Gap Identification Report

of the climate change impacts in the Murray-Darling Basin region of SA

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Executive summary

This report forms part of the first phase of an integrated climate change vulnerability assessment (IVA) for the South Australian Murray-Darling Basin (SA MDB) Region by the project partners: SA Murray-Darling Basin Natural Resources Management Board (SA MDB NRM Board), Regional Development Australia (RDA) Murraylands and Riverland Region, the Regional Local Government Association (LGA) and the Zone Emergency Management Committee (ZEMC).

The report was prepared in collaboration with the SA MDB Region project Steering Committee and relevant community leaders and technical experts.

The report provides the context of the study and the methodology to be used for undertaking an IVA as described by the Local Government Association SA (Chapter 1) and then defines the boundaries of the study region as agreed by the Steering Committee (Chapter 2). The climate of the Region is described and the likely changes that can be expected as a result of global warming examined and quantified where data is available (Chapter 3). Gaps in climate data are identified.

The following chapters of the report provide a detailed review of climate change research that has been undertaken in the Region and elsewhere of relevance for each of the five capitals: environmental (Chapter 4), physical (Chapter 5), financial (Chapter 6), social (Chapter 7) and human (Chapter 8) and includes the likely primary and secondary impacts that that climate change will have on a range of indicators for each capital. Gaps in our knowledge for each indicator are identified.

A summary of the key findings, input from a stakeholder engagement workshop and discussion about next steps are in the concluding chapters. Detailed appendices provide supporting information that will be of use in the following phase of the IVA process.

Because of the national importance of the Region as part of the whole Murray-Darling Basin, and the effects of the Millennium Drought over the past 10 years, there has already been a significant amount of research undertaken that considers the impacts of climate variability and in some cases climate change as well.

The future climate of the Region will be hotter and most likely drier than the historical case and will experience more frequent and intense bushfire and heatwave days, fewer frosts, longer droughts and possibly more intense rain when it does fall, sea level rise and changes to humidity, evaporation and other climate parameters. Impacts will be far reaching and complex in nature and there will be cross sectoral implications that require regional responses to ensure maladaptation is avoided.

The report provides a common reference for all groups working to reduce the impacts of climate change in the Region, and an analysis of the current gaps and hence future work that may be carried out. Despite the significant investment in the Region already, there will always be gaps in our knowledge with respect to climate change due to the complex and interlinked nature of its effects. The findings of this review and the stakeholder engagement workshop provide a broad range of identified gaps for each of the five capitals assessed. However, this fact should not stall the process of undertaking a full IVA once key gaps that are identified as a priority by the steering committee and stakeholders have been addressed.

In determining priorities for future action, consideration of the key decisions that need to be made by each of the sectors as captured in the stakeholder workshop should be considered with respect to their data needs and timelines. The identification of timelines should also inform the selection of climate change scenarios to be used in the full IVA. Stakeholders are encouraged to build on the existing networks and collaborations already in place and to ensure that as diverse a group as possible has the opportunity to be involved in the steps that follow in the development of a Regional Climate Change Adaptation Plan.
1 Background to the project

1.1 THE CONTEXT OF CLIMATE CHANGE

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (FAR) (IPCC 2007) states that the warming of the climate system is now "unequivocal", and is "evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level". It is also likely that despite current mitigation policies and related sustainable developments, the level of greenhouse gases in the atmosphere will continue to increase over the next few decades. As a result, the global climate system will very likely see changes that exceed those observed over the past century.

Over the coming decades, South Australia is likely to experience continued increases in average temperature, changes in rainfall (likely reductions in winter and spring), an increase in daily rainfall intensity but longer dry spells between rainfall events, an increase in evapotranspiration (the combined effects of evaporation and plant transpiration), an increase in very hot days and nights, a reduction in the frequency of frosts and a likely increase in the number of extreme fire danger days (Suppiah, Preston et al. 2006). In addition, ocean acidification as a result of dissolved carbon dioxide in sea water will continue and sea level rise will exacerbate storm surge events and coastal erosion (IPCC 2007).

These shifts in atmospheric and oceanic trends are expected to produce flow on effects to water resources, agriculture, forestry, fisheries, human settlements, ecological systems and human health. It is very likely that there will be large shifts in the geographical distribution of agriculture for some regions (IPCC 2007). Conventional farming of marginal land in drier regions is likely to become unsustainable due to water shortages. New biosecurity hazards and increased environmental degradation due to extreme events is also likely. However, it may also be possible to grow new crops or those displaced from other regions. Ecosystems will need to be able to adapt or migrate in tandem with their suitable climatic zone or sea level, or will face extinction. Hard physical infrastructure including roads, bridges, dams, buildings and other assets are likely to be affected by the increased extremes in the climate such as heat-waves, flooding, bushfire or extreme wind events. Social disruption to existing communities and networks are possible as the impacts affect the economic sectors of tourism, agriculture, fishing, forestry and others. New opportunities will also become available in the form of energy and resource efficiencies, renewable energy, carbon sequestration and business that provide solutions to the impacts caused by a changing environment.

1.2 SOUTH AUSTRALIAN MURRAY-DARLING BASIN CLIMATE CHANGE ACTION

South Australia has been a leader in climate change mitigation and adaptation research and policy for many years. The recently released Climate Change Adaptation Framework for South Australia Prospering in a Changing Climate highlights the need for a regional bottom up approach to developing adaptation responses and an inclusion of the economic, environmental and social dimensions impacts (Government of South Australia 2012). The four objectives of the Climate Change Adaptation framework aim to increase the resilience (reduce the vulnerability) of South Australia’s natural systems, productive landscapes and communities by developing policy responses founded in active participation at all levels, strong partnerships and best scientific knowledge. The tool identified in the framework for developing adaptation actions is a regional integrated climate change vulnerability assessment.

From 2006 to 2008 the Adelaide Mt. Lofty Ranges Natural Resources Management Board in collaboration with the SA Department of Water and Natural Resources (DEWNR), and the Federal Department for Climate Change undertook an assessment of key natural resource management systems that were vulnerable to climate change. This was the first project to develop and demonstrate methodologies for creating a regional framework for wider application in managing climate change risk and adaptation responses.
strategic policy.

opportunities, infrastructure, planning and examine climate change impacts, adaptation, a suite of projects valued at $1.6 million to Board partnered with 11 Councils to deliver the program the SA Murray-Darling Basin NRM Resources Management Board 2010). As part of (South

Wales, northern Victoria and south-eastern South Australia and represents 19.5 percent of the area of the total MDB. The Murray Region Factsheet (2008) summarises the finding of the work for the Region and highlights that if the recent (1997 to 2006) climate were to persist, average surface water availability for the Murray Region would fall by 30 percent, average volume of water diverted for human use in the Murray Region would fall by 13 percent, and end-of-system flows would fall by 50 percent by compared to the 1895 to 2006 average. The relative level of surface water use across the Murray Region would increase from 36 to 45 percent of flows (CSIRO 2008).

The SA MDB Region has also undertaken significant work in the fields of climate change impacts and adaptation. In 2010, the Australian Federal Government invested $200 million to establish the Strengthening Basin Communities program with the aim of expanding the region’s ‘understanding the implications associated with climate change on water availability, identifying strategies to adjust to a future with less water and securing water supply through the introduction of water saving initiatives’ (South Australian Murray-Darling Basin Natural Resources Management Board 2010). As part of the program the SA Murray-Darling Basin NRM Board partnered with 11 Councils to deliver a suite of projects valued at $1.6 million to examine climate change impacts, adaptation, opportunities, infrastructure, planning and strategic policy.

The Lower Murray Landscape Futures Project explored “different possible outcomes from implementing regional natural resource management plans and targets ... as influenced by different policy options, future climate change, commodity prices, and water availability and price. Landscape futures include the social and economic implications of achieving improvements in natural resource condition... and .. examined future scenarios where policy innovations encourage the widespread adoption of natural resource management actions in the form of carbon and water trading and the establishment of new industries such as biomass and biofuels production’ (http://www.landscapefutures. com.au/publications.html).

The Zone Emergency Management Committee (ZEMC) recently received funding through the National Disaster Resilience Fund to undertake a zone level Emergency Management Risk Assessment based on the National Emergency Risk Management Guidelines (2010). The risk assessment which is now underway for the Region will prioritise future risks and hazards (e.g. river bank collapse, flood, rural fires and storm events) and will include climate change and mitigation strategies.

A raft of economic studies have been undertaken by Regional Development Australia Murraylands and Riverland, a number of which consider the impacts of climate change including the influences on the economy from the Draft Murray-Darling Basin Plan, water availability, wind farms, carbon trading, agriculture, regional industry and the community. The Regional Roadmap states “a range of opportunities are being explored to improve environmental sustainability and diversify the economy, including food production and manufacture, biofuels, rehabilitation of degraded natural systems, renewable energies, efficient water management practices and non-agricultural tertiary industries” (RDA 2010).

Numerous other studies have considered likely climate change impacts and risks to the economic, social or environmental dimensions of the Region and include studies on the impacts of climate change on wetlands, terrestrial fauna, aquatic species, agriculture, the economy, communities and health. However, in 2012, the South Australian Murray-Darling Basin Natural Resources Management Board identified that:

‘Historically... in the region... government solutions to engaging with local communities has often been ad hoc and uncoordinated,
resulting in duplication and fragmentation of effort, wasted resources, over-consulted, frustrated and confused community. Consultation that respects the nuances of the local community, its environment and economic character is needed in developing local solutions.

‘Furthermore, the inter-connectedness of communities and industries and natural ecosystems across the region means that there is a need to consider the impact of climate change from an integrated, regional perspective to establish a regional context.’

Findings from all these studies have been considered in this review and each should be considered to be a critical source of information for a full integrated climate change vulnerability assessment.

1.2 PROJECT AIMS

In response to the SA Murray-Darling Basin NRM Board conclusions, a steering committee comprising the SA Murray-Darling Basin NRM Board, the Regional Local Government Association, the Regional Development Australia Boards, Murraylands and Riverland, SA POL emergency management in conjunction with the Regional Government Coordination Network and the Environment Institute at the University of Adelaide was formed. A project brief was then developed to review the extensive number of climate change studies undertaken across the Region and other relevant literature and to identify the gaps in data and knowledge that would be required to undertake a regional integrated climate change vulnerability assessment as a first step towards informing a regional climate change adaptation plan as encouraged under the State Climate Change Adaptation guidelines.

The project aims are to achieve:

(a) A higher level of understanding and adaptive capacity by local government and key regional partners of likely climate change impact and areas of vulnerability in the SA MDB Region (incorporating the Murray Mallee Local Government Region);

(b) Through the IVA a mutually agreed reference point for regional organizations;

(c) A more coordinated approach to adaptation planning for and managing climate change across the region;

(d) Contribute to emergency risk management in the Region by the provision of information and project findings;

(e) Improved efficiencies across agencies and regional stakeholders in planning and managing climate change in the region;

(f) An ongoing commitment and process that enables the influential people in regional and community organizations to remain informed with up to date, locally relevant information.

The project is to be undertaken in two phases. Outputs of the first phase will be:

• Interim Consultant Report;
• Final Report – Project findings including a gap analysis identifying action for further consideration by individual or collective stakeholders;
• Project Evaluation report;
• Background documents – on the process to develop and implement the project.

Phase Two outputs of the project (funding sought at a later date) will be:

• Fill the knowledge gaps identified through phase one work;
• Adaptation actions identified and prioritised;
• Test the IVA and regional adaptation actions with key stakeholders;
• Merge project activity with existing regional projects;
• Completed regional integrated vulnerability assessment report (well documented project findings including consolidated, evaluated and analysed regional vulnerabilities to climate change and recommendations outlining action for further consideration by individual or collective stakeholders);
• Regional adaptation plan (well documented project priorities Region adaptation options and recommendations outlining action for further consideration by individual or collective stakeholders);
• Project Evaluation report; and
• Background project documents.

1.4 PROJECT DELIVERABLES

The key outcome of this project (Phase 1) was to prepare in collaboration with the steering committee and relevant community leaders and technical experts, a report that included: the project context and scope; a succinct review of the research already undertaken in the South Australian Murray-Darling Basin Region (SA MDB) that will be of relevance to undertaking a fully Integrated Climate Change
Vulnerability Assessment (IVA) as outlined in the guidelines for undertaking an IVA by the LGASA; and a detailed gap analysis of necessary information and data that will be required for the full IVA.

1.5 PROJECT METHODOLOGY

In reviewing the work already undertaken in the Region and identifying the gaps, it was important to measure the existing findings against the inputs required to develop a regionally integrated climate change adaptation plan and as a first step in the process undertake a regional integrated climate change vulnerability assessment. Vulnerability assessments build upon a risk assessment by considering not only the impact and therefore risk of a potential climate change, but also the adaptive capacity of the system to overcome the stress. The IPCC defined vulnerability as ‘the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change’ and provided a conceptual framework that links exposure, sensitivity and adaptive capacity as illustrated in Figure 1 and described below (IPCC 2007).

- **Exposure** relates to the influences or stimuli that impact on a system.

- **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. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes.

- **Adaptive capacity** is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. Also defined as the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions.

As there are varying definitions in the literature for each of these components when used in practice, the Guidelines for undertaking an integrated climate change vulnerability assessment as part of developing an adaptation plan developed by the Local Government Association South Australia (2011) expanded on the Allen Consulting (2005) and IPCC (2007) definitions thus:

**Vulnerability:**

‘An assessment of vulnerability can be defined as a ‘measure of possible harm’ (Hinkel 2011). In this case harm to the environment would include such things as a loss of habitat or species diversity, disruption to food webs, reduction in ecosystem services or loss of ecosystem resilience and the capacity to bounce back from stresses, reduced water quantity or quality and an increase in habitat fragmentation. For the human population, vulnerability would describe an increase in physical morbidity or mortality, increased mental illness, a reduction in the educational standards of a region, reduced access to medical care or increased suicide rates. For the social systems vulnerability would be seen as a disruption to social networks and communications, a reduction in the capacity of volunteer organisations, reduced productivity as a result of reduced access to the workplace, increased illness, or occupational health and welfare policy that reduces working hours, reduced household incomes, reduced public services such as public transport, increase in crime rates, an increase in the proportion of the population considered to be socially excluded, a reduction in the levels of engagement or trust with government. Vulnerability of constructed physical systems would include the number or capital value of infrastructure assets that will be damaged or in need of increased maintenance.'
modification or relocation / retreat from the climate stressors and will include transport networks (roads, rail, ports), communication networks, buildings, land and service related infrastructure (water and energy networks).

Exposure:
‘Exposure is the changes expected in the climate for a range of variables including temperature, heatwave, bushfire, sea level rise, frost, rainfall, carbon dioxide levels in the atmosphere, acidity of the oceans, storm surge and combinations of these. Systems may also be exposed to secondary changes as a result of these primary climate changes – such things as reduced income due to rainfall reductions/drought, or an increase in weed or pest pressure. If a system is protected from some of these changes (e.g. an irrigated crop is protected from drought, a chicken housed in a shed is protected from the cold) then exposure to the stressor is reduced.

Sensitivity:
‘Sensitivity is the degree to which systems respond to the changes. Some systems will have a large reaction to a change in the climate while others will be less. For example, plants or animals that die in response to small changes in temperature or water availability are highly sensitive – physiologically they can’t cope with the stress. Small changes in a household income that results in bankruptcy or mental illness are examples of a highly sensitive social system. Sensitive systems are often those that are close to a threshold or tipping point that means a small change in stress results in a large reaction. Systems that can endure significant changes would be considered to have a low sensitivity.

Adaptive Capacity:
‘Adaptive capacity describes how well a system can adapt or modify to cope with the climate changes to which it is exposed to reduce harm – does it bounce back? Is it resilient? Examples of natural systems with low adaptive capacity are those with a limited gene pool and as a result a limited capacity to evolve, ecosystems affected by excessive land clearing, over extraction of ground or surface water, invasive species, soil erosion, salinity or environmental pollutants that do not have the resilience to adapt. Economic systems that have a high debt to capital ratio or minimal opportunities to increase income would also struggle to adapt to climate changes. Social systems that are disrupted, have poor communication networks, high crime rates or a prevalence of other socially dysfunctional behaviours such as domestic violence, suicide or drug addiction are also likely to be limited in their capacity to adapt. When the adaptive capacity of a system is reduced, it is considered to be more vulnerable to the impacts of climate change. By considering adaptive capacity it is possible to avoid attending to impacts that may be reduced by the system itself with minimal outside help, or putting systems that have no capacity to adapt as a low priority with the result that more harm occurs than expected.

In this review, existing information and data within the study Region was assessed against its capacity to describe exposure, sensitivity, impact and adaptive capacity for a range of indicators and gaps in knowledge identified. Traditionally, a triple bottom line approach that takes into account the social, environmental and economic dimensions of a region has been used in risk assessment studies. More recently, a five capitals approach which is considered to encompass all the resources that a community may be able to access has been introduced. The five capitals approach splits the original social capital into human and social capital and the original financial capital into physical and financial capital:

- **Human capital** – the skills, health and education of individuals that contribute to the productivity of labour.
- **Social capital** – reciprocal claims on others by virtue of social relationships, the close social bonds that facilitate cooperative action and the social bridging, and linking through which ideas and resources are accessed.
- **Natural capital** – the productivity of land, and biological actions to sustain productivity, as well as the water and biological resources.
- **Physical capital** – the value of capital items produced by economic activity from other types of capital and can include infrastructure, equipment and improvements in genetic resources (crops, livestock).
- **Financial capital** – the level, variability and diversity of income sources, and access to other financial resources (credit and savings) that together contribute to wealth.

By determining the relative strength of each capital one can identify ways that a region may prove to be resilient to the challenges of climate change and therefore increase its adaptive capacity and reduce climate change vulnerability (Allen Consulting Group 2005). In
addition, the effects of climate change on one capital can be assessed in the context of those for others in an integrated way. In particular, the identification of adaptive actions as part of the IVA will be framed within this integrative approach to ensure maladaptation does not occur. The term maladaptation usually refers to the implementation of adaptation options that cause problems elsewhere, such as the installation of refrigerant air-conditioning in homes that then causes unserviceable levels of electricity demand during heatwaves and results in blackouts across a region, or construction of a sea wall that causes flooding in other areas. Particular examples of maladaptation for the SA MDB Region would include the historical regulation of the Murray River to ensure water security and navigation but at a cost to both the environment and some communities in the event of drought.

The structure of the review and gap analysis considers the scope of primary and secondary indicators for each of the five capitals as identified in the Local Government Association SA guide (Table 1). The project was undertaken by a team of scientific researchers from the disciplines of ecology, social sciences, economics, climatology, agriculture, production modelling and water management. The project comprised six key stages that align with the preliminary steps in the development of an Integrated Climate Change Vulnerability Assessment as outlined in the methodology developed by the LGA SA.

**Task 1: Project management, stakeholder and steering committee consultation**

Project management processes, as recommended by the University South Australia Project Management Guidelines, were implemented. The scope of the project was developed in conjunction with the SA Murray-Darling Basin NRM Board, steering committee and relevant stakeholders at the first steering committee meeting (27th April 2012) to ensure the review and gap analysis developed addressed the key decisions and priorities for the region. The key decisions to be addressed by the analysis were identified and can be used to inform the indicators of climate change vulnerability and the climate change scenario to be used in the full IVA study.

**Task 2: Review and quantification of climate change stresses to the Region**

In consultation with the steering committee, a review of the current understanding of the likely climate change impacts on the Region was undertaken and data available assessed for its capacity to inform the development of an IVA climate change scenario for the study region. Relevant climate variables including moisture (humidity, rainfall and available water), temperature (heatwave, frost and ocean temperatures), bushfire frequency and intensity, sea level rise, ocean acidification, carbon dioxide levels were considered. The key climate related stresses / threats and gaps in knowledge for the region were identified.

**Task 3: Review of environmental capital of the Region**

The terrestrial environmental dimension of the study was undertaken by Dr. Tim Milne (EAC Ecological Evaluation) on the basis of work already undertaken for the study region and relevant studies from elsewhere. In addition, due to the significance of water to the study region, two hydrological researchers also had input to the project: Karla Billington and Dr. Kerri Muller. The water review includes water resources and usage by humans including agriculture with a discussion of future use volumes and patterns, and the influence of climate change on these parameters and a review of environmental water requirements. The environmental review also included the likely climate change impacts on key SA MDB Region indicator species and ecological processes, including an assessment of impacts on EPBC-listed threatened species / communities (e.g. Fleurieu swamps). A review of legislative, management and policy instruments, with regard to water resource management (including the requirements needed to adapt to climate change), was also included.

**Task 4: Review of the social and human capitals of the Region**

The social dimension of the review covers the fundamental aspects of the social and human environment in the study region of the Murray-Darling Basin and investigates areas of community strength and vulnerability in terms of climate change related challenges. Issues addressed include health and wellbeing, education and training, emergency management, social inclusion and community planning and development. Wherever possible local information was used to inform this discussion, but where local information did not exist, analogous data was sourced from outside the research area to ensure that the overview is as complete as possible.
Table 1: The primary and secondary indicators for each of the five capitals that were assessed in the review and gap analysis of climate change work previously undertaken in the SA MDB Region.

<table>
<thead>
<tr>
<th>Environmental Capital</th>
<th>Primary Indicator</th>
<th>Secondary Indicator</th>
<th>Vegetation communities</th>
<th>Biodiversity</th>
<th>Surface water</th>
<th>Groundwater</th>
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<tr>
<td>Landscape fragmentation</td>
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<td>Vegetation communities</td>
<td>% area of native vegetation</td>
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<td>Biodiversity</td>
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<td>Groundwater</td>
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<th>Secondary Indicator</th>
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<th>Communications networks</th>
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<td>Land assets</td>
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<td>Household Income</td>
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<table>
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<td>Household Income</td>
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<td>Public transport usage patterns</td>
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</table>
Task 5: Review of the financial and physical capitals of the Region

The economic dimension of review identifies the economic context of the Region and potential risks posed by climate change to key economic activities and physical capital (i.e., assets and infrastructure) in the region. A succinct profile of the regional economy was developed to identify key industry sectors and provide a context for understanding the most relevant threats posed by climate change. The review also includes the impact of climate change on future agricultural production in the Region based on research already undertaken in the Region that has highlighted vulnerabilities and adaptations that may be implemented.

Task 6: Gap analysis

On the basis of the literature review, experience of the research team and technical networks, and stakeholder and steering committee input, an analysis of gaps for each of the indicators assessed in the Region was undertaken and included in this report. In addition, outputs from the stakeholder meeting in the Region are provided.

The following chapters of this report: define the study region (Chapter 2); summarise the likely climate change impacts for the Region (Chapter 3); review the environmental (Chapter 4), human (Chapter 5), social (Chapter 6), financial (Chapter 7) and physical (Chapter 8) capitals for the Region including an assessment of gaps for each. Chapter 9 provides conclusions and recommendations.
The South Australian MDB Region as agreed by the steering committee in this study encompasses the South Australian Murray-Darling Basin Natural Resources Management Board (SA Murray-Darling Basin NRM Board) Region and corresponding Local Government Areas (LGAs), Regional Development Board (RDA) regions and the State Government regions.

In some places there is not close geographical agreement between the boundaries as defined by each of the stakeholders and in other cases necessary data sets (e.g. ABARE and ABS) do not align exactly with these boundaries. For the purposes of this study, then, the boundaries of the Region are considered to be ‘fuzzy’ so as to ensure that all data and information relevant to the study area are included (Figure 2). In cases where information is specific to the study region it will be referred to as the SA MDB Region, where is available on other scales (e.g. Murray and Mallee or whole Murray-Darling Basin), it will be described as such.

As defined, the SA MDB Region includes Councils in the Murray Mallee LGA (Coorong District Council, Southern Mallee District Council, District Council of Loxton Waikerie, Renmark Paringa Council, Berri Barmera Council, Gerard Community Council, District Council of Karoonda East Murray, Mid Murray Council, Regional Council of Goyder and Rural City of Murray Bridge), Southern and Hills LGA (Alexandrina Council and District Council of Mount Barker), and Outback LGA (parts of the Outback Communities Authority). The Regional Development Authority regions include the Murraylands and Riverland RDA and parts of the Adelaide Hills, Fleurieu and Kangaroo Island RDA and a small southern edge of the Flinders Ranges sub-region of the Far North RDA region.

