Building resilience to a changing climate

A climate change adaptation plan for the South Australian Murray-Darling Basin

Government of South Australia

Natural Resources
SA Murray-Darling Basin

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The Ngarrindjeri Regional Authority and the First Peoples of the River Murray and Mallee Region provided comments and input into the project.

Disclaimer

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Preface

We are pleased to present the first climate change adaptation plan for the South Australian Murray-Darling Basin.

The productive systems and natural environments we enjoy are interlinked and dependent on each other. They support agriculture, food production and tourism which are critical to our region's current and future economy as well as supporting the lifestyle of the people and communities in our region. Innovation will be critical to ensuring that our region is able to adapt to changing circumstances including droughts, floods and fires.

It is intended that the plan will provide decision-makers in our communities with a much more complete picture of the climate challenges ahead in both the short and long term. The plan was two years in the making and has engaged extensively with the key sectors of our diverse region taking a "triple bottom line" approach by bringing together various interest groups including regional development, natural resources management, local government, the health sector and industry.

The actions outlined in the Climate Change Adaptation Plan for the South Australian Murray-Darling Basin will need translating into strategies and actions for all sectors to ensure we are effectively preparing and planning together as a region for a different climate future.

At this time in our history it is time to drive innovation and new thinking by embracing new technology, research and development and taking up new business approaches to access new markets. Being open to new ways of doing things will ensure that we can overcome future challenges and be ready to take advantage of opportunities.

With your support, the projects that flow from implementing this plan will mean our region builds resilience and continues to be a great place to live and do business in.

We commend to the region the climate change adaptation plan for the South Australian Murray-Darling Basin.

Neil Martinson
Mayor, Renmark Paringa Council
and Chair, RDA Murraylands and Riverland

Sharon Starick
Presiding Member,
South Australian Murray-Darling Basin
Natural Resources Management Board

Mayor David Burgess
President
Murray and Mallee Local Government Association

Indigenous perspective

Indigenous culture has adapted and survived thousands of years of climate change and variability and holds lessons for the contemporary Australian way of living. As the value of traditional knowledge in developing an adaptation plan is seen as crucial, the steering group has seen as essential to put in place a process of early and ongoing engagement with the traditional owner groups and other Aboriginal people in the region.

Indigenous Australians experience a disproportionate vulnerability to the impacts of climate change. Indigenous peoples have been identified by the International Panel on Climate Change as particularly vulnerable to the detrimental impacts of a changing climate. Plants and animals important for cultural practices, cultural sites and health concerns are at risk due to changing climatic conditions.

Ngarrindjeri perspective

Ngarrindjeri are recognised as the traditional owners of the Lower Murray, the Lower Lakes and Coorong and surrounding areas and have lived on and managed their Ruwe/Ruwar (lands and waters) for thousands of years.

> Ngarrindjeri have long experience with climate change and sea level changes. Our Creation stories tell us about the flooding of our lands and changes to the river and the coastlines. Our Old people have watched the impacts of degradation of our lands and waters since European invasion. We recognise the huge impacts of global warning on our lands and waters and all living things.
>
> *(Ngarrindjeri Nation Yarluwar-Ruwe Plan 2006)*

The Ngarrindjeri are committed to full and comprehensive engagement with and participation in the planning and implementation of all activities that contribute to the restoration, protection and enhancement of Ngarrindjeri Yarluwar-Ruwe (sea country). Ngarrindjeri recognised the importance of climate change in their Yarluwar-Ruwe Plan (Sea Country Plan). This plan, through the Ngarrindjeri Yarluwar-Ruwe Program, guides Ngarrindjeri caring for country actions to build the health of the environment and thus the health of the Ngarrindjeri people.

Further, Ngarrindjeri knowledge integrates well with scientific knowledge to support a more holistic approach in addressing the complex issues associated with climate change adaptation.

Ngarrindjeri believe that human-induced accelerating climate change will have a long and significant impact on the region and thus major impacts on their culture, livelihoods and wellbeing. Negative impacts on the environment result in significant impacts to Ngarrindjeri health, wellbeing and cultural heritage.

Extension of current practices will be insufficient on their own to adequately address the extent of these impacts. Renewed efforts and further investments are necessary to further build resilience and adaptive capacity as is acting now to address long-term risks.

Ngarrindjeri have negotiated a Kungun Ngarrindjeri Yunnan Agreement (KNYA 2009) – Listening to Ngarrindjeri Talking Agreement with the Government of South Australia. This agreement lays the foundation for collaborative management of Ngarrindjeri Ruwe-Ruwar (lands and waters). The Ngarrindjeri Regional Authority (NRA), the representative body of the Ngarrindjeri Nation, has KNY agreements with other partners in the region and also supports the implementation of the Coorong, Lower Lakes and Murray Mouth Program component of the Murray Futures Program through a strong partnership with the Department of Environment, Water and Natural Resources (DEWNR). The NRA seeks ongoing partnerships to strengthen its active engagement and to build capacity for all communities.

Ngarrindjeri welcome this opportunity of ongoing involvement in all of the priority themes working from Ngarrindjeri's unique relationship with Ruwe/Ruwar. The NRA looks forward to additional partnerships to mitigate and adapt to the changing climate.

The First Peoples of the River Murray and Mallee Region

The First Peoples of the River Murray and Mallee Region (First Peoples), the Ngaiawang, Ngawait, Nganguruku, Erawirung, Ngintait, Ngaralte, and Ngarkat, are the traditional owners and custodians of the greater River Murray and Mallee region.

First Peoples aims include: supporting the continuation of culture and preservation of heritage; protecting and repairing country, waters, flora, fauna and air; promoting employment and education opportunities for the First Peoples; and building relationships with stakeholders and communities within the Murray and Mallee region.

The River Murray and Mallee region, particularly the river and its floodplains and wetlands, are of great spiritual and cultural significance to the First Peoples. The area has sustained them for many thousands of years and it continues to be a vital part of contemporary First Peoples culture.

First Peoples and other Indigenous people are very concerned about climate change and its likely impacts on the interrelated issues of community wellbeing, river flows, flora and fauna, Aboriginal heritage, and the ability to maintain traditional practices and knowledge.

First Peoples have been actively involved in the development of this regional adaptation plan to ensure their knowledge is utilised, their concerns are considered, and that they are involved in future decision-making and activities to address, or adapt to, climate change.

Executive summary

Context

The South Australian Murray-Darling Basin's social, economic and ecological systems are well adapted to climate variability, having had to adapt and respond to severe droughts in the past such as the Millennium Drought (1995–2009). Yet climate change will result in a long-term shift in the region's climate, with conditions expected to be warmer and drier on average, the risk of bushfires greater, and ocean conditions changing, such as sea level rise.

This regional adaptation plan is an initiative of the South Australian Murray-Darling Basin Natural Resources Management Board, Regional Development Australia (Murraylands and Riverland), Murray & Mallee Zone Emergency Management Committee, Murray Mallee Local Government Association and the Department of Environment, Water and Natural Resources. The aim of the plan is to show how the region can build resilience to the impacts of climate change and make sure the region is adaptive and sustainable and continues to be a place where people want to live, visit, invest and conduct business.

Process

Development of the plan was informed by past studies and reports relevant to climate change in the region as well as the experience and local knowledge of stakeholders from across all major sectors, with over 150 people participating in interviews, workshops, and information and feedback sessions.

The project was undertaken in three main stages: (1) values mapping and key decision timeline analysis to identify priority indicators for a vulnerability assessment; (2) an integrated vulnerability assessment which was used to identify key areas of decision-making; and (3) identification and prioritisation of adaptation actions within and between sectors.

Priorities for adaptation

Based on the results of the integrated vulnerability assessment, eight key areas of decision-making were developed to provide a focus for adaptation actions and relate to the following themes:

1. **Native vegetation**
2. **Pest plants and animals**
3. **Coorong and Lower Lakes**
4. **Vulnerable members of the community**
5. **Emergency services**
6. **Essential services**
7. **Irrigation**
8. **Dryland farming**

The identification of the themes in this list does not mean that other assets, services or characteristics of the region are not vulnerable to climate change, but that they were assessed to be less vulnerable than those listed. Indigenous knowledge, rights and interests need to be involved in each of the above as a high priority including Ngarrindjeri's unique relationship to Ruwe/Ruwar.

This plan identifies priority adaptation actions in relation to these key areas of decision-making. Most relate specifically to individual sectors in the region and will require them to further prioritise and implement the actions. Although some of the actions may form part of current practice or be existing ideas, adaptation will require their initiation or acceleration. A summary of immediate and high priority actions is provided in Table 1.

As a regional scale plan, consideration was also given to actions that are a priority across multiple key areas of decision-making and sectors (Table 2). This assessment was based on workshop feedback regarding cross-sectoral priorities and areas for potential maladaptation i.e. when action taken by one sector has a negative effect on another.

The first five adaptation actions are arguably a continuation of current practice. This suggests that the region has already built significant capacity to respond to a variable climate, influenced largely by experience with past droughts such as the Millennium Drought. In contrast, the future operation and location of the barrages is one of the most transformational adaptation actions identified in this plan.

Importantly, action is not required immediately regarding the barrages because sea levels are expected to rise slowly over the coming century. However, sea level rise impacts should be considered in the design of any future barrages upgrades. The immediate priority is to commence engagement to increase community awareness and to promote informed debate about the future operation and location of the barrages. Engagement needs to be supported by (a) detailed modelling of the impact of varying amounts of sea level rise on salt water incursions into Lake Alexandrina and (b) exploration of the sequencing of different adaptation options through time through use of an adaptation pathways approach.

Implementing the plan

Development of the plan aimed to understand the decision-making context for adaptation in the region at the present time, recognising that it ultimately influences what decisions they are willing to take. Stakeholders identified the following key enablers and barriers to adaptation that influence the decision-making context in the region:

Enablers

- Leadership, in the form of champions at all levels in the community;
- Knowledge, including local knowledge and science, about climate change impacts. This needs to be made available, accessible and relevant; and
- Greater involvement of youth, indigenous people and elected bodies from other locations to share their experiences, knowledge and information.

Barriers

- Time frame mismatches occur because many people and institutions only focus on the short term whereas adaptation requires planning now for the longer term. People also often only respond to an immediate crisis;
- Lack of resources, in terms of funding and flow on effects to lack of personnel and R&D; and
- Lack of knowledge about climate change impacts, the rural context and how to use existing adaptation options like the water market.

The need for information and knowledge appears near the top of both lists. This is a common response in discussions about adapting to climate change and requires particular attention in developing adaptation strategies for the region.

As the plan is implemented in the future, key stakeholder organisations in the region, including Aboriginal organisations, will need to further prioritise sector-specific and cross-sectoral adaption priorities and determine which of the enabling conditions and barriers to adaptation should be addressed.

The Government of South Australia has an agreement with the Ngarrindjeri Regional Authority which provides a mechanism for supporting Ngarrindjeri engagement. This and other agreements demonstrate commitment to working closely with Ngarrindjeri on projects like this adaptation plan.

This plan needs to be periodically reviewed, in the spirit of adaptive management, every two to three years to consider new information on climate change projections and impacts and to account for changes in adaptive capacity.

Table 1. Summary of priority actions for key areas of decision-making and lead stakeholders. DEWNR (Department of Environment, Water and Natural Resources)

Key area of decision-making	Priorities for adaptation	Lead stakeholder(s)
Native vegetation—how do we maintain functional vegetation communities that provide habitat for regional birds and mammals (many of which exist outside of DEWNR reserves) in the face of warmer and drier conditions and more frequent and intense bushfires?	Immediate priority is to support and promote landholders managing high value native vegetation on private properties.	Natural Resources South Australian Murray-Darling Basin (DEWNR)
Pest plants and animals—how do we improve our adaptive management to minimise the impact of pest plants and animals on agriculture and biodiversity from rangelands areas in the north of the region in response to warmer and drier conditions?	Immediate priority is to rapidly identify and assess the risk of emerging pest species. High priorities also include greater use of risk assessments to focus on current priority pest species and building greater government agency capacity to respond to a range of disturbance triggers like climatic extremes and ecological disturbance.	Natural Resources South Australian Murray-Darling Basin (DEWNR); Biosecurity SA

Table 1, continued.

Key area of decision-making	Priorities for adaptation	Lead stakeholder(s)
Condition of the Coorong and Lower Lakes—how do we protect key habitats and species in the Coorong and Lower Lakes region as river flows continue to decline, salinity levels in the estuary rise in response to increasing sea levels pushing more sea water into the region, and the risk of pest plant and animal incursions increases?	The immediate priority is to commence social engagement to increase community awareness and to promote informed debate about the future adequacy, operation and location of the barrages. Engagement needs to be supported by (a) detailed modelling of the impact of varying amounts of sea level rise on the frequency, duration and extent of salt water incursions into Lake Alexandrina and (b) exploration of the sequencing of different adaptation options.	Natural Resources South Australian Murray-Darling Basin (DEWNR); Murray-Darling Basin Authority; SA Water.
Vulnerable members of the community—how do we help vulnerable members of the community maintain health and well-being which may otherwise be affected by increasing frequency and intensity of extreme events such as bushfires and heatwaves?	Immediate priorities are to help vulnerable members of the community be better prepared for extreme events by building social capital (connectivity and resilience) and encouraging the construction of more climate resilient buildings. During extreme events there needs to be greater focus on response services like Telecross REDi service. After events the focus should be on counselling, social support and trauma services. This may require expanding the circumstances under which declaration is made to include severe heatwaves.	Regional Councils; NGO service providers; SA Health; State Emergency Service.
Emergency services management—how can we manage and reduce where possible the growing demand for emergency services as extreme events such as bushfires become more frequent and intense and rates of volunteering decline?	An immediate priority is to facilitate increased rates of volunteerism. Other priorities are to prepare for emergency events by encouraging the refurbishment or construction of critical new buildings and infrastructure so that they are more resilient to extreme events and installing replaceable or removable non-critical built structures in high risk areas.	Zone Emergency Management Committeeand emergency services providers
Essential services—how can we establish and maintain telecommunications, electricity and water management infrastructure, which together support the regional economy, in the face of climate extremes such as increasing frequency of bushfires, which may physically damage infrastructure, and generally increasing temperatures which are likely to increase demand for services?	An immediate priority is to develop adaptive infrastructure for local solutions to back up and power storage for water, sewer and telecommunications infrastructure, as well as domestic storage to support distributed power systems like solar photovoltaic (PV). Actions already being implemented as part of current practice that will continue to be important include: operational risk management strategies to protect critical assets from extreme events, and planning and risk assessment activities such as developing a key assets register using the National Emergency Risk Assessment Guidelines.	Essential service providers

Key area of decision-making	Priorities for adaptation	Lead stakeholder(s)
Irrigated horticulture—how can we build on existing work in the irrigation sector to ensure that levels and quality of production can improve in the face of warmer and drier conditions and potentially reduced river flows and water allocations?	An immediate priority is for further evolution of water market products and greater adoption of water-use efficient technologies.	Irrigators; irrigation trusts; water market operators; DEWNR.
Dryland (rain dependent) farming—how will farmers maintain the productivity of existing cropping-based farming systems under warmer and, most likely, drier conditions in the future?	No-till or reduced-till practice, crop breeding and soil improvement are high priority adaptation actions that form part of current practice and, where applicable and cost effective, should continue to be encouraged. High priority emerging adaptation actions are likely to focus on improved weather forecasting, which will benefit multiple other sectors, and greater adoption of collaborative farming models. Enhancing farmer business and decision-making skills is also important.	Farmers; industry associations and research and development organisations; Bureau of Meteorology.

Table 2. Summary of cross-sectoral adaptation actions.

Action	Related key area of decision-making theme	Lead responsibility
Improve the identification, prioritisation and management of pest plants and animals	Native vegetation, pest plants and animals, Coorong and Lower Lakes, irrigation, dryland farming	Natural Resources SAMDB (DEWNR), Biosecurity SA
Facilitate increased participation in community activities to build connectivity and resilience	Vulnerable members of the community, emergency services, pest plants and animals	Regional Councils
Improve water-use efficiency	Irrigation, but with region-wide economic benefits	Private irrigators with the support of irrigation trusts where relevant
Irrigation	Native vegetation, Coorong and Lower Lakes	DEWNR with support from water research organisations
Improve seasonal weather forecasting	Native vegetation, pest plants and animals, emergency services, irrigation, dryland farming	Bureau of Meteorology
Establish and implement bushfire management, response and recovery plans	Native vegetation, pest plants and animals, emergency services, dryland farming	Natural Resources SAMDB (DEWNR), Zone Emergency Management Committee and emergency services providers
Reassess the future operation and location of the barrages	Native vegetation, pest plants and animals, Coorong and Lower Lakes, irrigation	Natural Resources SA MDB (DEWNR), Murray-Darling Basin Authority, SA Water

1 Introduction

1.1 Background

The South Australian Murray-Darling Basin contains a diverse range of natural and cultural landscapes and production systems which together sustain the communities of the region. The region is characterised by a highly variable climate. Hot and mostly dry summers are followed by cool winters with rainfall that can vary significantly from year to year. Flows in the River Murray are driven mostly by rainfall in upstream catchments that is similarly highly variable between and within years. Together, this means that the environment and communities of the region already have a high tolerance to a variable climate, and production systems have had to develop strategies to respond to this variability. The most extreme recent example of this variability was the Millennium Drought, which negatively affected the economy, environment, and communities of the region as a result of locally low rainfall and record low inflows to the River Murray.

