).

37
38 The drafting team has developed this plan following three national 1.5 day workshops for key
39 stakeholders and researchers with an interest in settlements and infrastructure held in April-May
40 2009 in Cairns, Adelaide and Sydney. These workshops addressed the core issues of built
41 environment, urban and regional planning and management, vulnerable coastal communities
42 and infrastructure. An Issues Paper was prepared and distributed to the participants to form the
43 basis for discussion and elicit comments from the stakeholders on their adaptation issues and
44 information needs.

45
46 More than 100 participants from a wide range of stakeholder groups attended these workshops,
47 including: representatives from state and territory governments' planning, infrastructure,
48 transport and environment agencies; local government agencies; water authorities; coastal
49 management and port authorities; natural resource managers; researchers from universities and
50 national research agencies/centres; engineers (e.g. water, civil, electrical); insurers/re-insurers;
51 architects; property developers; representatives from the construction and transport industries;
52 and associations working on sustainability, livelihood and Indigenous issues.

1 Discussions during these workshops and feedback on the Issues Paper provided valuable
2 insights into decision-makers' and stakeholders' information needs and research priorities and
3 are reflected in this Consultation Draft.
4
5

6 **1.4 The Scope of this National Adaptation Research Plan**

7 The NARP for Settlements and Infrastructure identifies critical gaps in the information needed to
8 address the full range of issues arising from potential impacts of climate change on settlements
9 and infrastructure. The primary purpose of this NARP is to set out the priority research agenda
10 for the next 5-7 years to inform a better understanding of climate change risks and impacts on
11 the built environment and how these risks can be managed and the impacts reduced through
12 planned adaptation interventions. Implementation of the research plan will help inform a range
13 of strategic activities including:
14

- 15 • understanding and responding to community expectations concerning the built environment
16 and its amenity;
- 17 • assessing the vulnerabilities of human settlements taking into account differences in size,
18 location, demography and socio-economic circumstances;
- 19 • assessing the vulnerability of infrastructure at various spatial scales under both average and
20 extreme weather conditions;
- 21 • informing the revision of building codes and other standards as well as retrofitting measures
22 to reduce vulnerability of infrastructure and buildings to climate change impacts;
- 23 • promoting a more coordinated approach to urban and regional planning policy across
24 jurisdictions and between all levels of government;
- 25 • embedding climate change consideration into ongoing urban and regional planning,
26 including planning for coastal settlements, and decision-making processes;
- 27 • assigning priorities in the choice of adaptive strategies; and
- 28 • developing appropriate government policy responses to inequities that arise as a result of
29 the differential impacts of climate change on vulnerable communities.
30

31 This NARP will provide further stimulus to future thinking about how best to study the risks to
32 settlements and infrastructure, approaches to developing effective adaptation responses and
33 consideration of how to include these issues into policy developments and adaptive strategies
34 within other related sectors.
35

36 There are many stakeholders who have a need for improved knowledge on just how, where and
37 when the various components of climate change, acting singularly or in combination, will require
38 the introduction of adaptation strategies that will remove or reduce adverse impacts on property,
39 industry, services and infrastructure.
40

41 This research plan recognises that climate change adaptation issues are important to
42 Indigenous communities around Australia. We recognise that these issues are critical. They will
43 be considered more fully through a separate process.
44

45 This NARP will support adaptation efforts by identifying research priorities that are most relevant
46 to the needs of stakeholders. These priorities form a basis for improved decision making and
47 adaptive capacity across all levels of government, the private sector, community groups,
48 property owners and developers and the professions engaged in urban and regional planning,
49 design and infrastructure provision. The research plan will reference past and current research

1 into the impacts of climate change, including research on coastal settlements; public and private
2 infrastructure including building and facility design and construction; urban water security;
3 flooding and stormwater overflow; the social, economic and institutional implications of these
4 impacts, and implications for urban and regional planning, design, and management of
5 settlements and infrastructure.

6
7 Many research questions related to settlements and infrastructure show close affinities between
8 measures intended to reduce emissions and measures introduced to adapt to the impacts of
9 climate change. While there has been no explicit attempt in this NARP to exclude mitigation
10 issues the emphasis of this NARP is clearly on adaptation strategies.

11
12 This NARP is structured around four themes, which relate to both the issues and structures that
13 are vulnerable to the impacts of climate change. While there are overlaps between some
14 research questions in each of the themes, they individually offer scope for development of
15 research priorities across different sectoral interests, time scales, and, especially, different
16 spatial scales. The themes are:

- 17 • Urban and regional planning and management
- 18 • Built environment
- 19 • Vulnerable coastal communities
- 20 • Infrastructure

21
22 An analysis of research priorities that have emerged from consideration of these four themes
23 reveals a set of cross-cutting research questions. These questions, which are listed after the
24 discussion of the individual themes, have overlapping elements with each of the themes and
25 provide an additional set of research priorities to those developed for each theme.

26
27 Overlaps and synergies between the scope of issues addressed in this NARP and those
28 addressed in other NARPs are considered below. Section 2 outlines the projected impacts of
29 climate change and the need for adaptation to these impacts for settlements and infrastructure.
30 Section 3 discusses stakeholder information needs and formulates research questions for the
31 four themes described above. Section 4 outlines the process and criteria used to prioritise those
32 research questions and lists the research priorities ranked as high priority. The full prioritisation
33 matrix for all research questions is in Appendix 2. Section 5 concludes this NARP by discussing
34 implementation issues.

35
36 A fundamental input to achieving the research activities described in this NARP are sound
37 climate projections pertaining to parameters and scales that are relevant to the risks and
38 vulnerabilities of the sectors and interests on which this research plan is focused. This input will
39 require ongoing research to better understand climate change and its impacts at a regional
40 level. In particular, better information is required about what extreme events are likely to be
41 experienced at regional and local levels, and what their frequency, intensity and scale are likely
42 to be.

43
44 The discussion throughout this NARP is drawn from and supported by a range of sources. To
45 improve readability, references in the text have been minimised. A broader list of references is
46 included in the Suggested Reading section of this NARP (section 7).

49 **1.5 Links to and synergies with other National Adaptation Research Plans**

50 Adaptation policies and strategies for settlements and infrastructure will necessarily affect and
51 be affected by parallel strategies addressing the impacts of climate change on human health,
52 biodiversity, primary industries, emergency management, water, and social, economic and
53 governance issues. Some of the relationships and linkages between this NARP for Settlements

1 and Infrastructure and other NARPs, either completed or in preparation, are set out in Table 1.
 2 The implementation plans for these NARPs will ensure that the research priorities identified in
 3 these research plans are complementary and mutually supportive and seek to avoid duplication
 4 of research effort.

5
 6

Table 1. Links between settlements and infrastructure and other NARPs

Theme	Cross-cutting issues to be addressed in the Settlements and Infrastructure NARP
<i>Human Health</i> (completed December 2008)	<ul style="list-style-type: none"> • The adequacy of current health infrastructure to cope with extreme weather events • The need for building design and urban form to reduce risks of heat stress and minimise urban heat islands • Building standards to accommodate impacts of climate change such as increase wind resistance, flood proofing, insulation etc • Water security systems for human settlements (supply and water quality) • Capacity and resilience of key infrastructure
<i>Emergency Management</i>	<ul style="list-style-type: none"> • The urban and post-disaster planning and construction to reduce vulnerability to extreme weather events • Balancing urban development and private interests against community risk • Rationalisation of public safety thresholds for various natural perils; e.g. the (1-in-100 year event) Annual exceedance Probability enshrined in floodplain management policy and legislation versus the 1-in-500 year seismic ground shaking threshold for life safety in buildings • Learning from disasters rather than planning for their repetition • Capacity and resilience of key infrastructure
<i>Marine Biodiversity and Resources</i>	<ul style="list-style-type: none"> • Coastal storm/tide protection/fortification and its impacts on biodiversity • Planning of coastal zone for conservation and urban development • Protection of urban beaches – sand replenishment • The need for coastal planning to integrate potential shifts in fishing and aquaculture operations and the associated needs for available coastal land and infrastructure
<i>Terrestrial biodiversity</i> (Consultation draft in preparation)	<ul style="list-style-type: none"> • The special adaptation needs of peri-urban conservation areas
<i>Water</i> (Consultation draft in preparation)	<ul style="list-style-type: none"> • Urban/rural settlement water supply and security • Water management with regard to storm and waste water • Safeguarding water supply for urban settlements • (The Water NARP concerns itself mainly with river and wetland health, environmental flow and biodiversity issues.)
<i>Primary Industries</i> (Consultation draft in preparation)	<ul style="list-style-type: none"> • Planning and management of peri-urban areas; • Protection of good quality agricultural land; • Management of city-dependent peri-urban agricultural activities (eg horticulture) • Planning and management for rural-based industries
<i>Social, Economic and Institutional Dimensions</i> (Consultation draft in preparation)	<ul style="list-style-type: none"> • Social justice and institutional issues relating specifically to adaptation needs for human settlements. • Social and economic aspects of community vulnerability and adaptation.

2. The impacts of climate change on settlements and infrastructure and the need for adaptation

Climate change poses significant threats to the social fabric of our towns and cities and to urban and strategic infrastructure. Figure 1 illustrates how for any given region there can be a shift in averages and extremes of climate variables. Settlements and infrastructure will experience stress from the transition to new climate conditions as well as from the new conditions themselves. Moreover, settlements and infrastructure will need to adapt to ongoing changing conditions as well as to the projected future climate at any particular time. Settlements and infrastructure will also be affected by a range of social, institutional, political and economic factors, which may facilitate or impede progress towards adapting to the changes induced by global warming.

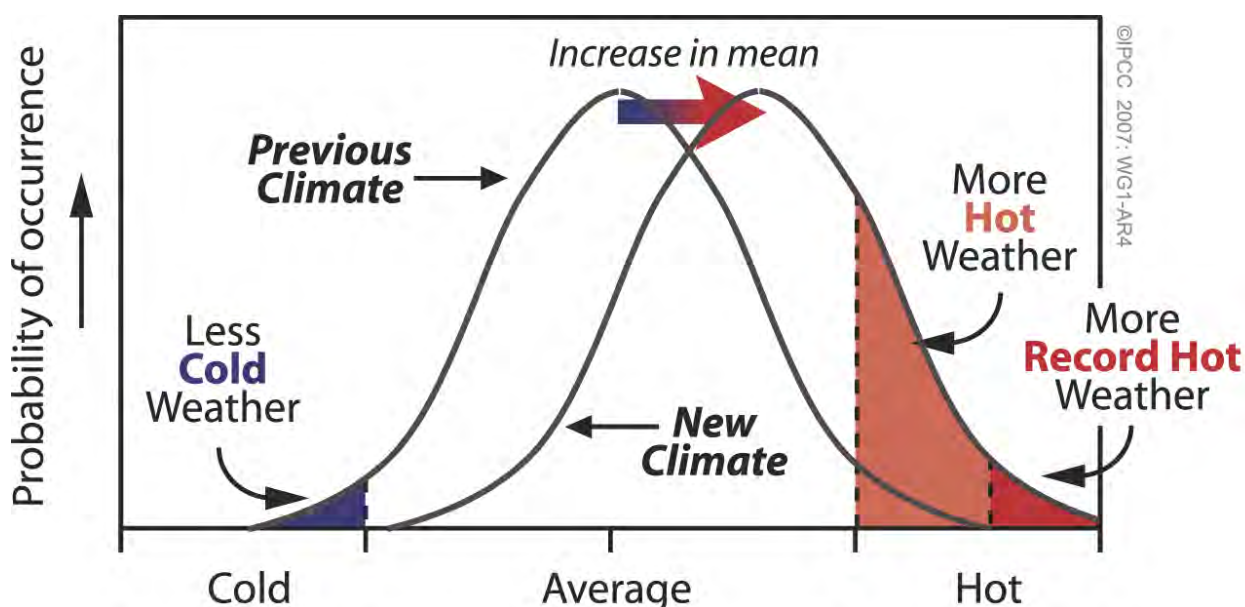


Figure 1. Effect of an increase in average temperature on extreme temperatures (Solomon *et al.*, 2007)

Climate change is likely to result in increased damage to buildings (e.g. concrete joints, steel and asphalt), energy services, telecommunications, transport structures (e.g. roads, railways, ports and bridges) and water services (IPCC, 2007; PMSEIC Independent Working Group, 2007; ATSE, 2008). Higher summer temperatures, for example, are expected to affect energy services by reducing transmission line conductivity and thus energy transmission efficiency. More frequent and intense extreme weather events will likely damage transport and electricity transmission infrastructure and services. More frequent extreme daily rainfall events are expected to affect the capacity and maintenance of storm water, drainage and sewerage infrastructure. Higher ambient temperatures will increase demand by individual households, businesses and public facilities on utilities and construction that must be incorporated into future management and planning of the nation's settlements. Tipping points¹ are likely to be reached when the capacity of a given infrastructure or service provision is exceeded, requiring major

¹ A tipping point refers to the critical point at which a small perturbation leads to/initiates a transition from one state to another or a change in the characteristics of a system.