The Region has six diverse ecological areas: the River Corridor, a 5–10 km wide floodplain that includes ‘a complex pattern of anabranches and billabongs’ and a narrow limestone gorge beyond Overland Corner; the Coorong and Lower Lakes, low-lying alluvial and coastal plains colonised by ‘sedgelands, grasslands and low shrublands’ that provide a wide range of habitats of international importance for migratory birds; the Murray Mallee and Murray Plains that include most of the region’s agricultural areas and defined by low rainfall mallee and shrubland communities; the Eastern Mount Lofty Ranges that support ‘stringybark forest, woodland and grassy woodland communities’ and the South Olary Plains, a low rainfall pastoral region that extends north of the River Murray and west of the border with New South Wales that comprises ‘mallee, woodlands and chenopod shrubland vegetation, the majority of which remains uncleared’. In addition, the ‘Coorong marine habitats, including complex near-shore reef systems and the marine organisms they support, are highly diverse. Species of conservation significance include the Leafy Sea Dragon, as well as migrating Southern Right and Humpback Whales. The bioregion also supports a number of marine species which are of importance to commercial and recreational fisheries’ (SA MDB NRM 2012).

The RDA regional overview describes the economic base of the Region as “dominated by primary production (broadacre grains, livestock, horticulture, fruit, nuts and wine grapes) and both production and revenue from these industries and the secondary industries that depend on them are closely tied to climatic conditions.” In addition, “tourism has traditionally provided an important second source of revenue to the region, and reduced water availability and climate change have re-emphasised the need for diversity within
the economy.” (RDA 2012). The majority of the population are employed in the agriculture sector.

Settlements in the region are small. Mount Barker is the largest township with 30,540 people and growing. The Region is highly multicultural – primarily as a result of the skilled migration of workers – and approximately 50 different nationalities are found in the region. As is the case in many areas of Australia, the population of the Region is ageing. Unlike other areas the education levels in the Region are somewhat lower.

Figure 2: The South Australian Murray-Darling Basin Natural Resources Management Board Region including local government Councils included in the study area, major waterways, roads and towns.
3 Climate Change and the Murray-Darling Basin of South Australia

3.1 The Climate of the South Australian Murray-Darling Basin Region

Like much of South Australia the SA MDB Region has a Mediterranean climate with hot, dry summers and cool, wet winters that shows a strong relationship with latitude. In the north (SA MDB Region and Mallee areas) the climate is hotter and dryer whilst in the south it tends to cooler and wetter (southern Wimmera and Mount Lofty Ranges). Mean annual temperature ranges from 7.9 oC to 17.4oC in the Lower Murray (Figure 7). “Mean annual rainfall ranges from 200 mm/yr in the north of the SA MDB Region to 1,400 mm/yr in the southern Wimmera. The annual moisture index follows a similar geographic pattern.” (Figure 3) (Bryan et. al. 2007).

The climate of the Region is highly variable on annual and decadal time frames as a result of influences from a number of global and regional climate systems including the El Nino Southern Oscillation, the Latitude of the Sub Tropical Ridge (or high pressure belt), the Southern Annual Mode and Indian Ocean Dipole. For a short and entertaining explanation on each of these climate systems visit the animated “Climate Dogs” on the Victorian Department of Primary Industries web site. All of these climate systems are driven by differences in temperature at the surface of the earth and higher altitudes and so will be affected by global warming. As a result of changes in the temperature, the climate as a whole will change.

This chapter reviews the current and expected changes in climate for the SA MDB Region and identifies gaps in our knowledge relating to each based on data available from the Bureau of Meteorology and the CSIRO. Thirty automatic weather stations in the study region set up by the SA Murray-Darling Basin NRM Board have been recording temperature, rainfall, humidity, frost and temperature degree days since 2006 for most locations. If considered useful, these data could be assessed as part of a full IVA for their capacity to supplement the formal weather recording networks or to fill spatial gaps in recent weather records for the available parameters.
3.1.1 Carbon dioxide levels

Between 1960 and 2009 human activity released 273 billion tonnes of carbon dioxide into the atmosphere as a result of fossil fuel burning (coal, oil, gas) and another 158 billion tonnes as a result of land clearing (Mikaloff-Fletcher 2011). Other greenhouse gases such as methane and nitrous oxide have been released as part of industrial processes and add to the warming of the planet (Figure 4). These rates of CO₂ pollution have risen by 3.4% per year between 2000 and 2008, more than 10 times faster than natural increases at any time over the past 22,000 years and faster than the worst-case scenario expected by the Intergovernmental Panel on Climate Change (IPCC) (Allison, Bindoff et al., 2009). The concentration of CO₂ in the atmosphere in July 2012 was 394 ppm.

Figure 4: Change in the concentration of greenhouse gases in the atmosphere including carbon dioxide (CO₂ – red), nitrous oxide (NO₂ – green), and methane (CH₄ – blue), compared to temperature (bottom) over the past 650 thousand years (IPCC 2007).

How this increase in greenhouse gas concentrations will affect the climate of the earth in the future is calculated using Global Climate Models (GCMs). GCMs take into account changes in solar radiation from the sun, volcanic eruptions and the presence of other particulates in the atmosphere as well as changes in greenhouse gases and aerosols. Model outputs have been tested for accuracy against historical data, and calculations of future climates take into account what the future emissions of greenhouse gases will be, how much aerosols and clouds will influence future temperatures (Sherwood 2011), and how sensitive the climate is to the extra warming. To include these variables, calculations of future climates are made for a range of different greenhouse gas emissions and climate sensitivity scenarios. Climate scenarios are defined by the IPCC as “plausible representations of the future that are consistent with assumptions about future emissions of greenhouse gases and other pollutants and with our understanding of the effect of increased atmospheric concentrations of these gases on global climate... assumptions include future trends in energy demand, emissions of greenhouse gases, land use change as well as assumptions about the behaviour of the climate system over long time scales” (IPCC-TGCIA 1999).

For Australia, the most recent climate projections were run using the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) Special Report on Emissions Scenarios (SRES) (Figure 5 left). In the upcoming IPCC Fifth Assessment Report (AR5), new emissions scenarios called “Representative Concentration Pathways” (RCPs) will be used instead (Figure 5 right) (Moss, Edmonds et al., 2010). The four RCPs will represent the full range of greenhouse gas emission concentrations that may occur in the atmosphere by the year 2100 and will range from 450 ppm up to 1300 ppm CO₂ equivalents. The climate projections from these scenarios are expected to be released in 2014. Projections provided in this review are all AR4 SRES Scenarios and are defined by the median (solid coloured line) and the range of global warming (shaded areas) expected with each scenario as modelled by a suite of global climate models (Figure 5 left).
The selection of suitable climate change scenarios for the second stage of the project should be based on the guidelines provided by the IPCC (See Appendix 1) and will be driven by the key decisions that will need to be made in the Region as per the LGA methodology for developing a climate change adaptation plan.

3.1.2 Temperature

In response to the increase in greenhouse gas concentrations, and in line with temperature increases both globally and across Australia, mean temperatures in the SA MDB Region between 1970 and 2011 have increased by up to 0.8°C (Bureau of Meteorology 2012). Spring minimum and maximum temperatures have warmed faster than other months in the Region (Figure 6).

![Figure 6: Change in seasonal minimum (top) and maximum (bottom) temperatures across South Australia between 1970 and 2011 in °C per decade (Source: Bureau of Meteorology 2012).](image)
Projections for future warming in the Region have been undertaken by CSIRO for South Australia (Suppiah et.al. 2006), the whole Murray-Darling Basin as part of the CSIRO Sustainable Yields Project (CSIRO 2008), the Lower Murray Region as part of the Future Landscapes Project (Bryan et.al. 2007) and the SA MDB Region as part of the Strengthening Basin Communities Project (Hayman et.al. 2011). For South Australia as a whole, the average annual temperature is expected to increase by between 0.6ºC and 2.0ºC by 2030 and 1.0ºC and 5ºC by 2070 compared to average temperature from 1980 to 1999 – known as the 1990 baseline (Figure 7). This warming is expected to continue to be greater inland and less along the coastal strip as has been observed already.

![Temperature Change](image)

**Figure 7**: Expected range of changes to annual temperature (ºC) for South Australia as predicted by a suite of Global Climate Models under low medium and high greenhouse gas emissions scenarios for the year 2030 (left) and 2070 (right) compared to the 1990 baseline (1980-1999 average) (Source: CSIRO 2007). The median expected change across all models is shown in the 50th percentile row and shows a likely increase in temperature.

High resolution climate change projection maps including changes to temperature for the Lower Murray Region were generated as part of the Lower Murray Landscape Futures study. Four scenarios were selected to cover the range of projections produced by CSIRO (Suppiah et.al. 2006) (Table 2) although they do not align with any particular timeframe (Figure 8).

**Table 2**: Future climate change scenarios selected for the Lower Murray Landscape Futures Project.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Temperature</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Mild Warming/Drying</td>
<td>1 deg. C warmer</td>
<td>5% dryer</td>
</tr>
<tr>
<td>S2</td>
<td>Moderate Warming/Drying</td>
<td>2 deg. C warmer</td>
<td>15% dryer</td>
</tr>
<tr>
<td>S3</td>
<td>Severe Warming/Drying</td>
<td>4 deg. C warmer</td>
<td>25% dryer</td>
</tr>
<tr>
<td>S4</td>
<td>Mild Warming/Wetting</td>
<td>1 deg. C warmer</td>
<td>5% wetter</td>
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</table>
Temperature projections were calculated as a summary table for the SA MDB Region for IPCC SRES scenarios as part of the Strengthening Basin Communities Project (Hayman et al. 2011) for the year 2030 and 2070 for a low (B1), medium (A1B) and high (A1FI) emissions scenario (Table 3).

Table 3: Projected changes in mean temperature in the SA MDB Region for three emissions scenarios (Low – B1, Medium – A1B and High – A1FI) for the years 2030 and 2070 compared to 1990 (Source: Hayman et al. 2011).

Regional projections were not found in the published literature for other SRES emissions scenarios or other years (e.g. 2050 or 2100) in map or table format. Downscaled climate projection maps and data are available as part of the Australian High Quality Climate Gridded Database managed by the Centre for Australian Climate and Weather Research (CAWCR) but would need to be extracted for the study site. The Bureau of Meteorology High Quality National Real Time Monitoring (RTM) gridded data set (previously known as the Australian Water Availability Project data set (AWAP)) is the accepted national high quality recorded climate data set and underpins the climate projections at a 0.05° x 0.05° grid (~5 km x ~5 km) resolution (Jones et al. 2009).
3.1.3 Extreme heat events and heatwaves

As is the case globally, the number of very hot days and very hot nights and the number of heatwave events or ‘warm spell durations’ (defined by the Bureau of Meteorology as an annual count of days with at least four consecutive days when daily maximum temperature greater than the 90th percentile) have increased in many areas of Australia since 1970. Conversely, the number of cold nights (annual count of nights with minimum temperature less than 5°C) has decreased (Figure 9).

![Figure 9: (Top left) Trend in the number of very hot days (days with maximum temperature > 40°C) and (Top right) very hot nights (nights with minimum temperature > 20°C) as a measure of heat extremes from 1970 – 2010; and Bottom left the trend in the number of cold nights (annual count of nights with a minimum temperature < 5°C percentile); and (Bottom right) the trend in cold spell durations (annual count of days with at least four consecutive days when daily maximum temperature > 90th percentile) (Source: Bureau of Meteorology 2011).](image)

In South Australia the number of very hot days (days above 40°C) has increased by between 4.5 and 9.0 days since 1970. The only high quality daily temperature data set within the study region is at the Strathalbyn racecourse. Both maximum and minimum temperatures at the site have increased over the 100 year record – the minimum more than the maximum (Figure 10).

![Figure 10: (Left) Annual maximum temperature; and (Right) annual minimum temperature at Strathalbyn racecourse from 1910 to 2010 (Source: Bureau of Meteorology 2012). The black line shows the 10 year running mean.](image)
Projections for future heatwave events indicate that by 2030 in Adelaide there will be several more days/year above 35°C and that by the year 2070 under a high greenhouse gas emissions scenario there may be twice as many extreme hot days as are experienced now (Bureau of Meteorology 2009). The number of extreme heat days (above 35°C) for a high warming scenario were calculated to increase from an average of 17 in 1990 up to 26 by the year 2030 – a 52% increase (CSIRO 2007). There are no published calculations for changes in heatwave frequency or intensity for locations in the SA MDB Region.

3.1.4 Rainfall

Rainfall across South Australia is highly variable from one year to the next but has decreased since 1900, most notably in the second half of the century (Suppiah, Preston et al. 2006). Annual rainfall since 1970 has decreased by 10 – 40 mm/decade – most dramatically across the north-east of the state. In the study region, on average, rainfall for all seasons except summer has also decreased from 1970 to 2011 (Figure 11). It should be noted that rainfall in the 1970s was relatively high compared to other decades (Figure 12).

![Total seasonal rainfall trend for South Australia from 1970 – 2011 (mm per decade)](image1)

![Total annual rainfall for South Australia from 1900 – 2011 (mm per decade)](image2)

As for temperature, projections for future rainfall in the region have been undertaken by CSIRO for South Australia (Suppiah et al. 2006), the whole Murray-Darling Basin (CSIRO 2008), the Lower Murray Region (Bryan et al. 2007) and the SA MDB Region (Hayman et al. 2011). Because of the complexity of the climate system and diverse mechanism for bringing rain to the State, changes in projected annual rainfall for South Australia are more difficult to model than changes in temperature. By 2030, annual average rainfall is expected to change by between -20% to +10% and by 2070 by -60% to +20% compared to 1990 levels (Figure 13) (Bureau of Meteorology 2011).
Figure 13: Expected range of changes to annual rainfall (%) for South Australia as predicted by a suite of Global Climate Models under low medium and high greenhouse gas emissions scenarios for the year 2030 (left) and 2070 (right) compared to the 1990 baseline (1980-1999) (Source: CSIRO 2007). The median expected change across all models is shown in the 50th percentile row and shows a likely decrease in rainfall.

High resolution rainfall projection maps for the Lower Murray Region were generated as part of the Lower Murray Landscape Futures study for the four scenarios described in Table 2 (Figure 14).

Figure 14: Mean annual rainfall (mm) for the four climate change scenarios shown in Table 2 as selected as part of the Lower Murray Landscape Futures Project (Bryan et.al. 2007).

As for rainfall, temperature projections were calculated as a summary table for the SA MDB Region for IPCC SRES scenarios for the year 2030 and 2070 for a low (B1), medium (A1B) and high (A1FI) emissions scenario (Hayman et.al. 2011) (Table 4). Regional projections are not available for other SRES emissions scenarios or other years (e.g. 2050 or 2100). Again, statistically downscaled climate projection maps and data for rainfall are available as part of the Australian High Quality Climate Gridded Database (CAWCR) and could be extracted for the study site.
Table 4: Projected changes in total rainfall in the SA MDB Region for three emissions scenarios (Low – B1, Medium – A1B and High – A1F1) for the years 2030 and 2070 compared to 1990 [Source: Hayman et al. 2011].

### Table 4: Projected changes in total rainfall in the SA MDB Region for three emissions scenarios (Low – B1, Medium – A1B and High – A1F1) for the years 2030 and 2070 compared to 1990

<table>
<thead>
<tr>
<th>Projection</th>
<th>Low (B1)</th>
<th>Medium (A1B)</th>
<th>High (A1F1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall %</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Percentile</td>
<td>10th</td>
<td>50th</td>
<td>90th</td>
</tr>
<tr>
<td>Annual</td>
<td>-7.5</td>
<td>-3.5</td>
<td>0</td>
</tr>
<tr>
<td>Summer</td>
<td>-15</td>
<td>0</td>
<td>7.5</td>
</tr>
<tr>
<td>Autumn</td>
<td>-7.5</td>
<td>0</td>
<td>7.5</td>
</tr>
<tr>
<td>Winter</td>
<td>-15</td>
<td>-3.5</td>
<td>0</td>
</tr>
<tr>
<td>Spring</td>
<td>-15</td>
<td>-7.5</td>
<td>2</td>
</tr>
</tbody>
</table>

3.1.5 Rainfall frequency and intensity

The number of extreme rainfall days has increased in north-west and central Australia but decreased across the south-west, south-east and central east coast (CSIRO 2007) (Figure 15).

Figure 15: (Left) Trend in very wet day precipitation (annual total precipitation when daily precipitation > 95th percentile) (mm per century) 1970 to 2011; and (Right) trend in highest one day rainfall total (mm per century) 1970 to 2011 (Source: Bureau of Meteorology 2012).

High quality daily rainfall stations in the study area are at Murray Bridge, Langhorne Creek, Swan Reach, Eudunda and Australia Plains. Total daily rainfall from 1995 to 2011 is shown for Murray Bridge and Swan Reach (Figure 16). Neither site shows a trend in daily rainfall totals over the period plotted.

Figure 16: Total daily precipitation and trend (shown as a black line) for (Left) Murray Bridge; and (Right) Swan Reach from 1995 to 2011 (Source: Bureau of Meteorology 2012). The trend for both sites is zero.

Darren Ray, Senior Meteorologist with the South Australian Bureau of Meteorology states that “Extreme rainfall events are highly connected with features of natural variability such as La Niña events, with the climate change influence from an intensifying hydrological cycle likely to become apparent through..."
an intensification of such events when they occur. The influence of climate change on the frequency of these types of events is still being researched, though a tendency towards El Niño like conditions, and so less frequent extreme events has been suggested. For South Australia, global climate models suggest an increase of only 1 to 2% the intensity of rainfall events in autumn by 2050 and only small changes in the return periods of such rainfall events in the Adelaide region. Slight decreases are possible in other seasons (CSIRO 2007), a trend that has been observed already (http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi?map=SDII&period=1970) in southern SA. (Darren Ray, Climatologist, Bureau of Meteorology South Australia, pers. comm. July 2012).

3.1.6 Evaporation

Since 1990, pan evaporation (the amount of water evaporating from an open pan of water) has increased for most parts of Australia as would be expected in a warming environment where the atmosphere is able to hold more water vapour (Gifford, Farquhar et.al. 2004; Wild 2004). Recorded evaporation trends can be seen in Figure 17 below and are the result of changes to a number of climate variables including temperature and wind at the local level (Bureau of Meteorology 2012). High quality evaporation data is only recorded at Ceduna, Woomera, Adelaide, Nuriootpa and Mount Gambier, none of which are in the study region.

Figure 17: Trend in total seasonal pan evaporation 1970 – 2011 (mm/year) (Source: Bureau of Meteorology 2012).

Projections for future changes in evaporation were also undertaken by CSIRO for South Australia (Suppiah et.al. 2006), and the SA MDB Region specifically (Figure 18) (Hayman et.al. 2011).

Figure 18: Expected range of changes to annual pan evaporation (%) for South Australia as predicted by a suite of Global Climate Models under low medium and high greenhouse gas emissions scenarios for the year 2030 (left) and 2070 (right) compared to the 1990 baseline (1980-1999) (Source: CSIRO 2007)(Source: Bureau of Meteorology 2009). The median expected change across all models is shown in the 50th percentile row and shows a likely increase in evaporation.
Projections for the expected change in pan evaporation for the SA MDB Region are available for the year 2030 and 2070 for a low (B1), medium (A1B) and high (A1F1) emissions scenario as a summary table (Table 5) (Hayman et al. 2011), graphs and in map format at a coarse resolution at a state scale. As with temperature and rainfall, regional projections are not available for other emissions scenarios or other years (e.g. 2050 or 2100) and maps are at a state scale and so do not show clearly the differences expected for each sub-region.

Table 5: Projected changes in potential evaporation in the SA MDB Region for three emissions scenarios (Low – B1, Medium – A1B and High – A1F1) for the years 2030 and 2070 compared to 1990 (Source: Hayman et al. 2011).

<table>
<thead>
<tr>
<th>Projection</th>
<th>Potential Evapotranspiration %</th>
<th>Low (B1)</th>
<th>Medium (A1B)</th>
<th>High (A1F1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentile</td>
<td>10th</td>
<td>50th</td>
<td>90th</td>
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<tr>
<td>Annual</td>
<td></td>
<td>0</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td>0</td>
<td>3</td>
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<tr>
<td>Autumn</td>
<td></td>
<td>0</td>
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<td>6</td>
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<tr>
<td>Winter</td>
<td></td>
<td>0</td>
<td>6</td>
<td>10</td>
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<tr>
<td>Spring</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

3.1.7 Bushfire incidence

Bushfire intensity is a result of a combination of factors including temperature, fuel loads, humidity and wind. The Forest Fire Danger Index (FFDI) is a measure of fire risk and seen an upward trend over the past decade across south-east Australia, probably as a result of the drying and warming trends in the region (Steffen 2009; Garnaut 2011). Fire danger weather has increased in many areas by 10 – 40% from 2001 – 2007 compared to the 1980 – 2000 period (Steffen 2009). In addition, four of the last five fire seasons (to 2007) were among the longest on record since 1942, a trend that has increased since the early 1990s (Lucas, Hennessy et al. 2007). Conditions recorded in the 2010 “Black Saturday” fires in Victoria were among the worst bushfire conditions ever recorded and included a drought of below average rainfall for a period of 12 years prior to the fire, wind speeds in excess of 100 km/hr and temperatures in the mid- to high 40 degrees Celsius – conditions that are likely to increase in frequency in a warming world (CSIRO 2011).

Historically for Adelaide the average number of days with a FFDI score above 25 (very high) per year was 18, above 50 (extreme) was 1.2 and there have been no days when the FFDI exceeded 75 (very extreme). A mean temperature increase of up 1.0°C would lead to an increase in the average number of very high fire days to 22 (a 22% increase), the average number of extreme fire days would rise to 1.8 (a 55% increase). In addition, it is expected that fire seasons will start earlier, end later and be “generally more intense throughout their length” (Lucas, Hennessy et al. 2007). There are no published projections for bushfire intensity or frequency in the study region.

3.1.8 Maximum wind gusts

Because the poles are warming faster than equatorial regions, wind intensity on average is expected to decrease globally. Advice from the South Australian Bureau of Meteorology Climate Group indicates that there are likely to be fewer severe wind events under future climate change scenarios (Darren Ray, SA Bureau of Meteorology pers. comm.). Projections for future changes in wind speed in the Region have been undertaken by CSIRO for South Australia (Suppiah et al. 2006) (Figure 19) and the SA MDB Region specifically (Hayman et al 2011).
Figure 19: Expected range of changes to annual wind speed (%) for South Australia as predicted by a suite of Global Climate Models under low medium and high greenhouse gas emissions scenarios for the year 2030 (left) and 2070 (right) compared to the 1990 baseline (1980-1999) (Source: CSIRO 2007). The median expected change across all models is shown in the 50th percentile row and shows no change.

Projections for the expected change in wind for the SA MDB Region are also available for the years 2030 and 2070 for a low (B1), medium (A1B) and high (A1Fi) emissions scenario as a summary table (Table 6) (Hayman et.al. 2011). As with the other parameters, regional projections are not available for other emissions scenarios or other years (e.g. 2050 or 2100) and maps are at a state scale and so do not show clearly the differences expected for each sub-region.

Table 6: Projected changes in wind speed in the SA MDB Region for three emissions scenarios (Low – B1, Medium – A1B and High – A1Fi) for the years 2030 and 2070 compared to 1990 (Source: Department of Environment and Natural Resources 2010).

### 3.1.9 Sea surface temperatures

The world's oceans have warmed by approximately 0.7°C since 1870, mostly in the top 1000 m (Roemmich and Gilson 2011). Analysis by many groups now confirms that the oceans have so far absorbed more than 90% of the increased heat associated with global warming (Church 2011). Sea surface temperatures around Australia have also risen, mostly around the south/south-east of the continent (Figure 20), probably because of the way ocean currents flow (Karl Braganza, National Climate Centre pers. comm. June 2010). During 2010, the sea surface temperatures in the Australian region were 0.54°C above the 1961 to 1990 average – the highest on record (Garnaut 2011).
3.1.10 Sea level rise

Global warming has caused oceans to expand and land-based ice to melt. As a result, global sea levels have risen by about 1.7 mm per year since 1970 or 17 cm in the past century – most rapidly (3.1 mm/year) since 1993 (Church 2011). Sea level rise is currently tracking at or near the upper limit of the IPCC worst-case projections (Figure 21). The sea level rise around Australia between 1920 – 2000 averaged about 1.2 mm/year (Church, Hunter et al., 2004). Increases in relative sea level vary along the coast as a result of tectonic movement, climatic influences such as the El Niño Southern Oscillation (ENSO), and human influences such as subsidence due to the draining of wetlands and other modifications. All measurements are considered accurate and are adjusted for tectonic movement, seasonal climate variations and anthropogenic land changes (National Tidal Centre 2009).