Responding to climate change, though, involves more than just dealing with increasing variability; the region will also need to respond to changing average conditions, like warmer summers and, most likely, warmer and drier winters. Planning for climate change is not new to the South Australian Murray-Darling Basin, and many sectors such as natural resource management, irrigation, and dryland farming have already invested in research to better understand impacts and response options. Furthermore, the region has recognised the benefits of working together to tackle climate change.

Development of this plan builds on past projects such as:

- The Strengthening Basin Communities Program climate change project, which was implemented by the South Australian Murray-Darling Basin Natural Resource Management Board and the 11 councils in the region, culminating in the Adaptation and Emerging Opportunities Plan for the SA Murray-Darling region (Siebentritt et al. 2011) and a Climate Change Adaptation Project impact assessment (Summers et al. 2011)
- Gap identification of the climate change impacts on the Murray-Darling Basin region of South Australia project (Balston et al. 2012).

1.2 This plan

Under South Australia's strategic plan (target 62) and the South Australian climate change adaptation framework, areas across the state are required to develop a regional climate change adaptation plan. In the South Australian Murray-Darling Basin, this is being progressed by representatives of the natural resource management, local government, regional development, emergency services management, indigenous and healthcare sectors.

The plan was developed over a two-year period in two phases, with this report being the culmination and collation of all available previous studies. Complementary processes and plans have been a rich source of information in this plan's preparation and each sectoral plan informed an integrated approach to climate change planning. Examples of other relevant regional plans include the South Australian Murray-Darling Basin Natural Resources Management Plan (Volume A – Strategic Plan), Murray Mallee Zone Emergency Plan, RDA Murraylands and Riverland Regional Roadmap and the Murray and Mallee Regional Public Health Plan.

Developing a regional adaptation plan will show how the region can limit the effects of climate change and take advantage of any opportunities that arise to adjust to impacts. By doing so, the plan will make sure the region is adaptive and sustainable and continues to be a place in which people want to live, visit, invest and do business.

The plan has been developed with the philosophy that

- we do not need to know everything to start planning and acting now
- we must continue to build our knowledge and fill gaps as new information becomes available and
- adaptation is a process and the plan provides a pathway forward that must be monitored and reviewed in order to change our course if needed.

The development of this plan aimed to:

- build increased understanding of the adaptive capacity of the region
- develop a more coordinated approach to planning for and managing climate change
- contribute to emergency risk management
- build collaboration and desire for regional partners to work together to identify risks and opportunities and
- develop a greater degree of understanding of the work already completed in the region and by whom.

The plan identifies:

- potential future impacts of climate change (Section 4)
- areas of decision-making that most need to consider climate change (Section 5)
- priority adaptation options (Section 6) and
- the approach to implementing the plan (Section 7).

While development of this plan has at times focused on learning about areas of vulnerability to climate change across the region's sectors, the focus is on building resilience; that is, taking action that can help the region to resist the effects of changing climate and, where change does occur, to respond and adapt in a timely and effective way.

2 The region[1]

The South Australian Murray-Darling Basin region covers 56,703 square kilometres or about 7 per cent of South Australia (Figure 1). The landscape varies from the low-lying coastal plains of the Coorong to the flat expanse of the Mallee to the steeper slopes of the Eastern Mount Lofty Ranges. The River Murray is a dominant and influential feature of the region due to the importance of its waters for irrigated agriculture and the environment and in meeting domestic, livestock, and industrial needs.

The region's climate can be characterised as Mediterranean, characterised by hot dry summers and cool wet winters. Annual rainfall is highly variable and ranges from 235mm at Loxton in the central part of the region, to 387mm at Lameroo, near the south-eastern corner of the region, to 768mm at Mount Barker at the south-western edge of the region.

The region supports a population of approximately 125,000 people (about 8 per cent of the state's population) across 15 local government areas. The population grew by 12 per cent between 2001 and 2011 largely due to growth in the Ranges to River district. Population is centralised around the larger river towns of Goolwa, Murray Bridge, Remark, Loxton, Berri, Barmera, Waikerie and Mannum, and the regional centres of Mount Barker, Burra, Karoonda, Strathalbyn and Meningie. The indigenous population comprises 2 per cent of the total population and between 2006 and 2011 there was a 2.2 per cent growth in the international migrant population.

The South Australian Murray-Darling Basin is one of South Australia's most ecologically diverse and agriculturally productive regions. It supports a wide range of flora, fauna, natural environments and human activities.

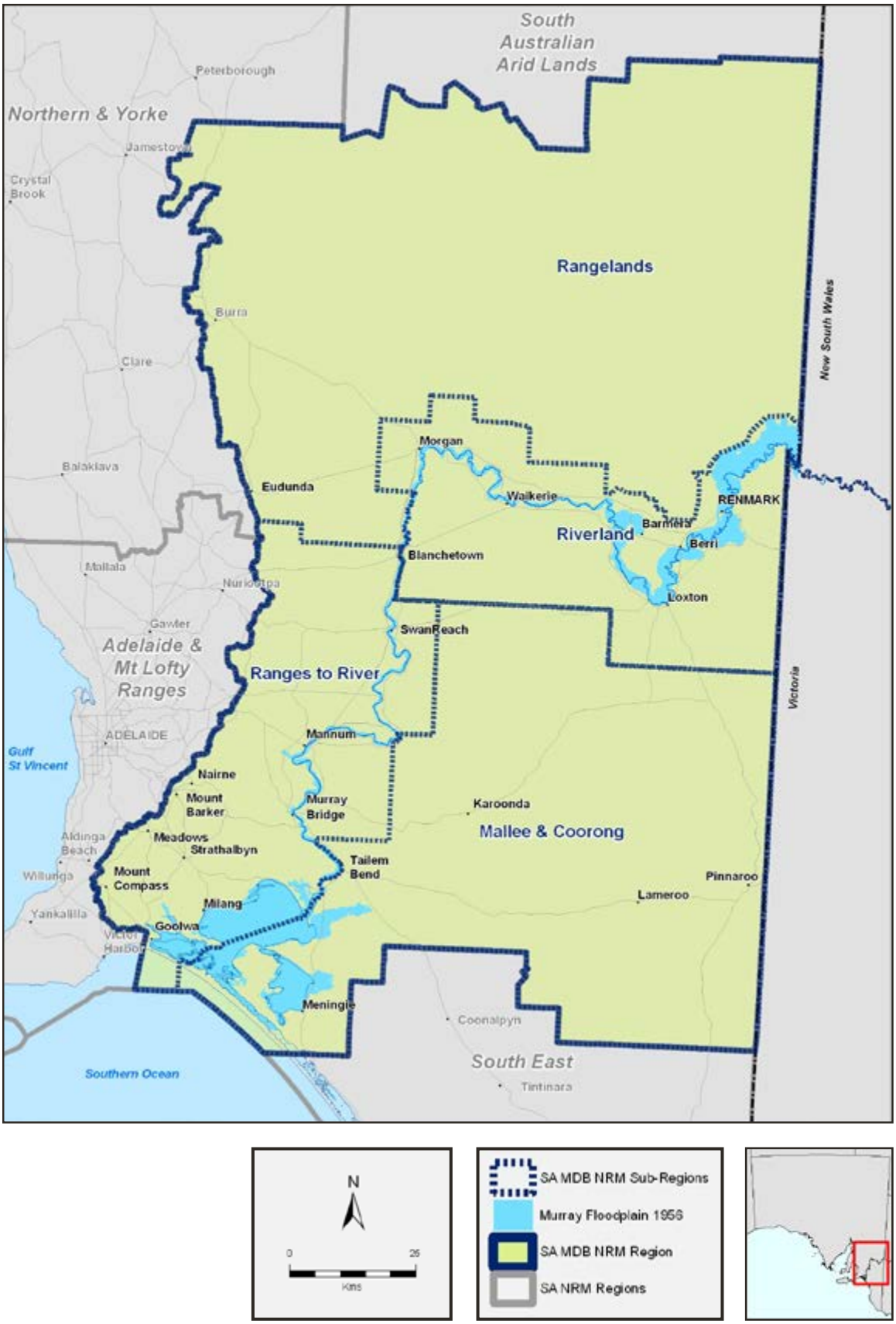
The regional economy is underpinned by agriculture (14% of employment across the region), health care and social services (12%), retail trade (11%) and manufacturing (11%). While agriculture is the dominant employer in the Mallee-Coorong (41% of employment), Rangelands (31%) and Riverland districts (19%), the Ranges to River district has a more diverse employment base with agriculture employing just 8 per cent by comparison .

Primary production and value-adding manufacturing in the region makes a considerable contribution to the state's food production particularly in the fruit, milk, vegetable, meat and grain production and processing areas. The region is also South Australia's largest producer of wine grapes, potatoes and onions. Water use and quality are dominant issues in this region, reflecting the importance of the Murray River to the region, and the state as a whole, for its water supply.

In some rural parts of the region, business expansion is reliant on the ability to attract a skilled workforce. In these areas healthcare and education services are limited and need to be maintained at an acceptable level to ensure sustainability of these small towns. One consistent observation across all regions is that during the period 2001 to 2011, employment in agriculture declined while employment in healthcare and social services increased. Employment in the construction sector also increased in the River to Ranges district reflecting the growing population in this area. The region as a whole has an aging demographic, which is due to a range of factors including the attractiveness of river locations for retirement living.

[1] This regional description is largely based on information contained in the South Australian Murray-Darling Basin Natural Resource Management Board's Strategic Plan (SAMDB NRM Board 2013).

Figure 1. Map of the South Australian Murray-Darling Basin Natural Resources Management Region.



3 How was this plan developed?

The plan was developed through a technically rigorous and participatory-based approach to climate change adaptation that sought to cover key sectors in the region. The steering committee's vision for the project was that people should be at the centre of the plan's development.

The engagement process was designed to create a positive discussion about building resilience in the region to combat the impacts of climate change and to identify partnerships that can help achieve this outcome. Stakeholders were selected from key sectors across the region covering agriculture (irrigated and rain-dependent farming), tourism, natural resources management, emergency services management, healthcare and community services. Tailored engagement processes were also undertaken with traditional owners and Aboriginal communities to better align with their practices.

The process that underpinned the development of this Plan involved the following three steps (see also Figure 2):

Step 1 – Values mapping and key decisions

- The focus of the first workshop was on establishing what stakeholders value in their region, generating a better understanding of the decisions that will be made by different sectors and understanding how these decisions will be affected by climate change. The values and key decisions identified during the workshop helped to identify indicators for use in Step 2. Input was also sought from additional key stakeholders via targeted interviews.

Step 2 – Integrated vulnerability assessment

- The second workshop focused on an Integrated vulnerability assessment consistent with the approach described in the Local Government Association of South Australia's *Guidelines for developing a climate change adaptation plan and integrated climate change vulnerability assessment.* Indicators were selected to represent the values and key decisions identified during the first workshop. Vulnerability scores were assessed and prioritised with input from the steering committee. The results of this assessment (see Section 5) have been used to develop key areas for decision-making to focus on when identifying adaptation options.

Step 3 – Identifying and prioritising adaptation options

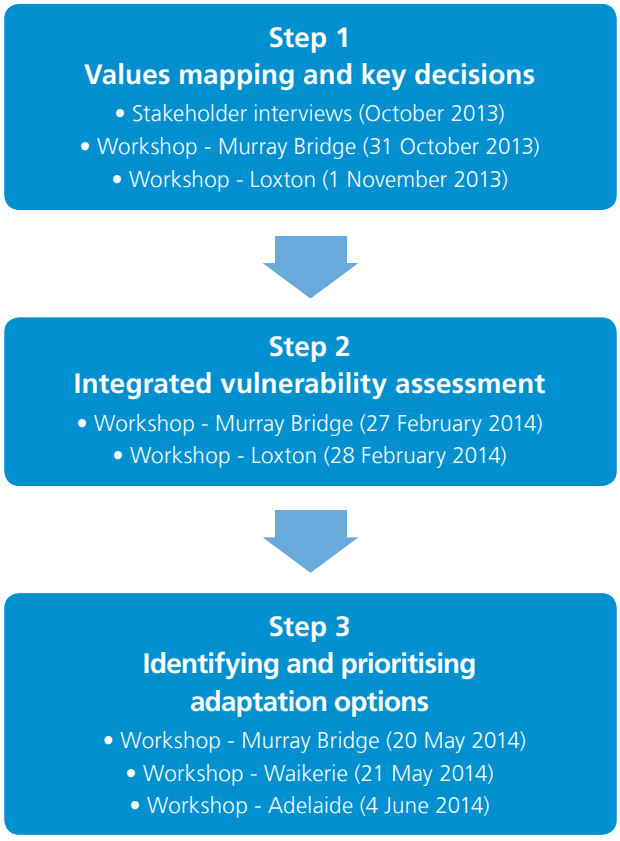
- The third workshop (a) confirmed the list of potential adaptation options, adding to those already identified in a discussion paper distributed before the workshop; (b) assessed and prioritised adaptation options; and (c) discussed conditions that would enable or act as a barrier to adaptation. The assessment and prioritisation element used a qualitative cost-benefit analysis, together with targeted questions about responsibilities for action and whether proposed actions should be delayed or commenced immediately.

For each step, workshops were held in Murray Bridge as well as Loxton or Waikerie to maximise attendance given the long travel times for stakeholders to attend meetings in the region. For the third step, an additional workshop was held in Adelaide to provide stakeholders from the essential services sector the opportunity to participate in the project.

A full description of the methodology used to develop this plan is provided in Attachment A.

A summary of stakeholders who attended workshops and participated in interviews is provided in Attachment B.

Figure 2. Three-step engagement process followed in development of the plan



4 How will climate change affect the region?

The South Australian Murray-Darling Basin region will be impacted by climate change through a warmer and, most likely, drier climate with increased risk of bushfires, reduced flows down the River Murray, and rising sea levels along the Coorong with higher temperatures and lower pH of marine waters.

4.1 Overview

Climate change is a consequence of the release of greenhouse gases like carbon dioxide, methane and nitrous oxide into the Earth's atmosphere. These gases are produced from a range of natural sources as well as from human activities like energy production, transport, industrial processing, waste management, agriculture and land management. Greenhouse gases trap the sun's energy in the Earth's atmosphere, leading to changes in the global climate.

Changes in the Australian climate have already been observed over the past 100 years. The nation's annual average surface air temperature has increased since 1910 (CSIRO and BoM 2007), particularly since 1950, with a warming trend of nearly 0.2°C per decade. Annual rainfall, on the other hand, has shown a variable but gradual decline in southern Australia since 1950.

The most authoritative source of information on climate projections is the modelling undertaken for the Intergovernmental Panel on Climate Change (IPCC), the world's leading authority on assessing climate change. Unless stated otherwise, the climate projections referred to in this plan are based on the IPCC's Fourth Assessment Report (AR4) and published on the Climate Change in Australia website[2] Projections information for this region have been summarised in SKM (2013).

It should be noted that the IPCC Fifth Assessment Report (AR5) was released in September 2013, which provides updated information on climate projections. At the time of preparing this report, information using these new models at the scale of the region was not available, however, the trends are broadly similar between AR4 and AR5 and will not change the relative priorities for adaptation in the region or the potential adaptation options. Information specifically for the region will be available in late 2014. An overview of the main conclusions of AR5 are outlined in Box 1.

[2] *www.climatechangeinaustralia.gov.au*

What is the evidence that the Earth's climate is changing? (IPCC 2013)

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for the assessment of climate change. The IPCC releases an assessment of the state of scientific knowledge relevant to climate change about every 6 years. Working Group I of the IPCC released its part of the Fifth Assessment Report in September 2013 and made the following conclusions that are relevant to adaptation planning:

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased;
- Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 when detailed temperature records began;
- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010;
- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901 to 2010, global mean sea level rose by 0.19 m;
- The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. Carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification;
- Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system; and
- Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

Table 3. Climate change projection summary for six towns in the South Australian Murray-Darling Basin region (Source: SKM 2013).