1 investments in protective infrastructure needed to prevent catastrophic failure of essential
2 physical assets and services. Property owners or major infrastructure managers such as port
3 authorities need to make decisions in advance of a tipping point being reached. By 2030, design
4 criteria for extreme events are very likely to be exceeded more frequently (Hennessy *et al.*,
5 2007). Many decisions relating to settlements and infrastructure are being made now, including
6 statutory land use plans, building codes, design standards, and infrastructure development,
7 maintenance, replacement or refurbishment. They come with long-term commitments and can
8 have consequences for periods of 30-200 years or more (Hallegatte, 2009). These decisions
9 and associated investments will therefore need to take into account future climate conditions.

10
11 Coastal settlements and infrastructure will be especially vulnerable to the effects of climate
12 change such as sea level rise, increased air and sea surface temperature, increased storm
13 intensity and frequency, ocean acidification, and changes to rainfall and run-off. Sea level rise
14 will cause greater coastal inundation, erosion, loss of wetlands and salt-water intrusion into
15 freshwater sources, with impacts on infrastructure, coastal resources and existing coastal
16 management programmes (IPCC, 2007). The concentration of urban development along our
17 coast intensifies these exposures (Chen and McAneney, 2006). Over 80% of the population in
18 Australia lives in the coastal zone (Hennessy *et al.*, 2007; see also Garnaut, 2008). By 2050,
19 current trends of population growth and ongoing coastal development, especially in areas such
20 as Cairns, south east Queensland and south west Western Australia are likely to exacerbate
21 risks from sea level rise and from increases in the severity and frequency of storms and coastal
22 flooding (Hennessy *et al.*, 2007; Gurrán *et al.*, 2008). Remote communities, including
23 Indigenous communities, may be severely impacted by climate change, especially sea level
24 rise. Cultural links of Indigenous communities to sea country creates some highly sensitive
25 issues when examining potential adaptation strategies to climate change.

26
27 The vulnerability of Australian settlements will vary depending on a range of factors, including
28 their form and size, location, geography, and economy. Vulnerability is a function of the extent
29 to which a system is exposed to climatic effects, the sensitivity or responsiveness of the system
30 to climatic influences, and the degree to which a system can adapt to change, i.e. its adaptive
31 capacity (IPCC, 2001). This concept of vulnerability can be used in the assessment of risk that
32 any community may face under specified or projected conditions of climate change. Changing
33 conditions for a given place can be studied as scenarios through mechanisms of visualisation
34 and other means of communicating both risk and adaptive strategies. Individuals, communities,
35 professions and decision makers may then see the potential damage of climate change in
36 vulnerable areas and, most important, assess how different adaptation options in terms of costs,
37 benefits, liabilities and political trade offs can be developed and implemented.

38
39 While the vulnerabilities of human settlements are acknowledged and understood in general
40 terms, quantification on a local scale will better assist with planning and management for
41 adaptation. Research efforts into effective and equitable adaptation responses will reduce the
42 current levels of knowledge deficit and uncertainty. However, decision makers face many
43 uncertainties in meeting the challenges of climate change, and some uncertainty will not be
44 reducible. The vulnerability of Australia's highly urbanized society requires close investigation
45 across the hierarchy of settlements, including capital cities, new greenfield peri-urban
46 settlements, inland towns, and remote, rural and Indigenous settlements, across Australia's
47 diverse geographic and climatic contexts from the tropics to cool temperate zones.

48
49 Research in this area will require a systematic application of knowledge from a range of
50 disciplines – including climate change science; geomorphology and hydrology; urban planning,
51 design and management; material science and engineering; and human behaviour and other
52 social sciences – to analyse how climate change is likely to affect our settlements and
53 infrastructure. Economics and actuarial studies, psychology, cultural studies, public policy,
54 communication theory and other social sciences will also be implicated in the development of
55 adaptation strategies to respond to those effects.

1
2 Developing appropriate adaptation responses will be critical in reducing the impacts of climate
3 change on settlements and infrastructure. A variety of adaptations have already been identified,
4 including revising, renewing and enforcing building codes to take account of changing climatic
5 conditions, introducing consistent planning measures (e.g. planned retreat, dune management,
6 building designs, and regulation of new structures), and managing urban sprawl in climate
7 sensitive areas through zoning and regulation (PMSEIC Independent Working Group, 2007).
8 Recent parliamentary inquiries are disclosing many of the issues confronting coastal and other
9 settlements in relation to the potential impacts of climate change (see NSW Legislative
10 Assembly, 2009; House of Representative Standing Committee, 2009). However, much still
11 remains to be done, especially in the implementation of adaptation responses and in promoting
12 shifts in the behaviour and expectations of urban, regional and remote area populations. There
13 are many barriers to adaptation for settlements and infrastructure, including lack of appropriate
14 information and data as well as access to such information and data, institutional inertia and
15 resistance to change, uncertainty in climate change impacts, and the existing urban envelope
16 and infrastructural legacies which limit the response options. Recognition of such barriers as
17 well as potential limits to adaptation is a necessary part of any attempt to develop and
18 implement adaptation strategies.

19
20 Taking climate change into account in decisions relating to settlements and infrastructure
21 remains a challenge for three reasons. First, changing climatic conditions will impact in different
22 ways on various types and locations of settlements and infrastructure in Australia. Second,
23 uncertainty of future climate conditions makes it impossible to just use the output of climate
24 models as input for planning and managing infrastructure and settlements. Therefore, it will be
25 critical to communicate risk scenarios based on probabilities to property owners, developers,
26 investors in infrastructure and service providers. Finally, these decisions will be taken in the
27 context of many other interrelated and to some extent competing issues, which require attention
28 in both the short and long term and involve priorities and attitudes that may not see climate
29 change impacts as relevant or as important. Yet the magnitude of impacts that are likely to
30 affect Australians as a result of climate change necessitate a program of detailed research into
31 adaptation issues that unless undertaken could lead to local, regional and national crises
32 affecting the sustainability of Australian society.

36 **3. Information needs and key research questions**

37 **3.1 Urban and regional planning and management**

38 Urban and regional planning is a process developed to manage, guide and direct change in
39 urban and regional systems to protect social and environmental values, gain economic, social
40 and environmental benefits and achieve efficiency in both the system and the change process.
41 Planning activities determine the arrangement of uses over a region and landscape, how land
42 can be used, the resulting traffic and transport and other infrastructure locations and corridors,
43 how and where waste is collected and disposed, where cultural or sports activities will be
44 focused and every other locational aspect of the human-built environment.

45
46 The magnitude and rate of climate change will significantly test a relatively static statutory
47 planning system that has underpinned urban management in Australia over the last 100 years.
48 Sea level rise, increased storm surge and temperature will all introduce new uncertainties,
49 potentially bringing non-linear change, and thus requiring a more adaptive and responsive
50 approach to urban planning. Urban planning and emergency management systems will need to
51 be more closely connected and may lead to new approaches to how we plan and manage future
52 settlements and infrastructure. However, the systems basis, information and evidence-based

1 analytical approach and participatory nature of Australia's planning process are inherent
2 qualities that support adaptation capacities.

3 4 5 *3.1.1 Stakeholders and key impacts of climate change*

6 Virtually every Australian citizen resides and every business operates in a community or rural
7 area which is subject to and benefits from urban and regional planning processes and the
8 decisions resulting from them made at the local, regional or state/territory level. Governments at
9 all levels are concerned to avoid risk to citizens and their property and well being and to
10 community infrastructure and services.

11
12 Stakeholders in planning decisions thus include residential and business property owners and
13 occupiers, transport and other infrastructure and service owners, operators and users, and
14 local, state and territory and Australian government decision-makers and advisors. The specific
15 group of stakeholders concerned with any particular risk, impact, location or decision depends
16 on perceptions of the potential implications of decisions affecting the location and stakeholder
17 groups. Thus determining the relevant stakeholders for any particular circumstance can be
18 challenging.

19
20 Sea level rise, rising temperatures and potentially more extreme weather events point to some
21 of the future climate change impacts on Australian cities and infrastructure. The way in which
22 large urban centres both generate and trap heat and thereby create "heat banks" or "heat
23 islands", the bushfire risks of the urban fringe and the flooding of coastal and low-lying
24 settlements are all expected to challenge the quality of life in our urban centres. Urban and
25 regional planning can make a critical contribution to the rebuilding or 'climate proofing' of
26 existing and new settlements and infrastructure.

27
28 It is unclear whether the impacts of climate change will fall equally throughout Australia or
29 whether the size and location of settlements affect impacts and responses in major cities,
30 regional townships, remote and rural settlements. The density of population, complexity of the
31 built environment and scale of infrastructure in capital cities will bring particular challenges. The
32 location of urban settlements will also lead to different impacts. For example, in northern
33 Australia, increased extreme weather events including cyclones will impact cities such as Cairns
34 and Darwin and southward movement of cyclones would result in other urban centres being
35 affected. Rising temperatures and lower rainfall in southern Australia will bring prolonged
36 drought and increasing risks of heat stress and bushfires to major urban centres, such as
37 Melbourne, Adelaide and Perth and many smaller cities and towns. Regional townships may
38 have their own shared set of issues such as distance from essential services and limited
39 alternative options, such as temporary housing or shelters in an emergency situation. The costs
40 of gathering evidence-based research on these types of localised climate change impacts may
41 be prohibitive to individual local councils in regional areas. Remote and Indigenous settlements
42 will have specific climate change vulnerabilities, some derived from cultural values and others
43 resulting from their economic and environmental circumstances.

44 45 46 *3.1.2 Adaptation Options and Adaptive Capacity*

47 Planning is concerned with the management of natural and human induced change, which can
48 be positive or negative and at times rapid.

49
50 The spatial impact of urban and regional planning is critical for climate change adaptation and
51 requires an understanding of what climate change adaptation means for 'place', the process of
52 planning and the possible consequences for urban governance. Additionally, cities and urban
53 settlements do not exist in isolation but are inextricably linked into a wider region which they rely
54 on for a broad range of services and functions. For example, the city region provides essential

1 physical infrastructure for the city, outdoor recreation opportunities for urban dwellers and is a
2 source of food, ecosystem services and open space. The protection of good quality agricultural
3 land and the proper management of rural based activities and industry, peri-urban agriculture
4 and peri-urban areas in response to climate change, are consistent research themes across this
5 NARP and others such as the Primary Industries NARP.

6
7 Urban and regional planning responses will require a suite of adaptive measures. These will
8 range in policy objective, from defending existing infrastructure, to modifying the built
9 environment and urban form, to retreat, and in some cases, to abandoning existing areas.
10 Significant retrofitting of existing built form may be required in the large cities, although
11 rebuilding or alteration in high risk zones may be economically unfeasible, and the relocation of
12 whole coastal townships may be required.

13
14 Most forms of urban planning offer opportunities for communities to adapt to changing climatic
15 regimes. Urban planning and management occurs across a wide range of spatial scales and
16 landscapes from local scale through regional and state/territory to national, and including urban,
17 peri-urban, regional and rural landscapes. Planning also occurs across temporal scales, e.g.
18 short and medium term (structure plans) to long term (strategic plans). In addition, it occurs
19 across a number of legal contexts involving statutory and non-statutory planning. Urban
20 planners face the combined challenges of how to modify existing urban landscapes to deal with
21 projected climate change impacts and how to minimise future impacts by avoiding or modifying
22 new development in areas of high vulnerability.

23
24 Urban and regional planning in Australia is predominantly governed at the state/territory and
25 local levels, where a range of tools is applied to manage urban growth and regional
26 development. These include dedicated planning legislation in each state and territory, supported
27 by a variety of regulatory mechanisms at local level, regional and metropolitan plans for major
28 cities, and regional planning in some non-metropolitan areas. All these spatial planning
29 processes and instruments involve a wide range of stakeholders across government, non-
30 government, industry and communities.