Figure 21: (Left) Global sea level changes in centimetres from 1970 – 2008. The envelope of IPCC scenario projections are shown for comparison (Steffen 2009). (Right) Australian sea level changes (mm/year) from the early 1990s when the National Tidal Centre Sea Level Rise project started to end June 2011. The measurements take into account changes due to tectonic subsidence and uplift and seasonal climatic influences (National Tidal Centre 2011).

In South Australia, there has been a sea level rise at the Thevenard tidal gauge (considered the most accurate and with the longest record) of 4.3 mm/year between 1992 and 2010 (National Tidal Centre 2011).

The AR4 projections for global sea level rise were between 0.20 and 0.59 m by 2090–2099 across the range of climate scenarios (IPCC 2007). These estimates included thermal expansion from oceans and freshwater contributions from glaciers, Greenland and Antarctica, but did not include uncertainties pertaining to changes in ice sheet flow. Research since AR4 suggests that there is a “considerable body of evidence now that points toward a sea level rise of 0.5 – 1.0 m by 2100” and that “sea level rise... towards 1.5 m cannot be ruled out” (Steffen 2009). There is certainly no credible research that predicts sea levels to be less than that predicted in the AR4 (Garnaut 2011).

However, it should be noted that even moderate increases in sea level rise can result in extreme sea level events associated with high tides and storm surges to occur hundreds of times more frequently than they currently do. As an example, an event that now occurs once every 100 years could be expected to occur two or three times every year by the end of the century (Steffen 2009).
For South Australia, if sea level rise continues at the current rate (4.3 mm per year), levels would be approximately 0.5 m higher than 1990 levels by the end of the century. Erosion of a sandy shore for this much sea level rise would mean the coastline could be expected to recede by between 25 m and 50 m over the same time frame or by 10-20 m by the year 2030.

### 3.1.11 Other ocean changes

Other changes in the ocean as a result of climate change include acidification of the water as carbon dioxide is converted into carbonic acid. Recent measurements world-wide indicate that the oceans are now about 30% more acid than they were prior to the industrial era (0.1 pH unit lower) (Allison, Bindoff et al. 2009). This level of acidity is the highest recorded in the past 25 million years and is fast approaching one that is unfavourable for coral formation (De’ath, Lough et al. 2009). Low pH in sea water also leads to the erosion of calcium carbonate shells built by other organisms such as oysters, sea urchins, mussels, crustaceans and calcifying plankton species (Steffen 2009).

Warming of the oceans has also led to a measurable decrease in dissolved oxygen (Allison, Bindoff et al. 2009). The combination of increased temperature, changes in currents, increased acidity and decreased oxygen in the oceans will result in catastrophic changes to marine ecosystems and the possible collapse of the food chain in some areas as has already occurred in some areas (e.g. Gulf of Mexico).

Global changes in ocean salinity and currents now confirm what would be expected as a result of altered rainfall and increased ice melt in Arctic and Antarctic regions (Garnaut 2011; Rintoul, Sallee et al. 2011).

If greenhouse gas emissions continue into the future as they have (the business as usual scenario), the expected increases in ocean acidification and warming are likely to “overwhelm even the most resilient of reefs sometime in the second half of the century” (Hoegh-Guldberg, Mumby et al. 2007) and hinder the production of shells for invertebrates. It is now predicted that by 2050 that ocean acidity could increase by 150% (Garnaut 2011). Continued reductions in dissolved oxygen levels will cause severe difficulties for many species.

### 3.2 GAP ANALYSIS OF CLIMATE INFORMATION FOR THE MURRAY-DARLING BASIN REGION OF SOUTH AUSTRALIA

As can be seen from the review, there has been a significant amount of work done to quantify the current and expected changes to the climate in the whole Murray Darling Basin and SA MDB Regions. Coarse resolution maps of recorded and projected changes to the climate are available for most climate parameters (temperature, rainfall, evaporation, wind, and sea surface temperature) at a state scale from the Bureau of Meteorology and the CSIRO OzCclim climate generator. High resolution maps of climate changes are available for the Lower MDB area for temperature, rainfall and a rainfall index for four selected scenarios that span the range of IPCC scenario projections for the Region but that are independent of time (Bryan et al. 2007). Future climate change projections for the SA MDB Region are available in table format for temperature, rainfall, evaporation and wind (Hayman et al. 2011) for the years 2030 and 2070 for a low (B1), medium (A1B) and high (A1FI) emissions scenario but not in map format. High resolution climate change projection maps could be generated for temperature and rainfall in the Region using the AWAP data set for the climate change scenarios available.

Projections of extreme events are not in map format but instead are for individual locations only – heatwave at Strathalbyn, rainfall at Murray Bridge, Langhorne Creek, Swan Reach, Eudunda and Australia Plains, and bushfire index at Adelaide. Projected changes in temperature, rainfall, evaporation and wind for the SA MDB Region do not appear in the literature for the years 2050 or 2100 but could be extracted from a number of sources. Projections for future heat wave and rainfall intensity and frequency are limited for centres within the SA MDB Region. Projected changes to the Forest Fire Danger Index (FFDI) have not been done for locations in the region.
4 The environmental capital of the region

The environmental capital of the Region includes water, soils, biodiversity, ecological processes and ecosystem services. The SA MDB Region supports a diverse selection of species, ecological communities and ecosystems. This section examines the current state of knowledge, and key gaps that would need to be addressed to conduct a vulnerability assessment for the environmental capital of the region.

4.1 DEFINITION OF BIODIVERSITY

“Biodiversity is the broad term used to describe the variety of natural organisms and includes the different species of plants, animals and micro-organisms, their genes and the ecosystems of which they are a part. Plants, animals and micro-organisms interact with the nonliving environment to form functional units described as ecosystems.” (SA MDB NRM 2009).

The overall effects of climate change on biodiversity will be difficult to predict, due to the complexity of natural systems. Changes are expected to affect interactions between species so as any one species becomes advantaged or disadvantaged, all species with which it interacts (e.g. pollinators, competitors, predators) may also be indirectly affected. These indirect biotic effects may have greater impacts on many species than the direct impacts of changes in temperature and rainfall (Steffen et.al. 2009). The combination of direct and indirect impacts will result in changes in trophic interactions, food web structure and ecosystem processes. As is the case for many places, our current understanding of the interactions between species is poor for the biodiversity of the South Australian MDB region.

4.1.1 Identified gaps for biodiversity

The SA MDB NRM Plan (2009) identifies numerous gaps in the knowledge of biodiversity in the region, including:
• lack of fine-scale vegetation community mapping;
• lack of condition mapping;
• lack of mapping of restoration activities;
• insufficient knowledge of the distribution and ecology of key biota;
• insufficient monitoring and research data to assess changes in condition and distribution;
• lack of access to indigenous biodiversity knowledge for managers;
• lack of knowledge of distribution, abundance and relative importance of threats;
• insufficient knowledge of fire management practices to protect and restore biodiversity;
• insufficient knowledge of post-fire recovery of vegetation;
• impacts of climate change on biodiversity.

These knowledge gaps will affect the outcomes of an Integrated Vulnerability Assessment (IVA) for climate change, and will be discussed as relevant in the following sections.

4.2 LANDSCAPE FRAGMENTATION AND REFUGIA

4.2.1 Landscape fragmentation

From an evolutionary perspective, for landscapes to respond to the direct and indirect effects of climate change, it is essential that they are both large enough to allow for in situ selection and also contain high levels of genetic variation (Steffen et.al. 2009). Highly fragmented landscapes minimise dispersal opportunities, increase chances of localised extinction, and compromise the adaptive capacity of species. Weed species also easily colonise isolated and fragmented areas of native vegetation (SA MDB NRM 2009). Thus, highly fragmented landscapes will have less inherent adaptive capacity to the impacts of climate change than more intact ones, and will be exposed to additional threats, such as weed and pest invasion. The degree of fragmentation within a region therefore provides an indication of the potential impacts of climate change.
Figure 22: Remnant vegetation remaining in the SA MDB Region by IBRA subregion (Source: Department of Environment and Natural Resources 2012).
Figure 22 shows the remnant vegetation remaining in the SA MDB Region within the Interim Biogeographic Regions of Australia (IBRA) subregions. The data shows that to the north of the River Murray the landscape is substantially intact, whereas in the southern and eastern parts of the Region the area of remnant vegetation in the landscape is very low. In agricultural areas of the Murray Mallee / Murray Plains and River Corridor, remnant vegetation generally occurs as small fragments of less than 20 ha (Kahrimanis et.al. 2001). As part of an IVA assessment, the fragmentation of different vegetation types could be considered along with vegetation communities and dovetailed into an assessment of the vulnerability of aquatic-terrestrial exchange and population connectivity in the various types of aquatic environments (see section on Environmental Water) to give a whole-of-landscape assessment of fragmentation and functional connectivity.

4.2.2 Refugia

Refugia have been identified as important landscape components to assist in the maintenance of biodiversity. In a climate change context, refugia will represent areas where there is least change in one place across time, or least shift in space of a set of conditions over time (Williams 2012). Identifying and managing refugia will be a vital component of successful adaptation across all spatial scales from the management of a specific microhabitat for a particular species through to large landscape scale refugia important in preserving habitats, species and processes (Hughes et.al. 2010). The presence of refugia, and the relationship of these refugia to the National Reserve System (Figure 24), will be valuable for determining the vulnerability of biodiversity to climate change. Figure 25 and Figure 26 on the following pages show “hotspots” for threatened flora and fauna in the Region (note figures show the DEWNR Murraylands region, not the NRM Board region).

Summers et.al. (2012) identified spatial conservation priorities across three NRM/Catchment Management Authority (CMA) regions, including the SA MDB Region. These priorities were based upon an assessment of the vulnerability of flora in the Region under three climate change scenarios. Priority areas largely occurred in the western SA MDB Region (Figure 23). In the context of the extent and distribution of the National Reserve System (NRS), the assessment by Summers et. al. provide an indication of the value provided by refugia to the adaptive capacity of the biodiversity of the Region to climate change effects.

Figure 23: Spatial conservation priorities based on native flora species vulnerability assessment for three climate change scenarios. High priority areas are shown in red, through to low priorities in blue. The clear line through the centre of each map is the state border, with the SA MDB Region to the left of this line (Source: Summers et.al. 2012).
Figure 24: National parks and reserves in the SA MDB Region (DEWNR 2012).
Figure 25: Threatened fauna species richness. The number of critically endangered, endangered and vulnerable fauna species were calculated within 1 km² grid cells from BDBSA records (Source Gillam and Urban 2010).
Figure 26: Threatened flora species richness. The number of critically endangered, endangered and vulnerable fauna species were calculated within 1 km² grid cells from BDBSA records (Source: Gillam and Urban 2010).
Moise and Milne (2010) examined permanent water sites in the north eastern part of the SA MDB Region. They found that these areas were providing refuge value at the current time, particularly for birds. However, these sites may not perform as refugia in an ongoing climate change context. In the River Channel and other aquatic environments of the SA MDB Region, the location and availability of refugia will change with changes in river flows and consequent water regime. For example, permanent wetlands may act as refugia in times of low River Murray levels if they remain inundated and connected to the main River Murray channel (DFW 2012). Further work should focus on better identifying terrestrial and aquatic refugia in the region, and their interconnectedness across time and space.

4.2.3 Identified Gaps for Landscape Fragmentation and Refugia

- Presence of threatened flora/fauna maps created for study region (current maps do not align to NRM regional boundaries);
- Identification of regional refugia (terrestrial and aquatic);
- Effects of River Murray and wetland water level manipulations on functional connectivity and availability of aquatic refugia.

4.3 VEGETATION COMMUNITIES

Balston et al. (2011) examined the vegetation communities of the Northern and Yorke region of South Australia as indicators for the vulnerability of the region to climate change. These communities were derived from the work of Berkinshaw (2006) and Pedler et al. (2007), and were akin to the societies described by Specht (1972). This examination included an assessment of the condition of the vegetation at the current time and in response to predicted changes in the climate by considering the exposure of these different vegetation community types to climate change stressors, the sensitivity of the vegetation community types based upon key attributes that predispose them to be susceptible to climate change, and the range, distribution and abundance of these vegetation community types. Weed invasion and exposure to fire, which may be significant threats in a climate change context were included as secondary exposure stressors. These two key threats are discussed in later sections of this chapter.

4.3.1 Terrestrial vegetation

There are no existing studies that focus specifically on the vulnerability of the terrestrial vegetation types within the SA MDB Region to climate change impacts. An ongoing monitoring and evaluation project for native vegetation condition is conducted by the SA Murray-Darling Basin NRM Board in partnership with the Nature Conservation Society of South Australia and would provide useful data on current condition and status of threats (Peter Mahoney pers. comm.). Data up to and including 2011 has been evaluated (Mahoney et al. 2011). Figure 27 on the following page shows an example of the data generated by this work. In addition, work by Caton et al. (2007) on the coastal vegetation of the Region would also provide detail on the current state and existing threats to coastal vegetation. Data could be generated using the existing DEWNR vegetation mapping layers on the extent, distribution, size and degree of fragmentation of different terrestrial vegetation types within the region.

The Lower Murray Landscape Futures (LMLF) project provides useful information on the effects of different policy approaches, climate change and changes in commodity prices with regard to NRM activities and outcomes in the region. The project examined future scenarios where policy innovations encourage the widespread adoption of natural resource management actions in the form of carbon and water trading and the establishment of new industries such as biomass and biofuels production. Simultaneously, scenarios were examined where climate change drives changes in water availability, agricultural production and associated environmental impacts. SA Murray-Darling Basin NRM Board targets that were current at the time guided scenario setting for remnant vegetation management and ecological restoration (revegetation). The project demonstrates that informed and deliberate spatial targeting can result in substantial gains in the efficiency of natural resource management actions and future landscapes (Bryan et al. 2007). The study will be useful for determining adaptive capacity and adaptation responses, especially regarding vegetation management and ecological restoration, within the context of biodiversity conservation.
4.3.2 Aquatic/water dependent vegetation communities

Pedler et al. (2007) provide an overview of semi-aquatic wetland vegetation types in the SA MDB Region. However, the approach taken to vegetation classification in the Department for Water Riverine Recovery Program (DFW 2012) may be more appropriate for an IVA, as it considers plant functional groups based on water regime. Wetland vegetation types and patterns are primarily driven by water regime, that is, the duration, frequency, extent, timing and depth of inundation, and variability of water presence. Using the functional groups of DFW (2012) as the basis of the IVA for wetland vegetation types would enable consideration of the impacts of changes in water availability over space and time, and vulnerability and adaptive capacity via water resource management options (see section on Surface Water), for each of these functional groups. The impact of climate change will obviously differ between groups, as those groups that are heavily reliant on specific water regimes and/or occur higher up the elevation gradient (e.g. terrestrial damp) are likely to be more vulnerable than those groups that are highly dispersive, exhibit a greater degree of plasticity with regard to water availability and occur lower on the elevation gradient.
There are also an extensive number of studies that have already been undertaken on wetland and floodplain plant ecological dependency on water regime and how water regime affects their growth, survival and capacity to reproduce (e.g. Roberts and Marsten 2011, Rogers and Ralph 2011). Of particular relevance is the work by Nicol et al. (2010) on the Chowilla floodplain that shows the four known ecosystem states (based on vegetation communities present) and factors that drive transitions between those states (Figure 28).

The flood regime is the major driver of transitions in state from vegetation types that require more frequent inundation (amphibious and flood dependent flora) to those that require less inundation (terrestrial dry). However, lack of floodplain inundation also drives the transitions to salt tolerant species and ultimately bare soil as salinity in the floodplain soils increases and soil moisture decreases over time since flooding. A transition may be irreversible under current river regulation (and thus reduced flooding) given that multiple and/or extended flushing flows will be needed to transition bare soil back to amphibious and flood dependent vegetation communities. Other factors such as reduced seedbank viability and soil sodicity may also limit or prevent this transition from occurring. Conceptual models like the one above and those produced by Souter (2009)

Figure 28: Conceptual model of floodplain vegetation community dynamics showing alternate states based on the functional groups present and the major factors that drive transitions in state (reproduced from Nicol et al. 2010).

will be valuable in terms of identifying significant thresholds for an IVA as they allow the effects of climate change on flooding regime (extent, duration, frequency, timing and depth) to be well-defined, or at least tightly described in terms of the climate change scenarios selected.

The effects that flow and water regime on the physico-chemical attributes, and thus water and sediment quality, of aquatic environments is also important and an IVA will need to consider tolerances of wetland vegetation types to pollutants such as nutrients, acid and salt. Tolerance data for aquatic and water dependent vegetation is sparse, particularly for native species in typical Australian environmental conditions, although available data has been well reviewed (e.g. Gehrig and Nicol (2010) and Bailey et al. (2002)).
4.3.3 Identified gaps for vegetation communities

- baseline condition data for vegetation communities in the region;
- modelling/forecasting effects of climate change on terrestrial vegetation communities/ecosystems, including potential transitions of vegetation communities to a different form;
- compiled dataset of existing knowledge of current condition and existing threats to terrestrial vegetation;
- evaluation of DEWNR vegetation mapping layers of the extent, distribution, size and degree of fragmentation of different vegetation community types;
- knowledge of future watering regimes for wetland vegetation types;
- knowledge of future water and sediment quality regimes for wetland vegetation types;
- knowledge of species specific responses to expected climate change impacts, including tolerances of salinity, acidity and other stressors associated with likely changes in water and flow regime.

4.4 FLORA AND FAUNA SPECIES

The responses of species to rapid climate change will be individualistic; some species will potentially be advantaged and others disadvantaged. The vulnerability of an individual species will depend on a combination of (Steffen, Burbidge et al. 2009):

1. Life history traits and other traits of the species;
2. The capacity if the species to adapt, either behaviourally or genetically;
3. The degree of exposure to climate change in the habitat/region where the species lives.

For points 1 and 2 above, factors expected to increase the vulnerability of a species include:

- Narrow range of physiological tolerance to factors such as temperature, water availability, water quality and fire;
- Low genetic variability;
- Long generation times, long time to sexual maturity and low reproductive output;
- Specialised requirements for other species (e.g. for a disperser, prey species, pollinator or photosynthetic symbiont) or for a particular habitat that may itself be restricted (e.g. a particular soil type or seasonally inundated habitats);
- Poor dispersal ability that may be further constrained by climate change impacts (e.g. increased fragmentation of vegetation, increased periods of cease to flow in streams or wetlands);
- Narrow geographic range;
- Dependence on environmental triggers or cues that may be disrupted by climate change (e.g. seasonal inundation of nesting sites for waterbirds);
- Specialised and/or inflexible ecology, including diet, habitat, microhabitat and behaviour (e.g. need for diadromous fish to move between freshwater and marine habitats to complete their life cycles);
- Susceptibility to disease or pathogens that may interact with climate change, such as the amphibian chytrid fungus.

Balston et al. (2011) state “It is very difficult to predict the consequences of climate change for any one species. Assessing vulnerability at the individual species level would require a comprehensive understanding of the ecology of each individual species as well as an overarching understanding of its relationships with other species in its local environment. Unfortunately our knowledge of the basic biology of most species within the study region is inadequate and does not allow us to predict specific responses to climate change with confidence. Threatened species, by definition, are already restricted in range, distribution and number, and as a corollary genetic diversity, all factors that predispose them to climate change vulnerability. Thus species status could be used as a surrogate indicator for climate change sensitivity in the absence of more definitive data.” This statement holds for the SA MDB Region, notwithstanding the individual studies that are detailed below.

Balston et al. (2011) thus used the species risk assessment work of Gillam and Urban (2008) as an indicator for regional vulnerability to climate change for flora and fauna. They also divided both flora and fauna into functional groups, to enable examination of specific climate change impacts on these groups, using the factors expected to increase the vulnerability of a species noted previously. These data are available for the MDB Region (Gillam and Urban 2010), although the boundaries of the assessment do not correspond exactly to the study area as defined here.

It is important to realise that there has been widespread and fundamental degradation of both riverine and floodplain biota in the SA MDB Region since European settlement.
and extensive water resource development. Davies et al. (2010) found that 20 out of 24 river basins within the Murray-Darling Basin were in poor or very poor condition based on their assessment of fish species, hydrology and macroinvertebrates. Furthermore, Pittock and Finlayson (2011) found that large tracts of floodplain forest have transitioned to terrestrial ecosystems suggesting that a major ecological shift driven by terrestrialisation is already underway. Assessing how climate change will affect the remaining biota in the SA MDB Region will need to consider these previous and continuing impacts.

Within the SA Murray-Darling Basin NRM Board Region and the broader Murray-Darling Basin, there are a number of studies that have already been undertaken, at both a functional group level, as well as a species level that could inform the assessment of the vulnerability of flora and fauna. These are discussed below:

### 4.4.1 Aquatic/water dependent fauna

Gonzalez et al. (2011) undertook a vulnerability assessment for native vertebrate fauna of the River Murray wetlands and floodplain. This extensive assessment took into account the current knowledge of twelve different life history traits for each individual species that related to climate change exposure and sensitivity, and applied a process to assign an overall vulnerability score based on these traits.

Species reliant on seasonal flooding and flow regimes, with narrow habitat requirements, a low tolerance to salinity, limited dispersal ability, small population size and low reproductive capacity and recruitment rates were found to be most at risk from climate change. Through a risk assessment process, 37 species of aquatic-ecosystem dependent vertebrate fauna were identified as most at risk (with regard to sensitivity and exposure) from the impacts of climate change. Adaptive management recommendations were “the provision of environmental flows through creeks and anabranches to support species reliant on flowing water habitat for foraging, reproduction and dispersal; environmental watering of temporary wetlands and floodplains; and maintenance of natural wetting and drying regimes to support species reliant on fluctuating water levels for foraging, reproduction and other life history requirements; the retention of long lived vegetation, such as river red gums identified as critical to the existence of a number of vulnerable species; and maintenance of aquatic and terrestrial habitat diversity and structure in still, flowing and floodplain habitats.” Adaptive capacity for these fauna was therefore primarily dependent on water availability, which in turn is primarily dependent on water resource management in large areas of the SA MDB Region where River Murray flows are the dominant water source (see Surface Water and Environmental Water sections below).

More specific climate change impact assessments for different aquatic fauna groups have been also been undertaken. For example, Balcombe et al. (2011) predicted the potential climate change impacts on 18 native fish species across their distributional ranges under past and continuing water-resource development scenarios for the whole Murray-Darling Basin. They conclude that “because the impacts of climate change on any given species are likely to vary from region to region, regional fish assemblages will also be differentially affected. The most affected region is likely to occur in the highly disturbed lower Murray River region, whereas the dryland rivers that are less affected in the northern MDB are likely to remain largely unchanged. Although climate change is a current and future threat to the MDB fish fauna, the continued over-regulation of water resources will place as much, if not more, stress on the remnant fish species.” This conclusion highlights the importance of water resource management in determining adaptive capacity (sections on Surface Water and Environmental Water).

Also important in determining vulnerability are the effects of water availability and other climate change factors on water and sediment quality in aquatic environments. Tolerance data for aquatic fauna is sparse. Our current understanding of the resilience of freshwater taxa to salinity levels, one of the more likely stressors to increase significantly under climate change, is limited and based on relatively few taxa, predominately aquatic macrophytes, invertebrates and fish (James et al. 2003; Rogers and Ralph 2011). Increasing stress levels can also affect biota indirectly, by influencing the physical (e.g. stratification) and chemical (e.g. nutrients) environment, interactions between biota and may act in synergy such as increased salinity and temperatures. These indirect and synergistic effects are less well understood than direct salinity impacts (Nielsen et al. 2003; Muller 2011) and are likely to limit an IVA in terms of predicting likely population dynamics, connectivity, habitat complexity, ecological processes and changes in community structure and function (e.g. loss of species essential for habitat or food provision, altered predation...
pressure and chains, limited or no successful recruitment or the depletion of propagules such as microinvertebrate eggs and aquatic plant seeds. Recent work by Ye et al. (2010) found that the early life stages of fish are the most sensitive and vulnerable to increased salinities and suggest that their tolerance values should be used as management triggers (e.g. maintain salinities below 5,000 E.C. to support recruitment). These tolerance values will be important thresholds for an assessment of vulnerability, although they are only available for a subset of species in the Region and thus surrogate species for different ecological assemblages would need to be used.