Climate variable	Reference period conditions (1980–1999)	2050 projections (low-high emissions)	2070 projections (low-high emissions)
Rainfall			
Annual average:			
Lameroo	381 mm	357-339 mm	350-324 mm
Loxton	250 mm	235-223 mm	229-213 mm
Meningie	452 mm	424-410 mm	416-387 mm
Mount Barker	702 mm	658-623 mm	646-597 mm
Murray Bridge	359 mm	337-321 mm	329-306 mm
Yongala	362 mm	362-340 mm	333-308 mm
Extreme daily rainfall (100-year average recurrence interval event):			
Lameroo	98 mm	106 mm (low only)	117 mm (high only)
Loxton	72 mm	79 mm	86 mm
Meningie	99 mm	108 mm	118 mm
Mount Barker	125 mm	136 mm	146 mm
Murray Bridge	103 mm	112 mm	123 mm
Yongala	100 mm	109 mm	118 mm
Temperature			
Annual average maximum:			
Lameroo	23.1°C	24.3-24.7°C	24.6-25.6°C
Loxton	23.5°C	24.6-25.1°C	24.9-26.0°C
Meningie	20.6°C	21.8-22.3°C	22.1-23.1°C
Mount Barker	20.2°C	21.4-21.8°C	21.7-22.7°C
Murray Bridge	22.8°C	23.9-24.4°C	24.2-25.3°C
Yongala	22.0°C	23.1-23.6°C	23.4-24.5°C
Annual average minimum:			
Lameroo	9.2°C	10.3-10.8°C	10.6-11.7°C
Loxton	8.7°C	9.9-10.4°C	10.2-11.2°C
Meningie	10.2°C	11.4-11.9°C	11.7-12.7°C
Mount Barker	8.4°C	9.5-10.0°C	9.8-10.9°C
Murray Bridge	9.8°C	10.9-11.4°C	11.2-12.3°C
Yongala	7.3°C	8.4-9.8°C	8.7-9.8°C

Table 3, continued.

Climate variable	Reference period conditions (1980–1999)	2050 projections (low-high emissions)	2070 projections (low-high emissions)
Heatwave – incidences of at least 2 days Tmax ≥ 40°C:			
Lameroo	1.3 days/y	2.3-2.7 days/y	2.7-3.5 days/y
Loxton	0.7 days/y	1.4-1.8 days/y	1.7-2.4 days/y
Meningie	0.2 days/y	0.4-0.6 days/y	0.6-1.1 days/y
Mount Barker	0 days/y	0.3-0.5 days/y	0.5-1.2 days/y
Murray Bridge	1.0 days/y	1.6-1.8 days/y	1.8-2.4 days/y
Yongala	0.4 days/y	1.0-1.4 days/y	1.4-2.4 days/y
Heatwave – incidences of at least 3 days Tav ≥ 32°C:			
Lameroo	0.2 days/y	0.2-0.3 days/y	0.3-0.6 days/y
Loxton	0 days/y	0.1 days/y	0.1-0.3 days/y
Meningie	0 days/y	0.1 days/y	0.1-0.2 days/y
Mount Barker	0 days/y	0 days/y	0 days/y
Murray Bridge	0.1 days/y	0.1 days/y	0.1 days/y
Yongala	0.1 days/y	0.1-0.2 days/y	0.2-0.3 days/y
Frost – incidences of days with Tmin ≤ 0°C:			
Lameroo	2.1 days/y	0.7-0.4 days/y	0.4-0.2 days/y
Loxton	15.6 days/y	9.1-6.5 days/y	6.9-3.3 days/y
Meningie	1.0 days/y	0.4-0.3 days/y	0.3-0.1 days/y
Mount Barker	7.4 days/y	3.1-2.1 days/y	2.1-0.8 days/y
Murray Bridge	3.8 days/y	2.2-1.3 days/y	1.3-0.6 days/y
Yongala	35.5 days/y	22.2-18.1 days/y	19.1-10.5 days/y
Forest Fire Danger Index (days per year with FFDI ≥ 50):			
Lameroo	1.8 days/y	5.0-8.1 days/y	7.3-14.0 days/y
Loxton	2.7 days/y	6.2-8.1 days/y	7.3-12.9 days/y
Meningie	0 days/y	0.3 days/y	0.3-0.4 days/y
Mount Barker	0 days/y	0.2 days/y	0.2-0.4 days/y
Murray Bridge	0.3 days/y	1.2-2.8 days/y	2.1-6.7 days/y
Yongala	0.9 days/y	2.3-4.0 days/y	3.4-8.3 days/y

4.2 Regional projections

Unless stated otherwise, the information in the following section comes from SKM (2013). A summary of climate projections for six towns in the region is provided in Table 3. Information about how climate modelling is undertaken, sources of variability, historical climate and projected climates is contained in SKM (2013).

Data reported here represent median model outputs[3]. Ranges represent the model results for different emissions scenarios. It should be noted that while medium emissions values are often reported in this plan, greenhouse gas concentrations are currently tracking on a high emissions path. Should this trend continue it means that median values from possible climate projections will underestimate temperature increases and rainfall reductions.

Temperature

Temperatures in the region will rise by 0.6–1.0°C by 2030 and 1.0–2.5°C by 2070, compared with the 1980–1999 baseline reference period. In practical terms this means that towns like Loxton and Murray Bridge which experience annual average maximum temperatures of 23.5°C and 22.8 °C under baseline conditions, will experience 24.9–26.0° and 24.2–25.3°C, respectively, in 2070. By 2030, projected temperature rise is the same across all seasons (0.6–1.0°C), whereas by 2070, winter temperatures will increase by 1–2.5°C compared to 1–3.0°C during summer.

Heatwave frequency and intensity is of significant interest to the region and has been assessed using two approaches. Traditionally, heatwaves are considered to be events with at least two consecutive days of high temperature (i.e. days over 35°C or 40°C), while heatwave-linked Extreme Heat Plans use the measure, "three or more consecutive days where the average daily temperature is equal to or greater than 32°C". This latter measure takes into account that human health and other issues associated with heatwave events increase where high overnight temperatures provide limited relief from extreme daytime heat loadings.

Using these measures within the region, sequences of three or more consecutive days with average temperatures of at least 32°C are projected to remain uncommon. However, the frequency of events with consecutive days over 40°C is projected to increase. For example, three consecutive days exceeding 40°C occurred two to three times every 10 years under baseline conditions for Lameroo and Loxton, but is projected to occur 7 years in 10 under the 2050 low emissions scenario and at least once per year by 2070 under a high emissions outlook. It should be noted that since 2000, heatwave events have already been occurring at rates projected to occur by 2050.

Recently, a new definition of heatwaves has been developed that accounts for when the long-term resilience of a system to high temperatures is overcome and when a heatwave event is unusual in relation to antecedent conditions (Nairn and Fawcett 2013). When applied to the region, it was found that at all locations, severe heatwave days per year could increase in frequency by a factor of at least 1.5 under a 2050 low emissions scenario or more than 3 times at most locations by 2070 under a high emissions scenario. Heatwave intensity could also increase by a factor of about 1.3–1.6 (Jacobs SKM 2014).

The heatwave of late January-February 2009 was the most severe recorded (1957–2012) at all of the locations considered in this analysis, with the exception of Yongala. It was also more intense than any heatwave projected for 2070 (with the exception of Yongala), based on the baseline reference period (Jacobs SKM 2014).

The incidence of frost and freezing conditions is projected to decrease in the region. For example, at Murray Bridge, the incidence of frost is projected to decline from 3.8 days per year historically to 0.6–1.3 days per year by 2070.

[3] *Climate projections are based on a range of global climate models. The data referred to are the median outputs, sometimes referred to as the best estimate, from across the range of models i.e. 50% of the models produce values higher and 50% lower.*

Rainfall

By 2070, the majority of climate models suggest a reduction in annual average rainfall. In winter and spring the most common estimate is for a 15% drying under a medium emissions outlook. While the majority of models suggest a drying trend and as much as a 30% decline in rainfall for winter, a minority of models suggest slightly wetter conditions (5% increase). Variability is greater again for projections of summer rainfall and although the most common estimate is for a 3.5% decline, model outputs vary from a 30% decline to a 30% increase (Hayman et al. 2011). It should be noted that there is generally higher variability in rainfall projections compared to temperature projections in part because of the greater difficulty in understanding the effect of regional climate systems on rainfall.

While greater variability exists in summer rainfall projections, the rainfall received at that time of year is much lower than during winter or spring and so the actual rainfall change that will be experienced is much less. The rainfall decline experienced across the region will also differ depending on the baseline conditions of towns. For example, the projected decline will see the reduction from the Loxton baseline of 250mm to 229–213mm by 2070 whereas Mount Barker, with a higher average of 702mm during the baseline period could decline by as much as 100mm to an annual average of 646–597mm by 2070 (SKM 2013).

Climate models suggest that for each degree of global warming, extreme daily rainfall may increase by 7%. If this was to occur in the region, the 100 year average recurrence interval daily rainfall event at Murray Bridge may increase from about 103mm historically to 112–123mm. The average recurrence interval of the historical 100-year event is projected to increase in frequency to 60 to 70 years.

Reductions in flow

Various estimates exist of the reduction in River Murray flow as a consequence of climate change. For example, work by CSIRO suggests that average surface water availability at Wentworth could reduce by 12% by 2030 under a median climate (CSIRO 2008). Other estimates suggest a reduction in flows within 50 years of 3,300 GL or 15% of average annual flow, while the worst case scenario is an estimated 11,000 GL or a 50% reduction (Earthtech 2003, Beare and Heaney 2002). No information is understood to be available on projected declines in River Murray flows to 2070, which is the timeframe considered for the vulnerability assessment.

Bushfire

The risk of bushfire is assessed using the Forest Fire Danger Index, which is calculated from daily temperature, humidity and wind speed together with (longer-term) changes in soil and fuel dryness. While not all parts of the region contain forest vegetation and many are likely to be more at risk of grass fires, the index still provides an insight into future fire risk. Values in the severe and extreme range (Forest Fire Danger Index ≥50) are indicative of the potential for difficult-to-control behaviour in any fires that become established.

There will be an increase in the frequency and intensity of fire risk in the region. The largest increase in fire risk is likely to be in Lameroo and Loxton which experienced less than 3 extreme fire risk days during the baseline period but are projected to experience from 7 to at least 13 days per year by 2070 depending on the emissions scenario. For Lameroo, this would be consistent with 1983, the year with the greatest number of days of severe and extreme fire risk. Not all parts of the region will be impacted though, with Mount Barker and Meningie projected to experience no significant change in fire risk.

Ocean

Climate change projections indicate that the Great Southern Ocean surrounding the Coorong will increase in height, become warmer and have a lower pH (more acidic). Rising sea levels will occur as a result of thermal expansion of the oceans as they warm and additional water will enter the world's oceans from melting ice from land areas. Sea levels have already been observed to rise across the globe, primarily as a result of thermal expansion, by 21 cm from 1880 to 2009[4]. Locally, sea levels have been rising at about 2 mm/year at Outer Harbour since about 1940 (DEH 2005).

The recent IPCC 5th Assessment Report (IPCC 2013) suggests that global mean sea level rise for 2046–2065 relative to 1986–2005 could be 0.26 m for more moderate emissions outlooks and up to 0.48 m by 2081–2100.

The world's oceans will continue to warm in the coming century as they absorb heat from the atmosphere. By 2046–2065 this could result in about a 1.4°C rise in global sea surface temperatures under a medium emissions outlook relative to 1986–2005 and a 1.8–2.2°C rise by 2081–2100 (IPCC 2013). While these projections may apply to the Great Southern Ocean, the extent of change in water temperatures in the Coorong is less clear given that this area is shallow and more directly influenced by air temperatures and incident solar radiation.

The IPCC Assessment Report 5 suggests that the earth's oceans will become more acidic (pH units decrease from the usual slightly alkaline values of 7.5 to 8.0 towards more neutral levels at pH=7) under all scenarios assessed. Projections for decreasing pH range from 0.06 to 0.32 by 2100, with a best estimate more likely to be in the order of a 0.2 pH unit decrease (IPCC 2013). This compares with a 0.1 pH unit decrease that has already been experienced since the beginning of the industrial era about 250 years ago.

Impacts on Aboriginal people and communities

The impacts of human induced accelerated climate change on Ngarrindjeri cultural heritage, health and wellbeing are very significant due to the close relationship between, Ngarrindjeri people, cultural economy and lands and waters. Ngarrindjeri need to carry out ongoing research to better understand the consequences of climate change and to develop strategies to mitigate the impacts. The following statement is taken for the Ngarrindjeri Nation Yarluwar-Ruwe Plan:

"In recent years we have observed changes in our local environment that tells us that climate change is a reality. We see that the breeding behaviour of birds is changing, and the fruiting and flowering of our bush foods is changing. We have watched our fresh water holes dry up or turn salty and we've seen our coastal camping places and middens washed away by rising sea levels. When we lose these places we lose not only part of our cultural heritage, but we also lose an irreplaceable record of Ngarrindjeri adaptation to climate change in the past." (Ngarrindjeri Nation Yarluwar-Ruwe Plan 2006)

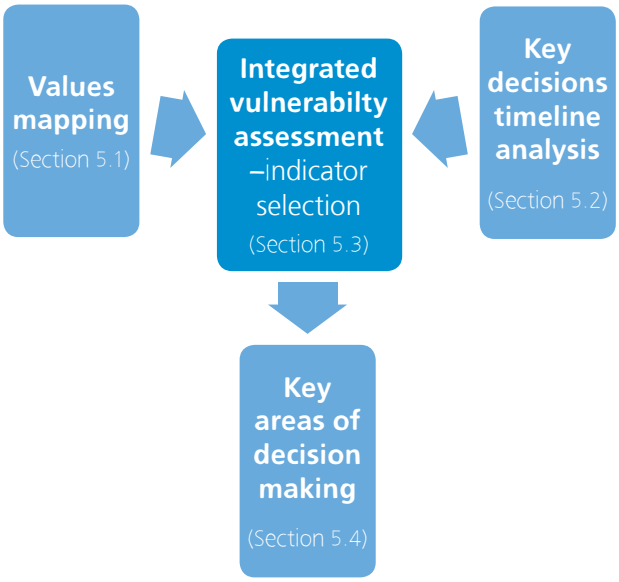
[4] *http://www.cmar.csiro.au/sealevel/sl_impacts_sea_level.html. Accessed 1 September 2014.*

5 Identifying priority areas for adaptation

Regional scale climate change adaptation planning needs to focus on issues fundamental to a region's long term viability and resilience. These issues can include factors that affect the economy, how the community functions, the condition of native ecosystems and the way in which these interact.

Narrowing down the suite of possible issues for adaptation planning was undertaken for this region by applying an integrated vulnerability assessment for which indicators were selected based on information from the values mapping exercise and identification of decisions that influence the long term viability or operation of different sectors (Figure 3).

Figure 3. Link between values mapping and key decisions analysis as a way to inform indicator selection for the vulnerability assessment.



5.1 Values mapping

Work was undertaken with stakeholders to better understand the values of people across the region (see Section 2.2 for further details). From this process the following values emerged as priorities to consider in adaptation planning (see Table 4):

- The River Murray is the lifeblood of the region
- Strong communities are important now and in the future
- Accessibility in, out and through the region is a strength
- The rural landscape and the ability to farm are important
- Links with the past-continuing cultural and natural heritage must be recognised
- The Coorong and Lower Lakes are iconic features.

5.2 Key decisions timeline analysis

A decision lifetime is the time taken to make a decision (lead time) plus the duration of that decision's implications (consequence time) (Stafford Smith et al. 2010). Some decisions made by individuals or organisations have lifetimes that are short (e.g. <5-10 years) and much less than the timeframes over which the major effects of climate change will occur. In contrast, there are decisions made today that have long lifetimes (e.g. >70-80 years) equivalent to the timing of some of the major projected impacts of climate change.

Using information collected during the stakeholder engagement process (refer to section 2.2), regional leaders identified key decisions relevant to their sector and the region as a whole and assessed their decision lifespans (Figure 4).