31
32 Urban and regional planning, which is directed towards or includes the impacts of climate
33 change, will add to these already-complex arrangements and may bring new alliances of
34 stakeholders, such as government, urban planners and the insurance industry, to plan for 'urban
35 climate change risk'. For example, to minimise impact on existing communities, urban planning
36 for existing settlements and infrastructure will require closer connections between the 'built form'
37 professions, climate change scientists, insurance providers and emergency management
38 officials. Engagement of the communities in this process will be essential to gain understanding
39 for local knowledge and acceptance of and legitimacy for possible adaptive strategies.

40
41 Planning is exercised through deliberately designed interventions into the natural and human
42 processes of change affecting, or expected to affect, our landscapes. Essentially urban planning
43 achieves this through two principal foci, namely (1) a development control focus (the day-to-day
44 matters of managing the development in urban settlements); and (2) a strategic focus (forward
45 planning that sets directions and pathways for the future location and form of settlement and
46 land use). Adaptation options for climate change through planning will need to address both
47 foci. Incorporating climate change considerations into the development control process will help
48 minimise impacts of climate change on settlements and infrastructure through modifying
49 zonings and regulations in statutory planning schemes.

50
51 Contemporary approaches to planning increasingly adopt performance-based approaches in
52 order to encourage innovative designs that are unconstrained by regulations or prohibitions
53 associated with prescribed land use zones of traditional statutory planning. Performance-based
54 planning relies on being informed by reliable and robust science. However we do not yet have
55 the necessary science to support these approaches across the full spectrum of statutory urban

1 and regional planning activity. Nor are the science requirements of the different forms of
2 planning fully understood. Caution will need to be exercised against an over-reliance on
3 modelling and a desire for “accurate” predictions of future climate change, especially as we are
4 dealing with a highly uncertain climate future. Specifically, we will need to explore ways to
5 embed climate change science into planning, particularly the planning instruments and tools of
6 statutory plans if we are to take full advantage of the opportunities for climate change adaptation
7 that urban planning offers.

8
9 Strategic planning will need to address adaptation measures in respect of issues such as:

- 10 • the management of urban sprawl in climate sensitive areas;
- 11 • minimising the heat island effects of high density urban areas;
- 12 • retrofitting existing urban areas, including the modification of urban form to accommodate the
13 adaptability of older communities to the adverse effects of climate change (e.g. thermal [heat]
14 stress);
- 15 • incorporation of climatic risk assessments; and
- 16 • in some instances, the planned strategic retreat from highly exposed areas.

17
18 Historically, most planning systems have been designed as static linear regimes which do not
19 lend themselves to incorporating subsequent modifications and amendments in the light of new
20 knowledge and experience. A cyclic (continuous) planning process can incorporate an adaptive
21 management framework that can account for short and long-term change and uncertainty – two
22 key dimensions of climate change. In this manner, decision-makers in government, vulnerable
23 industries and communities can develop and progress policies and plans in a ‘climate of
24 uncertainty’ characterised by ‘imperfect knowledge’ with a high degree of confidence that
25 policies can be adapted in the light of subsequent new learning.

26
27 A priority challenge is therefore to ensure that both statutory and non-statutory planning is
28 informed by climate change science, whilst taking an adaptive management approach. To a
29 large extent this will rely on the relatively unknown adaptive capacities of planning and natural
30 resource management agencies at all levels of government and the non-government sector,
31 industry, and communities. These may include innovative approaches that can deliver multiple
32 adaptation benefits across sectors. For example, recent research points to the considerable
33 potential for co-benefits of biodiversity-led adaptation initiatives. This includes the use of
34 mangrove and coastal revegetation to protect vulnerable shorelines from sea level rise and
35 storm surge, and the promotion of urban green spaces as a means of off-setting heat island
36 effects while also creating wildlife refuges.

37
38 The implementation of adaptation responses will need to understand the process of promoting
39 shifts in the behaviour and expectations of urban populations and other key stakeholders in the
40 planning process. Achieving resilient urban settlements and communities adapted to climate
41 change will require a new re-negotiated collaborative planning approach, to bridge multiple
42 landscape managers and to align the various plans and policies from the complex layers of
43 governance in which planning occurs.

44 45 46 *3.1.3 Information needs*

47 There are four main information needs for adaptive response in urban planning and
48 management: a) to assess the vulnerability of particular communities and locations; b) to
49 provide historical and current information that informs and supports future adaptation; c) to fill
50 information gaps that hinder or obstruct adaptation and d) to provide information management,
51 strategies, and decision tools to guide information producers and consumers towards useful
52 information with which to adapt to climate change.

1 Community vulnerability

2 Reliable information for estimating future risk will help urban planners and policy makers
3 implement land use strategies, map and reduce vulnerable populations and determine resilient
4 spatial design, critical infrastructure, and density planning goals. It can also help communities
5 and households to make informed decisions. While planners must also learn to operate under
6 conditions of ongoing change and irreducible uncertainty, accurate digital elevation mapping,
7 geophysical accounting, downscaled climate change and impacts modelling and social and
8 economic analysis of impacts and adaptive responses are needed across all scales of the
9 Australian settlements hierarchy. In particular, research is needed on the dimensions of
10 adaptive capacity relevant to urban planners and managers in various parts of the urban
11 landscape, from inner city to suburban and peri-urban, and how locations or communities
12 having low adaptive capacity increase the vulnerability of urban systems and vice versa.

13
14 To respond to this vulnerability mapping, improved and integrated quantitative and qualitative
15 data on impacts and responses are needed to set priorities for decision-makers and policy-
16 makers to undertake adaptive responses in urban planning and management. Some of this data
17 exists already, but must be compiled. For example, historical information exists on adaptive
18 responses to past flooding and on the efficacy of various institutional and behavioural responses
19 thereto. Similarly, data exists on the housing stock and householder investment in responding to
20 thermal stress in buildings (insulation and air conditioning) on the one hand; and water
21 management on the other. This data needs to be collected, analysed, and integrated so that
22 adaptive responses are developed that integrate distributed water management strategies for
23 climate adaptation with building design, materials choice, thermal efficiency, and heat
24 management strategies. These choices will be affected by climatic zone and by institutional
25 choices, and must therefore include social and economic analysis of the housing market,
26 including barriers that arise from market failures as well as cultural studies of occupant
27 behaviour and choices under different information conditions.

28
29 Historical information

30 Australian settlements have experienced many external pressures in the past. How
31 communities in these settlements adapted to these pressures is an important source of
32 information on their current and potential adaptive capacity in respect of future climate impacts.
33 Such information will also reveal the degree to which settlements have responded
34 autonomously and how much they depended on government support or regulation to make
35 transitions due to technological disruption, globalization of markets, global conflict, large-scale
36 immigration, etc. Research may also show what policy changes resulted in social and
37 institutional learning, especially comparative case studies using a consistent framework that
38 accounts explicitly for local and regional variation in climate, scale, and social-economic
39 variables. Case studies may also be needed to establish baselines against which future studies
40 can measure change and adaptive response. Such studies might also provide insight into the
41 economic costs and benefits of different urban planning and management adaptive responses,
42 and the impact of these on municipal assets and tax revenues.

43
44 Traditional knowledge (that is, tacit, artisanal, and locale-specific information that is handed
45 down over generations) may also be critically important to tailoring generic adaptive strategies
46 to a particular settlement. Indigenous knowledge may also provide important insight into
47 landscape and cultural values that are at risk, as well as management strategies in the face of
48 climate impacts.

49
50 Overcoming barriers to adaptation

51 Research into strategic planning under conditions of increasing complexity and the response of
52 local governments to different land-use and resource management policies and institutions is
53 particularly important, given that all adaptation occurs on a local scale. Studies of community
54 receptivity to change in matters such as building codes, planning zones, etc after catastrophic
55 events may be useful in the climate context, especially as risk data for coastal and other

1 vulnerable settlements becomes available to financiers, insurers, real estate agents, and current
2 and prospective purchasers. Information about the best techniques to promote integrated
3 mitigation-adaptation solutions and that support adaptation across more than one sector will
4 enhance decision-making about future urban form. Research into the future aspirations, goals,
5 and preferences of Australians as to what kind of settlements they want to live in and the
6 educational and media influences on these orientations will cast light on cultural resilience
7 versus rigidity, and possible barriers to adaptive responses to climate impacts.

8
9 Information for effective adaptation is often costly to create and of high value to users. The
10 extent to which such information should be available as a public good versus a privately
11 supplied service involves many tradeoffs and is a research question in its own right. The impact
12 of asymmetric information and of information disparities between different interests, both locally
13 and across scales, will affect the equity and efficiency of outcomes in both market and non-
14 market based adaptive strategies. Research into analogous issues may cast light on how to
15 manage critical information in the climate change adaptation context. Relatedly, research is
16 needed urgently on appropriate protocols for ensuring equal access to critical information, the
17 use of information created in the course of adaptive response, the rules for protection of
18 proprietary but critically-needed data disclosure, and the range of possible rules for sharing and
19 ownership of data sets, tools, and information management techniques. Two important research
20 questions are: what mix of “discovery” research into climate adaptation response driven by
21 which disciplinary and sector-based imperatives will work best with research focused on
22 practitioner knowledge based on multiple stakeholders? And, how can these two types of
23 information be integrated effectively in the process of its creation and use?

24 25 Knowledge uptake

26 Finally, research is needed on what type of information portals and networks will serve
27 Australian settlements in their planning response and help them to manage the impacts of
28 climate change. Such information systems could be integrated with existing sustainability
29 schemes such as BASIX in New South Wales (green rating of buildings). On the other hand it
30 might be argued that climate change demands a distinct strategy aimed at embedding key
31 issues into the mainstream information systems of all the major players in Australian urban
32 planning and management, including officials, corporations, civil society entities such as
33 professional associations, universities, etc. If a discrete system is established, questions arise
34 about its design, including whether it should match or traverse jurisdictional boundaries and
35 whether it should be self-organising in response to complexity and rapid change. An open
36 source repository of essential data, standards, planning approaches, and tool “wizards” (such as
37 the UKCIP) can facilitate rapid exploration of planning issues posed by climate change.

38 39 40 *3.1.4 Research priorities*

41 From the analysis of issues facing urban planning and the information needs identified above,
42 the following research priorities emerge:

- 43
44 1. How can existing urban planning principles accommodate climate change and the uncertainty
45 of climate change impacts? How should these principles differ based on the location and spatial
46 scale of the settlement? What can we learn about the adaptive capacity of settlements from
47 responses to stresses in the past?
- 48 2. How can planning approaches address the multiple objectives of urban adaptation to climate
49 change impacts, mitigation of greenhouse gas emissions and biodiversity conservation?
- 50 3. How can the governance of urban planning in Australia, including formal and informal rules,
51 nationally consistent approaches and guidelines and locally driven standards and outcomes,
52 and the institutions responsible for decision-making, be improved to facilitate planning
53 processes and outcomes which incorporate adaptation to climate change?

1 4. What are the particular planning needs of remote and Indigenous settlements under a
2 changing climate?

3 5. What information about urban and regional planning and climate change impacts, in what
4 form and at what resolution, should be publicly available? How should climate change impacts
5 and adaptation information be presented and made available to urban and regional planning
6 decision-makers?

9 **3.2 Built environment**

10 *3.2.1 Stakeholders and key impacts of climate change*

11 The built environment in this context refers to human-built structures from the large-scale civic
12 buildings to personal dwellings, the space in-between such structures and their spatial
13 arrangement on the landscape.

14
15 The impacts of climate change coupled with significant demographic changes and population
16 increases in vulnerable areas greatly increases the need for society to develop effective means
17 for adapting to a warmer climate. However, because most of Australia's 2025 built environment
18 is already in place, we must find least cost strategies for modifying or retro-fitting this
19 environment to enable it to adapt to changes imposed by climate and demographic pressures.
20 The 2009 heat wave in southern Australia highlighted the need to design the built environment
21 to be resilient and adaptable in the face of localised extreme weather events.

22
23 Consideration of how climate variables affect the utility and sustainability of the built
24 environment is an inherent part of the traditional urban design process. Integrated urban design
25 and development now needs to recognise climate as a variable factor that has implications for
26 how design, materials, structures and human behaviours are adapted for future Australian
27 communities.