4.4.2 Terrestrial flora

The vulnerability of species to climate change is generally assessed as a product of its susceptibility/sensitivity (defined by its intrinsic biological traits), exposure (does the species occur in a region of high climatic change), and adaptive capacity (Watson et al. 2012). The Landscape Futures program (Meyer et al. 2012) used plant species vulnerability and adaptive capacity to model likely distribution responses to climate change. As part of this project, Summers et al. (2012) modelled the vulnerability to climate change of 584 native plant species across three NRM/CMA regions including the SA MDB Region. Information from botanical surveys was used to identify the recorded distribution of 584 species in the region. This information was then used to characterise the habitat characteristics for the species. With climate change scenarios, new distributions were estimated that identified species that may shrink, expand and/or shift their geographic range. The study indicated that many species may have altered distributions under climate change. The modelling in the project was used to drive spatial conservation priorities (as discussed in the section on Refugia), but could also be examined to provide valuable data to assist in an overall vulnerability assessment for regional terrestrial flora.

4.4.3 Terrestrial fauna

A comprehensive vulnerability assessment undertaken by Gonzalez et al. (2011) for wetland dependent fauna could also be applied to the terrestrial flora and fauna of the region to provide a vulnerability assessment for each species, but would be relatively resource intensive. The methods used by Balston et al. (2011), whilst not as comprehensive as individual species risk assessments, could provide an indication of the vulnerability of functional groups of the region, and would require less resources to undertake. Threatened fauna species are discussed in latter sections of this document.

4.4.4 Aquatic/water dependent flora

Gehrig and Nicola (2010) reviewed the literature for aquatic and littoral vegetation downstream of Lock 1 in the River Murray. The review highlighted a number of knowledge shortcomings with regard to species response to environmental variations that would be expected if climate change resulted in sustained low flows over Lock 1, including:

- Impact of acid and heavy metals on propagule survival, germination, recruitment and colonisation of aquatic plants in wetlands experiencing drawdown or upon refilling;
- Mechanisms of recovery post-acidification or post-desiccation (i.e. how important is the resident propagule bank versus other mechanisms such as hydrochory, zoochory);
- Impacts of acid sulfate soil remediation (e.g. liming, bioremediation) on aquatic plant recruitment;
- Salinity thresholds for key life history stages (e.g. flowering and seed set, juvenile growth and survival, germination) for halophytes to determine freshwater requirements;
- Salinity tolerances of the local populations of key macrophytes such as Typha spp., Ceratophyllum demersum, Myriophyllum spp., Phragmites australis and Potamogeton spp.;
- Impacts (e.g. relative growth rate, seed production, turion production) of sub-lethal salinities on Ruppia megacarpa and Ruppia tuberosa; and
- Freshwater requirements to maintain Ruppia megacarpa populations.

Balcombe et al. (2011) assessed the likely impacts on key vegetation species such as river red gums (Eucalyptus camaldulensis), lignum (Muehlenbeckia florulenta), aquatic grasses, reeds, rushes and sedges as a precursor to undertaking predictions of fish responses to climate change. They found that changes in the frequency and magnitude of floodplain inundation events and increased air temperatures are likely to drive reductions in all vegetation types considered. Balcombe et al. (2011) conclude that mass mortality of trees and forests already stressed by water-resource development may occur as a result of the increased stress associated with climate change. Given that the other major floodplain...
tree species, black box (Eucalyptus largiflorens), occurs higher on the elevation gradient and thus receives water less frequently than river red gums do, it follows that black box are at higher risk of local extinction than river red gums and declining stands of black box will perhaps be the first indicators of floodplain areas undergoing terrestrialisation due to under climate change and/or inadequate policy implementation.

As for the aquatic fauna, the adaptive capacity for aquatic flora will be primarily dependent on water availability and water quality, and thus effective water resource management, in most of the SA MDB Region (see Surface Water and Environmental Water sections below).

4.4.5 Identified gaps for flora and fauna

- individual vulnerability assessments for terrestrial fauna following the methodology of Gonzalez et al. (2011);
- assessment of species specific flora vulnerability data of Summers et al. (2012);
- compilation of data of Gillam and Urban (2010) to inform IVA if individual vulnerability assessments are not undertaken;
- knowledge of ongoing environmental water availability; and
- knowledge of impacts of pollutants (e.g. acid, heavy metals and salinity) on aquatic and water dependent flora.

4.5 THREATENED SPECIES AND COMMUNITIES

4.5.1 Threatened communities

The regional NRM Plan (SA MDB NRM 2009) lists four EPBC listed ecological communities for the region:

- Iron-grass Natural Temperate Grassland of South Australia—listed as critically endangered;
- Peppermint Box (Eucalyptus odorata) Grassy Woodland of South Australia—listed as critically endangered;
- Swamps of the Fleurieu Peninsula—listed as critically endangered; and
- Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions—listed as endangered.

In South Australia, Buloke Woodlands occur in the far south-east of the Murray-Darling Depression bioregion, near Bordertown (Cheal et al. 2011) and within the South East NRM region of South Australia. Iron-grass and Peppermint Box communities are confined to the eastern parts of the region, within and adjacent to the Mount Lofty Ranges. The key threats to the survival of both ecological communities include clearing, grazing and weed invasion (DEWR 2007). Fleurieu Peninsula Swamps are confined to the Fleurieu Peninsula in the south west of the SA MDB Region. The reliance of these swamps on local falls and groundwater would make them particularly susceptible to the impacts of climate change.

There are also twenty ecosystems/plant communities within the region that are provisionally listed (DEWNR in prep.) as threatened at a state level (Table 7). There have been no specific studies on the vulnerability of these communities to climate change.
Table 7: State threatened ecosystems in SA MDB Region (adapted from Department of Environment and Natural Resources (in progress). Provisional list of threatened ecosystems of South Australia (Unpublished and provisional list).

<table>
<thead>
<tr>
<th>Ecosystem Type</th>
<th>Provisional Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus rubida ssp. rubida Open Forest on heavy soils of upland valleys</td>
<td>E</td>
</tr>
<tr>
<td>Eucalyptus macrocarpica ssp. macrocarpica Open Forest</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus camaldulensis var. camaldulensis Woodland on seasonally inundated flats</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus viminalis ssp. cygnetensis and/or Eucalyptus viminalis ssp. viminalis Woodland on alluvial soils in moist areas</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus fasciculosa Grassy Woodland on red terra rossa soils of low hills</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus fasciculosa +/- Eucalyptus leucoxylon Heathy Woodland on sandy loams of flats and slopes.</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus ovata +/- Eucalyptus viminalis ssp. cygnetensis +/- Eucalyptus camaldulensis var. camaldulensis Low Woodland in valleys and drainage lines</td>
<td>V</td>
</tr>
<tr>
<td>Eucalyptus odorata +/- Eucalyptus leucoxylon Grassy Low Woodland on loamy soils of low hills</td>
<td>E</td>
</tr>
<tr>
<td>Eucalyptus leucoxylon ssp. pruinosa +/- Eucalyptus odorata Grassy Low Woodland on loams of hill slopes</td>
<td>V</td>
</tr>
<tr>
<td>Allocasuarina verticillata Grassy Low Woodland on clay loams of low hills</td>
<td>V</td>
</tr>
<tr>
<td>Banksia marginata Grassy Low Woodland on sandy loam plains in higher rainfall areas</td>
<td>E</td>
</tr>
<tr>
<td>Eucalyptus behriana, +/- Eucalyptus odorata, +/- Eucalyptus dumosa Woodland/Mallee on gilgai soils on plains</td>
<td>E</td>
</tr>
<tr>
<td>Eucalyptus dumosa Mallee over Melaleuca uncinata +/- M. wilsonii on heavy soils on plains</td>
<td>E</td>
</tr>
<tr>
<td>Leptospermum lanigerum Closed Shrubland in non-saline wetlands</td>
<td>V</td>
</tr>
<tr>
<td>Lomandra effusa Tussock Grassland on shallow loams in low hills</td>
<td>E</td>
</tr>
<tr>
<td>Lomandra multiflora ssp. dura Tussock Grassland on shallow clay loams in low hills</td>
<td>E</td>
</tr>
<tr>
<td>Themeda triandra +/- Danthonia spp. Tussock Grassland on heavy, fertile soils of plains and hill slopes.</td>
<td>E</td>
</tr>
<tr>
<td>Gahnia filum Sedgeland in drainage lines and depressions</td>
<td>V</td>
</tr>
<tr>
<td>Baumea arthrophylla Sedgeland in drainage lines and depressions</td>
<td>V</td>
</tr>
<tr>
<td>Freshwater wetlands eg Triglochin procerum Herland</td>
<td>E</td>
</tr>
</tbody>
</table>

E = Endangered, V= Vulnerable

4.5.2 Threatened flora species

A total of 304 species of plant occurring within the Region are listed as threatened at national and/or state level. Of these, 36 are listed as nationally threatened, 302 are listed at a state level (many are wattles and orchids) and 35 are listed at both levels (SA MDB NRM 2009). Seventeen of the nationally threatened species currently have Recovery Plans written (Environment Australia 2012), which detail the ecology of, and threats to, the species and the actions required to improve its conservation status. These Recovery Plans could inform individual vulnerability assessments if undertaken. As noted previously, the regional conservation assessments undertaken by Gillam and Urban (2010) provide a dataset on regionally, state and nationally threatened species and could inform an IVA.

4.5.3 Threatened fauna species

There are three mammals, 16 birds, two reptiles, one frog and five fish that are listed as nationally threatened species and considered extant in the region. Of these, 18 currently have Recovery Plans written (Environment Australia 2012).
which detail the ecology of, and threats to, the species and the actions required to improve its conservation status. These Recovery Plans could inform individual vulnerability assessments if undertaken.

There are 143 fauna species known to exist in the Region that are rated as threatened at a State level: 19 mammals, 109 birds, 13 reptiles and two frogs (Environment Australia 2012). Gillam and Urban (2010) assessed the regional status of fauna species and found 14 mammals, 134 birds, 19 reptiles and amphibians, and 21 fish were of conservation significance (rare, vulnerable, endangered or critically endangered). The regional conservation assessments undertaken by Gillam and Urban (2010) provide a dataset on regionally, state and nationally threatened species and could inform an IVA.

4.5.4 Freshwater fish

There are currently five species of small and medium-bodied freshwater fish of national or state conservation significance in the SA MDB Region: Yarra pygmy perch (Nannoperca obscura) and Murray hardyhead (Craterocephalus fluviatilis), listed as vulnerable under the EPBC Act (1999), and river blackfish (Gadopsis marmoratus), southern purple-spotted gudgeon (Mogumda adspersa) and southern pygmy perch (Nannoperca australis), protected under the state Fisheries Management Act (2007). Risk analyses undertaken by Bice et al. (2011) showed that all of these fish were at risk of being extirpated during the sustained low flows in the River Murray between 2006 and 2010. These analyses, coupled with an assessment of likely future River Murray flow scenarios, could be used as the basis of a vulnerability assessment for threatened fish species.

It is important to note that the higher flows and wetter local climatic conditions recorded since 2010/11 resulted in better short-term security of aquatic habitats across the SA MDB Region but positive responses were not seen from all threatened native fauna, a finding that suggests that dispersal and recruitment may be limiting the overall population response or that fish are harder to catch with high flows and increased habitat availability (Bice et al. 2011). Because the lower River Murray Region is at the terminus of the Murray–Darling system and is highly regulated, the assemblages of riverine fish are already highly degraded and subtle changes to either temperature or flow may not result in significant additional impact (Balcombe et al. 2011). Regardless of current fish populations, if climate change leads to less flow and thus increased water temperatures, lower functional connectivity and possibly increased salinity, then available fish habitat will be further degraded. Balcombe et al. (2011) found that native fish typically associated with wetlands such as pygmy perch, flat headed gudgeons, un-specked hardyheads and Murray–Darling rainbowfish will be highly vulnerable to climate change.

4.5.5 Identified gaps for threatened species and communities

• individual vulnerability assessments for threatened terrestrial flora and fauna following the methodology of Gonzalez et al. (2011);
• compilation of data of Gillam and Urban (2010) to inform IVA if individual vulnerability assessments are not undertaken;
• knowledge of ongoing environmental water availability; and
• knowledge of impacts of pollutants (e.g. acid, heavy metals and salinity) on aquatic and water dependent flora.

4.6 WEEDS AND PEST ANIMALS

A plant or animal pest can be defined as one that exhibits adverse impacts on the environment, economy, primary production or the community including stock injuries and death, loss of biodiversity and ecosystem functioning, loss of soil because of ground cover changes, fouling of water courses and human health issues including disease. There are many pest plants and animals that have been either introduced into the SA MDB Region or are native to the area but have benefited from human modification to the environment. Increases in the spread and numbers of invasive species may be among the more important and least predictable effects of climate change in Australia (SA MDB NRM 2009). Changes to the climate are likely to affect pests in a variety of ways, in many cases unpredictably. Some species will benefit from the changes and expand in range or seasonal distribution while others will be disadvantaged and will be out-competed in their current extent. Some species that are currently not considered a pest will be spurred to more aggressive habits and become a problem, and other pests that are currently not even found in the Region are likely to invade as conditions change. Other climate change effects on ecosystems may also interact with the ability for weeds to spread and proliferate. For example, changed fire frequency and intensity may selectively
advantage some grassy weed species, or an increase in disturbance through extreme weather events may lead to increased opportunities for primary successional weed species (Kriticos et al. 2010).

The SA MDB Region has already undertaken a regional pest risk assessment (Harvey 2006), however this study did not take into account the effects on climate change on future risks posed by pest species. In moderate rainfall cropping zones, there are many weeds for which the climatic suitability will diminish in the future. In the higher rainfall areas of the SA MDB Region the climate “will increase in suitability for many weeds as temperatures warm. Thus, the threats posed by some weeds will increase through more vigorous growth and higher fecundity. Combined with decreasing herbicide efficacy, the management of weed threats in this Region could increase considerably in the future” (Kriticos et al. 2010). What is apparent from the modelling done by Kriticos et al. (2010) is that in general terms, weeds that are limited by high rainfall (i.e. are found in drier environments) are likely to spread into areas that are not currently suitable as they dry with the change in climate.

Low (2011) evaluated the weeds in the Murray-Darling Basin and concluded that “the evidence suggests that most of the weeds assessed are likely to benefit overall from climate changes. Reasons for this include longer growing seasons, less frost, more droughts reducing competition, and higher temperatures along with carbon dioxide fertilisation increasing plant growth rates in situations where water is not limiting and competition from native plants is minimal.”

Other climate change effects on ecosystems may also interact with the ability for weeds to spread and proliferate. For example, changed fire frequency and intensity may selectively advantage some grassy weed species, or an increase in disturbance through extreme weather events may lead to increased opportunities for primary successional weed species (Kriticos et al. 2010). The impact of weeds could be considered as part of the vulnerability assessment for vegetation communities as a secondary exposure as was done for Balston et al. (2011).

Terrestrial pest animals in the Region include introduced species such as foxes, rabbits, goats and cats (Harvey 2006). As noted in the Garnaut review, the ultimate outcomes (of climate change) “are expected to be declines in biodiversity favouring weed and pest species (a few native, most introduced) at the expense of the rich variety that has occurred naturally across Australia.” Feral and native animals that are abundant in some areas and considered a problem such as Western Grey Kangaroos, galahs, and Little Corellas (Harvey 2006) would also need to be considered as part of a vulnerability assessment because of their capacity to affect other species as they potentially expand their range.

The aquatic environments of the SA MDB Region contain significant pest fish species such as common carp, redfin perch, eastern gambusia and trout. Reviews of fish autoecology literature such as Ye et al. (2009) and Bice (2010) and hypotheses contained in RRP (2012) could be used to determine the likely impacts of future water and flow regimes on pest fish population dynamics there is a lack of knowledge on biotic interactions and other secondary ecological processes. In their review, Balcombe et al. (2011) found that the impacts of climate change on pest fish will not only affect their own population dynamics but also those of native fish. They conclude pest fish will undergo mixed responses to climate change, a reflection of the diverse range of climatic conditions from which they come. Brown trout (Salmo trutta) and rainbow trout (Oncorhynchus mykiss) are likely to contract in the southern part of the MDB to the likely benefit of many native fish. Common carp (Cyprinus carpio) may increase because of its opportunistic recruitment patterns, high rates of population growth and tolerance of suboptimal conditions. Similarly, eastern gambusia may increase in extent as well, a change that will have adverse impacts on native fish populations.

4.6.1 Identified gaps for weeds and pest animals

regional assessment of climate suitability for weed and pest animal species under climate change;
regional assessment of risk/benefits to different vegetation community types from weeds and pests under climate change; and
regional assessment of impacts of pest species on health, primary production and other social and economic parameters under climate change.

4.7 Impacts of bushfire on ecosystems

In semi-arid areas, such as the SA MDB Region, uncontrolled bushfires may become hotter and more frequent due to climate change (SA MDB NRM 2009). There are likely to be some
pre-adapted components of the Australian flora that will survive, or even benefit, if expected climate changes results in more frequent and/or more intense fires in many Australian ecosystems. Increased risk mitigation measures, such as an increase in the frequency of controlled burning on public lands to reduce fuel loads, will also impact on regional ecosystems. Climate change will probably have the most significant impacts on both the fire regimes and biodiversity of sclerophyll dominated vegetation such as the forests of south eastern Australia (Williams et.al. 2009). This type of vegetation is confined to the southern and eastern parts of the SA MDB Region. More fires could increase predation by cats and foxes on declining species, by removing protective vegetation cover.

4.7.1 Identified gaps for bushfire

- As noted previously, there are gaps in our knowledge with regard to:
  - fire management practices to protect and restore biodiversity;
  - post-fire recovery of vegetation.

4.8 SOILS AND LANDSCAPES

As noted by Balston et.al. (2011) “Differences in soil moisture holding capacity, physical and chemical properties, and the micro-organisms residing within them mean soils react differently under varied rainfall and temperature regimes. Warmer and drier conditions are likely to result in changes to the soil’s capacity to support vegetation and dependent fauna. More intense rainfall events will increase the likelihood of water erosion, and drier conditions will result in reduced vegetation cover and increased erosion from wind and water. Increased summer rains may lead to an increase in weed growth and consequent tillage by farmers. Reduced rainfall is likely to reduce the risks from acidification and dryland salinity as leaching is reduced and water tables recede, but increased irrigation in response to drier conditions may lead to an increase in irrigation salinity in irrigated areas.”

Also higher evaporation levels and less flushing from rainfall may lead to an increase in salinity levels in soils prone to non-watertable induced salinity. This phenomenon can occur where salts tend to be retained within the plant root zone due to clayey and poorly structured subsoils.

South Australian soils are also naturally low in fertility, highly weathered and erodible, characteristics that affect potential agricultural production and increase the vulnerability of natural and agricultural systems to changed climate conditions (Meyer et.al. 2012). The regional NRM Plan (SA MDB NRM 2009) provides a comprehensive overview of the soil types and associated threats in the region. Nine key soil groups are noted for the region. Of the cleared arable land in the region, Liddicoat et.al. (2012) indicates that 33% is at moderate or moderately high risk of wind erosion, and 10% is at moderate or moderately high risk of water erosion. Modelling conducted by Liddicoat et.al. (2012) suggests that drier, more marginal areas (such as across the agricultural areas of the SA MDB Region) will be most vulnerable to increasing erosion risk under a warming, drying climate. Erosion risk maps were generated as part of the work.

Parts of the northern Murray Mallee are among some of the lowest growing season rainfall cropping areas of the State. While relatively favourable soil properties that enable storage of moisture below the evaporation prone surface layer have contributed to the viability of cropping within these areas, rainfall declines will play a more significant role in determining potential future sustainable land use and land management options. Successful land managers in these low rainfall areas will have largely already adopted various risk management strategies to cope with unpredictable seasons. These risk management strategies will need to continue to evolve with any changes in climate (Liddicoat pers comm September 2012).

Liddicoat et.al. (2012) also note that “modelling results generally support field observations that some soil types outperform others across a range of climatic conditions. Shallow clayey soils are found to most vulnerable to poor yields and low stubble cover in dry years. In low rainfall environments, higher rates of evaporation and higher wilting point moisture levels in clay surface soils increases the risk of moisture stress and terminal drought, compared to sandy surface soils. Sandy surface soils combined with large PAWC (Plant Available Water Capacity e.g. deep sands or some sandy surfaced texture-contrast soils) are found to be the most resilient for cropping in drier environments.”

Whilst the study focussed on cropping and production outcomes, there is an inherent link between soil type and native vegetation. Thus native vegetation on shallow, clayey soils may be more challenged by loss of condition as a result of low rainfall, whereas vegetation on sandier soils may be exposed to higher degradation risk from erosion. Such degradation may have serious flow-on effects including:
change in structure and function of vegetation, localised loss of species, and increased susceptibility to invasion by weeds. Land used for livestock production will require careful management to avoid overgrazing and loss of cover as a result of wind erosion (Cole 2008).

4.8.1 Identified gaps for bushfire
Key gaps to further improve protection from soil erosion are the limitations in our current farming systems and the impact of increasing climate variability. For example, how do we protect soils if there is going to be less vegetation biomass? How do we maintain or increase soil carbon levels?

There is also a need to increase adoption of improved land management practices to improve protection of soils from erosion. Practices include identifying where improvements can be made, how land managers make such changes and how can they be encouraged to do so. Other options include improved farm planning based on productive potential, management of risks, and better integration of biodiversity conservation with production agriculture.

4.9 SURFACE WATER
4.9.1 River Murray channel
The River Murray is the most significant water resource in the South Australian Murray-Darling Basin Natural Resources Management (SA MDB NRMB) Region and the major water resource feature for the state of South Australia (SA MDB NRMB 2009). The River (which flows some 640 km from the border to the Coorong) and adjoining wetlands, support human, agricultural and environmental requirements.

There is very little inflow into the River Murray within South Australia. The volume of water in the River and consequently the volume available for use and the health of the aquatic environments are directly related to the volume that enters the state from upstream states (SA MDB NRMB 2009) and the State’s ability to manage this resource allocation to the maximum benefit.

Across eastern and southern Australia available surface water has decreased. This trend has resulted in a 55% decrease in the Murray-Darling Basin stream flow since 1950. During the 2000-07 period the average annual inflow to the river system was 4,150 GL/year compared to a long-term average of about 12,300 GL/year (Cai and Cowan 2008) (Figure 29). Rainfall for 1997–2006 was 7% lower than the historical average while surface water availability was 26% lower (CSIRO 2008b). In addition, development and water diversion has had a dramatic effect on the river and only 36 per cent of the natural mean annual discharge (or 27 per cent of the natural median annual discharge) now reaches the sea (Walker 2006). Drought has also resulted in a failure to meet entitlement flows (in 2006–07 water allocations were 60%; in 2007–08 they were 32%, and in 2008–09 they are 18%) (SA MDB NRMB 2009). As a result there were long periods of no river flow at the Murray Mouth over these years.

Figure 29: Changes in total water volume in the Murray-Darling Basin (2002 – 2008) (Source: Steffen 2009).
The authoritative source of information on water flows in the Murray-Darling Basin is the Murray-Darling Basin Sustainable Yields Project (CSIRO, 2007 and CSIRO, 2008). The project estimated the current and likely future (2030) water availability in each catchment and aquifer for the entire MDB and provided specific reports for each regional area. The reports consider the impact of climate change, surface-groundwater interactions and other factors that influence yields. Three global warming SRES scenarios were run through 15 global climate models, and future development including commercial forestry, farm dams and groundwater extractions modelled. The outputs of the study provide water resource availability volumes under different climate change exposure scenarios. Regional information for the Murray Region of the MDB (which compasses the Murray River within southern New South Wales, northern Victoria) and the Eastern Mount Lofty Ranges Region is provided within these reports.

The CSIRO 2008 report on the Murray Region, discusses the uncertainty in the analysis indicating that:

“The largest sources of uncertainty for future climate results are the climate change projections (global warming level) and the modelled implications of global warming on regional rainfall. The results from 15 global climate models were used but there are large differences amongst these models in terms of regional rainfall predictions. There are also considerable uncertainties associated with projections of future increases in commercial forestry plantations and farm dam developments and the impact of these developments on runoff”.

4.9.2 Eastern Mount Lofty Ranges

Other surface water resources of the Region are locally important to the ecology and economies of those areas. These include tributaries (Angas, Bremer, Finnis and Marne Rivers, and Saunders, Tookayerta and Curreny Creeks), wetlands and swamps in the Eastern Mount Lofty Ranges (SA MDB NRMB 2009).