This assessment revealed that there are many important decisions made by different sectors in the region which have lifetimes of 1–5 years, such as animal breeding and managing fuel loads (which are made every year), business strategic planning which often occurs on a 5-year cycle (reviewed every 2–5 years) and developing fire management plans (reviewed annually and audited every 10 years). These decisions do not need to consider long-term climate change impacts. In contrast, there are other decisions that have much longer lifetimes, such as:

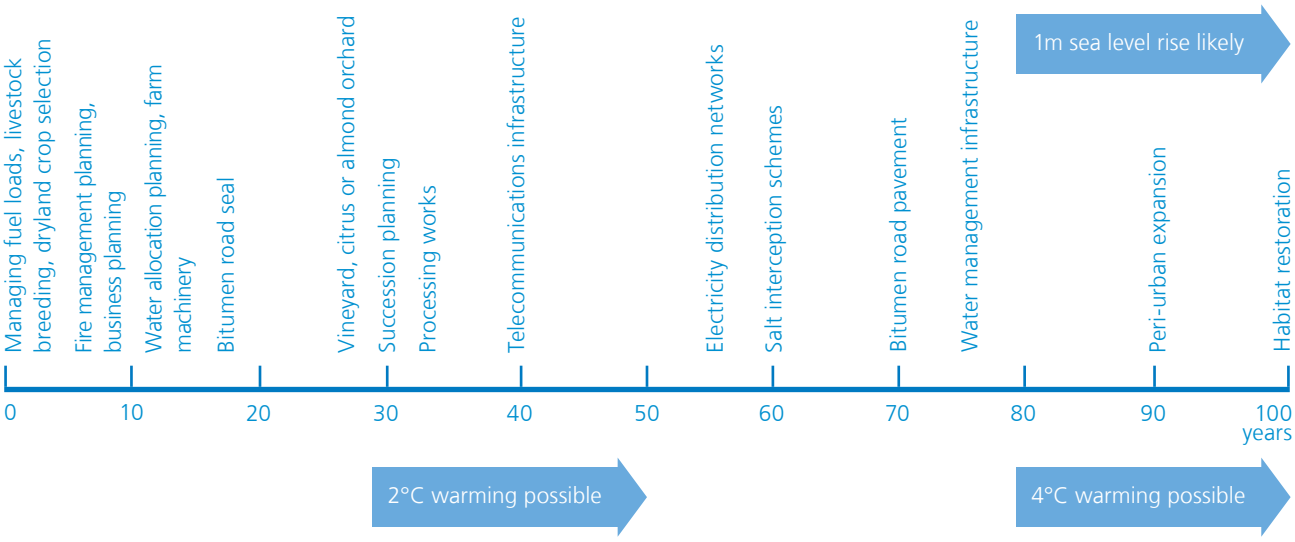
- establishing new perennial horticultural plantings, such as vineyards and citrus or almond orchards, which are based on a 20–30 year investment cycle but may have a productive life of well over 50 years depending on the crop type
- electricity distribution networks, which may take a decade to plan, a decade to construct and then have a 40 year operating life (estimated)
- peri-urban developments, which may take years to decades to plan and will be in place for at least 100 years, in most instances
- habitat restoration which may take 5–10 years to plan and remain for 100 years or more, depending on the species planted.

Identifying decision lifetimes has helped to demonstrate how sectors may be affected by climate change through some regional scale, cross-sectoral issues. For example, while irrigators may focus on water allocation planning, or dryland farms on livestock breeding, the viability of both sectors in the long term will be influenced by being able to continue to maintain access to transport infrastructure, such as roads. They are also collectively dependant on essential services and electricity distribution networks, both of which need to account for the long term effects of climate change.

Table 4. Values of the community that guide adaptation planning

Feature	Description
River Murray as the lifeblood of the region	The River Murray is a significant and iconic feature of the region. The river is valued for a range of reasons including the sport and recreation opportunities it provides, such as boating and skiing, fishing and catching yabbies; holidays; attracting tourists to the region; as an important source of biodiversity and quality habitat for fish and birds; as a source of water supply for the Riverland and Murray region, Adelaide and Barossa was identified with irrigation from the river a critical contributor to economic activity in the region.
Strong communities now and in the future	Regional communities are highly valued and there is a need to maintain them into the future. Centres for economic and social activity such as Renmark, Karoonda, Nairne, Mount Barker and Goolwa are critical to the survival of regional communities and especially farming populations. These centres must be able to provide a variety of facilities and services to retain existing residents and attract new people, business and industry so populations grow.
Accessibility in, out and through the region	Accessibility to and from the region to surrounding areas is a strength of the region with the freeway being the primary way to get in and out of the area. Accessibility is important not only for people living and working in the region, but also for tourists, movement of freight and emergency services.
The rural landscape and ability to farm	The rural landscape of the region is highly valued for farming. Variability in soil types gives flexibility to the types of crops that can be grown. Access to water resources, both from the River Murray as well as groundwater resources, is essential to the ability to farm in many areas.
Links with the past-continuing cultural and natural heritage	Various locations throughout the region provide connection and links to cultural and natural history. The whole region is important to a number of Aboriginal communities as the original inhabitants who continue to have a connection to the land. Locations such as Burra were identified for their cultural heritage as were towns in the Riverland such as Loxton and Paringa, which have a long history as irrigation settlements along the River Murray. Ngarrindjeri take a landscape approach as all things are connected; the lands, waters, economy, health and cultural heritage are all valued as part of the living body.
Coorong and Lower Lakes as iconic features	Like the River Murray, the Coorong is an iconic and highly valued location in the region. The Coorong was identified for its high environmental value as well as its attraction for camping and fishing and recreation. Similarly, Lake Albert was identified with participants discussing its environmental, recreational and aesthetic value. These areas, amongst many others throughout the region, were also discussed in terms of their significance for different Aboriginal groups.

Figure 4. Decisions and their indicative lifetimes identified for key sectors in the South Australian Murray-Darling Basin. This diagram has been modelled on the decision lifetime figure presented in Stafford-Smith et al. (2011).



5.3 Integrated vulnerability assessment

The integrated vulnerability assessment (IVA) was undertaken using 33 primary indicators and 80 secondary indicators that were selected using information from the values mapping exercise and the key decisions timeline analysis. To ensure coverage across sectors in the region, indicators were also selected so as to represent the five capitals: environment, human, social, financial and physical.

Analysis of vulnerability involved rating the exposure (score out of 5), sensitivity (score out of 5) and adaptive capacity (score out of 10) of indicators to climate change. Following the approach used in the LGA Guidelines (LGA SA 2012) the vulnerability score was then calculated as follows: exposure + sensitivity – adaptive capacity + 10 = vulnerability, where exposure represents the climate conditions against which a system operates and any change in those conditions; sensitivity reflects the responsiveness of a system to climatic influences and the degree to which changes in climate might affect that system in its current form; adaptive capacity is the ability of a system to respond to climate change (e.g. Allen Consulting Group 2005).

For the purpose of communicating the IVA results, vulnerability scores are summarised as Very low (<4); Low (greater than or equal to 4 but less than 8), Medium (greater than or equal to 8 but less than 12), High (greater than or equal to 12 but less than 16) or Very high (greater than 16). A summary of the IVA results is provided in Attachment C.

Results for the environmental indicators suggest that various components of the region's environment are likely to be highly vulnerable because of the high potential impact from factors such as increasing bushfire frequency, heatwaves and declining rainfall, combined with low adaptive capacity to respond due to a highly fragmented landscape. Priority indicators include:

- regional birds and mammals
- quantity and quality of water from Prescribed Watercourse Areas
- impact of pest plant and animal threats on the terrestrial environment and Coorong and Lower Lakes
- condition of the Coorong and Lower Lakes
- area of native vegetation cover outside of DEWNR reserves
- several native vegetation communities.

The potential vulnerability of other key environmental indicators (e.g. River Murray wetlands and Chowilla Floodplain) were moderated by higher adaptive capacity due to recent efforts to acquire environmental flows and environmental water management infrastructure that will help to adapt to projected flow reductions.

Analysis of human and social capital indicators suggest that adaptation planning needs to focus on how to maintain the health of vulnerable people in the community (e.g. the elderly), especially in relation to climate extremes like heatwaves. It will also be important that emergency services are adequately maintained, the demand for which is expected to rise at the same time that rates of volunteerism could fall. Priority issues for the financial and physical capital of the region typically relate to maintaining services networks, primarily telecommunications and electricity supply.

Despite these issues being identified, the IVA results suggest that a general view among stakeholders was that the region's economic base is more resilient than its environment, human and social capitals. This is largely driven by confidence in the region's producers being able to respond to reduced water availability based on experience demonstrated during the recent Millennium Drought.

The IVA results are heavily focused on environmental capital, and while the environment is important in its own right, it is also recognised as playing a critical role in many of the region's social, cultural and economic values, which rely on a healthy natural landscape. Furthermore, many of the environmental values in the region will require a similar adaptation response, which should lessen the task of addressing these priorities individually.

5.4 Key areas of decision-making

The following eight key areas of decision-making were identified based on the indicators of higher vulnerability identified in the IVA and by considering values for the region. Where possible, the key areas of decision-making were structured to address multiple indicators that ranked as having very high to high vulnerability. These areas of decision-making should be used as a focus point for identifying adaptation options:

1. Native vegetation

How do we maintain functional vegetation communities that provide habitat for regional birds and mammals (many of which exist outside of DEWNR reserves) in the face of warmer and drier conditions and more frequent and intense bushfires?

2. Pest plants and animals

How do we minimise the impact of new pest plants and animals entering important farming and natural environments from rangelands areas in the north of the region in response to warmer and drier conditions?

3. Coorong and Lower Lakes

How do we protect key habitats and species in the Coorong and Lower Lakes region as river flows continue to decline, salinity levels in the estuary rise in response to increasing sea levels pushing more sea water into the region, and the risk of pest plant and animal incursions increases?

4. Vulnerable members of the community

How do we help vulnerable members of the community maintain health and well-being which may otherwise be affected by increasing frequency and intensity of extreme events, such as bushfires and heatwaves?

5. Emergency services

How can we manage and reduce where possible the growing demand for emergency services as extreme events such as bushfires become more frequent and intense and rates of volunteering decline?

6. Essential services

How can we establish and maintain telecommunications, water and electricity supply infrastructure, which together support the regional economy, in the face of climate extremes such as increasing frequency of bushfires, which may physically damage infrastructure, and generally increasing temperatures which are likely to increase demand for services?

7. Irrigated horticulture

How can we build on existing work in the irrigation sector to ensure that levels and quality of production can be maintained in the face of warmer and drier conditions, and potentially reduced rivers flows and water allocations?

8. Dryland (rainfed) farming

How will farmers maintain the productivity of existing cropping-based farming systems under warmer and, most likely, drier conditions in the future?

6 Priority adaptation options for key areas of decision-making

Adaption options were identified for each key area of decision-making at the final series of workshops. Priority options were selected by stakeholders attending the workshop and then assessed using a qualitative cost/benefit analysis, which rated social, economic and environmental costs and benefits for each option as high, medium or low. The results of this analysis were then reviewed following the workshop with input from the steering committee to identify immediate and high priorities.

6.1 Native vegetation

Key area for decision-making

How do we maintain functional vegetation communities that provide habitat for regional birds and mammals (many of which exist outside of DEWNR reserves) in the face of warmer and drier conditions and more frequent and intense bushfires?

Context

Native vegetation is an important natural asset in the region, covering 53% of the area of private and public land combined (Ranges to River 18% native vegetation cover; Mallee–Coorong 25%; Rangelands 91%; Riverland 38%). In the drier, semi-arid areas chenopod shrublands are widespread, tending toward the dominant Mallee vegetation which occupies large parts of the region outside of the Eastern Mt Lofty Ranges (SAMDB NRM Board 2013). In the ranges, woodlands are more common with small areas of forest, wetlands and sedgelands (SAMDB NRM Board 2013). While of conservation value in its own right, this vegetation additionally provides a range of ecosystem services, including habitat for native fauna, soil protection, moderation of water table levels, and storing carbon in the landscape.

The vulnerability assessment found that most vegetation types will be highly susceptible to a changing climate. A warmer and drier climate will most likely stress native vegetation, with some species pushed beyond their natural tolerances. Changing fire regimes, as a result of the changing climate, will also be of critical importance, with increasing fire frequency and intensity likely to be a major driver of changes in vegetation communities. In higher rainfall areas such changes could lead to the loss of certain types of vegetation from the region altogether.

Priority adaptation options

The immediate priority adaptation option identified to help native vegetation communities adapt to future climate change was to **support and promote landholders managing high value native vegetation on private properties**. This is a no-regrets action that provides significant environmental benefit and recognises that much of the native vegetation in the region exists on private property. Managing native vegetation on private properties can also provide some social and economic benefits through improved well-being and productivity benefits through managing wind erosion and dryland salinity.

Informing, motivating and mobilising people will require continued support for current initiatives along with new ways of reaching a broader cross section of the wider community. For example, supporting landholders could also involve a clear commitment to existing volunteer community groups (e.g. Landcare groups) and promoting the establishment of new groups. Supporting the network of community groups already in place can help build strong communities, support community champions and assist in addressing a number of other priorities for adaptation identified in the plan. For example, groups can encourage people to share their own experiences and successes in pest control and vegetation management and lead to greater dissemination of information.

In the short to medium term (5–10 years), more attention will need to be given to **bushfire planning**. The increased fire risk in the region was cited as a major concern for native vegetation communities. Work now to **establish and implement bushfire management, response and recovery plans** is essential to be able to manage this impact in the future. It is recognised though that changing fire regimes could have a high impact on the health and safety of people across the region and needs to be managed carefully. It is therefore essential that any change to fire regimes be undertaken as part of an integrated planning exercise between NRM and emergency services management organisations.

Land use planning will also become a focus of adaptation actions to assist native vegetation management because of the potential impacts of activities like urban and peri-urban development and grazing of native vegetation. This is an attractive option because of the relatively low economic cost but high environmental benefit. It will require improved, more spatially explicit data to refine zoning and land use planning decisions and a better understanding of the implications of state government planning policy on local government. Working with local government provides an opportunity to better align NRM plan objectives with council strategic plan objectives which can then flow through to council development plans.

Identifying, prioritising and managing pest plants and animals is a win-win option that is already part of current management approaches but requires further investment to address emerging climate threats. If not managed, pest plants and animals also pose a major threat to production levels on private farming land. So, while this action is recognised as being high cost, it is also of high potential economic and environmental benefit.

There was a strong emphasis from stakeholders on identifying "sleeper" species that may be present now, but expand under a different future climate. Alternatively, some species recognised as pests may expand their range in the future, filling niches no longer occupied and therefore providing a functional role in the landscape. Further discussion on pest plant and animal control measures are provided in Section 6.2.

Recognising that some species will no longer find suitable habitat in their current location, there is a need for work to commence on **strengthening gene pools and identifying ecological linkages to enable species' migrations**. Both actions are seen as high cost and while a focus on linkages already exists in the region (previously through work on "corridors") and funding opportunities exist, strengthening gene pools is a novel approach that requires further scoping.

Additional, more active forms of adaptation may be required in the future and could include methods for large-scale habitat restoration, strengthening gene pools of existing species, species translocations and ecosystem engineering.

A summary of adaptation options relevant to managing native vegetation in the region is provided in Attachment D.

Key points

Immediate priority is to support and promote landholders managing high value native vegetation on private properties.

High priorities also include establishing and implementing bushfire management, response and recovery plans, and incorporating native vegetation protection into land-use planning.

Enablers and barriers to adaptation

Maintaining functional vegetation communities requires more community support. This can be in the form of private landholders further engaging in Landcare type projects or engaging youth to help with priority projects. This needs to be underpinned by environmental champions in the community and forms of landholder engagement that include simple application and reporting requirements and value for money delivery models.

Barriers to maintaining functional vegetation communities in the region include a lack of understanding of ecosystem services and the seemingly overwhelming size of the issue. Non-compliance and enforcement of native vegetation management breaches also is counteractive to the aims of better engaging private landholders.

6.2 Pest plants and animals

Key area for decision-making

How do we improve our adaptive management to minimise the impact of pest plants and animals on agriculture and biodiversity from rangelands areas in the north of the region in response to warmer and drier conditions?

Context

Pest plants and animals have had, and continue to have, a significant impact on environmental and agricultural assets in the region. Pest plants reduce agricultural production levels and increase input costs for farmers, as well as competing with native plants for habitat and resources. As such, they threaten key values identified for this region such as the rural landscape and ability to farm.

This key area of decision-making is particularly focused on the rangelands areas in the north of the region because of the ability for more arid zone pest plants and animals to take hold under the projected climate changes. However, this does not mean that pest plants and animals are unimportant for other key areas of decision-making, as demonstrated by their consideration in Sections 6.1, 6.3 and 6.7.

The increased risk of disturbance events, such as fire, may provide greater opportunities for existing weeds in the region to spread, while warmer and drier conditions may help the spread of new weed species like buffel grass.

Threats from existing pest animals may also increase, such as increased spread and invasiveness of rabbits and goats, that can affect native vegetation and agricultural crops, at the same time as overall production levels decrease. In addition, more arid-zone adapted pest animals, such as camels, may move into and start threatening northern parts of the region, as has already been observed in the northern parts of the Eyre Peninsula.

Priority adaptation options

Adopting **risk-based approaches to managing pest species** emerged as a priority for stakeholders. This is intended as an objective approach to identifying region-wide priorities for pest control, so could also easily be applied at a sub-regional scale. The use of risk assessments could be used to identify: (a) priority species for current management; and (b) new and emerging pest species. Using climate change information to identify the likelihood of pest species' spread could assist with identifying emerging threats.

Significant data sets and tools already exist for the region to assist with this task, such as the Landscape Futures Analysis Tool[6] which identifies potential changes in the distribution of weeds identified in the region based on an understanding of temperature range, rainfall and soil preferences (Meyer et al. 2013).

Future management efforts to minimise the impact of pest plants and animals also need to focus on building capacity to respond to threats. From a landscape scale perspective, this will require improved adaptive capacity and flexibility of the current pest planning process. With respect to the entities carrying out pest management, increased capacity is required:

- **within government agencies to respond to a range of disturbance** triggers like climatic extremes and ecological disturbance. This was rated by stakeholders as one of the highest priority adaptation actions. It is linked to the need to improve efforts to identify new and emerging pest species, and to act quickly to apply the necessary management response
- for public and private landholders, which can be implemented through an **education and awareness raising program.**

To support risk assessments and general capacity building, increased investment in research is required. While potential pest species can be identified based on observations from country to the north of the region, risk assessments will also need information on the ability for these species to compete with environmentally and economically important species already in the region, the rate at which they can spread to new areas and the effectiveness of control techniques.