28
29 Government regulators, the construction industry and developers especially need to embrace
30 climate change in their design of new development. However, as mentioned already, the biggest
31 differences to raising the resilience of communities would come from improving the existing
32 stock of buildings. The Australian Building Codes Board has representative participation from all
33 states and territories and seeks national agreement and adoption of any changes it introduces.
34 Thus the wind code regulations are national. However such regulations are not retrospective
35 and finding mechanisms and incentives to encourage retro-fitting of the existing building stock to
36 be better adapted to both the current and future climate remains a significant challenge.

37
38 Another aspect of the built environment that complicates design for climate change is the
39 resistance to change resulting from deep infrastructural legacies of historic decisions and
40 incumbent sectoral and local interests in government, industries and communities. For example,
41 the long term dominant use of fossil fuels for energy generation for heating, ventilation and
42 cooling and transport increases greenhouse gas emissions and constrains design innovation for
43 dispersed energy sources. Least-cost alternatives need to be developed for ensuring human
44 thermal comfort in a warmer climate, such as through the adoption of options such as passive
45 ventilation and cooling systems and mobility modes (walking, biking, public transport) better
46 adapted to climate change.

47
48 There is considerable uncertainty about the timing and intensity of future climate change
49 especially at regional and local scales. The economic situation contributes further uncertainty.
50 Nonetheless decisions about developments, many irreversible, will continue to be made, and
51 these need to increasingly take into account an awareness of both climate change and
52 uncertainty about its specific local implications. One sensible approach for large investments is
53 to undertake staged developments that allow for future expansion or additional adaptive

1 features to be implemented contingent on certain climatic thresholds being surpassed. These
2 so-called 'real options' allow for learning and flexibility in planning and design decisions prior to
3 any commitment of scarce resources. Optionality can add value to projects in a way that can be
4 priced with modern financial tools that avoid the pitfalls associated with traditional Net Present
5 Value calculations often used for cost-benefit analyses. This is also a significant issue for
6 infrastructure financing (see section 3.4).

7
8 Stakeholders concerned with the built environment include:

- 9
- 10 - Australian, state, territory and local governments, who regulate the construction industry,
11 urban development and home additions and modifications;
 - 12 - At-risk groups, including Indigenous communities, who are wanting guidance on how to
13 adapt and prepare for the consequences of future extreme weather events;
 - 14 - Urban managers and elected representatives of local government faced with deciding
15 upon development alternatives in the face of considerable uncertainty about the costs,
16 consequences and time horizon of future climate change impacts;
 - 17 - Design professions such as architects, engineers, landscape architects, planners and
18 urban designers as individuals in companies, government departments and professional
19 societies;
 - 20 - Financial institutions such as banks who are keen to avoid losses associated with
21 climate impacts;
 - 22 - Insurance companies who are developing long term policy responses to insuring risks
23 from extreme weather events;
 - 24 - Policy makers faced with establishing long term planning, legal and regulatory
25 frameworks and investments in future built environments in areas anticipated to be
26 exposed to weather extremes and population increase;
 - 27 - Developers and the construction industry;
 - 28 - Property owners and leaseholders who will ultimately bear much of the risk; and
 - 29 - Emergency management services, who respond to calls for assistance from owners and
30 leaseholders of buildings damaged by extreme events.
- 31
32

33 *3.2.2 Adaptation options and adaptive capacity*

34 Australia has the design and professional basis to support considerable adaptive capacity, with
35 good universities and schools, skilled architects, engineers and tradespeople and a well-
36 developed national regulatory mechanism via the Australian Building Codes Board. These
37 professions are very capable of responding to the challenge and need to be encouraged to
38 embrace global climate change in their activities through appropriate regulatory change. One of
39 the best examples worldwide of adaptation to the physical environment is the influence of
40 building regulations that stipulate more wind-resistant construction in tropical cyclone-prone
41 areas of Australia. These enhancements were introduced in the wake of devastating losses
42 caused by Tropical Cyclones Althea in 1971 and Tracy, which in 1974 almost completely
43 destroyed Darwin, the capital city of the Northern Territory. As a result of these construction
44 changes newer buildings are [now](#) generally much less vulnerable to wind damage.

45
46 However, beyond cyclones, no other natural hazard in Australia has invoked comparable
47 responses in terms of building standards and this is particularly true of climate change.

48
49 Many simple but effective adaptation options that increase local employment and participation in
50 climate adaptation activities are possible at a local scale. Examples could include designing and
51 constructing bicycle and pedestrian paths above peak flood levels, provided that their
52 construction does not impede the flow of floodwaters making these more dangerous. Similar
53 local scale adaptations include increasing the numbers of well-designed bus shelters, park
54 benches and tree plantings in high heat-stress areas and the identification and potential

1 relocation of coastal and riverside infrastructure that is likely to fail during future storm events.
2 There are also many opportunities for well-designed heating/ventilation/cooling systems at
3 residential, commercial and institutional building scales that adapt built environments with
4 minimal investment in terms of increased energy efficiency, reducing greenhouse gas emissions
5 and improving quality of life and well-being.

6
7 In particular, the standards adopted for public safety for floodplain management are quite
8 different from those for other hazards such as earthquake and bushfire and, even for a given
9 hazard, different states and territories interpret these standards differently.

10
11 Some existing elements of the built environment, including materials, processes and equipment,
12 are particularly vulnerable to failure during extreme events as evidenced through the heat wave
13 in southern Australia in 2009. These failure points need systematic identification and
14 rectification in order for the built environment to become better adapted to extreme climatic
15 conditions. Similarly, there needs to be more clarity on who bears the costs of disasters caused
16 by extreme weather events.

17
18 A focus on climate adaptation may not be enough to influence policy change and action and
19 alignment with other social and design agendas is required. There may not be sufficient local
20 and regional design capacity to respond to the innovation required to meet performance
21 measures versus compliance with prescriptive measures. Such a local and regional adaptive
22 capacity response by designers may require the ability to set design within an integrated
23 overarching urban planning and design strategy that is currently missing from state/territory and
24 national policy development.

25 26 27 *3.2.3 Information needs*

28 Stakeholders are seeking information for developing improved options for adapting to more
29 severe sea level extremes and are generally calling for consistent guidelines in relation to the
30 planning and design of the built environment in relation to climate change. Better climate and
31 sea level rise projections are necessary and need to be integrated with improved understanding
32 of possible storm surge impacts. For example comprehensive analyses of combinations of
33 storm surge and coastal flooding could be improved with better Digital Elevation Models
34 (DEMs). Scenario planning for a range of coastal flood and storm surge levels could then be
35 used to set heights for designing and constructing reliable infrastructure such as critical
36 evacuation routes that are above peak flood levels.

37
38 Better information is needed on the full social and environmental consequences of costs and
39 benefits of all adaptation options, and better communication is needed with decision makers on
40 the economic costs of “doing nothing” as opposed to taking innovative action. Cost-benefit
41 analyses must take into account the uncertainty about the timing and intensity of likely impacts.
42 Many designers also lack access to science and engineering journals and the latest
43 professional information. Consequently, there is a need for better built environment networks,
44 including means of incorporating practical knowledge from local tradesmen, and improved
45 remote broadband access to knowledge and experience about adapting to climate change.
46 Information on case histories and testable scenarios can help local governments make
47 decisions and develop more effective designs for the built environment.

48
49 There needs to be improved access to reliable, consistent and relevant data and modelling
50 results, including baseline data. It needs to be recognized that different types of information are
51 needed for design, planning, vulnerability assessment, risk assessment, decision making, and
52 investment.

1 There need to be decision support tools that go beyond hazard assessment to risk assessment,
2 including the assessment of adaptive capacity.

3
4 Valid peer-reviewed scientific information is needed to support evidence-based standards and
5 building codes for extreme events such as cyclonic winds, storm surge, floods and fire. This
6 information may need to draw on a broader base of data – ecological, geomorphologic, historic
7 and traditional local knowledge might contribute to understanding the frequency and severity of
8 extreme events, such as cyclonic winds and storm surge, and supplement current reliance on
9 point source anemometer and tide gauge measurements.

10
11 Information is needed on the implications of climate change for materials and structures to
12 inform standards development and revision. Practitioners also require regular updated research
13 to underpin key tools such as the Australian Rainfall and Runoff Handbook.

14 15 16 **3.2.4 Research priorities**

17 1. What are the biophysical pathways (material failure, coastal erosion, etc.) by which climate
18 change is likely to damage buildings and infrastructure? What climate and other information is
19 needed to understand likely damages and how can this information be presented in a clear,
20 useable form to decision-makers?

21
22 2. What are the design options and principles for adapting new buildings to climate change in
23 different locations and how can these be implemented? What are the full life-cycle costs of
24 different parts of the built environment and their critical inter-dependencies during extreme
25 events?

26
27 3. What are the design options and principles for adapting existing buildings to climate change
28 in different locations and how can these be implemented?

29
30 4. What are the costs and benefits of adapting the built environment and how can they be
31 reliably estimated? Who will bear these costs and who will benefit? What financial and other
32 policy instruments can be used to address equity impacts of these costs?

33
34 5. What additional information is needed concerning materials and loading to inform the
35 development of design standards that take appropriate account of future climate scenarios? At
36 what intervals should standards and tools (such as the Australian Rainfall and Runoff
37 Handbook) be reviewed to ensure that they provide effective guidance to decision makers?

38 39 **3.3 Vulnerable coastal communities**

40 **3.3.1 Stakeholders and key impacts of climate change**

41 Australian coastal settlements are variously exposed to climatic events that can cause loss of
42 life and significant damage to private and public assets. Geologic and historic records reveal
43 how extreme events under natural patterns of climatic variability have impacted on coastal
44 geomorphology, ecosystems and human structures. Long periods of relative quiescence in
45 storm frequency leading to coastal system recovery are interrupted by clusters of destructive
46 storm events.

47
48 Climate change projections by the IPCC (2007), reinforced by more recent studies in Australia
49 by CSIRO and others, indicate that a new set of climatic, hydrologic and oceanographic
50 conditions will be imposed upon, or will modify, the natural forces of variability that impact on
51 coastal environments. Coastal settlements can expect over this century and beyond, higher sea
52 levels, more intense tropical cyclones, longer dry spells, higher land and sea temperatures, and
53 generally more severe weather events. These changes will be manifested in two forms on

1 human settlements: (i) more intense and damaging extreme events involving storm surges,
2 urban flooding and foreshore erosion; and (ii) the “creeping” impact of progressive higher sea
3 levels as seen in more and more frequent flooding during high spring tides. Drier conditions in
4 the future may also affect coastal communities through evaporation of blocked coastal lakes
5 and lagoons, bushfires and water shortages. Uncertainty remains as to just how frequent,
6 severe and extensive will be these changes. Continued modelling and observations should
7 progressively refine our understanding of the probability of impacts under climate change that
8 settlements must plan for in different coastal regions.

9
10 Climate change exacerbates the risks associated with other changes in the coastal zone. For
11 example, the sea change phenomenon has resulted in rapid rates of population growth in high
12 amenity non-metropolitan coastal towns (see for example Salt, 2001 and 2003; ABS, 2004;
13 Burnley and Murphy, 2004; Smith and Doherty, 2006). As Smith and Thomsen (2008) highlight,
14 “The issue for sea change communities is the rate of change in low population areas, where the
15 effects of high percentages of growth on relative small communities may not be as easily
16 absorbed as in the cities”. The rates of change also create potential indirect impacts, such as
17 reduced social capital, which may translate into challenges for effective response to natural
18 disasters such as those emanating from climate change (Smith and Thomsen 2008).

19
20 The nature and extent of impacts induced by climate change on coastal settlements will vary
21 with location, settlement type and settlement history (Chen and McAneney, 2006). Cities with
22 embedded infrastructure designed to cope with a certain frequency of extreme flooding events
23 will be more limited in response by the very scale of the problem than many coastal villages. Old
24 canal estates built to a particular water level will be less able to manage higher tides than those
25 designed more recently to meet higher storm surge and tidal heights under climate change.
26 Therefore it will be necessary to examine various degrees of vulnerability, including exposure,
27 sensitivity and adaptive capacity of not only different settlement types, but also their particular
28 history and governance structures that may or may not limit effective adaptation.