Again the authoritative source of information on water flows for this area is currently within Murray-Darling Basin Sustainable Yields Project (CSIRO 2007). The CSIRO, 2007 report discusses the uncertainty in the analysis for the Eastern Mount Lofty Range, indicating that in addition to those associated with climate change projections (as stated above):

“The surface water model is considered suitable for assessing relative changes in average flows. However, the model overestimates total volumes by 14 percent and 21 percent respectively in the Mame and Angas-Bremer rivers independently evaluated. Projections of absolute current and longer-term flow volumes are thus uncertain. This may have implications for the use of these results to assess local in-stream environmental values and availability of water for users”.

“There are considerable uncertainties associated with the future development projections. There are multiple drivers for commercial plantation forestry and farm dams, many of which have not been considered, and the ways in which landholders will respond to the current policies is uncertain. Future development could be very different should governments impose different policy controls on these activities”.

The statewide “Impacts of Climate Change on Water Resources Project” aims to prioritise the risk of climate change impacts to water resources (Department for Water 2011) and will identify key priority areas for detailed downscaled climate change modelling under Phase 2 of the project. The additional modelling will significantly improve the resolution water modelling within these areas when compared to the CSIRO Sustainable Yield Assessments. To date, the study has examined sixty nine prescribed and unprescribed water resource areas for:

- the level of reliance on each of the water resources for public water supply, irrigation and industry needs, and environmental requirements;
- the vulnerability of each resource, based on factors such as its sensitivity to yearly rainfall variations;
- likely extent of climate change that each resource may be subject to, based on climate change projection maps produced by the CSIRO (2007)\(^1\).

Based on the above criteria, a total resource risk priority score was assigned and then each resource was ranked in order of climate change risk priority (Table 8).

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1 Projections are given relative to the period 1980-1999 (referred to as the 1990 baseline for convenience). The projections give an estimate of the average climate around 2030, 2050 and 2070, taking into account consistency among climate models. Individual years will show variation from this average. The 50th percentile (the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (lowest 10% and highest 10% of the spread of model results) provide a range of uncertainty. Emissions scenarios are from the IPCC Special Report on Emission Scenarios. Low emissions is the B1 scenario, medium is A1B and high is A1FI.
Table 8: First order risk assessment and prioritisation for impacts of climate change on water resources within South Australia (Source: Department for Water 2011).

<table>
<thead>
<tr>
<th>Prescribed/Unprescribed Water Resource Area</th>
<th>Resource</th>
<th>Risk rank (of 69) (1 = the highest risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMLR PWRA</td>
<td>Unconfined/confined aquifer</td>
<td>4th</td>
</tr>
<tr>
<td>EMLR PWRA</td>
<td>Unconfined aquifer (FR)</td>
<td>5th</td>
</tr>
<tr>
<td>EMLR PWRA</td>
<td>Surface water/watercourse</td>
<td>8th</td>
</tr>
<tr>
<td>Marne-Saunders PWA</td>
<td>Unconfined aquifer (FR)</td>
<td>19th</td>
</tr>
<tr>
<td>Marne-Saunders PWA</td>
<td>Surface water/watercourse</td>
<td>20th</td>
</tr>
<tr>
<td>Marne-Saunders PWA</td>
<td>Unconfined aquifer (TLA)</td>
<td>30th</td>
</tr>
<tr>
<td>Angas-Bremer PWA</td>
<td>Unconfined aquifer (Quaternary)</td>
<td>32nd</td>
</tr>
<tr>
<td>Angas-Bremer PWA</td>
<td>Confined aquifer (TLA)</td>
<td>37th</td>
</tr>
<tr>
<td>Mallee PWA</td>
<td>Unconfined portion of aquifer (TLA)</td>
<td>51st</td>
</tr>
<tr>
<td>Mallee PWA</td>
<td>Confined aquifer (TLA)</td>
<td>54th</td>
</tr>
<tr>
<td>Noora PWA</td>
<td>Confined aquifer (TLA)</td>
<td>64th</td>
</tr>
<tr>
<td>Peake, Roby and Sherlock PWA</td>
<td>Unconfined aquifer (TLA)</td>
<td>60th</td>
</tr>
<tr>
<td>Peake, Roby and Sherlock PWA</td>
<td>Confined aquifer (TCS)</td>
<td>65th</td>
</tr>
</tbody>
</table>

FR – fractured rock; TLA – tertiary limestone; TCS – Tertiary Confined Sand

The surface water and groundwater resources of the Marne Saunders and Eastern Mount Lofty Ranges have also been prescribed (SA MDB NRMB 2009). In both cases the Water Allocation Plans (WAP) do not take into account the impacts of climate change for either the resource availability or the future impacts on demand.

4.10 GROUNDWATER RESOURCES

Groundwater in the SA MDB Region is locally important to the ecology and economies of the area. Resources include groundwater systems in the Eastern Mount Lofty Ranges (including Angas-Bremer)” prescribed Wells Area (PWA), the Mame-Saunders, Mallee, rangelands (SA MDB NRMB 2009) and possibly the Coorong although this is unquantified (Webster 2005). Of particular importance is the Angas-Bremer Plains (although this has now been augmented by the pipeline from the River Murray) and the Mallee regions for irrigation and stock and domestic uses.

The CSIRO’s Sustainable Yields Project has considered groundwater scenarios for several Groundwater Management Units (including the Eastern Mount Lofty Ranges and Angas-Bremer). While useful, these assessments are still broad-scale, and have not considered the detailed interrelationships, between surface and groundwater, localised extractions and the needs of the environment. Data will be significantly improved by the planned downscaled assessments that will be delivered through Phase 2 of the Impacts of Climate Change on Water Resources Project (Department of Water 2011).

A reduction in groundwater levels can have a significant impact on the interaction with surface water wetlands, pools, rivers and creeks. A relatively small decline in groundwater levels can result in a disconnection between an aquifer and surface water ecosystems and so these ecosystems are highly sensitive to such changes. In comparison, the same reduction in groundwater level may not impact the sustainability of a groundwater bore. This point is particularly important in the Eastern Mount Lofty Ranges where early analysis of the hydro-geochemical results for groundwater and surface water samples suggest that the majority of the permanent pools and wetlands are largely dependent on groundwater inflows (Green 2007).

The four prescribed wells areas (groundwater only prescribed) are: Angas-Bremer; Mallee; Noora; and Peake-Roby-Sherlock. The surface water and groundwater resources of the Marne Saunders and Eastern Mount Lofty Ranges have also been prescribed (SA MDB NRMB 2009). In all cases the Water Allocation Plans (WAP) do not take into account the impacts of climate change for either the resource availability or the future impacts on demand.
4.11 RECYCLED WATER

The use of recycled water within urban townships and the agriculture industry enhances the resilience of the community by providing an additional source of water that can be treated for “fit for purpose” uses. Most towns along the SA River Murray have developed Integrated Water Management Plans (IWMP), that consider the use of recycled water alongside more traditional sources such as mains water, rainwater tanks and direct extraction from the River Murray. Currently, recycled wastewater has been utilised in preference to stormwater as wastewater is a more secure source with reliable flows on an annual and inter-annual basis. An investigation of opportunities for wastewater re-use in the SA MDB Region to help shape and accelerate investment in wastewater re-use programs commenced in 2005 (pers. com Mellissa Bradley, SA MDB NRMB). Project outputs to date and the subsequent IWMP’s provide sound information with regard to recycled water.

The specific impacts of climate variability, and or climate change, have been addressed to varying degrees in the plans and include a discussion of rainfall and temperature scenarios to an assessment of resource availability for dry, average and wet years and concluding that the impacts would be very minor, but without reference to analysis. The potential impact of climate change within the context of this variability (for example Renmark IWMP, Karoonda IWMP) is also considered. In general, the high rainfall variability in the Region will have a far greater impact on water resource availability than climate change in the short term. As a result, and to minimise significant gaps in knowledge, water resource assessments must take into account historic rainfall variability and its impacts (pers. comm. Karla Billington, Naturallogic 2011).

4.12 IVA AND WATER RESOURCE MANAGEMENT

To assess water resource vulnerability in terms of the climate change measures of “exposure”, “sensitivity” and “adaptive capacity” we need to determine quantitative measures for each element (for example, an assigned scale from 1 to 5 as was used in Balston et al 2011).

Exposure is a measure of the predicted changes in the climate, and for the purposes of water resources in the study region relates to the climate scenarios of reduced rainfall and increased temperature. As described in the climate section of the report, the scenarios are developed from downscaled global climate models and are subject to the accuracy of the models.

The element of sensitivity requires a detailed understanding of how the climate variables impact on water resources and specifically the assessed indicators including surface water (quality and quantity), groundwater (quality and quantity), water dependent ecosystems, demand, and water infrastructure. Sensitivity reflects the responsiveness of a system to climatic influences, and the degree to which changes in climate might affect the system in its current form and under the current management regime. Thus, knowledge is required not only on the change to water resource availability, but also the impact that an altered climate will have on end users and the environment. As stated, changes to water resource availability in response to changes in the climate have been modelled at the regional scale in projects such as the CSIRO Sustainable Yields project (CSIRO, 2007 and CSIRO, 2007), and will be further improved by the delivery of Phase 2 of the Impacts of Climate Change on Water Resources Project (underway by the Department of Environment, Water and Natural Resources).

What are harder to assess, and where significant gaps in knowledge occur, are the likely secondary impacts that these changes will have on other indicators such as agriculture, human health and the environment. The size of the secondary climate change impact will be influenced by the magnitude of the change and critical thresholds for specific systems, for example how sensitive are:

• irrigators to reduced surface water availability?
• graziers to increased salinity levels in the lower lakes?
• wetlands along the River Murray to declining water levels (including secondary processes such as acid sulphate soils)?
• critical human needs for potable water to reduced river Murray flows?

Secondary impacts will also vary depending on geographic location. For example, the irrigators of the Langhome Creek were more sensitive to reduce flows in the millennium drought than those along most the River Murray corridor. This was due to the relatively small flows within the Angas and Bremer Rivers compared to the River Murray.

Regional case studies or expert opinions that can quantify the primary and secondary
Impacts of climate change on hydrological and linked systems are critical inputs to evaluating the elements of a vulnerability assessment and will reduce influence from “perceived impacts” that may be assessed as high or low depending on the perspective of the individuals. Such information has been compiled for the region in reports of the Strengthening Basin Communities program, specifically, the Climate Change Impact Assessment Report for the SA MDB Region (Summers et al. 2011). The report provides considerable knowledge, but will need to be interpreted to provide quantitative scores of sensitivity.

The sensitivity of hydrological systems to climate change may be affected by current management regimes (such as application of irrigation water use efficiencies, reliance on a source of water, capacity of WAP to deal with extreme events). Where relevant, these management regimes must be noted within the vulnerability assessment and differentiated from future adaptive capacity options. Accessing historic management and policy information should be relatively easy. For example, actions that occurred during the Millennium drought provide an indication of adaptive capacity under extreme climate conditions. From historical records then, generalised learning’s about society’s ability to adapt can be projected.

National the draft Murray-Darling Basin Plan (the draft Basin Plan) is guided by the Commonwealth Water Act (2007), which specifies the measures the Basin Plan must contain to guide management of the water resources of the Murray–Darling Basin. A key feature of the proposed Basin Plan (also called the ‘draft Basin Plan’ in some literature) is the recommendation that the health of the Basin be improved by setting a long-term environmentally sustainable level of take (extraction) of water from its rivers for consumptive uses. The environmentally sustainable level of take aims to ensure that there is enough water left in the river system to meet environmental needs.

Currently the draft Basin Plan requires that State water resource plans describe how they can accommodate a wide range of climate and water availability scenarios. The draft Basin Plan also contains arrangements for meeting critical human water needs along the River Murray System in extremely dry scenarios and requires the same of State water resource plans. Limitations in the future regulatory framework currently occurs as the Basin Plan is yet to be finalised.

4.12.1 Identified gaps for water resources
- water resource assessments that do not account for the variability of resource availability;
- localised effects of climate change on rainfall and evaporation ratios (volumes and patterns) and their consequential transfer rates to run-off and recharge (surface and groundwater availability);
- poor capacity to forecast water availability (including droughts) across all water resources (surface and groundwater) even on an annual cycle;
- limited capacity to forecast water demands under different climate scenarios (urban and rural);
- knowledge of the full range of secondary impacts on catchment processes from alterations in rainfall, temperature, evaporation and evapotranspiration under different climate scenarios;
- limited capacity to determine thresholds for sensitivity for differing water resource scenarios on end users (including the environment);
- lack of detailed models for Eastern Mount Lofty Ranges water resources (surface and groundwater) and high uncertainty regarding climate change impacts (should be addressed with the delivery of Phase 2 of the Impacts of Climate Change on Water Resources Project);
- poor capacity to predict cumulative impacts of policy and management decisions that affect water resources (due to disseminated operational responsibilities and a lack of clear institutional leadership in South Australia and across the Murray-Darling Basin);
- knowledge of feedback effects from changing demand for water under financial and economic capital (surface and groundwater);
- poor capacity to predict potential for the construction of, and operational guidelines for, new water resource management infrastructure (e.g. new offtakes, new weirs or regulators, modified barrages, desalination plants, salt interception schemes) and their subsequent impact of the management of water resources;
- limited capacity to predict potential for water recycling to meet changing water demands and thus determine resilience of different communities and sectors;
- the finalised regulatory framework which will be within the Murray-Darling Basin Plan.
Environmental water is water held or provided under legislation for the express purposes of achieving environmental outcomes including: biodiversity, ecological functions, water quality and water resource health (e.g. South Australian Water Resources Act 2007). This requirement means that the impacts of climate change on environmental water need to be evaluated two-fold: first in terms of the impacts of climate change on the water needs of the environment (e.g. increased rates of evapotranspiration) and second in terms of our capacity to provide environmental water under changing water resource use and health. Therefore, climate change impacts on water resources, environmental water provisions (EWPs) and the interactions between them will need to be evaluated iteratively in the IVA. It is likely that this process will contain numerous uncertainties, particularly regarding interactions between water resource use and EWPs and any possible feedback loops.

Water resource development in the Murray-Darling Basin has led to: reductions in river flow, flooding and groundwater quality and quantity; terrestrialisation of aquatic ecosystems; reduced health of floodplain ecosystems; and loss of functional connectivity between aquatic ecosystems and across the aquatic-terrestrial gradient (e.g. Pittock and Finlayson 2011). These adverse outcomes are all indicative of a legacy of failure to provide environmental water requirements (EWRs) in the MDB as a whole. Given that the SA MDB Region lies at the terminus of the Murray-Darling Basin and has a history of relatively poor ecosystem health compared to some upstream valleys (MDBC 2008), it is likely that adverse impacts on environmental water will continue to be relatively high in the SA MDB Region. Thus, the impacts of climate change on environmental water in the SA MDB Region will be exerted on ecosystems already under severe stress from compounded and unsustainable water resource development and use.

This section reviews how well the EWRs of aquatic ecosystems in different parts of the SA MDB Region have been defined and the key water resource management tools used to deliver EWPs. The predicted efficacy of water resource management at meeting these target EWRs under future climate change scenarios would need to be assessed in an IVA. Baseline data, species threshold levels and ecosystem trend information that have gone into determining EWRs at a sub-catchment scale (e.g. MLR streams) will be valuable in determining adaptive capacity as part of the IVA.

### 4.13.1 River Murray channel, wetlands and floodplain

There is a relatively high level of conceptual understanding and operational experience concerning environmental water delivery in the River Murray channel, wetlands and floodplain that will be useful for the IVA (e.g. South Australia’s Environmental Watering Program under MDBA’s The Living Murray Initiative).

The lower River Murray region in South Australia is characterised by weirs and locks that constrain longitudinal connectivity throughout the river and lateral connectivity with associated wetlands and floodplains. The River Murray has for many decades been managed to provide relatively stable water levels in the main channel. This regulation of the water and flow regime, in addition to the general decline in flow, has disrupted ecological processes associated with the rising and falling phases of the flood pulse whilst advantaging those processes driven by stable water level (Walker et al. 1995). As a result of regulation, the water regime to South Australia’s River Murray wetlands and floodplains tends to sit at two opposite extremes: about 70% of wetlands (backwaters, side arms, anabranches, lakes, billabongs) are connected to the river at or below its operational pool level and are now permanently inundated (Walker 2006), while for the remaining 30%, the operation of the river at a defined operational pool level and reduction in flow has isolated these wetlands and floodplains from the river for longer than would have naturally occurred. Consequently, these areas now only receive water irregularly when river levels are high enough to overtop the banks or the sills and into the temporary wetlands.

Across the SA MDB Region landscape there has been a reduction in the ‘pulse of productivity’ normally associated with variable flooding and drying (Walker 2006). This change affects ‘system resilience’ - the capacity of the river-floodplain ecosystem to respond to variability, change and/or significant events, such as climate change. Estimating the effects of reduced resilience on the capacity of the environment to adapt to changes in EWPs in the IVA will be difficult. The most likely impacts will be:

- Further alterations to natural hydrology;
- Changes to stream geomorphology;
- Reduced inundation frequency, extent and duration in some wetland and floodplain areas;
• Loss of wetlands and floodplains through terrestrialisation;
• Increased areas of bare and saline soil;
• Increased evapo-transpirative water loss;
• A decline in wetland condition;
• Shifts in ecological character at local and regional scales;
• Declines in river red gum and black box woodlands along the channel, in wetlands and on the floodplain (i.e. poor recruitment and survival);
• Reduced abundance and diversity of fauna (e.g. flood-dependent colonially-breeding waterbirds);
• Altered patterns of fish migration and reduced recruitment success;
• Increased dominance and distribution of tolerant alien species; and
• Colonisation of alien species not currently present in SAMDB.

The IVA can draw upon the experiences of the multiple EWR determination processes that have been implemented in the Murray-Darling Basin and the SA MDB Region to assess the components of vulnerability including adaptive capacity. For example, the MDBA underwent a process of identifying water regime requirements (volume, duration and timing) for 106 hydrologic indicator sites, including 18 key environmental assets and 88 key environmental functions in the MDB. The 18 asset sites were considered to be key hydrologic indicator sites for the 2442 assets identified in the MDB on the basis that:

“... if sufficient water is provided for key ecosystem functions at one location it will be sufficient for those functions at many locations, both upstream and downstream. This same water will also provide for floodplain and wetland ecosystem functions associated with environmental assets, as well as contributing to the ecosystem functions associated with the rivers connecting the assets together. Moreover, this water will provide for the broader environmental water requirements of ecosystem services, the productive base, and the key environmental outcomes for the water resource.” (MDBA, 2010b, p. 90).

These sites have been embedded in the MDBA’s draft Basin Plan, which requires that State water resource plans describe how they can accommodate a wide range of climate and water availability scenarios. The draft plan also contains arrangements for meeting critical human water needs along the River Murray system in extremely dry scenarios, and requires the same of State water resource plans. However, it does not state how environmental water will be provided under extremely dry conditions – a limitation for the IVA.

Pollino et.al. (2011) undertook an analysis of the capacity of the Basin Plan to deliver SAMDB EWRs under five scenarios. The five Basin Plan scenarios were: without development; baseline; and three water buy-back scenarios (3000 GL, 3500 GL and 4000 GL). The EWR assessment was made against: two key environmental assets – Riverland-Chowilla and the Coorong, Lower Lakes and Murray Mouth (CLLMM, see below); three key ecosystem function sites – SA Border, Morgan and Wellington; and also considered sources upstream of the South Australian border. The water quality assessments considered several sites along the River Murray channel.

The Riverland-Chowilla site comprises the Chowilla Floodplain in South Australia and the Lindsay, Mulchra and Wallpolla Island complexes across the border in NSW and Victoria. The EWRs for the Riverland-Chowilla icon site in the SA MDB Region are based on providing a given inundation area to support the dominant river red gum (Eucalyptus camaldulensis) and black box (E. largiflorens) communities (Pollino et.al. 2011). The operation of regulators or locks to manipulate water levels in the Riverland–Chowilla site was not considered. Pollino et.al. (2011) assumed that because the Riverland-Chowilla asset is a hydrologic indicator site, the provision of EWRs to that site would be intended to meet the SA MDB Region’s EWRs in their entirety, not just localised requirements. The authors concluded that not all the Riverland–Chowilla EWRs will be met under any of the Basin Plan scenarios. However, the EWRs of less than 100,000 ML/day would be met more frequently and there would be sufficient volume on an annual basis to meet SA Murray-Darling Basin EWRs under the 4000 GL scenario, and under the 3500 GL scenario (the latter depending on the model), but not under the 3000 GL scenario. The researchers also suggested that the MDBA EWRs for the Riverland-Chowilla site based on tree needs underestimate the water needs of the site if other biota, such as waterbirds, are taken into account. This evaluation will be valuable for the IVA for the icon sites in the SA Murray-Darling Basin but with the exception of the Ecological Associates (2010) draft report that considers the stretch of the River Murray from the SA border to Wellington, very little has been documented in terms of the EWRs for the main river channel.
Given the lack of hydrological (longitudinal and lateral) and population connectivity in this highly modified and regulated river, any further reductions to flow will most likely result in lower functional connectivity and will lead to further degradation of populations of native flora and fauna that utilize floodplains and associated water bodies. The major limitation for an IVA for the aquatic environments of the SA Murray-Darling Basin will be the determination of likely future River Murray flows and water quality. A robust assessment of the future hydrology will need to be undertaken before any vulnerability assessment of ecological impacts and environmental water provision can be done. Another major limitation will be predicting what impacts future droughts (akin to the Federation and Millennium Droughts) will have because the draft Basin Plan fails to address how environmental water will be delivered under climate change or drought conditions.

The adaptive capacity for delivery of sufficient EWRs for the SA MDB Region will be highly dependent on successful implementation of improved water resource development policy. There is a focus now on the creation of a ‘New Functional River’ in South Australia that is both healthy and resilient, meaning that its major natural features and its functionality and biodiversity should be present, resilient and sustained into the future. The fundamental principle of the New Functional River concept is that it can be scaled according to the amount of available water, with the aim of re-establishing a resilient natural system.

When water is scarce the river will be ‘scaled down’ to a series of high value ‘core’ assets. Conversely, when water is available the system will be expanded, with water applied more widely to ‘scaled’ areas that were deprived of water during times of scarcity. Another major project is the Riverine Recovery Program (DFW 2012) that seeks to introduce intermittent water regimes to previously permanently connected wetlands via the construction of new regulators on wetland inlets. The new regulators will allow available environmental water to be applied to areas of the landscape in most need, which could mitigate some impacts of climate change in some wetlands. The approach will increase South Australia’s ability to manage environmental water throughout the landscape, and may increase adaptive capacity but it creates another level of uncertainty for the IVA in terms of predicting future condition, environmental water management and capacity to deliver EWRs.

### 4.13.2 Coorong, Lakes Alexandrina and Albert and Murray Mouth

The Coorong, Lakes Alexandrina and Albert and the Murray Mouth (CLLMM) region is a vast complex of coastal lagoons and freshwater lakes that sits at the junction of the Murray-Darling Basin and the Southern Ocean. Lakes Alexandrina and Albert, are the largest permanent freshwater lakes in South Australia, and cover an area of approximately 400 km² (Figure 2). Lake Alexandrina is the larger of the two lakes and connects the River Murray to the Murray Mouth estuary, the terminal Lake Albert via a highly constrained channel (the Namung Narrows) and the Coorong. The vast majority of freshwater inflows into Lake Alexandrina originate in the River Murray (Phillips and Muller 2006), although additional relatively minor volumes of freshwater come from the Eastern Mount Lofty Ranges tributaries (e.g. the Finniss River, Currency Creek, Bremer River) or via groundwater or local rainfall (DEH 2000). Water moves back and forth between the two lakes as long as lake levels are greater than sill level and no blocking banks are in place. Lake Alexandria is separated from the Murray Mouth and Coorong by a series of five barrages containing 593 independently operated gates that control the flow of water between the Lakes and the Coorong.

The Coorong is a 110 km long series of estuarine and saline lagoons connected to Encounter Bay and the Southern Ocean via the Murray Mouth – the only connection between the MDB and the sea. Two narrow sand peninsulas (Sir Richard and Younghusband Peninsulas) separate the Coorong and the ocean. The system is an inverse estuary meaning that the salinity increases away from the sea connection because the freshwater inflows enter at the same end of the lagoonal system as the river mouth, rather than the more-usual configuration of having fresh inflows enter at the opposite end to the connection to the sea. This configuration creates a natural gradient from estuarine conditions around the Murray Mouth and hypersaline conditions in the South Lagoon of the Coorong.