Additional, more active forms of adaptation may be required in the future and could include targeted post-disturbance management of weeds and controlling pest species in parts of the environment that provide refuge during climatic extremes and ecological disturbances.

A summary of adaptation options relevant to managing pest plants and animals in the region is provided in Attachment D.

[6] *www.lfat.org.au*

Key points

Immediate priority is to rapidly identify and assess the risk of emerging pest species.

High priorities also include greater use of risk assessments to focus on current priority pest species and building greater government agency capacity to respond to a range of disturbance triggers like climatic extremes and ecological disturbance.

Enablers and barriers to adaptation

Improving the adaptive management of pest plants and animals requires greater involvement of community champions and encouraging people to share their own experiences and successes in pest control. This recognises that landholders already allocate significant resources to maintaining these impacts. The high cost of pest plant and animal control means that significant gains could be made through establishing additional federally funded incentive programs.

Barriers to improved pest plant and animal control are historical values and landholders continuing to do what they have always done. In addition, motivation levels can be low to act because of the seemingly overwhelming scale of the problem and the difficulty many farmers have in resourcing control compared with the benefits they receive.

6.3 Condition of the Coorong and Lower Lakes

Key area for decision-making

How do we protect natural, built, economic and cultural assets in the Coorong and Lower Lakes region as river flows continue to decline, salinity levels in the estuary rise in response to increasing sea levels pushing more sea water into the region, and the risk of pest plant and animal incursions increases?

Context

The Coorong and Lower Lakes are an internationally recognised wetland system and an Australian environmental icon. They provide habitat for migratory wading birds, diverse native vegetation communities and a unique mix of fishes, among other features. The region has significant built assets in low-lying areas such as the barrages, roads and houses in residential communities such as on Hindmarsh Island and also supports economic activity such as farming and tourism.

The region's people and environment were significantly negatively affected during the recent Millennium Drought (1995–2009) which arguably provided a glimpse into the potential effects of climate change. Reduced flows resulted in shallow water levels in the Lower Lakes and loss of habitat, exposure of water logged soils leading to areas of acid sulfate soils, elevated salinity in the Coorong driving a change in the system's ecology, and reduction of agricultural production due to limited or no access to water which was of poor quality even where available.

Climate change will affect the area in two ways. It will reduce flows down the river and change ocean conditions[7] . Declining average rainfall in upstream catchments will cause flows to reduce, changing salinity levels in the Lakes and Coorong. The largest potential effect though may come as a result of changing conditions in the Great Southern Ocean. Warmer ocean waters and decreased alkalinity will affect mixing in the column and the form and abundance of species living in the Coorong estuary. Perhaps of greatest concern though is the possible effect of sea level rise, which could result in more regular saltwater incursions into the Lower Lakes, more persistent marine conditions in the Coorong and, ultimately, regular failure of the barrages[8].

[7] *A detailed summary of the potential consequences of climate change for the Coorong and Lower Lakes is provided by Matthews (2005).*

[8] *Failure of the Barrages occurs when they are not performing their function, which is to separate the freshwater water of Lake Alexandrina from the Coorong and Goolwa Channel. This could occur as a result of water on the estuary side of the Barrages flowing through or over the Barrage gates or over the land surrounding the Barrages.*

The barrages were installed to maintain separation of freshwater in Lake Alexandrina from the estuarine environment of the Coorong and Goolwa Channel. They already experience significant variations in water levels on the estuary side as a result of normal and extreme tides (plus surge), as well as storm and wave effects. The boundary landforms of Mundoo, Ewe and Tauwitchere Islands flood if water levels reach 0.81 m AHD (Matthews 2005). Water levels monitored in the Coorong Lagoons from the mid-1990s to mid-2000s showed that estuary levels rarely peaked above 0.80m AHD and that the common seasonal range of filling and draining is between –0.1 to 0.8m AHD (Matthews 2005). With projected sea level rise, however, estuary levels are more likely to peak above 0.80m on a more regular basis.

No detailed modelling is available that considers the potential frequency, duration and extent of failure of the Barrages under varying amounts of sea level rise. However, stakeholders involved in developing this plan were commonly of the view that the Barrages will fail under even moderate levels of sea level rise. Matthews (2005) suggested that if a rise of, for example, 0.4m occurred in the next 50–60 years the seasonal range of water levels in the Coorong could shift upwards to +0.3 to 1.2 m AHD. If this was to occur, regular incursions of water through or around the barrages would be expected on an annual basis without adaptation.

Priority adaptation options

Stakeholders involved in the project considered a range of adaptation options that will be required to protect key habitats and species in the Coorong and Lower Lakes in the face of climate change. Many of these actions are the same as were identified and implemented during the Millennium Drought. They continue to be implemented and investigated and so in this regard adaptive capacity is already being built. However, the majority of discussion amongst stakeholders on priority adaptation actions focused on the future of the Barrages.

Any assessment of the future of the barrages needs to consider: (a) that sea levels are generally expected to rise slowly over the course of the coming century, and (b) the design life of the barrages. The latest information from the IPCC suggests that under a medium emissions scenario sea level could rise by 0.26m by 2046–2065 relative to 1986–2005 and up to 0.48m by 2081–2100.

The Barrages were constructed from 1935 to 1940 and while operated by SA Water, are jointly owned by the Commonwealth, New South Wales, Victoria, and South Australian governments. It is understood that the barrages are nearing the end of their design life and that replacement options may need to be considered within one to two decades. This would suggest that sea level rise of at least 0.5m or possibly more will occur within the life of any new structure and should therefore be considered in its design or location.

The highest immediate priority identified by stakeholders was to **commence social engagement to increase community awareness and to promote informed debate about the future operation and location of the barrages**. This was regarded as having high positive social, economic and environmental benefits and is required before any decision is made about future operation of the barrages. This would need to be informed by (a) detailed modelling of the impact of varying amounts of sea level rise on the frequency and duration of time that estuary side water levels exceed 0.8m AHD, and the extent of salt water incursions into Lake Alexandrina and (b) build on recent work regarding ecological thresholds and habitat refuge e.g. MDBA 2014, Lester et al. 2009.

Operationally, it was considered that **adaptation or modification of the barrages** for faster operation is a no-regrets option and is required in the short term to provide better ability to manage high water levels on the estuary side of the barrages. This is already occurring, and supports existing industries in the region by minimising saltwater incursions, but needs to be accelerated.

More substantial options canvassed by stakeholders were the need to **raise the height of the barrages or relocate them.** While not supported by any modelling analysis, the general view was that raising the height of the Barrages would only be applicable for sea level rise below 0.5m. It was suggested that raising the height of the Barrages may be required within 10 years whereas relocation would not be required for 30 years. Although both options are potentially controversial, they need to be compared with a "do nothing" approach.

Considering future sea level rise impacts in the design or operation of major infrastructure near or on the coast is already occurring elsewhere in Australia and the world. For example, the design of the parallel runway at Brisbane Airport has allowed for a 30 cm rise in sea levels (Box 2). A commonly cited example for a structure with a similar purpose to the Barrages is the Thames Barrier in London, which was constructed to prevent parts of London being flooded by high tides and storm surges. Work by Reeder and Ranger (2011) examined the range of options that may be required to respond to sea level rise. Importantly, not all options need to be implemented now but can be sequenced through time as the future extent and rate of sea level rise becomes clearer. Multiple potential pathways will need to be explored given that there may be competing goals and values in the region regarding the future role of the barrages.

Brisbane Airport–Parallel Runway Project (Adapted from DIICCSRTE 2013)

The privately operated Brisbane Airport Corporation commenced site preparation for its parallel runway in 2012 with completion expected by 2020. The runway will deliver an expected regional economic benefit of around $5 billion per year by 2035 and deliver the capacity needed to meet the predicted continued growth in flights in and out of Brisbane.

Given the role weather plays in the operation of an airport, the runway design considered historical and future weather and climate predictions. The height above sea level of the runway became the major climate change related design issue. The final design had to take account of historic and projected severity and frequency of sea level rise, storm surge and local/regional flood events.

The runway design team considered:

- current storm surge level of 1.5m Australian Height Datum (AHD);
- wave set up freeboard of 500mm;
- climate change increase of 400mm (including 300mm sea level rise and increased cyclone frequency).

Consideration of potential climate change impacts on the parallel runway at Brisbane Airport will ultimately result in safe and continuous operation of this infrastructure in a changing climate.

In the short term, any work required to determine how to best implement the Drought Emergency Framework for Lakes Alexandrina and Albert (MDBA 2014) should also consider the implications for longer term climate change planning.

A summary of adaptation options relevant to managing impacts on the Coorong and Lower Lakes is provided in Attachment D.

Key points

The immediate priority is to commence social engagement to increase community awareness and to promote informed debate about the future adequacy, operation and location of the barrages.

Engagement needs to be supported by: (a) detailed modelling of the impact of varying amounts of sea level rise on the frequency, duration and extent of saltwater incursions into Lake Alexandrina, and (b) exploration of the sequencing of different adaptation options through time.

Barriers to adaptation

Barriers to protecting key habitats and species in the Coorong and Lower Lakes in the face of climate change relate to a lack of understanding about potential effects, the long timeframes over which impacts could occur and limited understanding of the consequences of a "do nothing" approach.

[9] *http://www.bne.com.au/corporate/upgrading-your-airport/brisbane-airports-new-runway. Accessed 11 July 2014.*

6.4 Vulnerable members of the community

Key area for decision-making

How do we help vulnerable members of the community maintain health and well being which may otherwise be affected by increasing frequency and intensity of extreme events such as bushfires and heatwaves?

Context

The region already has members of the community who are vulnerable due to factors such as poor health, limited access to transport services, dependence on others for care and mobility (e.g. the frail, the aged, and children), and people receiving support from social services. Some aspects of climate change, such as warmer winters, may prove beneficial to vulnerable members of the community, but most projected changes will exacerbate existing stressors. For example, extreme events such as heatwaves could increase in frequency by threefold and intensity by nearly double (Jacobs SKM 2014).

Based on recent local experience, heatwaves have a significant effect on human health, leading to increased morbidity and mortality. In addition to the direct health impacts, heatwaves will also potentially increase demand on health care providers, as well as on council-operated facilities such as libraries and community centres, to provide refuge from the heat. Increasing bushfire risk will also place some vulnerable members of the community at greater risk, particularly as some older people find it difficult to maintain priorities and clear fuel loads, and potentially have low mobility to avoid serious fires.

Priority adaptation options

There is a strong focus on identifying adaptation actions that can help vulnerable members of the community to better prepare for, respond to and recover from extreme events. The immediate priorities for preparing for extremes are building social capital and improving building design. Building social capital requires work by government and non-government organisations to facilitate increased participation in community activities to improve connectivity and resilience within the community.

Stronger communities can provide a greater range of social networks to draw upon during extreme events such as heatwaves and bushfires. This was considered by stakeholders as being a moderately expensive activity that would take time to implement and require cultural change, especially given generally declining levels of volunteering. However, the value of social networks was demonstrated during the Millennium Drought when the community self-organised to respond to the increased stress of low water allocations to irrigators and reduced rainfall for dryland farmers.

Constructing more climate resilient buildings is a way to reduce exposure to extreme events, especially heatwaves. It can also reduce reliance on power to heat and cool by incorporating passive design elements and therefore provide other benefits such as cost savings to vulnerable members of the community. While this may be more expensive now compared with the business as usual cost, it is expected that costs will come down over time as new technology becomes available. Better understanding the full life cycle cost may also help to demonstrate long term financial savings.

Adopting climate resilient building designs could also create new opportunities for manufacturing of building products in the region. The rate at which improved building design delivers benefits to vulnerable members of the community will depend on whether it applies to new developments, is incorporated as part of the refurbishment of existing developments and whether it is mandated by state government planning policy. Given that at least some vulnerable members of the community will occupy government-owned dwellings, an improved building design program could be initiated by government agencies.

Other priorities to assist with preparing for extreme events will be to:

- **educate and raise awareness regarding preparation and recovery and explore options for incentivising mandatory preparation** such as reducing fuel loads and identifying alternative power and water sources; and
- **scope potential government responses to provide heat refuges**, including who will operate them and how back-up power will be supplied. It is recognised that this is potentially a high cost option and could require significant coordination, though it is considered a secondary option if education and awareness raising activities are not as successful as required.

To assist during events, there is interest in **enhancing extreme event response services** like Telecross REDi service which is used during heatwaves. As part of the service, Red Cross volunteers call pre-registered clients up to three times a day to ask people how they are coping and remind them of measures to help them through extreme weather. Helping vulnerable members of the community could also be done during events by increasing access to, and providing more flexible, emergency relief and evacuation arrangements.

In the recovery phase from extreme events the focus of services needs to shift to **counselling, social support and trauma services**. These are currently provided for declared emergency events like major bushfires or floods, but may need to be expanded in the future to include extreme heatwaves. The revised heatwave definition developed by Nairn and Fawcett (2013), used in developing this plan, could assist in this regard.

Additional, more active forms of adaptation may be required in the future and could include making available various transport options for people to access heat refuges, reviewing waring systems for tourists and visitors to the region and increasing the flexibility of emergency relief and evacuation arrangements.

A summary of adaptation options relevant to managing effects on vulnerable members of the community is provided in Attachment D.

Key points

Immediate priorities are to help vulnerable members of the community be better prepared for extreme events by building social capital (connectivity and resilience) and encouraging the construction of more climate resilient buildings.

During extreme events there needs to be greater focus on response services like Telecross REDi service. After events the focus should be on counselling, social support and trauma services. This may require expanding the circumstances under which declaration is made to include severe heatwaves.

Enablers and barriers to adaptation

Implementing adaptation options to help vulnerable members of the community respond to a changing climate can draw on existing community champions, programs and community warning systems. Stakeholders recognised that many communities in the region are already highly resilient and connected.

Barriers to implementing adaptation options will include the time taken to generate change in policy and encourage the community to adopt new practices, especially where they are geographically dispersed and have varying levels of capacity.

6.5 Emergency services management

Key area for decision-making

How can we manage and reduce where possible the growing demand for emergency services as extreme events such as bushfires become more frequent and intense and rates of volunteering decline?

Context

Emergency services deal with a wide range of incidents in the region including natural hazards like fire and flood. It is a highly valued service and central to the key stakeholder value of "strong communities now and in the future". The sector draws on organisations like the South Australian Police (SAPOL), Country Fire Service (CFS), State Emergency Service (SES) and Ambulance Service (SAAS). Volunteer resources from the community play a vital role for the SES, CFS and SAAS in protecting social, economic and environmental assets in the region.

A complimentary risk assessment process to this adaptation plan has been delivered by the Murray & Mallee Zone Emergency Management Committee who is responsible for the local planning required to put in place measures to plan, prepare, respond to and recover from emergencies. They do this by taking a community-based approach to emergency management and understanding the local resources available to deal with the risk.

Climate change will increase the risk of bushfires in the region, although not consistently, with some localities more affected than others (see Section 4). With the increasing threat will come an associated increasing demand for emergency services. However, this could occur at the same time as volunteer resources are in decline, especially if the community is impacted by:

- economic decline
- competing demands for volunteer time
- a reduction in volunteers due to ageing communities.

Another concern is heatwaves, which have the biggest human health effect of all hazards. This will result in increased mortality and morbidity and affect the SES and SAAS through an increasing number of callouts.

Priority adaptation options

An immediate priority for the emergency services sector is to facilitate increased rates of volunteerism. This will also benefit other sectors in the region such as service provision for vulnerable members of the community and natural resource management. Accelerating current efforts or trialling new approaches to **increase rates of volunteerism** could include:

- providing childcare for volunteers
- increasing the enjoyment of participation
- greater reward and recognition programs
- creating time for people to participate
- encouraging part time and ad hoc volunteers
- creating tax benefits and incentives
- reducing red tape and administrative requirements
- creating roles for older people.

Another immediate priority is to encourage the **refurbishment or construction of critical new buildings and infrastructure** (e.g. regional health care facilities) so that they are more resilient to extreme events. Stakeholders believed that this could be achieved with the support of councils and state government through revision of planning policies and building codes, encouraging the use of new building materials and technology, and giving greater consideration to the requirement for backup power supplies. In contrast, greater emphasis is required on **installing replaceable or removable, non-critical built structures in high risk areas**. This could include toilets, BBQs and outdoor furniture in open space and recreation areas.

Other priorities focus more on measures that will reduce the risk of exposure to emergencies. For example, there is strong interest in enhancing the **preventative care services** provided by some not-for-profit organisations. This could reduce the need for emergency service callouts and would include providing a house gutter cleaning service. Another preferred preventative measure is greater use of **early warning systems** such as status updates, more locality specific information and the use of individual contacts.