29
30 Consideration needs to be given to the methods used to determine the physical risk to coastal
31 communities from both gradual and extreme events across the range of coastal settlement
32 types. Some of the approaches that have been developed for more temperate coastal regions
33 may not be so appropriate in tropical areas. Methods currently in use need to be subjected to
34 wider scientific scrutiny, for instance in relation to historical and geologic recorded events, in
35 order to ascertain their robustness for estimating these risks to coastal communities that are
36 vulnerable to the impacts of climate change. Such scrutiny should include the effectiveness of
37 statutory and policy measures used in a particular area.

38
39 There is inconsistency in approaches to regional hydrodynamic modelling, which in turn, gives
40 rise to differences in the interpretation of coastal inundation and riverine flooding data. There
41 are gaps in the network of gauges used to measure tides. This information is fundamental to
42 developing more accurate assessments of future risks.

43
44 Responsibility for developing and implementing adaptation strategies in coastal settlements in
45 Australia rests with a range of stakeholders. The bulk of assets in the coastal zone are owned,
46 built and managed by private individuals or firms. State and territory governments have primary
47 constitutional responsibility for land management in the coastal zone and local councils
48 operating under state laws perform key roles although precise powers will vary from state to
49 state/territory. The Australian Government also has interests in the coastal zone. These relate,
50 for example, to Australian Government assets and a range of natural resource management
51 issues. Within local areas the role of community groups in supporting coastal actions aimed at
52 meeting the challenges of climate change is becoming more and more evident often with
53 individual property owners, their insurers and banks, and developers in the front line of decision
54 making. Understanding local impacts is one of the main challenges facing all stakeholders in
55 coastal settlements.

1
2 Special attention needs to be made to Indigenous communities in terms of communicating
3 impacts, consequences and means of adaptation to climate change in vulnerable coastal
4 locations occupied by such communities. Approaches required for these communities need to
5 be different to those adopted for other coastal communities where the cultural links to sea
6 country and exposure to climatic and oceanic forces threaten those links and physical
7 structures. Torres Strait Island communities are particularly vulnerable to sea level rise, coastal
8 erosion and storm surges.

11 3.3.2 Adaptation options and adaptive capacity

12 There is a wide range of options to adapt to climate change impacts on vulnerable Australian
13 coastal communities. These options can be described or categorised in many ways, but
14 generally fall within the following three generic categories: i) retreat (e.g. property relocation); ii)
15 accommodate (e.g. natural disaster management); and iii) protect (e.g. hard and soft
16 engineering options) (Klein *et al.*, 2000).

17
18 While these categories provide a useful starting point for considering coastal adaptation options,
19 there has been increasing awareness of the need to consider these within the context of
20 Australia's coastal management system(s) and the decision-making options available. The
21 various case studies that have begun to explore coastal adaptation options commissioned at an
22 Australian Government, state and territory or local level have tended to use a Risk Management
23 framework to describe adaptation options (see Table 2).

25 **Table 2: Generic adaptation categories based on a Risk Management Framework (Based**
26 **on IPCC, 2001; AGO, 2006; Travers *et al.* 2009)**

Spread Risk	Insurance and diversification strategies e.g. geographical diversification by relocating property in highly vulnerable areas
Prevent Effects: Structural & Technological	Prevent effects through engineering solutions and changed practices e.g. scale up coastal protection works
Prevent Effects: Regulatory & Institutional	Prevent or mitigate effects through revised regulations and planning e.g. increase resources for coastal planning; amend building design standards
Avoidance	Avoid or exploit changes in risk: e.g. change location of new urban developments
Research	Improve understanding of relationship between climate change and risk e.g. improved understanding of relationships between changes to frequency and magnitude of extreme events and critical thresholds for individual risks
Encourage behavioural change through Education, Information	Educate and inform stakeholders about the risks of climate change

27
28 Although there appears to be an increasing awareness of these options, driven by various
29 coastal risk assessments nationwide, the mechanisms for effectively choosing between them is
30 in its infancy. Decision-support methods for coastal adaptation, such as risk-benefit and cost-
31 benefit, have begun to be explored through case studies and strategic-level assessments,
32 however many practical and methodological issues need to be effectively addressed before
33 these approaches can be applied with rigour and consistency. This is a significant research
34 challenge.

35
36 The adaptive capacity of coastal communities is highly variable. Some communities, such as
37 those in some large urban centres have the benefit of access to considerable financial
38 resources, information bases, skilled personnel and leadership. In contrast, other communities

1 have extremely limited access to such resources and attributes. There are a number of factors
2 that influence adaptive capacity of coastal communities, including (Travers *et al.*, 2009):
3

- 4 • Information access: there is readily accessible information to organisational staff and
5 relevant stakeholders, i.e. effective monitoring or other programs are in place to detect
6 changes to the coastal environment.
- 7 • Flexibility and resources: changes can be made easily and there are appropriate
8 resources (personnel and financial) in place.
- 9 • Susceptibility to non-climate risks: susceptibility to non-climate related risks can
10 influence ability to respond to climate related risks

11
12 While these factors contributing to the adaptive capacity of coastal communities are emerging
13 through site-specific coastal risk assessments, there remain challenges in scaling these findings
14 to both a national and regional level in order to support coordinated national adaptive capacity
15 building efforts.
16

17 The capacity for coastal communities to adapt to climate change will be determined to some
18 extent by the degree to which statutory and regulatory provisions constrain or prohibit building in
19 exposed locations. States and territories and local councils in Australia have a variety of
20 provisions and policies that guide decisions on land use. Effectiveness of these provisions in
21 preparing coastal communities for the impacts of climate change is a matter of debate, including
22 being the subject of an active House of Representatives enquiry. The Federal Government has
23 no constitutional power to ensure nationally consistent management and planning practices that
24 will potentially minimise adaptation costs on future budgets and community interests (Thom,
25 2008).
26

27 Climate change impacts around the Australian coast constitute a national problem not just a
28 state/territory problem. The level of technical advice available to local councils is variable, a
29 potential difficulty when priorities for investment in adaptation measures should be based on the
30 best available information and consideration of adaptive capacity.
31
32

33 *3.3.3 Information needs*

34 Coastal settlements are variously exposed to the impacts of climate change. Requirements for
35 information to support long term decision making will not be the same for each settlement.
36 There will be different needs, for instance, for greenfield developments compared to long
37 established population centres. Yet there are a range of basic information needs that can assist
38 decision makers to plan for the future.
39

40 There is a need to better understand past and present extreme climate events and how these
41 events interact with hydrologic and geomorphic processes and impacts. Specifically,
42 consideration should be directed towards obtaining information on the extent and nature of
43 landform modification under extreme wave and wind conditions. There is also the need to
44 improve the capacity of hydrodynamic models linking riverine floods with wave-induced storm
45 surges. Coupled models of fluvial-estuarine-oceanic phenomena are required in order to
46 improve assessment of low-lying coastal lands at risk of inundation under extreme events. Such
47 models should be tested against historical flood events in coastal settlements. Risk assessment
48 methods and decision-support tools can be made more robust when they incorporate
49 knowledge of past and present-day extreme events and then tested against scenarios of
50 impacts of these hydrodynamic processes as envisaged under local and regional climate
51 change conditions.
52

53 Effective risk assessment involves a continued commitment to collection and dissemination of
54 information on risk. New techniques such as LIDAR can now offer high resolution data on

1 elevations and combined with scenario modelling offer land owners and public asset managers
2 vital information required to assess impacts of extreme and creeping events (NSW Dept.
3 Planning 2008). Most critically it is important that property owners and occupiers are notified of
4 the risks and regularly updated as new information becomes available.

5
6 Building codes and standards may need to be modified to accept new information on exposure
7 and risk. Much has already been done in tropical regions faced with cyclone impacts. However,
8 housing affordability, location of low cost services and availability of flat land may entice
9 developers and councils to accept lower standards than that are required to protect
10 communities from surges and floods. Design and retrofit of buildings and services for impacts of
11 creeping flood tide events may also need to be revised to accommodate climate change. The
12 extent to which insurance can be provided or maintained under these conditions both for
13 property owners and councils must also be looked at in relation to standards, locations and
14 approvals processes.

15
16 There is a need for decision makers to understand the benefits of developing adaptation
17 strategies and communicating those benefits regularly to communities. Loss of public assets
18 such as beaches is an example. Sea-level rise by itself may not destroy a beach until a
19 threshold is reached. Conditions need to be assessed when nourishment is required otherwise
20 a city or tourist dependent town may lose one of its prime assets. Community attitudes to loss or
21 change of environmental assets or facilities, what can be done to ensure they are protected,
22 and who will pay, are issues that vulnerable coastal settlements must assess.

23
24 Coastal communities may be faced with trade offs between environmental, amenity and
25 property protection. Resources for maintaining or improving natural resources and public access
26 to wetlands, beaches, littoral forests, dunes, sea grasses and reefs, may locally be in
27 competition with demands for protective works such as sea walls, revetments, levees and
28 associated pumping stations to limit inundation.

30 31 *3.3.4 Research priorities*

32 1. How will demographic pressures and changes in different Australian coastal settlement types
33 affect (1) potential impacts of extreme and gradual climate change, and (2) current policy and
34 regulatory settings which govern the decision-making by government agencies, businesses and
35 individuals? How will planning for coastal climate change impacts respond to local
36 circumstances?

37
38 2. How do coastal communities perceive coastal vulnerability in different settlements and to
39 what extent is that influencing adaptive capacity now and likely to influence it in the future under
40 scenarios of climate change?

41
42 3. How well do we understand the relationship between climate and coastal processes? How
43 can methods currently used to determine the physical risk on a regional basis of extreme
44 inundation and coastal erosion from climatic and oceanic processes, either singularly or in
45 combination, be improved and new methods developed and applied?

46
47 4. Better information is needed about hydrodynamic processes and interrelationship with
48 sediment supply over time, including thresholds and tipping points that could result in
49 fundamental landform changes. What is the switchover point from accreting to erosion? How
50 soon is this phenomenon likely to happen? What are the locations at greatest risk?

1 **3.4 Infrastructure**

2 *3.4.1 Stakeholders and key impacts of climate change*

3 Infrastructure in this context includes the traditional areas of Energy, Water Security,
4 Stormwater and Flooding, Transport, and Communications. In discussing adaptation of
5 infrastructure with climate change, social, economic, environmental and health issues are also
6 of relevance – these will not be directly included herein, however their relevance and
7 importance should not be overlooked.

8
9 Virtually every member of the community is a primary stakeholder in the sustainability of
10 effective infrastructure, as a user of the services provided by the infrastructure. Many people are
11 also stakeholders as owners, operators or employees of private or public infrastructure.

12
13 Representing community interests are the three levels of government, a range of authorities,
14 service providers and industry groups employing managers, professionals (engineers,
15 architects, planners, scientists) and support staff who make or implement decisions relating to
16 design, maintenance, operation, replacement and overall management of infrastructure. Within
17 major cities infrastructure is generally managed by state/territory government, corporatized
18 authorities or private industry. In non-urban regions there is an increasing role for local
19 government in the design, maintenance, operation, replacement and management of
20 infrastructure across all sectors. Even within energy generation the role of local government is
21 already growing with the establishment of local/regional carbon reduction targets and
22 development of distributed renewable sustainable energy (e.g. methane gas from landfills, wind
23 turbines).

24
25 Another group of stakeholders are the researchers and funding bodies that undertake or fund
26 research. Some of these researchers are located within the above listed stakeholder
27 organisations, while many are based in universities and government research agencies, such as
28 CSIRO.

29
30 In order of confidence of prediction, the climate changes that are likely to impact operating
31 infrastructure are:

- 32 • increasing temperature – widespread – all persons and infrastructure impacted to some
33 degree
- 34 • sea level rise – widespread and very significant for all coastal cities and settlements as
35 well as estuarine systems – large populations, major infrastructure and high value
36 assets directly impacted
- 37 • more variable rainfall – spatial and temporal changes across different regions - shifts in
38 seasonality, reduced rainfall occurrence (less rain days and more time between rain
39 events) in some regions whilst intensity of rainfall when it occurs may increase with
40 higher flood risk in other regions – large populations, major infrastructure and high value
41 assets may be impacted on a regional basis
- 42 • reduced catchment runoff in many regions – result of increased temperature, reduced
43 and seasonal shifts in rainfall combined with increased evapo-transpiration indicate
44 significant reductions in catchment runoff and water resources – direct impact on water
45 security that will require increased water storages or alternative sources for major cities
46 and regional towns
- 47 • increased storminess and more extreme weather – this area of climate change science
48 is the least reliable as the Global Climate Change models operate at much larger
49 temporal and spatial scales than is necessary to accurately resolve the forcing
50 mechanisms of cyclones/hurricanes/typhoons or tornados - large populations, major
51 infrastructure and high value assets may be impacted on a regional basis.