The CLLMM site is listed as a Wetland of International Importance under the Ramsar Convention and is one of six Icon Sites in the MDB (DEH 2000). The wetlands meet eight of the nine criteria specified by the Ramsar Convention for determining Wetlands of International Importance and are likely to qualify against the ninth criteria as well, although adequate data for determination is not available (Phillips and Muller 2006). There
has been a long-term decline in the condition of the Region since European settlement (Sim and Muller 2004) and particularly during the sustained low River Murray flows during the Millennium Drought from 2006 – 2010 when the barrages remained closed and lake levels dropped to an unprecedented low.

The recent environmental and operational responses to the Millennium Drought in the CLLMM region will be extremely useful inputs to the IVA. The low water levels in the lakes during 2006–2010 were unprecedented and forced exploration of various management interventions. Key environmental stressors during that period were increased salinities, increased nutrients, disconnection and desiccation of the ‘bath-ring’ of aquatic vegetation and the threat of widespread acidification from mobilisation of acid sulfate soil oxidation products. The ecological consequences of widespread acidification, introduction of seawater to the lakes to prevent acidification and maintenance of very low lake levels with freshwater River Murray inflows were examined in detail by Muller (2011). The ecological consequence methods and indicators used by Muller (2011) could be used as the basis for an IVA for a range of River Murray inflow scenarios. The results of the ecological consequence assessment could also be used as a case study given that reduced River Murray flows are a likely outcome of climate change and thus managers may be presented with the dilemma of how to manage the lakes to prevent acidification again in the future. Other management options tested will also provide excellent case studies for the IVA.

The comprehensive determination of the EWRs for the CLLMM region undertaken by Lester et al. (2011) will also be a key input to the IVA. Lester et al. (2011) developed a series of eight ecological objectives linked to 33 specific outcomes for a ‘healthy and resilient’ wetland system. These covered key ecosystem objectives such as self-sustaining populations, functional connectivity, habitat complexity, salinity gradients, aquatic-terrestrial exchange and redundancy. The report also contains vegetation, macroinvertebrate, fish and ecosystem process indicators linked to each of those ecological objectives and outcomes, salinity targets for Lake Alexandrina (electrical conductivity of 1000 µS cm⁻¹ 95% of the time) and lake level targets (e.g. >0.35 m AHD at all times, periods of >0.95 m AHD to stimulate floodplain processes). Hydrological modelling to determine the EWR for the Lower Lakes is reported in Heneker (2010), and the hydrodynamic implications for the Coorong of delivering the EWRs to the lakes is reported in Lester et al. (2011). Further investigation into additional Coorong-specific water requirements, the effects of delivering less River Murray water than recommended by the EWRs and interactions with a proposed expansion of the Upper South East Drainage scheme were also undertaken. This work will be extremely valuable for an IVA process for not just the CLLMM region but other parts of the SA MDB Region as well, particularly those with similar species and communities.

Delivery of adequate freshwater to the CLLMM region will be dependent on delivery of adequate River Murray water over the South Australian border – see River Murray channel assessment above. Inflows from the Eastern Mount Lofty Ranges tributaries are ecologically important for the CLLMM site (in particular Lake Alexandrina) because of the seasonal timing and relatively good water quality but Eastern Mount Lofty Ranges inflows are not of sufficient volume to meet a significant quantum of the CLLMM EWR. Pollino et al. (2011) conclude that not all EWRs for CLLMM will be met under the draft Basin Plan scenarios but EWPs will be improved compared to current conditions with the greatest improvement under the 4000 GL/y and the least under the 3000 GL/y scenarios. The thresholds developed could be used in the IVA.

### 4.13.3 Eastern Mount Lofty Ranges

Less is known about EWRs and how to deliver EWPs in the Eastern Mount Lofty Ranges (EMLR) compared to the main river channel and CLLMM. This will limit the IVA but the current process of Water Allocation Planning in the EMLR will generate more information over time that may be able to be incorporated.

The eastern face of the Mount Lofty Ranges forms the south-western boundary of the Murray-Darling Basin. Sixteen streams run off the EMLR into the River Murray and Lake Alexandrina. There are also a number of catchments that give rise to streams that do not persist and contribute little water into the River Murray. These streams gain water from catchments that vary greatly in current rainfall from 350 mm to 850 mm annually, and from aquifers across the hills and plains that are recharged by stream flow and rainfall (Phillips and Muller 2006). Most of the rainfall and runoff occurs in winter and early spring. The Eastern Mount Lofty Ranges and the Marne Saunders PWRAs contribute about 0.5 % of the total annual runoff to the Murray-Darling Basin (CSIRO 2007) with a collective resource capacity of approximately 108 GL/y (SA MDB NRM Board 2011).
The lower reaches of the Finniss River, Currency Creek and Tookayerta Creek lie within the CLLMM Ramsar site, as do the mouths of the Angas and Bremer Rivers. The EMLR also contains the EPBC-listed Fleurieu Swamps (see section on Threatened Species and Communities above).

EWRs for aquatic and water dependent biota in the EMLR were determined as part of the Water Allocation Planning process (VanLaarhoven and van der Wielen 2009) and can be used in the IVA. An expert panel method was used to determine the EWRs, based on knowledge of local ecology, hydrology and geomorphology. Water-dependent biota were divided into functional groups of similar life histories and flow requirements and the ecological processes required to support self-sustaining populations of each functional group were identified, as were the components of the flow regime required to support those processes. Generic river reach types were applied based on biotic functional groups and processes and then aggregated EWRs were determined for each reach and translated into measurable hydrologic ‘metrics’ that correspond to key parts of the flow regime (e.g. duration of zero flow events in the Low Flow Season).

Out of the 135 sites tested across the whole Mount Lofty Ranges, only two sites passed all flow metrics and 50% of sites passed less than 75% of the metrics (VanLaarhoven and van der Wielen 2009). This result suggests that the water dependent biota of the EMLR is already under stress and climate change impacts will compound current stressors. Climate change has not been explicitly considered in the development of the EMLR Water Allocation Plan (see section on Surface Water above). However, the plan is underpinned by the requirement to return low flows to the environment (applies to existing licensed users, existing non-licensed users with dams >= 5 ML, and new dams or diversions), and will ensure that the environment receives some water before the licensed users if implemented effectively. However, it is unknown what relative proportion of the EMLR EWRs will be provided for by low flow bypass.

The capacity to meet EWRs during low flow seasons and years is likely to significantly deteriorate under climate change, and will increase the risk of extirpation of aquatic biota and loss of aquatic habitats. These changes will be difficult to predict. The ‘flow metrics’ method has its limitations but assessing the efficacy of climate and/or water resource policies to meet the target flow metrics would be a useful component for the IVA.

4.13.4 Identified gaps for environmental water provision

- EWRs for aquatic flora and fauna species;
- Inconsistent approaches and quantum of EWRs for SA MDB Region assets by different levels of government;
- Knowledge of effectiveness of EWPs for icon and hydrologic indicator sites delivering whole-of-ecosystem EWRs;
- Knowledge of effects of current status of populations of indicator flora and fauna species on future vulnerability;
- Likely future River Murray flows under various water resource management options.

4.14 ECOCLOGICAL IMPACTS OF SEA LEVEL RISE

4.14.1 Coorong and Lakes Alexandrina and Albert

Webster (2009) undertook a preliminary assessment of likely effects of climate change driven sea level rise on water level in Goolwa Channel and the Coorong near Tauwitchere barrage to predict if the barrages that separate the freshwater lakes from the saline parts of the CLLMM site will be overtopped and allow seawater to enter Lake Alexandrina. To do this, Webster (2009) applied a hydrodynamic model that relates water level measured at Victor Harbor (~20 km away) to water levels at Goolwa barrage for three different degrees of river mouth channel opening. The measured maximum water levels at Goolwa barrage in each month of record are generally less than those measured at Victor Harbor possibly due to attenuation inside the Murray Mouth. Webster’s (2009) analysis suggests that the vulnerability of barrage overtopping by the sea would be increased as the mouth channel becomes more open and that the annual duration of exceedence of current barrage operating levels (c. 0.8 m AHD) would be expected to increase significantly with the sea level rises considered (0.2 and 0.5 m rise in above 1976-2005 levels). It is assumed in the study that future water level fluctuations will be similar to those currently recorded and that the elevation of the Murray Mouth will increase as sea level increases. Possible increases in storm surges and other oceanic processes associated with climate change were not considered. However, the study indicated limitations in the capacity to predict future River Murray flows, lake water levels, effects of storm surges, the degree of Murray Mouth openness and effects of sea level rise greater than 0.5 m.
Possible engineering works to mitigate the impacts associated with rising sea level that would be considered in an IVA include: raising the barrages, installing bunds across parts of the wetland system and building a weir near Wellington. Little work has been done on the ecological and hydrological impacts of raising the barrages although, as pointed out by Rolls (1988), this would require either the lake levels to also be raised via increased River Murray inputs or the lake levels to remain around +0.75 m AHD any ‘excess’ freshwater pumped out to the Coorong and Murray Mouth during periods of high River Murray flows or floods. Bunds were installed at Clayton on Lake Alexandrina and across the Namung Narrows (between Lakes Alexandrina and Albert) during the 2006 to 2010 drawdown and the subsequent reports (e.g. Nicol and Ward 2010) could be used in an IVA. The ecological consequences assessment for preventing acidification of the lakes (Muller 2011) also contains information and methods for assessing impacts of such bunds over time. Similarly, the preliminary risk assessment done for the proposed weir at Pomanda Island (near Wellington; Muller 2008) contains information and methods for assessing the ecological outcomes should a weir near Wellington be proposed as a possible climate change mitigation action.

4.14.2 Coastal dune system
The coastal dune system that separates the Coorong and Murray Mouth estuary from the sea formed during the Holecene period and the initial shoreline was established approximately 7,000 years ago when the sea level stabilised (Short and Hesp 2006). The persistent high wave power on the ocean side of the dunes has produced beaches that are able to accommodate and dissipate wave energy. However severe storms can cause erosion, that temporarily damages the foredunes and releases sand for deposition elsewhere (Short and Hesp 2006). In terms of a response to sea level rise, Short and Cowell (2009) found a highly uniform response along the shoreline where shoreline recession was driven by sea level rise and sand loss. Maximum recession rates for a +1.5 m sea level rise along the Coorong beach (1% probability) to 2030, 2050 and 2109 was estimated to be 40 m, 95 m and 250 m respectively. When they modelled the full range of sea level scenarios to 2109 the recession ranged from the maximum of 250 m (1% probability) to a minimum of 40 m (99% probability). Given that the narrowest section of the dune barrier along Sir Richard Peninsula is around 350-400 m wide, it is unlikely that the barrier will be breached by sea level rise in the next 100 years. This data defines the degree of sea level rise impacts for the Coorong, Murray Mouth and lakes to sea water entering through the Murray Mouth.

4.14.3 Identified gaps for ecological impacts of sea level rise
• poor capacity to predict future River Murray flows and lake water levels;
• poor capacity to predict the degree of Murray Mouth openness especially under elevated rates of sand deposition from enhanced foredune erosion;
• knowledge of the differences in sea level changes between Victor Harbor and the Murray Mouth;
• knowledge of whether sea level will change the meteorological response of water levels relative to the mean water level;
• knowledge of the effects of storm surges on water level attenuation within the Murray Mouth and duration of exceedence of given water levels that relate to operating structures and environmental water requirements;
• poor capacity to predict future barrage operating rules and alterations to infrastructure (e.g. raising of barrages, relocation of barrages).

4.15 ECOSYSTEM SERVICES
Ecosystem services are a recognised part of the ‘ecological character’ of wetlands under the Ramsar Convention (1971) and can be described as the benefits and services that humans derive from ecosystems. Very little work has been done on the identification of ecosystem services associated with the SA MDB Region even though changes in the linkages between ecosystem health and type are likely to drive significant changes in social and financial capital. Table 9 contains a list of ecosystem services likely to be provided by the ecosystems of the SA MDB Region based upon the Ramsar Convention (1971) and the Millennium Ecosystem Assessment. An IVA would need to develop conceptual understanding of the effects on ecosystem services by changes in ecosystem health and character to assess impacts of climate change.

4.15.2 Identified gaps for ecosystem services
• identification of ecosystem services associated with different SA MDB Region ecosystem types;
• conceptual understanding of linkages between biota, ecosystem health, ecosystem processes and provision of ecosystem services;
• knowledge of impacts of changing ecosystem service provision on social and financial capital.

Table 9: Examples of ecosystem services from natural and/or cultivated ecosystems in the SA MDB Region. (Adapted from the Millennium Ecosystem Assessment (2005) and Ramsar Convention (1971)).

<table>
<thead>
<tr>
<th>Ecosystem service category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provisioning services</strong></td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>Crops, livestock, wild fisheries, aquaculture, native foods</td>
</tr>
<tr>
<td>Fibre</td>
<td>Timber, bamboo, cotton, eucalypt, hemp, other</td>
</tr>
<tr>
<td>Freshwater</td>
<td>Rivers, lakes, groundwater, rainfall, wetlands, springs</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>Genes, genetic information, biotechnology elements</td>
</tr>
<tr>
<td>Biochemicals, medicines, pharmaceuticals</td>
<td>Medicinal herbs, traditional medicines, food additives, antiseptics (e.g. tea tree oil)</td>
</tr>
<tr>
<td>Shade and shelter</td>
<td>Shelter belts, building materials, residential shading</td>
</tr>
<tr>
<td>Biomass energy</td>
<td>Biochar, fuel, fire wood, charcoal, biofuels, manure</td>
</tr>
<tr>
<td><strong>Regulating services</strong></td>
<td></td>
</tr>
<tr>
<td>Air quality control</td>
<td>Sources (e.g. fires), sinks (e.g. lakes, oceans)</td>
</tr>
<tr>
<td>Climate regulation</td>
<td>Greenhouse gas emission/absorption, evaporative cooling, influence on local rainfall</td>
</tr>
<tr>
<td>Water regulation</td>
<td>Water retention on floodplains, aquifer recharge, flood mitigation, water storage in landscapes</td>
</tr>
<tr>
<td>Erosion control</td>
<td>Prevention of soil loss, increased retention and recharge</td>
</tr>
<tr>
<td>Water purification and Waste treatment</td>
<td>Removal of harmful pollutants, decomposition of organic waste, assimilation and detoxification</td>
</tr>
<tr>
<td>Disease regulation</td>
<td>Changing abundance and incidence of human pathogens (e.g. Ross River virus)</td>
</tr>
<tr>
<td>Pest regulation</td>
<td>Changing abundance and incidence of crop and livestock pests (e.g. beneficial insects/predators)</td>
</tr>
<tr>
<td>Pollination</td>
<td>Transfer of pollen from male to female flowers (e.g. bees and Colony Collapse Disorder)</td>
</tr>
<tr>
<td>Natural Hazard regulation</td>
<td>Reduce damage (e.g. decomposition of fire fuels, protection of shoreline)</td>
</tr>
<tr>
<td><strong>Supporting services</strong></td>
<td></td>
</tr>
<tr>
<td>Nutrient cycling</td>
<td>Flow and recycling nutrients through ecosystems (e.g. decomposition improves soil fertility)</td>
</tr>
<tr>
<td>Primary production</td>
<td>Energy for food webs, formation of organic matter</td>
</tr>
<tr>
<td>Water cycling</td>
<td>Flow through solid, liquid and gaseous phases</td>
</tr>
<tr>
<td>Habitat provision</td>
<td>Maintenance and regeneration of habitats</td>
</tr>
<tr>
<td><strong>Cultural services</strong></td>
<td></td>
</tr>
<tr>
<td>Recreation and tourism</td>
<td>Activities in ecosystems (e.g. hiking, canoeing, bird watching, camping)</td>
</tr>
<tr>
<td>Ethical values</td>
<td>Indigenous connections to country, spiritual renewal, religious, aesthetic, intrinsic, existence or sense-of-place values attached to ecosystems</td>
</tr>
</tbody>
</table>
4.16 CONCLUSIONS FOR ENVIRONMENTAL CAPITAL

There is a large amount of relevant data and highly useful conceptual models to support an IVA for the Environmental Capital, particularly with regard to water resources. There are also well-defined targets for environmental condition for many components of the Environmental Water Capital that will be extremely useful thresholds against which to assess possible impacts of climate change. This reflects the substantial investment that has been made to date in understanding the role and function of water in the South Australian Murray Darling Basin Landscape.

However, across the breadth of Environmental Capital the assessment will be constrained by factors such as: a lack of fine-detail and/or relevant mapping products (e.g. locations of refugia); limited understanding of how individual species may be affected by climate change; and our poor understanding of how population dynamics, trophic interactions, indirect effects of stressors (e.g. temperature, salinity, moisture availability) and dispersal mechanisms will be affected by climate change. Gaps such as the lack of foundational reports specific to the study region (e.g. assessment of the effects of climate change on terrestrial vegetation) are likely to take considerable resources and time to fill, therefore the use of surrogate or indicator species that we have a good understanding of and the development of conceptual models of key ecosystem processes and services will be essential.

For the SA MDB Region the most important gap in our knowledge is our very poor capacity to predict River Murray inflows and water demand and thus determine how much water is likely to be available for the different components of the Environmental Capital dependent on water. It will be possible to interrogate available data and models to develop a tight set of climate based scenarios for an IVA but there will need to be explicit assumptions made about how water will be differentially allocated between human and environmental users by policy makers under different climate conditions to proportion water to the environment.

Quantifying the governments and community ability to adapt under given climate change scenarios will be challenging. Actions that occurred during the Millennium drought provide an indication of historic adaptive capacity under extreme climate conditions, but also suggest that society have a limited capacity to predicted future actions that may be required.
5 The physical capital of the region

The following chapter considers potential impacts from climate change and gaps in knowledge on the physical capital in the SA MDB Region. Physical capital encompasses assets used in production including infrastructure, utilities, buildings, equipment, plant and machinery and improvements in genetic materials (e.g. crops, livestock).

5.1 TRANSPORT NETWORKS

5.1.1 Road and Rail

The SA MDB Region features an extensive road network, and to a lesser extent, rail network, which is vitally important for transporting people, goods and produce throughout the Region and links the Murray-Darling Basin Communities to neighbouring regions and metropolitan Adelaide. There is a major east west rail system operating for passengers, freight and bulk handling of grain. Links have been forged with the Adelaide Darwin railway and provides greater access to markets in South East Asia (RDA Murraylands and Riverland).

In recent years attention has been paid to investigating a proposed realignment of the main interstate rail line through the Adelaide Hills, including a bypass of Adelaide using a route to the north of the Adelaide Hills. The demand for an alternative route has been prompted by community concerns regarding noise levels, safety and inconvenience associated with freight trains passing through the Hills while a flatter and straighter route may also be more efficient from an operational perspective (GHD 2010). No decision to proceed with an alternative route has been made at this stage. A benefit cost analysis of alternative options found that the capital costs of establishing alternative rail alignments did not outweigh the benefits derived from these options (GHD 2010).

One of the few studies addressing the impacts of climate change on road and rail infrastructure in the SA MDB Region is the Environment Institute’s Climate Change Impact Assessment, Adaption and Emerging Opportunities for the SA MDB Region, Milestone 1 report. The report briefly identifies some of the most likely climate change-related impacts on road/pavement construction and maintenance as part of broader potential impacts on local government business. These impacts include:

- ‘Changes in rates of deterioration – faster deterioration in wetter areas but potentially slower deterioration in areas where rainfall decreases;
- ‘Deterioration may also result from higher temperatures and increased solar radiation;
- ‘Changes in frequency of interruption of road traffic from extreme weather events and emergency transport routes disrupted; and
- ‘Rail tracks buckling during heatwaves. (The Environment Institute, 2010).

The report provides little additional detail regarding climate change impacts on road and rail infrastructure in the SA MDB Region (which would reflect that such detail is beyond the scope of the report but also that such impacts have not been studied in detail to date).

The Central Local Government Region Integrated Climate Change Vulnerability Assessment (Balston, et.al. 2011) and Garnaut Climate Change Review report Impact of Climate Change on Australia’s Roads and Bridge Infrastructure (Maunsell Australia 2008), both address the impacts of climate change on road and rail infrastructure across Australia in a general sense. These studies are useful to illustrate likely impacts of climate change on road and rail infrastructure in the SA MDB Region.

Balston et al (2011) identified the following potential climate change impacts with respect to the maintenance and durability of road infrastructure, and are consistent with those identified in the Environment Institute’s report:
“Higher temperatures are expected to result in more rapid oxidation of bitumen, and to more frequent resealing/resurfacing (Youman 2007). Changes in moisture also affect pavement deterioration – moisture weakens flexible pavements and makes them more susceptible to damage from heavy vehicles (Austroads 2004). A decrease in rainfall may therefore lead to lower road maintenance costs due to reduced pavement deterioration. However, any benefits from reduced rainfall may be offset by increased damage from more frequent extreme events including heatwaves and bushfires.” (Balston et.al. 2011).

Workshop participants in study specifically identified an increase in the frequency of heatwaves and bushfires as a potential threat to the physical capital of the Central Local Government Region from climate change. The former not only reduces the structural integrity of bitumen but reduces the availability of maintenance crews, while bushfires may damage roads by melting bitumen. Another potential impact identified related to impacts on unsealed roads. Workshop participants noted that “unsealed roads need to be kept moist to perform best and a decline in rainfall and increase in dry periods will lead to increased break up of unsealed roads. Any increase in rainfall intensity would lead to increased damage to unsealed roads” (Balston et.al. 2011).

Some of the likely impacts of climate change on road and bridge infrastructure outlined in the Garnaut Review report include:

- Increase in frequency and severity of damage to bridge structures and abutments;
- Increase in frequency and duration of inundation to road infrastructure;
- Increase in shrink and swell of soil under foundation of roads and bridges;
- Increase in asphalt degradation;
- Reduced durability of materials (i.e. concrete);
- Reduced certainty of performance materials and roads;
- Drying and loosening of unsealed road surfaces;
- Scouring of unsealed road surfaces.

In terms of climate change threats to rail infrastructure, an increase in the frequency and/or intensity of heatwaves poses a threat to rail infrastructure given ‘the potential of rail lines to buckle under extreme temperatures’ (Balston et.al. 2011).

Both road and rail located adjacent coastline would be subject to risk from rising sea levels and more frequent and extreme high sea level events under climate change (Balston et.al. 2011). The extent of road and rail infrastructure in the Region at risk from potential coastal impacts is unknown. While the vast majority of road infrastructure in the Region is located inland and therefore immune to coastal impacts, road infrastructure around the Murray mouth and at major coastal centres such as Goolwa may face potential risks. Beyond the Victor Harbor to Mount Barker railway line that runs through Goolwa, there is no other known rail infrastructure in the Region at risk from coastal impacts.

5.1.2 Airports

There are no major regional airports in the SA MDB Region; small licensed airfields exist at Murray Bridge, Loxton, Renmark, Waikerie, Tintinara, Meningie and Pallamana (RDA Roadmap Murraylands and Riverland, 2011 to 2013). Research on the impacts of climate change on airports in the SA MDB Region is limited. Potential climate change impacts on road infrastructure identified in the previous section would be relevant to airports (i.e. increased degradation due to heatwaves). The other likely impact may be indirect if carbon pricing raises the cost of air travel. The vulnerability of airports to climate change in the SA MDB Region is unknown and requires further research.

5.1.3 Public transport

Public transport in the Region is limited and infrequent, it is largely delivered through a licensed passenger transport model i.e. community transport. Research on the effects of climate change on public transport is limited but is likely to be small given the small scale of public transport in the region. Any impacts are likely to be indirect in terms of higher running costs due to a carbon price (Balston et.al. 2011). The vulnerability of public transport to climate change in the SA MDB Region is unknown and requires further research.

5.1.4 Identified gaps for transport networks

The Environment Institute’s Climate Change Impact Assessment, Adaption and Emerging Opportunities for the SA MDB Region, Milestone 1 report briefly mentions likely impacts of climate change on road and rail infrastructure in the SA MDB Region. Other non-region specific literature identifies general risks to transport
infrastructure in terms of increased degradation due to heatwave events, changes in rainfall patterns, damage due to extreme events such as bushfires and rising sea levels. Existing gaps in relation to the effects of climate change on transport networks in the SA MDB Region include:

- Kilometres of road and rail at risk of sea level rise and inundation along the coastal regions of Alexandrina and the Coorong;
- Kilometres of roads (sealed and unsealed) and rail at risk from bushfire;
- Kilometres of roads (sealed and unsealed) and rail at risk from extreme temperatures;
- Airport infrastructure at risk; and
- Public transport infrastructure at risk.