Additional, more active forms of adaptation may be required in the future and could involve accelerating a number of the initiatives identified for increasing rates of volunteerism and providing direct support for people to undertake maintenance for residential properties that mitigates the risks from emergencies like bushfires e.g. gutter cleaning, fuel load management.

A summary of adaptation options relevant to emergency service management in the region is provided in Attachment D.

Key points

An immediate priority is to facilitate increased rates of volunteerism. Other priorities are to prepare for emergency events by encouraging the refurbishment or construction of critical new buildings and infrastructure so that they are more resilient to extreme events and installing replaceable or removable non-critical built structures in high risk areas.

Enablers and barriers to adaptation

Adaptation in the emergency services sector can be facilitated through drawing on the experience of other regions and their solutions, education about the impact of climate change, more region specific information, and involvement of key influencers in the region. Continued collaborative work by councils is also seen by stakeholders as important in having a greater voice for the region.

Barriers to adaptation recognise that many people are focused on what are perceived as more imminent priorities and that unless extreme events are occurring frequently or recently, they are "out of sight, out of mind". Concern was also raised about the inability of short-term planning and institutional processes to prioritise resourcing and consider long-term issues like climate change.

6.6 Essential services

Key area for decision-making

How can we establish and maintain telecommunications, electricity and water management infrastructure, which together support the regional economy, in the face of climate extremes such as increasing frequency of bushfires, which may physically damage infrastructure, and generally increasing temperatures which are likely to increase demand for services?

Context

Essential services such as electricity, water and telecommunications support the social and economic well-being of the region. They are also important elements in enabling adaptation to climate change. Telecommunications enables easier information sharing which can be essential before, during and after emergencies; potable water is essential for towns, and electricity is required for industry and to protect the standard of living and individual well-being in the region. Electricity is especially important for: (a) pumps that are required more than ever before because of the need for pressured irrigation systems, and (b) cooling units for intensive animal husbandry especially poultry.

Climate change could affect the provision of essential services through increased frequency of extreme events. While bushfires can directly damage network infrastructure like electricity poles, wires and substations, manual disconnections can also occur during high risk days as a precautionary measure.

Elevated temperatures, especially heatwaves, will be a major issue for electricity supply. The rating of the transmissions lines describes how much power can be put through the lines under normal weather conditions. However, when temperatures increase, the metal expands and the rating declines; the lines can also droop creating greater hazard of sparking, especially during periods of high wind. Increased temperatures can also create greater demand on the distribution system and require power companies to load-shed through rolling blackouts.

Priority adaptation options

An immediate priority is to create adaptive infrastructure which focuses largely on developing local solutions for back-up and power storage for water, sewer and telecommunications infrastructure, as well as domestic storage for distributed power systems like solar photovoltaic (PV). Other types of **adaptive infrastructure** suggested by stakeholders were underground power lines and other critical infrastructure for existing and new developments. While this would be effective in protecting infrastructure it is also expected to be expensive.

Several other priority adaptation actions identified form part of current practice. For example, **operational risk management** will continue to be an important adaptation option. This involves establishing bushfire, flood, wind, storm, and heatwave protection for critical assets, such as creating wider corridors where vegetation is managed near power lines and substations. Planning and risk assessment will also continue to be important and there was support for:

- a **key assets register** using the National Emergency Risk Assessment Guidelines, which is currently being developed (immediate priority)
- **risk assessment to inform investment prioritisation**
- **new network rules** to cater for changing demand.

With respect to water management infrastructure in the region, the greatest issue raised by stakeholders was with respect to the **barrages**, which are expected to be affected by sea level rise in the coming century (see Section 6.3).

More active adaptation in the future may require accelerated adoption of protection strategies listed above such as electricity feeder automation, undergrounding of power cables and installation of backup power supplies.

A summary of adaptation options relevant to essential services in the region is provided in Attachment D.

Key points

An immediate priority is to develop adaptive infrastructure for local solutions to backup and power storage for water, sewer and telecommunications infrastructure, as well as domestic storage to support distributed power systems like solar photovoltaic (PV).

Actions already being implemented as part of current practice that will continue to be important include: operational risk management strategies to protect critical assets from extreme events, and planning and risk assessment activities such as developing a key assets register using the National Emergency Risk Assessment Guidelines.

Enablers and barriers to adaptation

There were two major adaptation barriers identified specific to the electricity supply and distribution part of the essential services sector. First is the role of the Australian Energy Regulator, which regulates networks under the *National Electricity Law* and Rules. The National Electricity Objective, as stated in the *National Electricity Law*, is "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to – price, quality, safety, reliability, and security of supply of electricity; and the reliability, safety and security of the national electricity system". The Australian Energy Regulator undertakes network pricing determinations for five year periods. The challenge is to determine how to encourage the Regulator to incorporate climate change considerations into determining what is in the long term interest of consumers. Similar regulatory issues apply to provision of potable water supplies, which in South Australia is regulated by the Essential Services Commission of South Australia.

Second, is the high uncertainty in power supply and demand in the future. While many climate change projections are focused on conditions in 40–60 years' time, essential services sector stakeholders were of the view that understanding power supply and demand (even in the short-term) is difficult given the increased adoption of distributed power systems which are changing the demand for electricity from the network. This will make investment decisions in electricity supply and distribution increasingly difficult.

Workshops, such as those conducted with essential service providers in developing this plan, were seen as important enablers of adaptation because they help to share information across key organisations such as Electranet, SA Power Networks, Telstra, and SA Water.

6.7 Irrigated horticulture

Key area for decision-making

How can we build on existing work in the irrigation sector to ensure that levels and quality of production can improve in the face of warmer and drier conditions and potentially reduced river flows and water allocations?

Context

Irrigation is a major contributor to the region's economy. It defines and influences the culture and structure of the region's towns. Irrigation using waters from the River Murray occurs from the Riverland to the Murraylands, and includes crops such as almonds, wine and table grapes, stone fruit and citrus, as well as dairying. In the Mallee, annual irrigated crops such as carrots, potatoes and onions are grown with groundwater.

The region is already regarded as being well-adapted to low water availability as a result of experience gained during the recent Millennium Drought. This put a focus on adapting to low water availability over several years.

Climate change will impact irrigated horticulture in two ways. Declining rainfall in the upper Murray is likely to reduce flows entering major water storages meaning that water available for allocation to irrigation will decline. In the Mallee, declining rainfall will have little influence on recharge rates for groundwater due to the ancient nature of the groundwater resource and its lack of connectivity to infiltration. However, a reduction in soil moisture for crops due to reduced rainfall may require greater use of groundwater for irrigation. Rising temperatures, and the associated extremes of increasing heatwaves and fewer frosts, will also place additional stress on crops, changing various factors like growth rates, quality and quantity of produce, timing of harvest, prevalence of disease, and the abundance of pest plants and animals.

Priority adaptation options

The highest priority adaptation action identified by stakeholders was **water trading**. While the ability to trade water has existed since the 1980s, the recent Millennium Drought demonstrated that it is an essential mechanism for enabling Murray irrigators to respond to low water allocations. The importance of water trading in the future is also noted in the Basin Plan *(Water Act 2007–Basin Plan 2012)* which identifies as an objective the creation of a more efficient and effective market that enables water dependent industries to strengthen their capacity to adapt to future climate change.

Water trading continues to evolve and there is interest in emerging water market products such as forward contracts, options and derivatives trading. It should be noted though that while water trading is a vital tool for irrigators, the ability to purchase water is price and availability dependent. How water prices will change if long-term water availability on the Murray declines as a consequence of climate change is not understood. This highlights the need to better understand the impact of climate change on River Murray flows and subsequently annual allocation of water to access entitlements. Given that most environmental entitlements on the River Murray have the same reliability profile as irrigation entitlements, this will therefore also be of interest to environmental water managers.

Improved water-use efficient infrastructure and technology both require more electricity than traditional sprinkler or gravity-fed irrigation systems. This means that irrigators have become more affected than ever by electricity supply and pricing, potentially reducing rather than building resilience. A priority adaptation action for irrigators is therefore to **ensure the continuity of supply of electricity** during heatwaves in particular. Soil water content levels are so tightly managed that if drip irrigation systems were unable to function because of power outages there could be a major impact on plant health and possibly production levels. The rise in use of telemetry for irrigation systems, also a part of the adoption of water-use efficiency technology, means that telecommunications systems will also become increasingly important.

Within current irrigation systems, especially horticulture, better preparing for more hot weather will see a rise in the use of **mesoclimate management infrastructure (i.e. managing the climate of the vineyard or orchard)**. This can include use of a range of measures in the set-up of a production area (block) including:

- irrigation sprays
- netting
- trellising
- higher density plantings.

More active adaptation may require irrigation businesses to start to consider alternative crops more suitable to a different future climate and establishing integrated dryland-irrigation farms. The latter could involve value adding to existing dryland farming operations such as combining irrigation of lucerne with growing prime lambs.

A summary of adaptation options relevant to irrigated horticulture in the region is provided in Attachment D.

Key points

An immediate priority is for further evolution of water market products and greater adoption of water-use efficient technologies.

To support improved understanding of water availability, further research is required into the impacts of climate change on River Murray flows and the implications for allocations to water access entitlements.

Continued reliance on water-use efficient infrastructure and technology places greater focus on maintaining the continuity of supply of electricity and telecommunications to the region.

Continued innovation in mesoclimate infrastructure when establishing new production areas (blocks) will also be a priority for further adaptation.

Enablers and barriers to adaptation

Uptake of adaptation measures will be influenced by growers' comfort with new approaches. For example, although some growers traded water during the Millennium Drought there is still a view that many people have limited capacity to use the water market and limited knowledge of emerging water market products. Encouraging community champions to get behind new technologies and approaches will be a vital way to sell the success of new adaptation measures.

A major enabler in the region for continued adaptation is expected to be the reinvigorated Loxton Research Centre. This will overcome issues with the decline in irrigation extension activities. Combined with the funding from the South Australian River Murray Improvement Scheme, there is expected to be significant innovation in the region in the coming decade.

6.8 Dryland (rain dependent) farming

Key area for decision-making

How will farmers maintain the productivity of existing cropping-based farming systems under warmer and, most likely, drier conditions in the future?

Context

Dryland farming in the region includes a mixture of cereal cropping and cattle and sheep grazing, the latter for meat and wool. Dryland farmers are well-adapted to climate variability given wide season-to-season variation in the quantity and timing of rainfall, suggesting they have high adaptive capacity. Most of the region is low rainfall and so there is significant experience in dealing with low-water availability.

Climate change could affect agriculture in the region by reducing the long-term yield of pasture and cropping as a consequence of warmer and drier conditions. This could favour more pastoral or forage-based grazing systems in the drier parts of the region on country that is currently marginal for cropping. In areas with higher rainfall, cropping will continue but possibly with reduced yields. The economic productivity of the region will be influenced by commodity prices. If these rise and productivity falls, net economic value for the region could still increase.

Priority adaptation options

By number and variety, more adaptation options were identified for the dryland farming sector than any other during the stakeholder engagement sessions. Proven practices for cropping in a low rainfall environment must continue and involves:

- **traditional crop breeding** – this can deliver high benefits through underpinning greater food security and reducing herbicide use, but also comes at a high cost and takes significant time to deliver new traits
- **soil improvement through the addition of clay and other amendments** – this can increase water and nutrient retention in the soil, however, northern Mallee farmers noted that clay addition can be cost-prohibitive unless suitable clay can be accessed close to where it will be applied
- **no-till cropping** – this practice retains organic matter in the soil and helps to preserve soil water and nutrient retention. This is already being practiced by the majority of farmers and needs to continue to be encouraged. It was noted by stakeholders though that there is high reliance on herbicides to control weeds which is leading to greater rates of application as resistance builds. If herbicide use can be reduced, this will continue to be a win-win action into the future

- **increased grazing in dryland farming systems**– this involves introducing more fodder shrubs and other perennials and mixed farming systems in marginal land less suitable for cropping. It will keep people on the farm and in the community, and will diversify cash flow, but it will also create higher workloads, and may require new skills to be developed, and expenditure on watering points, fencing and yards. It is expected that this will be adopted incrementally in low-rainfall areas now, and in medium-rainfall country within 10 to 20 years.

Emerging adaptation priorities will include improved weather forecasting, greater use of soil modification through application of biochar and other amendments and greater adoption of landscape scale farming through use of collaborative farming models. Among these, **improved weather forecasting** was rated as the highest priority and will have flow-on benefits to other sectors such as irrigation and emergency services.

Collaborative farming, also described as farming at the landscape level, is seen as a more strategic way to farm which focuses on land capability. While there is some concern that this would contribute to a decline in the size of rural communities, it could also create more community cohesion and knowledge-sharing. The sharing of infrastructure and machinery could also make this a lower cost option and support development of more viable farms. This is a comparatively new model for farming in the region and, as such, is expected to take time (10 to 20 years) before it is widely adopted.

Soil modification through the use of biochar is a field of emerging interest, with the hope that it can provide long-term soil enhancement while also producing energy from local agricultural residues or organic waste as a by-product. While it is an action that stakeholders believe should not be delayed, the research, development and farmer extension costs are expected to be high, along with the development of equipment to produce and apply it. This means that it will take some time to be widely adopted.

There was substantial interest and debate about the future role of **genetically modified crops** in dryland farming. A moratorium currently exists on their use in South Australia, though there is a view among some stakeholders that they will deliver new traits more suited to hotter and drier conditions at a rate faster than that offered by traditional breeding programs. The costs and benefits of genetically modified crops were discussed at length with agreement that it requires real debate and evidence, particularly exploring whether concerns such as health and environmental risk are valid. If the risks are low, then the benefits of increasing or more resilient farm income could be of benefit to rural communities and food security. It was agreed that this is not an action that should be pursued now but that debate should be encouraged.

Experience during dry periods in the past decade highlighted the role of business planning as an adaptation strategy. Improving farmers' business and decision-making skills through improving their ability to identify and analyse potential enterprise costs, benefits and risks and providing the right tools to assist in decision-making is likely to become an increasingly important adaptation strategy (Doudle et al. 2009).

Active adaptation may require accelerating a number of the adaptation options identified in this project such as soil improvement and traditional and advanced crop breeding.

A summary of adaptation options relevant to dryland farming in the region is provided in Attachment D.

Key points

No-till or reduced-till practice, crop breeding and soil improvement are high priority adaptation actions that form part of current practice and where applicable and cost effective should continue to be encouraged.

High priority emerging adaptation actions are likely to focus on improved weather forecasting, which will benefit multiple other sectors, and greater adoption of collaborative farming models. Enhancing farmer business and decision-making skills is also important.

Enablers and barriers to adaptation

Dryland farmers are well-suited to responding to climate change because there is a strong history and culture of dealing with climate variability and responding to low water availability in many parts of the region. They have first-hand knowledge of the variable effects of climate on people, their families and community and are therefore motivated to act when threats arise.

A major barrier to adaptation could be the perception that growers already have high resilience to future climate change. While this may be true in some instances, the future climate for most growers will differ from their past experiences and new adaptation strategies will be required. Furthermore, and as highlighted by northern Mallee farmers, margins in cropping are already limited and so unless a clear business case exists for adopting new approaches, innovation relevant to climate change impacts may be limited. This will be further exacerbated by what is perceived to be declining investment into research and development.

7 Cross-sectoral adaptation priorities

This plan has identified priority adaptation actions for individual sectors in relation to key areas of decision-making. Many of these actions will need to be implemented or further prioritised by individual sectors.

As a regional scale plan, consideration also needs to be given to which adaptation actions are priority across multiple sectors. These were identified by selecting those actions that were a priority for each key area of decision-making and then using information from the stakeholder workshops to determine which actions were a priority for other sectors or which were potentially maladaptive, giving equal weighting to both.

The following cross-sectoral priorities were identified[10] :

1. Improve the identification, prioritisation and management of pest plants and animals

This action was originally identified under the native vegetation key area of decision-making, but is also relevant to other issues in this plan such as pest plants and animals, irrigation and dryland farming. There is recognition that there needs to be a focus on (a) educating and supporting both public and private landholders to manage pests and (b) facilitating risk assessment and adoption of transformational management through increased investment in research.

Lead responsibility: Natural Resources SAMDB (DEWNR), Biosecurity SA

2. Facilitate increased participation in community activities to build connectivity and resilience

This action was identified as a priority under the vulnerable members of the community theme but also relates to emergency services management, better management of native vegetation through initiatives like Landcare and could assist with managing pest plants and animals on public or private land.