52

1 As noted by ATSE (2008) in the Assessment of Impacts of Climate Change on Australia's
2 Physical Infrastructure, the major potential impacts arise from combinations of predicted climate
3 change scenarios. Adopting standard risk assessment techniques ATSE identified the
4 infrastructure most vulnerable to be:

- 5 • Energy generation and distribution – due to extreme temperatures, bushfires and
6 drought (reduced cooling water)
- 7 • Low –lying coastal developments – due to sea level rise, storm surge and/or extreme
8 rainfall
- 9 • Drainage, stormwater and sewerage infrastructure where significant rainfall intensity is
10 projected.

11
12 The consequences of climate change on the transport and communications sectors will be
13 minor-to-moderate, relative to these others, with adaptation measures requiring only minor to
14 moderate investment. That said, where this infrastructure is located in a vulnerable area, such
15 as a low-lying or flood-prone area, it will obviously require attention, especially when it concerns
16 key assets such as major transport routes and nodes, hospitals, and communications
17 transmitters.

18
19 A major review of the impacts of climate change on Australia's infrastructure is currently
20 underway, supported by the Australian Government Department of Climate Change.

21 22 23 *3.4.2 Adaptation options and adaptive capacity*

24 Throughout Australia all sectors of infrastructure operate at or beyond design capacity at
25 various locations and times. There is a recognized need (without the additional impacts of
26 climate change) for significant infrastructure investment to raise capacity. However, very little
27 infrastructure is designed to meet peak demand, with some demand management measures
28 being applied. The likely impacts of climate change need to be recognised and an adaptive
29 management approach to designing and managing investment is essential.

30
31 Climate conditions will change considerably over the life of long-lived infrastructure, such as
32 bridges (100 years) and rail tracks (60+ years). The capacity for such assets to incorporate
33 adaptation treatments or adjustments to their maintenance regime will in part determine their
34 resilience to accelerated degradation of materials and fatigue of structures due to increased
35 intensity and frequency of extreme events (storms, wind, rainfall, bushfire). Assets which are
36 periodically renewed, such as roads having a life expectancy of less than 20 years, are likely to
37 have a larger adaptive capacity than long lived assets, such as bridges. Although a road surface
38 may be degraded more rapidly than a bridge from increases in temperature, solar radiation and
39 flooding events, each periodic renewal of the road (four times in 100 years) can incorporate
40 knowledge about then-current and anticipated climate conditions in its design and new
41 technologies and materials in its mix of materials. Integrating such renewal options in long-lived
42 infrastructure would also help enable periodic improvements to these assets as knowledge
43 improves.

44
45 The adaptive capacity of each of the infrastructure sectors as a whole is complex and relates to
46 a range of drivers of adaptation and barriers to adapting within each sector. Some of the key
47 adaptation drivers include: the level of early climate change impact to a sector's key assets or
48 service provision; increase in capital and operational costs due to climate impacts; and
49 regulatory, investment and liability pressures to increase adaptive capacity of the network or
50 new assets. Some of the key adaptation barriers include: understanding the cost versus the
51 benefit of incorporating adaptation capacity into new and existing assets; knowledge gaps for
52 infrastructure specific climate information (extreme rainfall events) to inform decision makers;
53 and climate change adaptation not being specified in investment, design, operation and
54 maintenance requirements.

1
2 For all infrastructure sectors, adaptive capacity is directly related to the present condition of the
3 infrastructure, life expectancy, service level expectancy, maintenance regime, levels of
4 investment and lead times for planning, design and construction of adaptation options such as
5 protection, reinforcing and elevation adjustments. Information which enables users to avoid
6 unwittingly damaging the infrastructure or rendering it ineffective during extreme events can also
7 increase the adaptive capacity of the infrastructure system.

8
9 Energy
10 The combined effects of higher temperatures, bushfire risk, and reduced water resources are of
11 major concern to energy infrastructure. In a warmer environment, cooling water requirements for
12 thermal power plants (be they oil, coal gas or nuclear-fired) will need to compete with
13 diminishing water resources. Air cooling and/or hybrid air-water cooling provides some adaptive
14 capacity, albeit at a cost in efficiency. The environmental and ecological impacts of power
15 station warm water releases into warmer receiving rivers, lakes, estuaries or coast require
16 careful consideration.

17
18 Many existing power plants are located close to the coast, near to major cities and coal
19 deposits. Sea level rise will directly impact on these power stations, although it is likely that
20 adjustment will be relatively inexpensive, where staged adaptation of the plant and flood levee
21 protection is feasible.

22
23 Thermal power is expected to continue to provide the bulk of Australia's energy needs for some
24 considerable time. The relative effectiveness of non-thermal renewable energy sources
25 including current solar, photovoltaic, wind, wave and hydro technologies are individually known
26 but can be expected to change in time with technological development, energy demand and
27 pricing policy. The integration of distributed energy sources with the existing concentrated
28 transmission grid offers an opportunity to improve resilience of the overall energy supply
29 system. Energy demand reduction is clearly a most effective adaptation option for which the
30 community has demonstrated capacity, and this could play an effective part in avoiding
31 catastrophic system failure. Uncertainty in the transition path from centralised high carbon
32 energy to dispersed low emission renewable sources is limiting adaptation progress with
33 uncertain investment priorities and timing.

34
35 Water security
36 For many locations (especially major cities) the combined effects of higher temperatures and
37 more variable rainfall are expected to result in lower annual rainfall but more intense
38 precipitation events. Both drought and extreme rainfall will also affect the quality of drinking
39 water supplies. The options for adaptation are to reduce demand (lowest cost adaptation
40 strategy) and to increase storage and/or alternative sources (groundwater, rainwater tanks, re-
41 use or desalination). Community capacity to reduce water demand is substantial and has been
42 demonstrated in various drought affected cities/regions.

43
44 Re-use includes various combinations of potable and non-potable with direct and indirect
45 delivery. Potable re-use is presently not socially acceptable with the majority of the population.
46 Desalination and potable re-use options require high energy consumption. If this energy cannot
47 be provided by renewable energy sources, those options may conflict with climate change
48 mitigation objectives.

49
50 Reduced water flushing of sewage systems reduces solid waste transport capacity as well as
51 creating a changed bio-chemical environment with impacts on system longevity. Higher sea
52 levels will directly impact on the hydraulic performance of the extensive pipeline and pumping
53 networks within coastal communities.

54

1 The present state of the distribution pipe networks for both supply and waste disposal are of
2 concern. Most water authorities are making major investments in this area to improve adaptive
3 capacity into the future. Long lead times and major investment in new systems for the changing
4 climate require adaptive investigation, design and planning.

5 6 Stormwater and Flooding

7 Changed rainfall variability (both spatial and temporal) and changes in extreme weather events
8 are expected to result in many regions in longer periods of drying, with precipitation occurring in
9 more intense events. We can reasonably expect more frequent and potentially more severe
10 flooding events, with associated risks to human life and property. The economic costs of flood in
11 Australia are likely to be far greater than official estimates, since these are largely based on
12 reports of insurance industry payouts and/or government (Australian, state and territory and/or
13 local) costs. There are a large number of affected properties and infrastructure at risk from
14 flooding and coastal inundation (particularly resulting from projected sea level rise), along the
15 open coast and around bays and estuaries. Specific hydrology/hydraulic investigations are
16 required on a regional basis to determine risk profiles for damage from increased stormwater
17 flow and coastal flooding.

18
19 Engineer's Australia is presently revising the guideline document (Australian Rainfall and
20 Runoff) for assessment of rainfall, runoff, water resources and flooding to include issues related
21 to climate change.

22
23 Most urban areas will be unable to expand either the carrying capacity or storage components
24 of regional stormwater or natural river/creek systems to handle increased flows from either
25 minor (frequent events with an average return interval of less than 10 years) or major events
26 (infrequent damaging events with an average recurrence interval of more than 50 years). This is
27 especially problematic in the coastal zone, where the effects of rainfall/runoff changes interact
28 with coastal storm surges and sea level rise. The costs of such solutions may well prove to be
29 prohibitive or, at best, sub-optimal. The community will need to consider accepting lower
30 standards of nuisance stormwater flooding in minor events and seek to avoid locating
31 infrastructure in vulnerable locations.

32 33 Transport and Communications

34 Although less vulnerable to climate change than the infrastructure sectors discussed above,
35 recent fire and flood events in Victoria and Queensland/NSW have highlighted the importance
36 and fragility of these infrastructure sectors during extreme events. Ports and bridges are more
37 vulnerable transport assets due to sea level rise, storm surge and extreme rainfall events.
38 Adaptive capacity shortcomings in the transport sector relate to the levels of investment
39 required and long lead times for planning, design and construction.

40
41 Even in normal operational environments our public transport systems frequently exceed
42 capacity. Rail services in most major cities cannot presently meet the increased peak demand
43 arising from the recent community shift towards public transport. Rail assets are generally in a
44 poorer condition compared to other transport assets and are more vulnerable to track buckling
45 in the southern states of Australia as they are not designed for high temperature thresholds. The
46 maintenance and operation of rail during heatwaves is a key current adaptation factor for this
47 sector.

48
49 Freight transport infrastructure especially in established major city environments (where urban
50 encroachment is a major constraint) requires more effective integration of port, rail and road
51 transport.

52
53 Many of our major airports are located on reclaimed land established over the seabed and are
54 thus directly vulnerable to sea level rise and changes in coastal extreme weather, risks that can
55 be addressed relatively easily with the raising of perimeter seawalls.

1
2 The communications sector has high adaptive capacity due to the rapid development and
3 community adoption of new technology. Government support of major investment in high speed
4 internet is expected to overcome present deficiencies and raise Australia's system to a
5 competitive international level. However, many small and remote communities, which have
6 relatively limited adaptive capacity, have limited mobile telephone and high speed internet
7 communications, and providing better options is difficult.

8 9 Systemic, cascading and cumulative impacts

10 In addition to the discrete impacts of climate change on particular infrastructure assets, there
11 are also significant risks of concatenating or cascading network failures. These failures can
12 affect multiple systems, with potentially unpredictable impacts on essential services.
13 Concatenating impacts are “downwind” or “downstream” impacts, such as a stormwater system
14 failure that results in release of pollutants that pollutes groundwater or receiving waters.
15 Cascading effects are those with extended causal chains, for example bushfire might destroy
16 transmission lines which in turn impacts on other critical infrastructure such as
17 telecommunications, water purification, sewerage disposal and emergency services. More
18 research is needed into understanding the ways in which infrastructure systems interact and are
19 likely to behave under particular future scenarios of climate change and extreme weather.

20 21 22 *3.4.3 Information needs*

23 Data and information

24 There is a large resource of data, reports and related information relevant to infrastructure,
25 climate change and adaptation planning held by various agencies that is not known of nor
26 available to others to whom it could provide insights and guidance. There is a clear need for this
27 data and information to be collated, publicised, quality controlled, data based, archived and
28 accessible to all stakeholders in a managed and effective nation wide system. There is need for
29 a national host gateway that should provide the pathways/links to the various host or collecting
30 agencies where the data and information will continue to reside and be managed. There is a
31 need by all stakeholders to access consistent and reliable information for purposes of decision
32 making and for developing decision support tools to be used by all sectors.

33 34 Governance

35 There are barriers to adaptation resulting from the lack of clearly defined areas of responsibility
36 and authority between the three levels of government (Australian, state and territory and local).
37 This results in confused policy and reduces effective governmental planning and management.
38 Research could inform future institutional arrangements that might best support effective
39 adaptation by infrastructure regulators and providers. Some aspects of effective arrangements
40 may reflect the particular circumstances relating to infrastructure but other aspects may be
41 common to other sectors and reflect the nature of climate change.