5.2 SERVICE NETWORKS

5.2.1 Electricity networks and renewable energy

A reliable electricity supply is vital to provide basic human services including medical services, water treatment, heating and cooling in homes and businesses. South Australia, and hence the SA MDB Region, is part of an interconnected national electricity transmission grid comprising five states. Electricity is generated in the state from conventional sources (i.e. coal and gas power stations), renewable sources, particularly wind farms, supplemented by electricity purchased from interstate during peak times. In addition, a number of private residences derive part of their electricity needs from onsite solar power that can feed back into the electricity network.

It is estimated that the Murraylands and Riverland account for about 5% of the state’s electricity use (Siebentritt et. al. 2011). A Local Energy Security Study prepared for the SA Murray-Darling Basin Community notes that the Region has a greater than average reliance on energy as an input (12% compared to a statewide average of 8%) which ‘is considered to be a strategic vulnerability for the Region in a climate of rising energy costs and challenging economic conditions’ (The Energy Project, 2011).

The Adaptation and Emerging Opportunities Plan for the SA MDB Region, Milestone 4 report, notes climate change will drive the expansion of renewable energy across South Australia in line with the federal government target of 20 per cent renewable energy produced by 2020. Strategic plans for Berri Barmera, Karoonda East Murray, Murray Bridge and Mid-Murray Councils indicate that local government within the Region is actively promoting the development of renewable energy infrastructure in response to climate change.

In the near future only a small fraction of the forecast growth in renewable energy is predicted to occur in the Murraylands and Riverland region (RDA Roadmap Murraylands and Riverland, 2011-2013). However, potential exists for the establishment of major renewable energy projects in the SA MDB Region including solar, wind, biofuels and biomass. This move would enhance and diversify the local energy supply and enable the Region to produce energy with lower carbon emissions. Renewables SA has specifically identified the potential for:

- Wind energy in the Wellington-Meningie area;
- Biogas generation in the Murray Bridge – Strathalbyn area; and
- Biomass and solar energy north of Berri and Waikerie. (The Energy Project, 2011)

Little research appears to have been conducted on the direct impacts of climate change on electricity networks in the SA MDB Region and no mention of the effects of climate change is made in the Local Energy Security Study for The South Australian Murray-Darling Basin Community. We must consequently rely on studies conducted in other regions and energy infrastructure impacts more generally.

One of the primary mechanisms through which climate change will affect energy networks is through changing demand for energy. Balston et.al. (2011) summarised these impacts as follows:

‘Climate has a direct impact on energy use via demand for heating and cooling. An increase in average temperature can be expected to decrease demand in cold climates and increase demand in warmer climates, as the overall change in demand is determined by region specific factors (Howden and Crimp 2001). An increase in peak electricity demand during summer periods represents a key risk given that meeting peak electricity demand has been an ongoing challenge in regions such as Adelaide. A 1oC rise in temperature is likely to lead to a 5% increase in peak electricity demand for Adelaide, although overall...’
energy demand would be unchanged or even slightly lower due to reduced electricity demand during the winter period (Howden and Crimp 2001). An increase in peak electricity demand poses an increased risk of electricity supply failure and there may consequently be a need to allow for some level of redundant capacity (Allen Consulting Group 2005).

A potential increase in peak energy demand may consequently present a risk to the reliability of electricity supplies in the region. In respect of the latter, the Local Energy Security Study states that ‘existing infrastructure [in the SA MDB Region] exhibits some available capacity in the key regional centres but is very limited beyond these locations. Electricity reliability is a limiting factor outside of the main centres. Access to reticulated natural gas is confined to a few major centres and results in limited energy supply diversity’.

Climate change has the potential to not only affect demand for energy but also the reliability and efficiency of electricity supply infrastructure. Extreme weather events, higher winds and bushfire pose a threat to transmission and distribution infrastructure, including wind farms (Allen Consulting Group 2005, Balston et.al. 2011). In terms of energy efficiency, it has been estimated that a 1oC increase in warming can lead to a 3% decrease in thermal efficiency in some energy facilities, and a decrease in transmission line efficiency (Pittock 2003).

The Garnaut Climate Change Review report Impact of Climate Change on Infrastructure in Australian and CGE Model Inputs identifies the following impacts on electricity distribution and transmission networks:

- Damage to transmission and distribution above ground assets resulting in increased blackouts;
- Reduced network capacity;
- Accelerated deterioration of assets; and
- Potential blackout due to demand exceeding supply.

5.2 Water networks and condition

Water from the SA Murray-Darling Basin is crucial to support a number of activities including irrigators of grapes and other agriculture, tourist facilities, municipal services and residents. The Murray River provides the primary source of water to the region. Current water practices are unsustainable and the Draft Murray-Darling Basin Plan (released in November 2011) was established to provide equitable access to water for all States in a sustainable manner to ensure the long term survival of the river.

The Murray-Darling Basin needs additional environmental flows as approximately 40 per cent of the Basins natural river flow is currently diverted for human use and irrigation in an average non-drought year (Commonwealth Environment Water 2011). Reduced flows have caused environmental problems (see sections on water in the chapter on the Environmental Capital) with increased salinity and algal blooms, diminished native fish and bird populations and poor wetland health (Commonwealth Environment Water 2011).

To overcome issues associated with reduced inflows and over allocation of water the Commonwealth government has purchased back water entitlements from irrigators along the Murray River to provide target flow rates in rivers and inundate wetlands and some floodplains (Commonwealth Environment Water 2011).

The Climate Change Impact Assessment Report for the SA MDB Region, Milestone 1 report, indicates reduced rainfall and therefore lower run-off into rivers and streams in the SA MDB Region will result in lower river flow, greater evaporation rates and reduced allocations of water. Measurements taken over the last 50 years indicate the warmer drying trend of the climate is evident, especially over the past 10 to 15 years. During the next 20 years it is expected that rainfall in the SA MDB Region will decline by 3.5 per cent and by 10 per cent over a 60 year period and this will adversely affect the availability of surface water throughout the SA MDB Region (The Environment Institute 2010).

The general impacts of climate change on water networks across the Murray-Darling Basin were also identified by Balston et.al. (2011). Excerpts from the report that are relevant to the SA MDB Region include:

“The impact of climate change on surface waters and storage in the Murray-Darling Basin will also be felt in the region as a number of towns and other production activities such as irrigation are reliant on River Murray supplies. The CSIRO estimates that surface water availability may decline by 11% across both the MDB and in the Murray region of the MDB by 2030, under a median climate change scenario (CSIRO 2008). Given the nature of current water sharing arrangements, surface water use under a median climate scenario is projected to fall by 4% for both the Murray region and MDB more broadly. In other words, the impact of
climate change is expected to be relatively less severe on surface water use than on surface water availability. Any residual reduction in surface water availability is expected to fall on the environment.”

“Climate change has the potential to reduce the reliability and magnitude of water supplies. A reduction in rainfall and higher evaporation rates will tend to reduce the amount of surface water that can be captured, while lower rainfall will reduce the recharge of groundwater resources (Government of South Australia 2010). At the same time, higher average temperatures are likely to increase demand for water.” (Balston et al. 2011)

While research has been conducted with respect to the impact of climate change on water availability in the SA MDB Region, there appears to have been less research into potential physical impacts on water infrastructure. Nonetheless, some climate change impacts are expected. For example, Maunsell Australia (2008) state that for a hot, dry business as usual climate scenario, “the increase in temperature, evaporation and reduced rainfall will reduce soil moisture and generate increased ground movement accelerating the degradation and failure of water distribution infrastructure such as mains water pipes”2. However, this analysis applied to water infrastructure in capital cities, and the authors observe that “regional centres have a different supply profile and constraints” (Maunsell Australia 2008).

Workshop participants at the stakeholder meeting in July as part of this study identified gaps in knowledge in respect of impacts on water infrastructure in the region. There is considered to be data gaps and uncertainty regarding the potential failure of river infrastructure (e.g. dams), flood impacts on water networks (as well as transport and energy infrastructure), and the overtopping of barrages at the Murray mouth during storm surges. A further uncertainty relates to changes in upstream policy and prescription, which will have implications for economic, social and environmental capitals in the region. The sustainability of groundwater resources over the longer term (i.e. 200 to 300 years) was also identified as a gap.

2 Other assumptions for this future scenario included A1FI emissions path, 10th percentile rainfall, 90th percentile temperature surface and mean global warming of approximately 4.5°C by 2100.

5.2.3 Identified gaps for service networks
The Climate Change Impact Assessment Report for the SA MDB Region, Milestone 4 report (Summers et al. 2011) identifies the likely expansion of renewable energy generation projects across South Australia but does not identify the extent of expected growth in the SA MDB Region or the physical impact of climate change on renewable energy infrastructure. Further research on effects of climate change on service networks in the SA MDB Region are required into:

- Effect of climate change on energy demand and supply;
- Kilometres of energy networks at risk from bushfire;
- Percent of traditional energy assets at risk from bushfire;
- Percent of renewable energy assets at risk from bushfire; and
- Percent of water networks at risk from bushfire.

5.3 COMMUNICATIONS NETWORKS
5.3.1 Telecommunications infrastructure
Telecommunications infrastructure allows information to be transmitted over significant distances and allows for timely sharing of information between government, businesses and communities.

Research on the specific effects of climate change on telecommunications networks in the SA MDB Region is sparse. One must consequently rely on other studies for insight into potential climate change impacts on telecommunications infrastructure.

As part of the 2008 Garnaut Climate Change Review, Maunsell Australia (2008a) identified the following potential impacts on Australia’s telecommunications infrastructure:

- Flooding of exchange/roadside manholes and underground pits in extreme rainfall;
- Storm and wind damage to above ground transmission during extreme wind;
- Erosion exposing major cables and trunk routes during intense storms;
- Increased saline corrosion of telecommunications broadcast towers;
- Degradation of aerial caballing;
- Decline in stability of tower structures and foundations.
• Overheating of exchanges and base stations;
• Road closures due to flooding inhibiting service and/or restoration efforts; and
• Exposure of telecommunications infrastructure to bushfire.

These impacts would not all apply to a single region as the specific risks encountered would depend on the future climate profile. For instance, increases in rainfall are generally not expected for South Australia, which implies that risks related to flooding and storms are less significant. Risks are probably greater for increases in dry periods, which may lead to increased ground movement, and result in the degradation of foundations and tower structures and affect mobile voice, data and broadcasting that are reliant on fixed tower structures (Maunsell Australia 2008a).

Balston et.al. (2011) identified the following general climate change threats to telecommunications infrastructure:

“Climate change has the potential to reduce reliability of the telecommunications network via damage caused by higher temperatures, increased bushfire frequency and sea level rise. Furthermore, an increased risk of emergencies under climate change will have the effect of increasing pressure on communication networks.” (Balston et.al. 2011).

Threats to existing telecommunications infrastructure may be mitigated by existing technological trends, including the development of new wireless technologies that are less reliant on fixed on the ground infrastructure.

5.3.2 Identified gaps for communication networks

Effectively no literature was identified that considered the physical effects of climate change on communication networks in the SA MDB Region. Existing gaps for the SA MDB Region include:

• Percent of cables and trunk routes at risk due to erosion by major storms;
• Caballing at risk of degradation;
• Tower structures and foundations at risk of degradation; and
• Percent of telecommunications networks at risk from bushfire.

The last two indicators are probably most relevant for the SA MDB Region based on general climate change forecasts for South Australia, impacts identified in the available literature and feedback received from workshop participants as part of the Central Local Government Region IVA (Balston et.al. 2011).

5.4 BUILDINGS

5.4.1 Buildings (housing, schools and hospitals)

Buildings provide shelter – a basic human need – while the home is the primary source of wealth for many households, and provides intangible benefits in terms of privacy, sense of security etc. In addition, buildings provide storage for goods and equipment; host a variety of production and service activities, across both the private and public sector spheres.

The Climate Change Impact Assessment, Adaption and Emerging Opportunities for the SA MDB Region, Milestone 1 report provides a brief description of the potential general risks posed to buildings by climate change. Potential impacts include damage or destruction due to changes in the frequency of wind, rain, hail, flood and storm events; changes in heating and cooling costs in response to fluctuations in temperatures; and greater risk of damage due to bushfires. These impacts are consistent with those buildings identified by Balston et.al. (2011) in the Central Local Government Region IVA:

“Increases in average temperature will increase cooling demand and therefore energy costs, increase the risk of cracking and failure of roofs, windows etc., and may affect foundations from increased soil drying and movement (BRANZ Limited 2007). An increase in the frequency of hot days may increase bushfire intensity and frequency and lead to increased potential costs from fire, smoke and water damage to property and contents. Climate change may also produce some benefits, such as reduced winter heating costs due to higher average temperatures, and reduced mould damage due to reduced humidity (BRANZ Limited 2007). Workshop participants also noted that reduced frost incidence would be a positive factor for building stock.” (Balston et.al. 2011).

The other key risk posed by climate change to buildings is damage from inundation as a consequence of rising sea levels, a potential increase in the frequency of high sea level events and shoreline regression. Given that the vast majority of settlement in the SA MDB Region is located inland, only a very small proportion of buildings in the Region would be at risk from
potential coastal impacts. The Department of Climate Change and Energy Efficiency’s (2009) First Pass National Assessment of Climate Change Risks to Australia’s Coasts estimated that between approximately 640 to 1,300 existing residential buildings in the Alexandrina Local Government Area were at risk of inundation from sea-level rise of 1.1 metres. No data was published for The Coorong – the only other Local Government Area in the SA MDB Region with coastal exposure. However, the report did state that:

“Management of the Murray mouth, the Coorong and Lower Murray lakes under climate change is complicated by the existence of barrages and controls over water flows in the Murray–Darling Basin. Adaptation responses will need to be informed by further studies to define future impacts associated with rising sea levels, reduced freshwater inputs and various hydrological changes in this estuarine–lagoonal region.” (DCCEE 2009).

5.4.2 Identified gaps for buildings

The general risks posed climate change to buildings have been well identified, at least in a qualitative sense. However, further research is required to understand potential impacts on buildings in the SA MDB Region in the context of expected future climate change developments for the region. From an IVA assessment perspective, further information is required on:

- Number of houses at risk from bushfire;
- Number of public buildings (schools, hospitals, libraries etc) at risk from bushfire;
- Number of flood, fire, and heat refuges at risk from bushfire; and
- Number of houses and public buildings at risk from inundation in the Coorong.

5.5 LAND ASSETS

There was insufficient time and resources available to consider the climate change literature in respect of land assets. This is not a significant deficiency since climate change impacts on land assets are to a large extent addressed in other sections of the report (e.g. agriculture with respect to farmland). Data on the extent of existing land types in the region should be available from existing Geographic Information Systems.

5.5.1 Identified gaps for land assets

Workshop participants at the stakeholder meeting in July identified a gap in terms of how much land will be available in the future and for which uses it could be applied given productivity and capability under future climate change scenarios. A further unknown related to the implications of raising the barrages to combat rising sea levels in terms of potential impacts on current land use for irrigation and impacts on infrastructure (e.g. water off-takes, ferries, bridges, levees). In the short to medium term, there is a need to determine appropriate land uses for the Lower Murray Swamps in the context of expectations regarding future climate change impacts.

5.6 SUMMARY GAP ANALYSIS OF PHYSICAL CAPITAL FOR THE MURRAY-DARLING BASIN REGION OF SOUTH AUSTRALIA

There are significant gaps in literature regarding the effects of climate change on transport infrastructure, service networks, communication networks and buildings in the SA MDB Region. Some climate change effects relating to buildings, roads and renewable energy infrastructure are described briefly in the “Milestone reports” but do not provide detailed descriptions of the broad effects of climate change on all types of SA MDB Region infrastructure. Typical for regional areas, quantitative estimates of potential impacts are sparse to date.

For transport networks further research is required into the amount of road (sealed and unsealed) and rail at risk from climate change and its degree of vulnerability to climate change stressors. It is also necessary to investigate whether there are any roads and/or rail at risk in the Alexandrina and Coorong Region from coastal inundation. Airport services and public transport services are limited in the SA MDB Region and so the effects of climate change are likely to limited to the impact of the carbon price on air travel and cost of fuel but further investigation would be required.

For service networks further research is required into the effects of climate change on electricity networks i.e., the amount of traditional energy and renewable energy assets at risk from bushfires, heatwaves, extreme temperatures and other climate change stressors and the likely impacts of climate change on energy demand and supply. It is also necessary to investigate the possible growth in renewable energy generation as the Region tries to adopt
a low carbon emission approach. Water network infrastructure and their condition throughout the SA MDB Region needs further research such as the likely impact of reduced rainfall and river inflows on the region.

For telecommunications networks further research is required into the effects of climate change on telecommunications infrastructure including cables, trunk routes and telecommunications towers at risk from climate stressors.

The Environment Institute’s Milestone 1 report provides limited discussion of the general effects of climate change on buildings in the SA MDB Region, but does not provide specific impacts on houses, schools and hospitals. Further research is needed into the number of houses and public buildings at risk from bushfires. The First Pass National Assessment of Climate Change Risks to Australia’s Coasts provides an estimate of the number of existing residential buildings at risk of inundation in the Alexandrina LGA, but notes that further research is required to understand coastal dynamics at the Murray mouth in The Coorong LGA.
6 The financial capital of the region

Financial capital comprises the various economic activities that give rise to income generation, and other financial resources (e.g. credit, savings and capital markets) that contribute to wealth generation. From a sectoral perspective, key financial activities in a climate context include agriculture, mining and fishing, followed by secondary activities such as manufacturing, construction, engineering and tourism.

6.1 Primary Industries Excluding Agriculture

6.1.1 Mining

The SA MDB Region contains a number of prospective commodities including heavy mineral sands, gypsum, coal, copper, gold, silver, lead, zinc and uranium. PIRSA reports a major exploration focus on heavy mineral sands in the Region that has led to major discoveries. In spite of these discoveries, mining’s contribution to the RDA Murraylands and Riverland regional economy is presently very small, accounting for just 0.5 per cent ($23.1 million) of gross regional product in 2009/10 (EconSearch 2011). There are two major operating mines in the region: Terramin’s zinc mine near Strathalbyn and Hillgrove Resources’ Kanmantoo copper, gold and silver open pit mine. A third mine – Murray Zircon’s Mindarie Mineral Sand Mine near Karoonda – is expected to commence operation in the fourth quarter of 2012.

Climate change can impact on mining through reductions in the availability of water and energy, reduced operational efficiency of plant and equipment and heightened health and safety risks to workers.

The Environment Institute’s Climate Change Impact Assessment Report for the SA MDB Region Milestone report 3, notes the most significant impact of climate change on the mining industry in the SA MDB Region is likely to be water availability. More specifically, the report states:

“One of the biggest impacts of climate change on mining will be water availability. The National Water Commission (National Water Commission 2010) recognises that while nationally mining uses limited water, there are a number of regions where mining is the primary consumer of water. Access to sustainable water resources for mining may become increasingly important in the SA MDB. If reduced agricultural activity was to occur and the region were seeking economic production from other sectors, mining may also be water limited.” (Summers et.al. 2011).

The authors note that mining may be less susceptible to reductions in water availability than other activities such as irrigation due to the sector’s greater capacity to purchase water rights (Summers et.al. 2011). In terms of water-related impacts on the mining industry in Australia in general, it has been observed that increased evaporation rates would ‘affect tailings dams, heap leaching operations, and also increase dust production’ (Hodgkinson et.al. 2010).

The Environment Institute’s report does not identify any other climate change impacts in the context of the mining sector. Other studies have identified potential impacts of climate change on the mining sector in terms of energy availability and impacts on equipment and human resources. In terms of energy availability, the Central Local Government IVA states that:
“Increases in temperature may increase energy losses during transmission. Some of the adaptation strategies to climate change, for example increased automation and remote control, would require additional energy and increase the need for energy supply and/or more efficient energy use during production. Interruptions to transport infrastructure due to more frequent/extreme weather events may also disrupt supplies of fuels.” (Balston et al. 2011)

The report notes that that a warmer climate would affect the operational efficiency of machinery and equipment in mining, while more extreme weather conditions would present health and safety risks to workers, in addition to reducing their effectiveness (Balston et al. 2011).

6.1.2 Forestry
Forestry is a small industry in the SA MDB Region and generates $6.7 million in gross value added in 2009/10, which is equivalent to just 0.1 per cent of total gross regional product (EconSearch 2011). In 2010 South Australia had 188,000 hectares of plantation forest. Most plantations are located in South East South Australia, Adelaide Hills, Kangaroo Island and the Mid North (PIRSA Forestry).

Pinkard and Bruce (2011) consider the potential ramifications of climate change for South Australia’s plantations. Likely direct impacts on plantations (as summarised in the Central Local Government Region IVA report) include:

- Increases in mean temperatures are unlikely to affect the distribution of Blue gum or Radiata pine during the first half of the century, and may promote productivity provided mortality does not increase;
- The main impacts of high temperature events will be on growth and survival. Even short heatwaves with temperatures above 40 °C can cause tissue damage and mortality;
- While both Blue gum and Radiata pine can acclimatise to drought, productivity declines as water limitation increases, because of reductions in both growth rate and the length of the growing season;
- While frost frequency is likely to decline, a reduction in frost hardening associated with warmer night-time temperatures and increasing atmospheric carbon dioxide concentrations means that damage from unseasonal frosts may become more of an issue in the future;
- Although evidence is sparse, elevated carbon dioxide may increase crown size and density, and decrease wood density and coarse root biomass, and make trees more susceptible to wind damage;
- Increasing atmospheric carbon dioxide concentrations may promote plantation productivity, but this is only likely to occur when growth is not limited by water and nutrient supply.

Pinkard and Bruce also identify a number of possible indirect impacts. These are summarised by Balston (2011) as follows:

- Warmer mean temperatures particularly in winter are anticipated to favour many insect pests of plantation forests, and could result in a longer period of insect activity, more generations per year and increased damage. This change may be counteracted by a reduced quality of food source and resultant reductions in insect fecundity and survival. Changes in host defence mechanisms may also influence levels of damage;
- Diseases often require high relative humidity to promote infection and spore production and the distribution of some leaf diseases may decrease if rainfall declines;
- Drought conditions favour many stem borers and bark beetles, and an increase in borer or bark beetle activity may occur if plantations become more water stressed;
- Increasing temperatures may affect weed composition as C4 weeds will be advantaged over C3 weeds with warming and drying;
- The efficacy of herbicides may change as a consequence of changing temperature and elevated carbon dioxide levels. The changes are likely to vary between chemicals, and may be positive or negative for weed control;
- Increased frequency and severity of drought events, particularly when combined with heatwaves, may result in a rise in plantation mortality and reduced growth rates. Modelling suggests the risk of drought death will significantly increase in the northern regions of the plantation estate with an increase of around 5 high risk days per year by 2070;
- Fire risk is likely to increase in the future, associated with an increase in weather conditions favourable to fire (including catastrophic fire risk days), increased drying of fuel, and changes in the dynamics of litter build-up and decomposition.
The above excerpt provides a summary of the effects of climate change on forestry across South Australia so these potential impacts of climate change are also directly applicable to forestry in the SA MDB Region, at least to the extent that forestry currently exists in the region.

6.1.3 Identified gaps for primary industries excluding agriculture

Milestone 3 report provides identifies the issue of water availability for mining companies operating in the SA MDB Region and the need for sustainable water resources for the successful expansion of mining in the region. Further research is needed into the impact of climate change in the SA MDB Region on:

- Energy availability to mining operations;
- Operational effectiveness of equipment and effectiveness of human resources under climate change;
- Health and safety of mining employees; and
- Impact of climate stressors on future development of forestry.

6.2 PRIMARY INDUSTRIES

AGRICULTURE

Agriculture in the SA MDB Region includes sheep for meat and wool, grains, beef cattle, dairy cattle; intensive agriculture including pigs and poultry, viticulture, vegetables, fruit and nuts and services to agriculture (Table 10). In total these commodities accounted for 21 per cent ($936 million) of gross regional product in the 2009/10 financial year (EconSearch 2011). Viticulture earned 3.5 per cent ($154 million) and vegetables 3.3 per cent ($147 million). Other big contributors to the gross regional product are grains, fruit and nuts, sheep and pigs. Dryland agriculture dominates 2330,423 ha of the SA MDB Region (54%) and irrigated agriculture takes up 102,284 (38%) of the total area. The SA MDB Region relies heavily on primary production to support its economy (Siebentritt et.al. 2011).