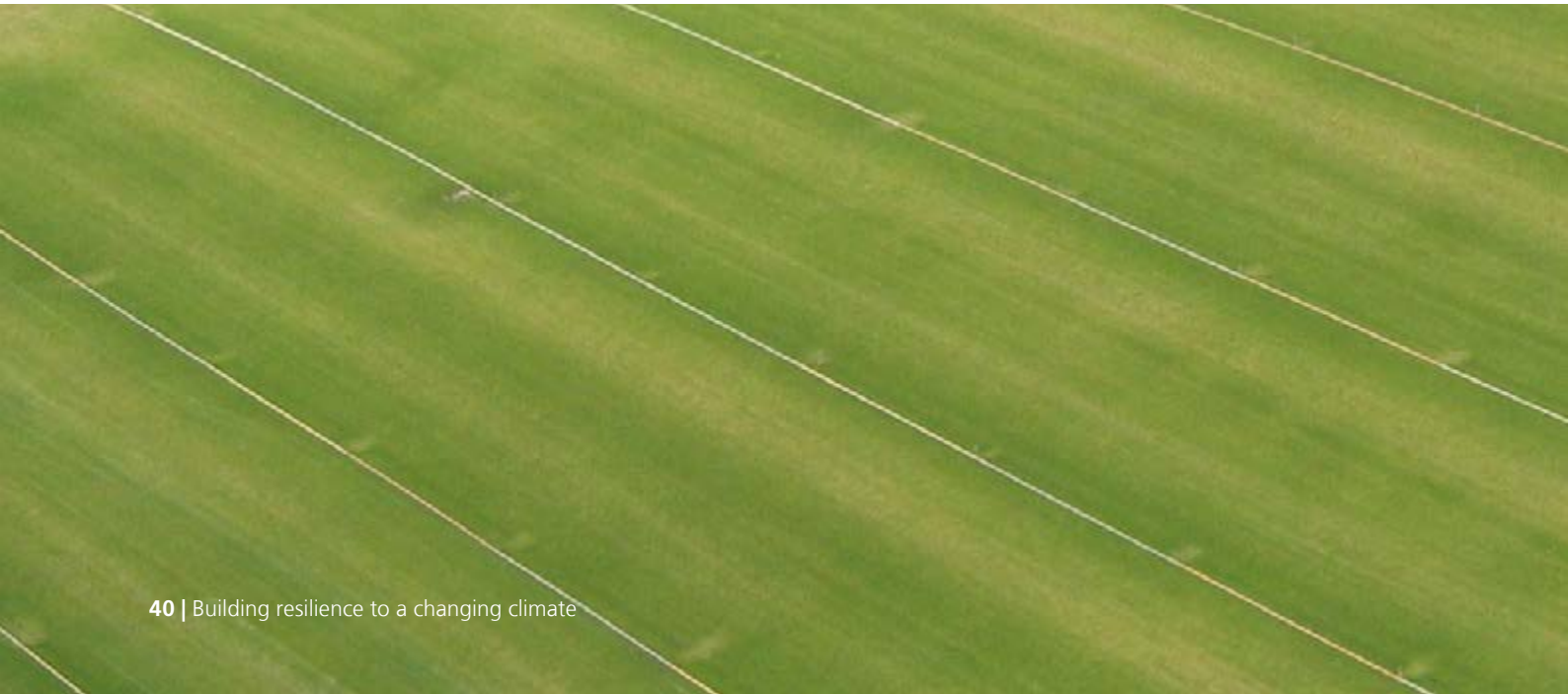
Lead responsibility: Regional councils

3. Improve water-use efficiency

The focus of this adaptation option was on greater uptake of water efficient technologies like automation and telemetry. While substantial work has already happened across the region in relation to water-use efficiency, this was identified as a cross-sectoral priority because continued adoption is seen as essential for long term viability of the irrigation sector which supports much of the region's economy. The region is well positioned to increase adoption of water-use efficient technologies because of the South Australian River Murray Improvement Scheme, which is a major funding source for this type of approach.

Lead responsibility: Private irrigators with the support of irrigation trusts where relevant

[10] *No ranking is intended by the order of actions*



4. Further research into climate change impacts on River Murray flows

This action was identified for the irrigation sector, but is also relevant to management of the river and floodplain environment and the condition of the Coorong and Lower Lakes. Central to further research is better understanding the impacts of climate change on annual allocations to water access entitlements.

Lead responsibility: Department of Environment, Water and Natural Resources with support from water research organisations

5. Improve seasonal weather forecasting

This action was identified as a priority under the dryland farming theme but will also be of interest to irrigation, emergency services management and essential services. This action will require further enhancements of existing weather forecasting models by the Bureau of Meteorology.

Lead responsibility: Bureau of Meteorology

6. Establish and implement bushfire management, response and recovery plans

This action was identified as a priority under the native vegetation theme but will be relevant to all sectors where bushfire risk poses a threat. This issue arose because of the view that bushfires will shape vegetation communities and enable the spread of pest plants and animals while being a major issue for emergency services.

Lead responsibility: Natural Resources SAMDB (DEWNR), Zone Emergency Management Committee

7. Future operation and location of the barrages

This was identified as a priority for discussion by stakeholders involved in considering the impacts of climate change on the Coorong and Lower Lakes and arose out of concerns for the effect of sea level rise on barrage operation. It was also identified as a major source of maladaptation (i.e. an action that will have negative consequences on other sectors). Importantly, this action is not required immediately because sea levels are expected to rise slowly over the coming century. However, it should be considered in the design of any future barrages upgrades, which may occur within the next one to two decades.

The immediate priority is to commence social engagement to increase community awareness and to promote informed debate about the future operation and location of the barrages. Engagement needs to be supported by (a) detailed modelling of the effect of varying amounts of sea level rise on the frequency, duration and extent of salt water incursions into Lake Alexandrina and (b) exploration of the sequencing of different adaptation options through time.

Lead responsibility: Natural Resources SAMDB (DEWNR), Murray-Darling Basin Authority, SA Water

The first six actions identified above are arguably a continuation of current practice, albeit at an accelerated rate. This suggests that the region has already built significant capacity to respond to a variable climate, influenced largely by experience with past droughts such as the Millennium Drought. In contrast, the future operation and location of the barrages is one of the most transformational adaptation actions identified in this plan and requires significant consideration of alternative options and how to sequence adaptation, as has been done in other examples of coastal infrastructure such as the Thames Barrier near London in the United Kingdom.

8 Implementing the plan

8.1 Enabling adaptation

In the final stage of the third workshop, project participants were asked to identify 'enablers' and 'barriers' to implementing the adaptation options they had identified for their sectors. Common themes apparent from participants' feedback on enablers and barriers to adaptation are described in Attachment E. The top three responses for enablers and barriers are as follows:

Enablers

- Leadership, in the form of champions at all levels in the community
- Knowledge, including local knowledge and science, about climate change effects. This needs to be made available, accessible and relevant
- Greater involvement of youth, indigenous people and elected bodies from other locations to share their experiences, knowledge and information.

Barriers

- Time frame mismatches occur because many people and institutions only focus on the short term whereas adaptation requires planning now for the longer term. People also often only respond to an immediate crisis
- Lack of resources, in terms of funding and flow on effects to lack of personnel and R&D
- Lack of knowledge about climate change effects and how to use existing adaptation options like the water market.

Uptake and implementation of options generally requires approval through a decision-making process. Options will be more or less acceptable to decision-makers depending on the existing values (v), rules (r), and knowledge (k) which they are drawing upon. For example, there was some discussion in the workshops about whether genetically modified crops might eventually be required under conditions of extreme climate change. This option is currently not feasible as it is not supported by current societal values and existing laws. Acceptance of genetically modified crops and even animals as an adaptation option would require changes in current societal values and rules, which is adaptation at the societal scale.

In the enablers and barriers to adaptation identified by participants, the need for information and knowledge appears near the top of both lists. This is a common response in discussions about adapting to climate change. The inclusion of 'knowledge' and 'values' from different groups and leaders was also identified as an important enabler for adaptation focused decision-making. This reflects a desire to change the 'rules' about who gets to participate in decision-making. A wide-spread focus on the short term is another example of existing 'rules' that participants felt inhibited taking action on climate change.

There was quite a strong focus on existing factors that enable adaptation. Many of these related to existing initiatives, particularly in relation to vulnerable members of the community. It will be important to consider these in any future planning activities, to ensure they are not adversely impacted.

Adaptation that has occurred during the last drought was also seen as an enabling factor for future adaptation. However, it is likely that in the longer term the climate extremes will be greater than those experienced during the drought.

The Ngarrindjeri Regional Authority (NRA) has played a key role in the implementation of the Murray Futures Program. This has built capacity within the NRA and the Ngarrindjeri community to support these types of programs. Ongoing Ngarrindjeri involvement in implementation of this Plan will support the strengthening of the unique relationship Ngarrindjeri have with their country and this will have flow-on effects to the broader community and region.

8.2 Periodic review

This plan presents adaptation priorities based on published information available at the time of its development and the opinions and local knowledge of stakeholders who participated in interviews and workshops. While many actions could be seen as part of current practice, adaptation will require accelerating their adoption or initiating uptake of existing ideas that are yet to be implemented.

The plan needs to be periodically reviewed, in the spirit of adaptive management, every two to three years to consider new information on climate change projections and impacts and to account for changes in adaptive capacity. This should be done by the organisations participating in the Regional Sector Agreement process.

Any review of this Plan should be done with consideration of the periodic reviews of the Basin Plan *(Water Act 2007 – Basin Plan 2012)*, which requires that "A review must be undertaken having regard to the management of climate change risks and include an up-to-date assessment of those risks, and consider all relevant knowledge about the connectivity of surface and groundwater, the outcomes of environmental watering and the effectiveness of environmental works and measures."

Future planning by organisations participating in the Regional Sector Agreement process needs to adopt an approach underpinned by agreed principles and focus more on (a) understanding whether climate-related thresholds exist for social, economic or environmental systems and the extent to which more transformative change may be required to respond to complex issues such as the future operation and location of the barrages and (b) identifying opportunities and encouraging investment that can build resilience to climate change, such as that previously identified for the region (Siebentritt, M et al. 2011).

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Attachment A
How was this plan developed?

A.1 Underlying approach

The plan was developed through a technically rigorous and participatory based approach to climate change adaptation that sought to cover key sectors in the region. The steering committee's vision for the project was that people should be at the centre of plan development.

The engagement process was designed to create a positive discussion about building resilience in the region to combat the impacts of climate change and to identify partnerships that can help achieve this outcome. Engagement occurred with stakeholders from key sectors across the region, covering agriculture (irrigated and rain dependent farming), tourism, natural resources management, emergency services management, health care and community services. A summary of stakeholders who attended workshops is provided in Attachment B. In addition to tailored workshop processes to engage with stakeholders, engagement with traditional owners and aboriginal communities was also undertaken (see Section A.3).

Underpinning the project design was recognition of the role that the decision-making context can play in determining what action is taken. Adaptation planning often focuses on "decision problems" such as how coastal infrastructure might adapt to rising sea levels, or how to assist vulnerable communities to respond to an increasing frequency and intensity of heatwaves. However, it has recently been suggested that attention should also be given to the " decision-making context", specifically what influences whether and how decisions are made (Gorddard et al. in review).

In describing the decision-making context, three factors are important: (i) the values that are affected by the decision; (ii) knowledge of how the socio-ecological system(s) operates and will be affected by the different management actions or options; and (iii) rules that define the criteria and process for combining knowledge and values to produce a decision and which enable the resulting decisions to be translated into a societal response. Rules can include policies, legislation, and governance arrangements. This understanding of the decision-making context influenced the workshop process by: (a) focusing on values in the first workshop; (b) using values and knowledge to inform the vulnerability assessment; and (c) referring to values, rules, and knowledge in identifying barriers or enabling conditions for preferred adaptation options.

A.2 Key elements of the engagement process

The engagement process that underpinned the development of this plan involved the three steps identified below. For each step, workshops were held in Murray Bridge as well as Loxton or Waikerie to maximise attendance given the long travel times for stakeholders to attend meetings in the region.

Step 1 – Values mapping and key decisions

The focus of the first workshop was on establishing what stakeholders value in their region, generating a better understanding of the decisions that will be made by different sectors, and understanding how these decisions will be impacted by climate change.

The decisions based analysis (following from Stafford Smith et al. 2010) was used to better understand the lifetime of critical decisions that will be made now by different sectors, determining which decisions have a long lifetime, and therefore which decisions need to account for the longer term effects of climate change. The values mapping exercise was used to understand how people orient themselves within a particular environment, landscape or locality. From this information, values were then extrapolated about what aspects are important or valued.

The values and decisions identified through the first workshop were supplemented by others identified during phone interviews conducted with key stakeholders unable to attend the workshop. During these interviews, stakeholders were asked the following three questions: (1) which reports/studies/ projects do you think have been most important to date for understanding the effects of climate change on your sector; (2) what are some of the key decisions that are made by people and/or organisations in your sector that influence the viability of the sector and; (3) what are the climate variables (e.g. rain, temperature, sea level rise) of most interest to your sector and why?

The values and key decisions identified during the workshop and phone interviews helped to identify indicators for use in step two, the Integrated Vulnerability Assessment.

Step 2 – Integrated vulnerability assessment

The project undertook an integrated vulnerability assessment (IVA) by adapting the approach described in the Local Government Association of South Australia's *Guidelines for developing a climate change adaptation plan and integrated climate change vulnerability assessment*. Indicators were selected to represent the values and key decisions identified during the first workshop. An initial scoring process was undertaken by the project team which assessed exposure, sensitivity, potential impact, adaptive capacity and vulnerability for a range of climate variables (see Section 4 for a description of the climate variables used in the IVA). Team scoring was informed by published information and other data sources where available such as the landscape futures analysis tool, which describes the potential effect of climate change on agricultural productivity and native plant and weed distribution in the region. These preliminary scores were then reviewed and refined by stakeholders at the second workshops, with a focus on sensitivity and adaptive capacity scores.

Following the second workshops, the vulnerability scores were assessed and prioritised with input from the steering committee. The results of this assessment are summarised in Section 5 of the plan, where they have been used to develop key areas for decision-making to focus on when identifying adaptation options.

Step 3 – Identifying and prioritising adaptation options

The third step of the project focused on identifying and prioritising adaptation options. Stakeholders were provided with a discussion paper describing potential adaptation options relevant to key areas of decision-making prior to attending their workshop. The purpose of the third workshop was to (a) confirm the list of potential adaptation options, adding to those already identified in the discussion paper where needed; (b) assess and prioritise adaptation options and (c) discuss conditions that would enable or act as a barrier to adaptation.

The assessment and prioritisation element used a qualitative cost-benefit analysis, together with targeted questions about responsibilities for action and whether proposed actions should be delayed or commenced immediately.

For this step, the workshop was repeated in Murray Bridge and Waikerie, with an additional workshop held in Adelaide to provide stakeholders from the essential services sector the opportunity to participate in the project.

Identification of adaptation options has also been informed by feedback from presentations of this project to existing forums, workshops and meetings (Table A.1).

A.3 Engagement with traditional owners and aboriginal communities

Indigenous culture has adapted and survived thousands of years of climate change and variability and holds lessons for the contemporary Australian way of living. As the value of traditional knowledge in developing an adaptation plan is seen as crucial, the steering group has seen as essential to put in place a process of early and ongoing engagement with the traditional owner groups and other Aboriginal people in the region. These engagement processes include internal mechanisms that are more culturally appropriate and consistent with Ngarrindjeri ways of working through the issues and developing options for future actions.

Indigenous Australians experience a disproportionate vulnerability to the impacts of climate change. Indigenous peoples have been identified by the International Panel on Climate Change as particularly vulnerable to the detrimental impacts of a changing climate. Changing climatic conditions risk impacts on the plants and animals, livelihoods, culture, health and wellbeing of Aboriginal people. Adapting to the changes will present ongoing challenges.

Constructive dialogue to include an indigenous perspective into regional climate change planning is continuing through ongoing discussions with Ngarrindjeri leaders and elders of the region.

Table A.1. Summary of forums/workshops and meetings at which presentations on this project have delivered to gather additional stakeholder feedback.

Forum/workshop/meeting	Date
Local Government NRM Advisory Group	7 May 2013
Mallee-Coorong NRM Group Presentation	1 May 2013
Alexandrina Council	9 July 2013
Murray Mallee LGA	2 August 2013
Coorong Council	15 October 2013
Local Government Planner's Forum	4 October 2013
Ngarrindjeri Regional Authority Ngarrindjeri Yarluwar-Ruwe Program	22 November 2013
Ngarrindjeri Yarluwar-Ruwe (Indigenous)	22 November 2013
Presentation to SAMDB NRM Team Talk	10 December 2013
Flood and Riverbank Collapse (Emergency Management)	3 April 2014
Southern Hills LGA Public Health Plan	8 April 2014
Coorong, Lower Lakes, Murray Mouth Community Advisory Panel	10 April 2014
Extreme Weather Workshop (Emergency Management)	13 May 2014
First Peoples presentation Riverland	21 February 2014 & 11 July 2014
Essential Services Workshop	4 June 2014
Northern Mallee Farmers Forum	13 June 2014
Regional Development Australia (Murraylands and Riverland)	19 June 2014
Mid-Murray Council	14 July 2014

Attachment B
Interview and workshop participants

The people identified in the following table either attended one of the three project workshops or participated in a key stakeholder interview at the commencement of the project.