42 43 Vulnerability

44 There is a need for organisations at various levels to test the resilience of infrastructure that
45 they manage to gain a sound understanding of its potential vulnerability to the additional
46 conditions imposed by climate change. Such investigations should identify the features of
47 particular infrastructure components that render them vulnerable to climate change, and
48 whether there are design or operational solutions to those features. The interdependence of key
49 infrastructure was recognised – highlighting the need for understanding how infrastructure
50 systems interact and are likely to behave with possible serious concatenating or cascading
51 impacts under particular future scenarios of climate change and extreme weather.

52 53 Energy and Water

1 Clearer information needs to be more broadly available to specific stakeholder agencies as well
2 as the broader community. Information is needed about the sustainability and adaptive
3 strengths of the various long term options for water supply, waste management and water re-
4 use options, including risk assessment, life cycle analysis and social acceptance. Information is
5 also needed about the options and sequencing for transitioning from the existing centralised
6 thermal energy system to incorporation of distributed non-thermal alternative renewable energy
7 generation sources including solar, photo-voltaic, wind, wave and hydro. For instance, both
8 industry professionals and the community needs to understand how this could be undertaken,
9 what it would cost and the extent to which it would improve energy system capacity and
10 resilience for decision makers to be able to make significant changes to existing arrangements.

11
12 The strong interdependence of water supply with energy warrants an improved understanding of
13 the linkage between energy and many water supply, waste management and water re-use
14 options including “water needs for energy generation” and “energy implications of adaptive
15 water supply options”.

16 17 Coastal infrastructure

18 Better understanding is required of the best tools and mechanisms for adaptive planning of
19 infrastructure in the coastal zone. Essential further research areas include flood hydrology, flood
20 hydraulics, flood hazard, vulnerability, warning and evacuation, social and economic risk
21 assessment and the combined probability of flood peaks with ocean storm surges and sea level
22 rise.

23 24 Design standards and planning periods

25 The lack of national design standards and planning periods for infrastructure at all levels is a
26 serious deficiency for existing planning and for adaptive management with climate change.
27 Design standards specified as Average Recurrence Interval (ARI years) or Annual Exceedance
28 Probability (AEP %) need to be developed and adopted nationwide for specific regions and
29 infrastructure. Guidelines (in lieu of standards) for planning periods also need to be developed
30 nationwide by region and infrastructure. The Building Code of Australia is a possible instrument
31 to implement these needs.

32 33 Financial analyses

34 Traditional Benefit/Cost analyses based on Present Worth method with relatively high discount
35 rates and short planning periods are not appropriate to the long planning periods inherent in
36 adaptation to climate change over the next century (and longer). Financial analyses for
37 assessing infrastructure projects need to be modified to incorporate and take account of risks
38 that are likely to change with climate over an extended timeline. Alternative financial and
39 business models need to be investigated for use by government and private sectors for
40 adoption in options assessment and investment decision making in the new climate era.

41 42 Tipping points

43 The climate system is changing incrementally as global temperature rises but step changes in
44 the range, extremity and behaviour of regional and global conditions are also occurring.
45 Anticipating the occurrence and effect of these step changes or tipping points would enable
46 infrastructure managers to prepare for new local or global conditions. For instance, the rapid
47 and ongoing reduction in Perth’s rainfall was only recognised a decade later and characterised
48 after two decades. Some rapid changes, such as rapid sea level rise resulting from a significant
49 mass of land ice entering the ocean can be anticipated in general terms but not in specific
50 timing.

51
52 New infrastructure which involves long lead times for planning and decision-making will benefit
53 from early identification of relevant tipping points. Climate and other parameters that determine
54 when tipping points will occur need to be identified and monitored.

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3.4.4 Research Priorities

1. What is the vulnerability of infrastructure (individual and interlinked critical sectors) to existing and predicted climate change conditions at various spatial scales, considering average and extreme weather conditions?
2. What key infrastructure may have concatenating or cascading impacts during extreme climate events, and how might these impacts be avoided?
3. What design standards (ARI or AEP) and planning periods for the various infrastructure components should be adopted for particular locations and over what time frames?
4. What financial analysis tools will allow longer planning periods and climate change adaptation options to be realistically evaluated and ranked?
5. What are the best tools and mechanisms for adaptive planning of management regimes for infrastructure and assets?

3.5 Cross-cutting research issues

The analysis of the four themes within this research plan and development of associated research questions led to the recognition of the need for a set of cross-cutting research questions to achieve a more complete programme of research on adaptation to climate change for settlements and infrastructure. These questions, which are listed below, have overlapping elements with each of the themes and provide an additional set of research priorities.

Research Priorities:

1. What would a climate-adapted Australian settlement look like?
2. How can communities' (of place/interest) expectations, behaviour and capacity in relation to climate change be influenced and what measures need to be used?
3. What are the barriers to adaptation planning in urban areas and how can factors that contribute to maladaptive decision making be minimised / removed?
4. What tools/methods for managing data and information are needed for identifying tipping points and for assisting decision making in relation to climate change?
5. What sectors of society are most vulnerable to climate change in urban and regional settlements? What is the nature of those vulnerabilities? At what spatial and temporal scales should adaptation responses for vulnerable communities be developed?
6. To what extent can geologic/geomorphic/historical/traditional/local knowledge be best applied to assessing vulnerability of existing settlements under different climate change conditions?
7. How can communication of climate change impacts and uncertainties be improved and communities be engaged in adaptive responses for settlements and infrastructure?

4. Research prioritisation

4.1 Criteria and considerations for prioritising research activities

Actions aimed at addressing the likely impacts of climate change span a wide spectrum of sectors. The COAG National Climate Change Adaptation Framework 2007 identifies eight sectoral areas, including settlements and infrastructure, for implementing adaptation actions. Since resources and capacity currently available in Australia for adaptation research are limited, the National Climate Change Adaptation Research Facility has developed a set of six criteria to be used for prioritising research topics within each theme area (see Appendix 1 for details). These criteria are being used in all the research plans being developed by NCCARF.

The criteria are:

1. Severity of potential impact to be avoided or degree of potential benefit to be derived (essential)
2. Immediacy of required intervention or response (essential)
3. Need to change current intervention and practicality of alternative intervention (essential)
4. Potential for co-benefit (desirable)
5. Cross-sectoral relevance (desirable).
6. Equity considerations (desirable)

A number of issues need to be considered when assessing priorities for climate change and adaptation research for settlements and infrastructure, in order to achieve the 'best' outcomes. An essential front-end need is for information about the (likely) magnitude of adverse impacts due to climate change, to guide decisions about the choice of adaptive interventions. It is relevant to seek evidence of actual impacts of climate change, particularly in vulnerable sectors or locations; although other factors will affect the amount of evidence required to guide decision-making. For example, less evidence may be needed to justify a relatively low-cost undertaking that will be useful in both current and future situations in any event. Research into adaptation and adaptive strategies must also address both short- and long-term time horizons.

4.2 Prioritising research activities related to adaptation to climate change for settlements and infrastructure

Ranking areas for research into high and low priority is difficult, given that many aspects of research are not directly comparable and timeframes for research vary. Nonetheless, an attempt has been made to apply the six prioritisation criteria to the lists of research questions identified in Section 3.

Applying the prioritisation criteria, research priorities were ranked from low to high. The full assessment matrix is in Appendix 2. From this, a list of high priority topics emerged and is provided in Table 3.

1 **Table 3. High Priority Research Questions for Settlements and Infrastructure**

Urban Planning and Management
<ul style="list-style-type: none"> • How can existing urban planning principles accommodate climate change and the uncertainty of climate change impacts? How should these principles differ based on the location and spatial scale of the settlement? What can we learn about the adaptive capacity of settlements from responses to stresses in the past? • How can the governance of urban planning in Australia, including formal and informal rules, nationally consistent approaches and guidelines and locally driven standards and outcomes, and the institutions responsible for decision-making, be improved to facilitate planning processes and outcomes which incorporate adaptation to climate change? • What are the particular planning needs of remote and Indigenous settlements under a changing climate?
Built Environment
<ul style="list-style-type: none"> • What are the design options and principles for adapting new buildings to climate change in different locations and how can these be implemented? What are the full life-cycle costs of different parts of the built environment and their critical inter-dependencies during extreme events? • What are the design options and principles for adapting existing buildings to climate change in different locations and how can these be implemented?
Vulnerable Coastal Communities
<ul style="list-style-type: none"> • How will demographic pressures and changes in different Australian coastal settlement types affect (1) potential impacts of extreme and gradual climate change, and (2) current policy and regulatory settings which govern the decision-making by government agencies, businesses and individuals? How will planning for coastal climate change impacts respond to local circumstances? • How well do we understand the relationship between climate and coastal processes? How can methods currently used to determine the physical risk on a regional basis of extreme inundation and coastal erosion from climatic and oceanic processes, either singularly or in combination, be improved and new methods developed and applied?
Infrastructure
<ul style="list-style-type: none"> • What is the vulnerability of infrastructure (individual and interlinked critical sectors) to existing and predicted climate change conditions at various spatial scales, considering average and extreme weather conditions? • What key infrastructure may have concatenating or cascading impacts during extreme climate events, and how might these impacts be avoided? • What design standards (ARI or AEP) and planning periods for the various infrastructure components should be adopted for particular locations and over what time frames?
Cross-cutting Issues
<ul style="list-style-type: none"> • What would a climate-adapted Australian settlement look like? • What sectors of society are most vulnerable to climate change in urban and regional settlements? What is the nature of those vulnerabilities? At what spatial and temporal scales should adaptation responses for vulnerable communities be developed?

- To what extent can geologic/geomorphic/historical/traditional/local knowledge be best applied to assessing vulnerability of existing settlements under different climate change conditions?

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5. Implementation issues

A detailed implementation plan is being developed in parallel to the development of this National Adaptation Research Plan for Settlements and Infrastructure. This section provides a broad overview of the resourcing issues that are likely to arise in the implementation of this research plan.

5.1 Research capacity

Across Australia there are a limited number of active professionals, academics and researchers well informed and already undertaking relevant and valuable research related to climate change adaptation. In general however professional planners, engineers, managers and environmental scientists working for government, industry and infrastructure agencies are poorly informed and only recently becoming aware of climate change adaptation issues. There is clearly considerable scope and a need to develop capacity for practising professionals, academics and researchers in this area.

The issue has been recognised by various state and territory and local governments in requiring considerations of climate change related to developments/projects/infrastructure subject to flooding and coastal erosion/inundation for several decades. There are numerous reports to government and also independent publications by professional and learned associations, including: ATSE's 2008 Assessment of Impacts of Climate Change on Australia's Physical Infrastructure; SMEC's 2007 Climate Change Adaptation Actions for Local Government; and the Institution of Engineers Australia's 2004 Guidelines for responding to the effects of Climate Change in Coastal and Ocean Engineering.

Substantial debate and research is reported in Australian planning, built environment and engineering conferences across settlements and infrastructure incorporating themes of urban planning, built environment, coastal environments and infrastructure (energy, water, flooding, transport and communications). Refereed journal publications related to climate change adaptation are however few but expanding in recent years.

However, research capacity in settlements and infrastructure adaptation is distributed sparsely across the nation in relatively small research groups (varying in member numbers and activity) housed within various University Departments/Centres in engineering, built environment, planning, economics, environmental and social science. Specific research groups are also evident in Australian Government agencies such as CSIRO, Geoscience Australia and Bureau of Meteorology. In the main these research groups are engaged with stakeholders including government, infrastructure authorities, industry and consultants. The research is at varying levels multi-disciplinary.

There is a valuable role for NCCARF and the Adaptation Network for Settlements and Infrastructure to support and progress valuable research by raising awareness across the various research groups and providing the opportunities for collaboration and access to prioritised funding.

1 **5.2 Engagement**

2 It is essential that the needs of research end-users be taken into account early in the design of
3 research priorities to ensure that research outputs are useful, and of value to a variety of
4 stakeholders. Much of this research involves issues where problem identification and research
5 framing are substantial research issues in their own right: working out the right question is often
6 more important than working out the answer. This frequently involves strong participatory
7 engagement between researchers and end users or research partners.

8
9 These participatory or 'action research' approaches seek to engage key stakeholders in helping
10 to define the research questions to be addressed (such as through advisory groups or steering
11 committees), rather than looking within the research community to define the research agenda.
12 Such approaches have been shown to generate highly innovative research projects and
13 outcomes, in part because they inject new ideas and encourage cross fertilisation between
14 disciplines in order to address these externally-defined challenges.