Full name	Organisation
Terry Banks	Natural Resources SAMDB
Jenna Barry	District Council of Loxton Waikerie
David Beaton	Berri Barmera Council
Kim Blenkiron	Ranges to River NRM Group
Simon Bradley	Rural City of Murray Bridge
Tina Brew	Department of Environment, Water and Natural Resources
Nerida Buckley	Department of Environment, Water and Natural Resources
Les Buckley	SAPOL
Lauren Burton	Department of Environment, Water and Natural Resources
Michelle Campbell	Berri-Barmera Council
Joe Carli	Mid Murray LAP
Joe Caruso	SA Power Networks
Greg Cock	Primary Industries and Regions South Australia
David Cooke	Biosecurity SA
Steve Coombe	Eastern Hill & Murray Plains LAP
Frank Crisci	SA Power Networks
Ian Darbyshire	Murraylands Tourism Partnership (Chair)
Peter Doumouras	SA Water
Anna Dutkiewicz	Natural Resources SAMDB
Geoff Eaton	Department of Environment, Water and Natural Resources
Michelle English	Department of Environment, Water and Natural Resources
Tony Farrell	Landholder Mid Murray
Brian Featherston	Department of Education and Child Development
Craig Ferber	Loxton to Bookpurnong LAP
Rohan Fernandez	ElectraNet
Ruth Firstbrook	District Council of Loxton Waikerie
Denise Fowles	Natural Resources SAMDB
Graham Gates	Coorong LAP
Craig Gillespie	Department of Environment, Water and Natural Resources
Mark Gishen	SA Wine Industry Association
John Gitsham	Goolwa-Wellington LAP
Kelvin Goldstone	Mid Murray Council

Full name	Organisation
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Robert (Bob) Green	Telstra
Rohan Hamden	Department of Environment, Water and Natural Resources
Trevor Harden	Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
David Harmon	State Emergency Service
Paul Harvey	Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
Tim Herrmann	Department of Environment, Water and Natural Resources
Stuart Hicks	Department of Environment, Water and Natural Resources
Greg Hill	Mid Murray Council
Geoff Hodgson	Department of Environment, Water and Natural Resources
Hugo Hopton	Natural Resources SAMDB
Humphrey Howie	Irrigator; Renmark Irrigation Trust; Renmark to the Border LAP
Nicolle Jachmann	Regional Development Australia
Warren Jacobs	Ranges to River NRM Group; dairy farmer
Mandy James	Educator
Sharon Jardine	Renmark Paringa Council
Noel Johncock	SAFECOM
Glen Jones	Boating SA; Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
Andrew Kassebaum	Natural Resources SAMDB (board member); Berri-Barmera Council (elected member);
Bernie Lawson	Natural Resources SAMDB
Elizabeth Lescheid	Renmark Paringa Council
Brenton Lewis	Regional Development Australia
Barry Lincoln	Ngarindjerri Regional Authority
Sue Luchich	Renmark to Border LAP
Greg Lundstrom	Department of Environment, Water and Natural Resources
Shen Mann	Alexandrina Council
Caren Martin	SA Murray Irrigators
Neil Martinson	Renmark Paringa council (Chair); Zone emergency management committee (Chair); Murraylands and Riverland RDA (Chair)
Glenys Matthews	Educator
Greg McCarron	Central Irrigation Trust
Andy McConnell	Telstra
Chris McDonough	Rural Solutions
Peter McGinn	Sustainable Mount Barker
Teagan McKillop	Renmark to Border LAP

Full name	Organisation
Gavin McMahon	Central Irrigation Trust
Tony Meissner	Riverland NRM Group
Peter Michelmore	Natural Resources SAMDB
Paul Mickan	Barossa Council
Deana Mildren	SAMDB NRM (board member)
Kerri Muller	Kerri Muller NRM
Bruce Munday	Private farmer
Francis Murphy	Parilla Premium Potatoes
Andrew Nance	St Kitts & Associates
Jai O'Toole	Department of Environment, Water and Natural Resources
Rhona Parker-Benton	SA Country Health
Bill Paterson	Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
Jill Paterson	Coorong, Lower Lakes and Murray Mouth Community Advisory Panel
Russell Peate	Mid Murray Council
Pippa Pech	SAFECOM
Mike Penhall	Natural Resources SAMDB
Bradley Perry	Representative for Member for Chaffey
Greg Perry	Berri-Barmera Council
Neville Pfeiffer	Southern Mallee District Council
Rod Ralph	Natural Resources SAMDB (board member)
Sally Roberts	Alexandrina Council
Veronica Rothe	Berri-Barmera Council
Greg Sarre	District Council of Mt Barker
Maddie Sarre	Youth Ambassador
Kitty Schianski	Landholder Mid Murray
Liz Schofield	Angas River Catchment Group
Russell Seaman	Department of Environment, Water and Natural Resources
Mark Skewes	SARDI
Joshua Smith	ElectraNet
Tim Smythe	Primary Industries and Regions South Australia
Sharon Starick	Natural Resources SAMDB NRM Board, Presiding Member
Ken Stokes	Riverland NRM Group
Fred Strachan	Irrigator
Susan Sweeney	Department of Environment, Water and Natural Resources
Gerald Thompson	Goolwa-Wellington LAP

Full name	Organisation
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Duncan Tullett	Rural Solutions
Vince Varricchio	Department of Planning, Transport and Infrastructure
Gemma Walker	Mallee Sustainable Farming
Peter Ward	Ranges to River NRM Group
Terry Wheeldon	Educator
Monique White	Ranges to River NRM Group; Dairy SA
Grant Whiteman	Calperum Station
Grant Whiteman	Australian Landscape Trust
Craig Williams	SAPOL
Jacqui Wilson	Goolwa-Wellington LAP
Tony Wilson	Rural City of Murray Bridge
Shane Wiseman	Department of Environment, Water and Natural Resources
Danielle Witham	Natural Resources SAMDB
Bryce Wood	SAPOL
Mike Wouters	Department of Environment, Water and Natural Resources
Lloyd Wright	Rural Financial Counselling Service

Attachment C
Integrated vulnerability assessment results

This plan has been informed by the results of an integrated vulnerability assessment (IVA). The IVA followed the method described in the Local Government Association of South Australia's *Guidelines for developing a climate change adaptation plan and integrated climate change vulnerability assessment.*

Table C.1. Summary results for an Integrated Vulnerability Assessment prepared for the South Australian Murray-Darling Basin. Results relate to primary indicators. Very low < 4; ≤ 4 Low < 8; 8 ≤ Medium < 12; 12 ≤ High < 16; > 16 Very high.

Primary indicator	Vulnerability description
Environmental capital	
Water	Very high
Pest plants and animals	High
Biodiversity	High
Financial capital	
Agriculture (impact of pest plants and animals)	High
Manufacturing	High
Dairy production (irrigation)	High
Intensive livestock production (e.g. chickens, pigs)	High
Broadacre cropping	High
Irrigated horticulture–viticulture	High
Irrigated horticulture–tree crops	High
Mining	Medium
Tourism	Medium
Fisheries	Medium
Irrigated horticulture–fresh produce (e.g. potatoes, carrots)	Medium
Retail trade	Medium
Construction and engineering	Medium
Waste management	Medium
Beef, sheep and wool production	Medium
Human capital	
Health	Very high
Social inclusion/exclusion	High
Education	High
Community connectivity	High
Community participation	High
Public safety	High
Social capital	
Community planning and development	High
Emergency management	High

Primary indicator	Vulnerability description
Physical capital	
Service networks	High
Communications networks	High
Water management infrastructure	Medium
Transport Networks	Medium
Buildings	Medium
Land assets	Medium
Recreation	Medium

Attachment D
List of adaptation options

The full list of adaptation options identified in relation to key areas of decision-making is listed below. The numbering in the table does not relate to any ranking of actions.

Key area of decision-making	Adaptation options
Native vegetation: How do we maintain functional vegetation communities, that provide habitat for regional birds and mammals (many of which exist outside of DEWNR reserves), in the face of warmer and drier conditions and more frequent and intense bushfires?	1. Implement Regional Recovery Plans for threatened species 2. Identify, prioritise and manage pest plants and animals 3. Identify and develop ecological linkages to enable species migration, but avoid assisting pests to migrate 4. Develop methods for large-scale habitat restoration, especially in heavily cleared landscapes 5. Incorporate into land use planning the relative importance of habitat area, environmental diversity, habitat connectivity and isolation, and different types of habitat/climate refugia 6. Protect isolated patches of native vegetation and provide additional buffers in a way that is self-sustaining 7. Identify and manage parts of the environment that provide recognised habitat and climate refugia for species during climatic extremes and ecological disturbances 8. Establish and implement bushfire management, response and recovery plans 9. Support and promote landholders managing high-value native vegetation on private properties 10. Establish prescribed burning regimes 11. Strengthen genepools of existing species 12. Species translocations involving moving species to new areas outside the region 13. Ecosystem engineering involving replacing ecosystems no longer viable in the region with new ones.
Pest plants and animals: How do we minimise the impact of new pest plants and animals entering important farming and natural environments from rangelands areas in the north of the region in response to warmer and drier conditions?	1. Improve adaptive capacity and flexibility of the current pest planning process at the landscape scale 2. Rapidly identify and assess the risk of new and emerging pest species 3. Identify and monitor corridors and vectors for pest species movement 4. Review and adapt pest animal baiting programs such as through increased intensity and range 5. Educate and support public and private landholders managing pest plants and animals 6. Facilitate risk assessment and adoption of transformational management through increased investment in research 7. Greater use of risk assessments to focus on priority pest species 8. Build government agency capacity to respond to a range of disturbance triggers like climatic extremes and ecological disturbance 9. Prioritise pest management in areas of high conservation value 10. Develop protocol for targeted post-disturbance management of weeds 11. Control pest species in parts of the environment that provide refugia for species during climatic extremes and ecological disturbance 12. Establish and implement bushfire management, response and recovery plans 13. Establish prescribed burning regimes

Key area of decision-making	Adaptation options
Coorong and Lower Lakes: How do we protect key habitats and species in the Coorong and Lower Lakes region as river flows continue to decline, salinity levels in the estuary rise in response to increasing sea levels pushing more sea water into the region, and the risk of pest plant and animal incursions increases?	1. Strategically revegetate exposed soils during drawdown 2. Undertake liming to offset the impacts of acid-sulphate soils 3. Raise the height of the barrages and constructing levees on the islands between the barrages 4. Relocate the barrages 5. Protect habitat refugia 6. Implement captive breeding programs during periods of drought 7. Plan for the control of pest plants and animals 8. Establish temporary levees to protect freshwater refugia 9. Sand pumping at the River mouth 10. Adapt and modify the barrages for faster operation 11. Social engagement to increase community awareness and to promote informed debate about the future operation and location of the Barrages 12. Increase accessibility to relevant information
Vulnerable members of the community: How do we help vulnerable members of the community maintain health and well-being which may otherwise be impacted by increasing frequency and intensity of extreme events such as bushfires and heatwaves?	1. Implement and enhance heatwave response services e.g. Telecross REDi service 2. Scope potential government responses relating to provision of heat refuges 3. Provide support for not-for-profit organisations or other service providers to vulnerable members of the community 4. Enhance local and regional support networks 5. Make available various transport options for people to access heat refuges 6. Facilitate increased participation in community activities to build social capital (connectivity and resilience) 7. Raise education and awareness regarding health impacts of climate hazards 8. Raise education and awareness regarding preparation and recovery and explore option for incentivising mandatory preparation 9. Provide counselling, social support and trauma services 10. Provide assistance and support for carers 11. Consider the suitability of existing industry code of practices for outside contract work 12. Review and refine state arrangements for emergency warnings and communications for tourists and visitors to the region 13. Increase access to and flexibility of emergency relief and evacuation arrangements 14. Appropriate building design that reduces climate impacts

Key area of decision-making	Adaptation options
Essential services: How can we establish and maintain telecommunications and electricity supply infrastructure, which together support the regional economy, in the face of climate extremes such as increasing frequency of bushfires, which may physically damage infrastructure, and generally increasing temperatures which are likely to increase demand for services?	1. Undergrounding power lines and other critical infrastructure in existing and new developments 2. Backup power and generators for water, sewer and telecommunications infrastructure 3. Local solutions for backup and domestic power storage 4. Distributed power supply 5. Improve feeder automation 6. Review the rating of assets 7. Low lying coastal infrastructure 8. Fix or replace the barrages 9. Escalation points for Telstra 10. Future asset plan development 11. Streetscape planning 12. Risk assessment to inform investment prioritisation 13. Key assets register using the National Emergency Risk Assessment Guidelines 14. New network rules to cater for changing demand 15. Avoid construction of essential services buildings in high risk areas 16. Turn off power to high fire danger areas 17. Establish bushfire, flood, wind, storm, heatwave protection for critical assets 18. Wider corridors near power lines or substations 19. Manage potable water during significant events
Irrigation: How can we build on existing work in the irrigation sector to ensure that levels and quality of production can be maintained in the face of warmer and drier conditions, and potentially reduced rivers flows and water allocations?	1. Water trading 2. Farming new varieties of existing crops 3. Farm different types of crops 4. Change harvesting techniques 5. Ensure continuity of electricity supply and telecommunications 6. Greater use of distributed energy systems to support pumping 7. Improve water-use efficiency 8. Adopt off-farm income 9. Change to dryland farming enterprises 10. Improve prices through market development 11. Higher density plantings to better utilise available water 12. Diversify farm production, e.g. aquaculture 13. Use alternative water sources e.g. desalination of drainage water or saline ground water 14. Research and development for chill units 15. Innovative production systems, e.g. pick pomegranates in the field for paste 16. Plant sensing techniques for water stress 17. Agreed chemical control options (need effort into summer weed control, safety) research and development 18. Mesoclimate manipulation such as netting to reduce radiant heat

Key area of decision-making	Adaptation options
Dryland farming: How will farmers maintain the productivity of existing cropping-based farming systems under warmer and, most likely, drier conditions in the future?	1. Enhance business planning and decision-making 2. Establish new crop varieties from traditional breeding programs 3. Ensure no till cropping systems 4. Improve seasonal weather forecasting 5. Improve soils through the application of clay, biochar and other amendments. 6. Increase income diversification 7. Consider genetically modified crops 8. Utilise more resilient animal breeds 9. Move to pastoralism or grazing systems 10. Transition away from food-based farming (industrial hemp, Mallee oil, ecotourism, methane production from organic waste) 11. Shift from agriculture to carbon sequestration 12. Moving from traditional farming to ecosystem services (earning income for maintaining landscapes, environment and vegetation) 13. Shift grazing to perennial system plants more adapted to drier conditions such as fodder shrubs 14. Improved understanding and management of native grazing systems 15. Increase farm sizes 16. Different farm system models e.g. collaborative farming 17. Intensification of animal farming (controlled climate, efficient, managing animal welfare issues) 18. Alternative crops (food) better adapted to lower rainfall or rainfall at different times of year i.e. mustard, vetch 19. Farming landscapes rather than working at an individual farm scale 20. Coatings on crop seeds such as fungicides and insecticides for increased germination 21. Water-use efficiency

Attachment E
Enablers and barriers

Enablers and barriers to adaptation are identified for different sectors below. The number of comments made during workshops from each sector is identified against each theme.

Enablers								
	Native vegetation	Pest plants and animals	Coorong and Lower Lakes	Vulnerable members of the community	Emergency services	Essential services	Dryland farming	Irrigated farming
Leadership, in the form of champions at all levels, existing and wanted	2	2		1	4		1	1
Knowledge, including science, about impacts, available and accessible, being accessed and made relevant		1			2		3	2
Involvement of youth, indigenous, elected bodies; from other locations and sharing experience, knowledge and information	2				5	1		
What's working now, existing programs, rural resilience, incremental adaptation		1		4			1	
Extreme events create (and have created) opportunities for change		1	1	1			2	
Resources, for staffing, R&D, incentives and facilities	2	1						1
Relevance to other issues								2
Market forces such as commodity prices								1

Barriers								
	Native vegetation	Pest plants and animals	Coorong and Lower Lakes	Vulnerable members of the community	Emergency services	Essential services	Dryland farming	Irrigated farming
Time frame mismatch. Occurs because many people and institutions only focus on the short term whereas adaptation requires planning now for the longer term. People also often only respond to an immediate crisis.			3	3	7	3		
Lack of resources, in terms of funding and flow-on effects to lack of personnel and R&D	2	4		1		1	2	2
Lack of knowledge about climate change, of the rural, of the water market, of options	1	2	2				2	3
Complexity of issues and sectors, in terms of their scale, distribution, diversity, uncertainty and unpredictability	1	4		2		1		1
Current values and beliefs of government, the media, about climate change and "this is what we have always done."	1	1	1		3			1
Lack of political will	1		1	2			2	
Current rules about GM and rules not being enforced	1					1	1	

For further information

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