15
16 Early genuine engagement and a continuing partnership ethic is seen as valuable central
17 features of the research. This engagement also provides an important platform for identifying
18 what insights are useful or of interest to different stakeholder groups, and assisting the
19 communication of these ideas and tools to relevant constituencies.

20
21 Understanding the context and manner in which research will be used will help determine what
22 modes of dissemination and uptake are most appropriate. Very few end users will access
23 primary research directly through traditional academic publications, preferring instead toolkits,
24 presentations and workshops, interactive web-based material, CDs, DVDs and so on. The
25 expected beneficiaries of adaptation research are, in general, secondary consumers of research
26 outputs.

27
28 A critical starting point in deciding how best to disseminate information and promote uptake will
29 be to identify relevant primary and secondary end-users for particular research priorities and
30 clarify the uses to which research outputs will be put. For example, will research results be used
31 to assist individual responses to climate change 'from the bottom up', or primarily used to inform
32 'top down' policy, legislative and regulatory responses? Some work, for example, may directly
33 inform the business decisions. Other research may speak directly to policy-makers, informing
34 their choice of policy intervention.

35
36 There are already several key industry groups and peak bodies supporting the work of the
37 stakeholders who will need to use the research outputs of this NARP. NCCARF will work with
38 these groups as well as the research network for Settlements and Infrastructure to ensure that
39 existing mechanisms are used as much as possible but supplemented where necessary to
40 enhance the prospects that research outputs will be applied.

43 **5.3 Additional funding sources**

44 It will be necessary to look for funding sources additional to those made available through the
45 Adaptation Research Grants Program to fully address the key research objectives outlined in
46 this NARP and to undertake essential research programs.

47
48 The Australian Research Council grants program is likely to be the first port of call for many
49 researchers and research institutions that seek additional support. Relevant grants offered by
50 the ARC include

- 51 • Discovery Projects. A variety of fellowships are offered under the scheme to nurture the
52 talents of Australia's most promising early-career researchers and support established
53 researchers.

- 1 • Discovery Future Fellowships. Future Fellowships are offered to promote research in areas
2 of critical national importance by giving world class researchers incentives to conduct their
3 research in Australia.
- 4 • Linkage Infrastructure, Equipment and Facilities. The scheme fosters collaboration through
5 its support of the cooperative use of national and international research facilities. Essentially,
6 the scheme provides funding for large-scale cooperative initiatives so that expensive
7 infrastructure, equipment and facilities can be shared by researchers in partnered
8 organisations. However, the ARC may fund single-organisation proposals in some
9 circumstances.
- 10 • Linkage Projects. The scheme supports collaborative research and development projects
11 between higher education organisations and other organisations, including within industry, to
12 enable the application of advanced knowledge to problems. In recommending funding for
13 proposals under Linkage Projects, the ARC may take into consideration the likely benefit of
14 the research to Australian regional and rural communities.
- 15 • Linkage International Projects. The scheme encourages networks and collaborations
16 between researchers, research teams and research centres of excellence in Australia and
17 overseas. Researchers awarded Linkage International funding may participate in national
18 and international exchanges between research organisations.

19
20 Further potential funding sources, particularly relevant to urban and regional planning, include
21 state and territory government agencies and local government collective organisations. This
22 form of direct research funding would be outside of their possible involvement in ARC Linkage
23 applications.
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Appendix 1 Criteria for setting research priorities

The criteria listed below will guide the research planning process to set research priorities.

Essential

1. Severity of potential impact/ or degree of potential benefit

What is the severity of the potential impact to be addressed or benefit to be gained by the research? Potentially irreversible impacts and those that have a greater severity (in social, economic or environmental terms) will be awarded higher priority.

2. Immediacy of required intervention or response

Research will be prioritised according to the timeliness of the response needed. How immediate is the intervention or response needed to address the potential impact or create the benefit? Research that must begin now in order to inform timely responses will receive a higher priority than research that could be conducted at a later date and still enable a timely response.

3. Need to change current intervention and practicality of intervention

Is there a need to change the intervention used currently to address the potential impact being considered. If yes, what are the alternatives and how practical are these alternate interventions? Research that will contribute to practicable interventions or responses will be prioritised. Does research into the potential impact of the intervention being considered contribute to the knowledge base required to support decisions about these interventions?

Desirable

4. Potential for co-benefit

Will the research being considered produce any benefits beyond informing climate adaptation strategies?

5. Potential to address multiple, including cross-sectoral, issues

Will the research being considered address more than one issue, including cross-sectoral issues?

6. Equity considerations

Will research priorities recognise the special needs of particular groups in Australia?

Appendix 2. Prioritising research needs

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
1.	Urban Planning and Management							
1.1	How can existing urban planning principles accommodate climate change and the uncertainty of climate change impacts? How should these principles differ based on the location and spatial scale of the settlement? What can we learn about the adaptive capacity of settlements from responses to stresses in the past?	High	High Need to influence current planning practices, as planning decisions come with long-term commitments and can have consequences over many decades	High	Yes	Yes enhance public health	Yes	High
1.2	How can planning approaches address the multiple objectives of urban adaptation to climate change impacts, mitigation of greenhouse gas emissions and biodiversity conservation?	Medium	High	Medium	Very High Planning actions can most effectively link the multiple needs	Yes	Yes	Medium
1.3	How can the governance of urban planning in Australia, including formal and informal rules, nationally consistent approaches and guidelines and locally driven standards and outcomes, and the institutions responsible for decision-making, be improved to facilitate planning	High	High	High				High

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
	processes and outcomes which incorporate adaptation to climate change?							
1.4	What are the particular planning needs of remote and Indigenous settlements under a changing climate?	High	High	High			Very High Little effort has been undertaken to address the long term needs of these communities	High
1.5	What information about urban and regional planning and climate change impacts, in what form and at what resolution, should be publicly available? How should climate change impacts and adaptation information be presented and made available to urban and regional planning decision-makers?	Medium	Medium	Medium				Medium
2.	Built Environment							
2.1	What are the biophysical pathways (material failure, coastal erosion, etc.) by which climate change is likely to damage buildings and infrastructure? What climate and other information is needed to understand likely damages and how can this information be	High	Medium	Medium				Medium

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
	presented in a clear, useable form to decision-makers?							
2.2	What are the design options and principles for adapting new buildings to climate change in different locations and how can these be implemented? What are the full life-cycle costs of different parts of the built environment and their critical inter-dependencies during extreme events?	Medium	High	High			High	High
2.3	What are the design options and principles for adapting existing buildings to climate change in different locations and how can these be implemented?	High	High Vast numbers of existing buildings lack provision for the impacts of climate change	High	Yes			High
2.4	What are the costs and benefits of adapting the built environment and how can they be reliably estimated? Who will bear these costs and who will benefit? What financial and other policy instruments can be used to address equity impacts of these costs?	High	Medium	Medium			High	Medium
2.5	What additional information is needed concerning materials and loading to inform the development of design standards that take appropriate account of future climate scenarios? At what	High	Medium	Medium				Medium

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
	intervals should standards and tools (such as the Australian Rainfall and Runoff Handbook) be reviewed to ensure that they provide effective guidance to decision makers?							
3.	Vulnerable Coastal Communities							
3.1	How will demographic pressures and changes in different Australian coastal settlement types affect (1) potential impacts of extreme and gradual climate change, and (2) current policy and regulatory settings which govern the decision-making by government agencies, businesses and individuals? How will planning for coastal climate change impacts respond to local circumstances?	High Population growth in vulnerable coastal areas is projected to increase dramatically over the next 20 to 30 years	High Planning reforms in many states provide opportunities to address issues of population pressure in areas potentially subject to impacts of climate change	High				High
3.2	How do coastal communities perceive coastal vulnerability in different settlements and to what extent is that influencing adaptive capacity now and likely to influence it in the future under scenarios of climate change?	Medium	Medium Generally of longer term significance	High Better understanding of communities' perceptions of their vulnerability will help understand how they respond to changes				Medium
3.3	How well do we understand the	High	High	Medium				High

	RESEARCH TOPIC	Severity Or Benefit	Essential		Potential co-benefits	Desirable		Overall Priority Ranking
			Immediacy	Need to change intervention / Practicality		Cross-sectoral relevance	Equity considerations	
	relationship between climate and coastal processes? How can methods currently used to determine the physical risk on a regional basis of extreme inundation and coastal erosion from climatic and oceanic processes, either singularly or in combination, be improved and new methods developed and applied?	Exposure to extreme events in the past and at present in coastal areas provide lessons for impact analysis and also reveal gaps in knowledge of processes which require further research						
3.4	Better information is needed about hydrodynamic processes and interrelationship with sediment supply over time, including thresholds and tipping points that could result in fundamental landform changes. What is the switchover point from accreting to erosion? How soon is this phenomenon likely to happen? What are the locations at greatest risk?	High	Medium	Medium				Medium
4.	Infrastructure							
4.1	What is the vulnerability of infrastructure (individual and interlinked critical sectors) to existing and predicted climate change conditions at various	High	High For existing infrastructure need to understand which	High Consideration to be given to likely tipping points when				High

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
	spatial scales, considering average and extreme weather conditions?		infrastructure is already vulnerable and needs to be retrofitted. As infrastructure decisions generally come with long-term commitments, new infrastructure needs to consider future climate change projections.	major new structures or protective works will be required to lessen the impacts of climate change				
4.2	What key infrastructure may have concatenating or cascading impacts during extreme climate events, and how might these impacts be avoided?	High	High	High				High
4.3	What design standards (ARI or AEP) and planning periods for the various infrastructure components should be adopted for particular locations and over what time frames?	High	High	High Current codes and standards do not consider uncertainty estimates of climate change impacts	Yes	High		High
4.4	What financial analysis tools will allow longer planning periods and climate change adaptation options to be realistically evaluated and ranked?	High	Medium Generally of longer term importance	Medium				Medium

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		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
4.5	What are the best tools and mechanisms for adaptive planning of management regimes for infrastructure and assets?	Medium	Medium	Medium				Medium
5.	Cross-cutting							
5.1	What would a climate-adapted Australian settlement look like?	High	High Decisions relating to settlements come with long-term commitments, so any decision made today will have impacts over several decades	Low Completely new visions of settlements may require significant changes to the way settlements are currently planned and may require time before they are accepted (both politically and by the public)	Yes Relevant to multiple fields of research, especially mitigation and sustainability issues	Yes Relevance for mitigation, health	Yes	High
5.2	How can communities' (of place/interest) expectations, behaviour and capacity in relation to climate change be influenced and what measures need to be used?	High Many adaptation responses fail because they are not accepted by the community, so a better understanding of	Medium Important over the long-term	Medium			Yes	Medium

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
		communities' expectations and behaviours will help develop appropriate adaptation responses						
5.3	What are the barriers to adaptation planning in urban areas and how can factors that contribute to maladaptive decision making be minimised / removed?	Medium	Medium Important over the long term	Medium Some barriers may be difficult to remove, for example if they are due to the way organisations or institutions are set up in our political / economic system				Medium
5.4	What tools/methods for managing data and information are needed for identifying tipping points and for assisting decision making in relation to climate change?	Medium	Medium Tipping points unlikely to occur immediately, so more relevant for the longer term when climate change impacts more severe / pronounced	Medium				Medium
5.5	What sectors of society are most vulnerable to climate change in	High Not all sectors	High Decreasing	High			High	High

	RESEARCH TOPIC	Essential			Desirable			Overall Priority Ranking
		Severity Or Benefit	Immediacy	Need to change intervention / Practicality	Potential co-benefits	Cross-sectoral relevance	Equity considerations	
	urban and regional settlements? What is the nature of those vulnerabilities? At what spatial and temporal scales should adaptation responses for vulnerable communities be developed?	of society will be as equally vulnerable so important to identify most vulnerable ones to address their specific vulnerabilities as early as possible	vulnerability of communities generally a medium-long term strategy so needs to commence as soon as possible, thus important to identify most vulnerable communities as early as possible					
5.6	To what extent can geologic/geomorphic/historical/traditional/local knowledge be best applied to assessing vulnerability of existing settlements under different climate change conditions?	High	High	High				High
5.7	How can communication of climate change impacts and uncertainties be improved and communities be engaged in adaptive responses for settlements and infrastructure?	High Appropriate communication tools and methods for community engagement can lead to more effective adaptation responses	Medium	Medium				Medium