The agricultural industries most likely to be impacted by climate change in the SA MDB Region are irrigated and dryland farming (Siebentritt and Sharley, 2010). The combined regional impact of warmer and drier conditions on irrigation and dryland farming could be two fold. First it may result in a decline in economic activity through job losses that will reduce the economic viability of towns as people leave to find alternative work. Secondly a reduction in output of farms may result in reduced farm values. The reduction in profitability of industry is a key impact because it reduces the ability for adaptation and may lead to businesses and community collapse. The results indicate that these impacts are all encompassing – social, environmental and economic – and therefore incentives and support services must be provided to ensure the transition to sustainable agricultures and communities (Siebentritt and Sharley 2010).

<table>
<thead>
<tr>
<th>Industry</th>
<th>$m</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>936.6</td>
<td>21</td>
</tr>
<tr>
<td>Viticulture</td>
<td>154.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Vegetables</td>
<td>147</td>
<td>3.3</td>
</tr>
<tr>
<td>Grains</td>
<td>139</td>
<td>3.1</td>
</tr>
<tr>
<td>Fruit &amp; nuts</td>
<td>110</td>
<td>2.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>98.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Pigs</td>
<td>71.2</td>
<td>1.6</td>
</tr>
<tr>
<td>Dairy cattle</td>
<td>52.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Services to agriculture</td>
<td>50.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Other agriculture</td>
<td>41.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>33.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Poultry</td>
<td>24.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Climate change may result in a change in the area of land under production systems. For dryland farming, this change could mean less cropping area and increased grazing area. The most likely options for alternative agricultural practices in the Region are perennial plantings for biomass industries, perennial grasses and fodder crops (e.g. lucerne, old man saltbush), local native species for carbon trading, and the widespread adoption of conservation farming systems. Recent work has suggested that plantings for a biomass industry and carbon trading may be viable for the SA Mallee Region (Bryan et.al. 2005 and Bryan et.al. 2007a). If alternative land uses such as growing biomass for electricity generation or growing crops are introduced to the region, they would add to the diversity of production systems. Biofuel and biomass agriculture can provide significant economic benefits. However, their economic viability is driven largely by the price on carbon emissions (Summers et.al. 2011). Biofuels and biomass were included as new actions allowed under future scenarios to complement the actions of vegetation management, ecological restoration, conservation farming, and deep-rooted perennials in the study by Byran et.al.
2007a. The reviewed studies form a good basis for further analysis in a full IVA.

Summers et al. 2011 suggests water trading may also be a viable alternative industry. They looked at the period of 2004 through to 2009 during the Millenium drought. As water became more expensive, it was traded from less valuable to more valuable production systems. For example, growers with low establishment costs (e.g. growing pasture for dairy) could generate more revenue by selling their annual water allocation, buy in dry feed and leave land fallow or revert to alternative dryland systems. Converseversely growers with high value crops that have very high opportunity and establishment costs were able to buy in water to maintain their crops (Summers et al. 2011).

Figure 30 demonstrates the change in irrigated land use overtime in the Riverland district. The set of maps shows land use in the growing season from 2003 to 2006 remain relatively unchanged. However, as the drought became more severe in 2007-2008 there were some obvious land use changes. In the Riverland district, dominated by high value crops such as stone fruit, citrus and vines, there was an increase in the amount of land in transition – mostly land that was left fallow or was in transition to dryland uses, with minor increases in the amount of vegetables and field crops (Summers et al. 2011).

Despite these alternative land uses in the SA MDB region, changes are unlikely to threaten food security for the region, South Australia or Australia, but the region may see a shift in current agricultural practices (Summers et al. 2011).
Figure 30: Time series demonstrating change in irrigated land use 2003-2009 derived from River Murray irrigated crop survey and annual datasets. The data used to create these maps was provided by the SA Murray-Darling Basin NRM Board, Central Irrigation Trust, Renmark Irrigation Trust, The Department for Water and the Department for Environment and Natural Resources (Summers et al. 2011).
6.2.1 Dryland agriculture
The impact of a warmer, drier climate on dryland farming areas will be that traditional cropping becomes more marginal with lower production for current crops and an incentive to switch to new crop types or in some areas a shift towards pastoralism. A reduction in the variable input costs may make farming more viable but this will mean amalgamation of 2-3 properties may be necessary. The dryland areas of the Lower Murray Region have been subject to land clearance and agricultural development for more than 80 years. The most serious impact of dryland agricultural development in the Lower Murray is the clearance of native vegetation and the resultant degradation of biological diversity. The replacement of deep-rooted vegetation with shallow rooted annuals has also led to increased dryland salinisation and salt contribution to the River Murray through saline groundwater intrusion. In addition, land clearance has increased the exposure of soils to wind erosion, now a significant problem in the Region (Bryan et al. 2007a).

APSIM (Agricultural Production Simulator) is a complex yield prediction model that incorporates soil type, daily rainfall, temperature, soil nutrients, and carbon dioxide levels to simulate cereal crop growth on a daily time step. The model was used to simulate the agricultural productivity, deep drainage and wind erosion impacts of a representative set of farming systems for the Lower Murray: continuous cropping, cropping/grazing rotation and continuous grazing (Bryan et al. 2007a). Productivity and environmental impacts were also simulated for the natural resource management actions of conservation farming, deep-rooted perennials and cropping for biofuels production. Climate change was found to drive a significant increase in the productivity and environmental impact of farming systems in the Lower Murray. Productivity was significantly reduced under the more severe warming and drying climate change scenarios tested. In terms of environmental impacts, deep drainage was greatly reduced and wind erosion increased as a result of increased exposure of soils under warmer, dryer futures. Simulation results suggest that conservation farming could result in a reduction to wind erosion factor scores because of the maintenance of surface biomass and reduced soil exposure. Deep-rooted perennials virtually eliminate deep drainage on the whole and are also effective at reducing wind erosion. Biofuels have a similar impact to conservation farming as the production of wheat and canola crops for biofuels and feedstock employs conservation farming techniques (Figure 31 on the following page) (Byran et al. 2007b).

6.2.2 Grains
Grains in the SA MDB Region accounted for 3.1 per cent of the gross regional product ($139 million) in the 2009/10 financial year (EconSearch 2011), the third highest agricultural income earner. Cereals, legumes and oilseeds cover an area close to one million hectares in the SA MDB Region (ABS 2007) and is largely sensitive to seasonal variability in rainfall which causes large variations in yield and the quality of outputs. Much of the cropping area in the Region receives low rainfall (less than 350 mm annual average rainfall). Grain production in low rainfall areas has been observed over the last decade to be most vulnerable to climate change because of low rainfall years and extreme heat events. Frost also affects grain production in the region. Whilst average minimum temperatures are predicted to increase, only one frost at flowering time (in spring) is required to wipe out a grain crop (Rebbeck and Knell 2007). However, low rainfall years and drought pose the greatest threat to grain production in the SA MDB Region.

Increased carbon dioxide concentrations in the atmosphere (the most certain aspect of climate change) would be expected to increase wheat growth rates and water use efficiency (Gifford 2004). While there is reasonably high confidence of the benefits of increased carbon dioxide concentrations on plant growth in water limited environments, it is important to note that the production of weeds and pests will also benefit from increased carbon dioxide and thus additional costs of control may be encountered. It is also important to note that where nutrients and water are limiting plant growth that there will be little benefit from increased carbon dioxide concentrations.
Figure 31: Simulated yield/biomass productivity (t/ha/yr) of various farming system rotations and land management regimes by scenario (Bryan et al., 2007 b)
A study by Reyenga et al. (2001) used the APSIM model to investigate the potential impact of several different climate change scenarios on wheat yield. The scenarios included increased carbon dioxide and temperature and both increased and decreased rainfall. The study concluded that only a reduced rainfall scenario (-15% summer rainfall, -20% winter rainfall) would reduce yield by 10-35% and SA’s current cropping boundary (known as Goyder’s line) would move south. As a result, the northern areas of the SA MDB Region would see a contraction of viable cropping country southwards.

A sensitivity approach can also be used to determine the impact of rainfall decrease and temperature and CO₂ increases on yield. Results from the point scale APSIM sensitivity analyses done for the Central Local Government region (Balston et al. 2011) also apply to the Murray-Darling Basin NRM as wheat and cereals are mostly rainfall dependant in both regions. The results illustrated that significant decreases in rainfall would lead to decreases in yield and in the low rainfall regions (less than 350 mm annual average) the impact increases with decreases in rainfall to the point when sowing opportunities may not exist. Specifically the modelling indicates wheat yields are reduced with increased temperatures but are more sensitive to the rainfall declines (here calculated between 0 and -20%) than the temperature changes (here between 0 and +2°C). At Roseworthy (average annual rain 450 mm) a 5% reduction in rainfall decreased yield by around 5% while a 20% reduction in rainfall corresponded roughly with a 20 to 25% decline in yield. At Morchard (300 mm annual average rainfall) the relationship between yield and reduced rainfall was more extreme if rainfall declines more than 10%. For example, yield is predicted to decline by up to 30% in response to a 20% reduction in rainfall (Figure 32). Again this is most likely to be because sowing opportunities will occur less often under a 20% rainfall reduction.

![Figure 32: Yield simulations for a wheat crop at Morchard using APSIM for a typical Morchard soil (Plant available water capacity (PAWC) 145.5mm; Loam over clay loam over sandy clay loam (Morchard Hill No604), with 70 kg soil nitrogen plus 90 kg nitrogen added at sowing for six different temperature scenarios (0-2°C) and four different rainfall changes (0-20% decrease). Climate change yields are compared to the yield with no rain or temp changes and CO₂ at 350 ppm. All climate change runs are done at CO₂ 450 ppm (Balston, et al. 20121).](image)

Biofuels are currently cropped in the southern regions of the SA MDB Region around Lameroo and Pinnaroo but tend not to be planted in drier years. Figure 33 below shows the viability of sowing biofuel crops over the whole SA MDB Region under four different warming and drying scenarios and carbon prices as labelled. Scenario one (S1) is 1°C increase in temperature and 5% decrease in precipitation. Scenario two (S2) is a 2°C increase in temperature and 15% decrease in precipitation. Scenario three (S3) is 4°C increase in temperature and 25% decrease in precipitation (scenarios are from Bryan, King et al. 2010). By 2030 Scenario 2 is the most likely outcome. As drying and warming gets worse, the viable biofuel areas contract further to the south.
It is likely that semi-arid cropping may become more financially risky as warming increases and drying decreases. This increased risk may translate into lower viability especially for those areas and enterprises that are already marginal. The demise of marginally viable enterprises is often precipitated by a sequence of events such as very dry years and very low market prices. If this is so then areas that are currently marginal are likely to become increasingly unviable (Summers et al. 2011).

Bryans et al. (2007) used the APSIM to model the impact of various warming and drying scenarios on the viability of continuous cropping under conservation farming (Figure 34) and a crop pasture rotation (Figure 35). The warming scenarios were S0, S1, S2 and S3 as above and the warming and wetter scenario (S4) is 1°C warmer and 5% wetter.
Figure 34: Simulated productivity (yield) from continuous cropping (W-W-Lup-W) under conservation farming. Under different climate scenarios (S0, S1, S2 and S3) and carbon price (as labelled). S1 is 1°C increase in temperature and 5% decrease in precipitation, S2 is 2°C increase in temperature and 15% decrease in precipitation, S3 is 4°C increase in temperature and 25% decrease in precipitation (Bryan et al. 2007).

Figure 35: Simulated productivity (yield) from cropping/grazing rotation (W-Ps-Lup-Ps) under conservation farming. Under different climate scenarios (S0, S1, S2 and S3) and carbon price (as labelled). S1 is 1°C increase in temperature and 5% decrease in precipitation, S2 is 2°C increase in temperature and 15% decrease in precipitation, S3 is 4°C increase in temperature and 25% decrease in precipitation (Bryan 2007).
Both figures show that as warming and drying increases, productivity reduces. However, the more viable option under the worst case scenario (S3) would be to keep pasture in the rotation.

Another approach to testing the viability of cropping in marginal areas is to use spatial analogues. This can be done by asking producers what they would do differently if they cropped a region that was 10% drier than where they currently farm. Cereal producers engaged in a study by Hayman et al. 2010 were asked what they would do if cropping in marginal areas (such as those in the SA MDB Region). Producers said they would tend to drop canola and pulse crops from their farming system and rely on cereals and they would run lower input cereal operations. Actions also included the option to cut out opportunity crops or only crop in the season with good starts and good stored soil moisture. In the areas north of Goyder’s line though there may be the need for more transformational changes to the enterprise. The level of adaptation would reflect the expected level of yield decline.

Cereal production is a valuable commodity to the SA MDB Region. Cereals are extremely rainfall dependant. In the lower rainfall cropping regions of the SA MDB Region a 20% reduction in growing season rainfall (max projection by 2030) may well lead to a reduction in yields of 30% in the absence of improvements in varieties or adaptation options. A warming and drying trend is likely to challenge the viability of grain and possible biofuel production in these marginal regions. In these areas transformational adaptations changes may be necessary, such as biomass production (e.g. Mallee trees).

Adaptation in cropping can include modifying management to make current enterprises more robust, modifying current enterprises to include a mix of both cropping and pasture or cropping, pasture and biofuels. However transformational change may need to be considered in the drier margins of the SA MDB Region. Some alternatives have been explored by the Landscapes Futures program and are discussed below. Mostly biofuels are considered as a long term plan for the drier parts of the region, but we need to consider their long term viability since opportunity crops such as canola are often cut from a rotation in drier years.

Adaptation to manage current enterprises includes what producers currently do to manage seasonal climate variability and include methods that maintain soil structure such as no till, methods that limit heat and water stress, diversification, finding new sources of off farm income, strategic planning to limit heat and water stress, amalgamating farms to increase viability, collaborative farming to reduce input costs (Kellet et al., 2010).

Other adaptation of current enterprises in the SA MDB Region may include:

- Using less water or using water more efficiently;
- Adopting new crop varieties with greater resistance to salinity or drought;
- Selecting new varieties suited to a warmer climate;
- Conversion to organic farming to reduce chemical input and access alternative markets;
- Developing new crops more tolerant to salt and low water availability (e.g. dates) (Siebentritt and Sharley, 2010);
- Transformational changes; and
- Developing agro forestry to generate income from the Emissions Trading Scheme (Siebentritt and Sharley, 2010).

As climate change becomes more severe, biomass production may become more viable than biofuels and traditional agriculture (Bryan et al. 2010b). This is because the productivity of traditional agriculture decreases with warming and drying while biomass crops (e.g. Mallee trees) are less affected. The introduction of the price on carbon may make this option more viable, however a detailed economic analysis is required as is the viability of growing woody species in the River Murray Corridor for use for electricity generation, carbon markets and other by-products.

Siebentritt et al. (2011) recommend a biomass and biofuel trial in the SA MDB Region and detail the recommended outcomes. It was also recommended that a concept of low carbon communities be developed through the Green Towns Concept Plan (Siebentritt et al. 2011). It was also recommended that the Region could collaborate to create a climate change adaptation alliance (Siebentritt et al. 2011).

6.2.3 Identified gaps for Grains

Since much of the cropping area in the SA MDB Region is low rainfall and the need for long-term transformational change will be eminent, producer support for long-term planning would be beneficial. Furthermore new projects
are emerging to support producers to take advantage of the carbon market. However, support for the long-term triple bottom line viability needs to be provided.

Under the SA Murray-Darling Basin Landscape Futures Program reports, biofuels are considered as a long-term plan for the drier parts of the region, but we need to consider their long term viability since opportunity crops such as canola are often cut from a rotation in drier years and they do not perform as well under a warmer and drier future.

6.2.4 Livestock and pasture

Livestock in the Region includes sheep, lambs, beef cattle, calves, dairy cattle, pigs and poultry. Together these industries contributed 6.3 per cent of the gross regional product ($281 million) in 2009/10 (EconSearch 2011). Sheep and cattle dominate the broad acre grazing industry in the SA MDB Region with a gross value of $230 million in primary products alone (ABS 2007). Grazing systems in the SA MDB Region range from semi-arid in the north of the region to near temperate in the south (Summers et.al. 2011).

Pastures

Pasture grazed by sheep and cattle in the semi-arid northern regions of the SA MDB Region is native while pasture is generally sown in the temperate areas of the region. Some pasture close to the river is flood irrigated and provided mainly to dairy cattle. The impact of higher temperatures and in particular heatwaves is minimal on pasture but significant on livestock health. In some areas where pasture growth is limited by frost, average temperature increases of up to 2ºC may help improve pasture growth (Balston et.al. 2011). As figure 37 shows, at Morchard a temperature increase of 2ºC over winter especially could improve pasture growth even with a small decline in rainfall. However, as pasture is highly rainfall dependant, in times of larger rainfall declines pasture yields may well be compromised.

Pasture production is projected to decline by 2030 over much of southern and eastern Australia (MLA, 2012). In the IPPC 4th assessment report Howden (1999b) suggests that 20% reduction in rainfall is likely to reduce pasture productivity by an average of 15%. However more recent research shows that pasture production will be affected differently in different climates around Australia (MLA, 2012). Warmer temperatures may improve growth in those areas where frost stunts growth significantly in winter, however the spring growing season may generally contract.

Doubled CO₂ concentrations and warming are likely to result in only limited changes in the distributions of native C3 and C4 grasses. In general, C4 grasses are more water efficient but need higher temperatures and light levels to begin photosynthesising. C4 photosynthesis is found in drier, hotter land plants, including grasses and grains. C3 photosynthesis occurs in woody, round-leafed plants – 95% of all plants.

Pasture models have been developed to determine the likely impacts of climate changes to pasture production. The pasture production model GrassGro (Moore et.al. 1997) has been used to estimate likely changes in pasture growth at various regions around the state but not within the SA MDB Region. The model uses pasture species in each region, a selected soil from each region and rainfall and temperature data. Pasture production can be determined using climate change projections from four Global Circulation Models (GCM’s) (chosen as best representative for the region). Climate change data is downscaled using the “Weather Maker” modelling program (Weather Maker 2009). The modelled findings were similar around the state and are represented in Figure 36 on the following page.

For the SA MDB Region the impacts on pasture production are likely to manifest as shorter growing seasons. Pasture will be available for shorter periods of time, reduced in quality, less available in autumn and there will be greater variability in pasture growth and farm gross margins. These impacts were confirmed by nearly 200 livestock producers from the Murray-Darling Basin region, who were consulted in a series of workshops run by the South Australian Research Development Institute (Rebbeck 2008).

Further modelling has been performed using the SGS pasture growth model using a range of representative sites in each region of SA. The model shows a higher mean pasture growth in winter and early spring but a contraction of the spring growing season (Cullen et.al. 2009).
Sensitivity analyses have been performed by using incremental temperature increases and rainfall decreases to examine the impact of climate change on pasture production. Although none have been done for the SA MDB Region, results from the Central Local Government region (Balston et al. 2012) can be applied. Using the SGS pasture model (Johnson et al. 2003) temperature increases from 0 to 2°C above baseline, rainfall declines of 0 to 20% from the baseline and carbon dioxide concentration of 450 ppm in all scenarios were used.

The modelling indicated that at Roseworthy, pasture production decreased by no more than 10% with a rainfall reduction of up to 10% and temperature increase of up to 2°C. For a 20% reduction in rainfall, pasture production at Roseworthy was predicted to decrease by between 7 and 20% depending upon the temperature increase. Where pastures are affected by frost in winter, growth was usually slower. At Morchard (a low rainfall area of SA) pasture growth would be similar to the low rainfall regions of the SA MDB Region. Results for this region showed that the modelled pasture growth increased even with relatively high reductions in rainfall. The SGS model predicted that an average temperature rise of 2°C (with no rainfall decline) would increase pasture growth by about 30% and for a 20% reduction in rainfall there would be no change to pasture production. The modelling also shows that if there was no temperature increase and a rainfall decline of 20% there would be a reduction in production by up to 20%. This result suggests that the increase in temperature that we are locked into by 2030 may enhance pasture growth even with a rainfall decline in low rainfall areas. However, more detailed analyses are necessary and modelling for the SA MDB Region is required.
Figure 37: Pasture growth simulations using SGS pasture model for a brown calcareous earthy soil at Morchard in the Southern Flinders sub-region. The pasture composition includes 75% early annual grass and 25% medic. Production is displayed as a percentage change from the baseline modelling. All future climate change runs use CO₂ levels of 450 ppm.

A sensitivity analysis was also performed using the APSIM model as part of the Landscape Futures Program (Bryan et al. 2007). Mixed annual and perennial pastures were compared with deep rooted perennials under three warmer and drier futures and one warmer and wetter future. Scenario one (S1) was a 1°C increase in temperature and 5% decrease in precipitation, Scenario two (S2) was a 2°C increase in temperature and 15% decrease in precipitation, Scenario three (S3) was a 4°C increase in temperature and 25% decrease in precipitation and Scenario four (S4) a 1°C warmer and 5% wetter future (Figure 38).

Figure 38: Simulated productivity (yield) from continuous grazing under pasture (Bryan et al. 2007).

Figure 39: Simulated productivity (yield) from continuous grazing under deep rooted perennials (Bryan et al. 2007).
The modelling in Figure 39 shows that deep rooted perennials may be more viable than continuous grazing alone. However more work is needed on pasture use efficiency as it is important to know when the pasture is in its highest carbohydrate form for animal fat conversion and also when in the year it is most palatable and available to animals. These factors also need to be considered in tandem with calving and lambing dates. In other studies it has been found that an annual perennial mix is more economically viable when grazed by sheep in the Keith region (Rebbeck 2012).

Figure 40 shows the results of pasture growth simulations using Grass Gro (MLA et al. 2012) for a general pasture species and soil types for different regions across southern Australia. It also uses projected rainfall for 2030, 2050 and 2070 using four global climate models (CCSM3, ECHAM5, GFDL-CM2.1 and UKMO-Hadgem1). The results show that climate change is likely to affect pasture growth differently in different regions and that there is significant differences in projected growth between models. These findings largely reflect the differences in rainfall projections between models. The results include the lower SA MDB Region.

Figure 40: Projected pasture growth by 2030, 2050 and 2070 using Grass Gro, representative pastures and soils in each region and projected rainfall using the model CCSM3, ECHAM5, GFDL-CM2.1 and UKMO-Hadgem1 (Source: MLA 2012).

The sensitivity analyses with both the crop simulations and the pasture simulations show that rainfall will be the critical limiting factor of biomass (Cullen et al. 2009). However, projections for rainfall patterns into the future seem to vary as much between global climate models as they do over time (e.g. 2030 to 2070) and this is reflected in the growth simulations shown. Thus a sensitivity analyses that uses trends and looks at areas that are drier than the current region are other methods for exploring potential climate change impacts (Peter Hayman, SARDI Climate Applications, pers comm. 2011).

The use of seasonal climate forecasts, in tandem with measurements of stored soil moisture, pasture reserves on ground and the decision support tools discussed can help support producers make tactical decisions within the growing season.

**Wool production**

There are likely to be many detrimental impacts from climate change for wool production as a result of changes in pasture condition, increased thermal stress to sheep as a result of increased temperatures, changes to pest and disease incidence and animal health (Dwyer 2009). These impacts include a decline in wool production and clean wool yield, changes to wool quality as fibre diameter may decrease, tender wool incidence may increase and there may be a possible increase of lambs with impaired secondary follicle production. There will, however, be a reduction in the frequency of cold stress events and possible increases in production in colder, wetter areas (Howden et al. 2004, Balston et al. 2012). Australian wool may also face greater competition from other areas around the world that are currently too cold for sheep and wool production (e.g.

The GrassGro model was used to simulate gross margins per hectare for wool on a sheep enterprise at Booborowie in the Central Local Government Region of SA (Balston et al. 2012). Future climate change projections for the year 2030 were compared to the baseline years (1974–1994). The Grass Gro simulations for wool illustrated that there is more variability in gross margins by 2030 than for the baseline years and three of the climate change model projections simulated that production by 2030 is likely to be equivalent or reduced compared to the baseline years. The modelling also suggests that while there may be some downgrading of wool quality in poorer seasons, there is also opportunity for improvement (Balston et al. 2012).

Heat stress

At SARDI run workshops in the SA MDB Region (Rebbeck 2008) nearly 200 producers discussed the impacts of climate change on direct livestock health and pasture growth. Under warmer temperatures livestock managers said they recorded decreased production rates and increased mortality rates as a result of heat stress. Animals respond to heat stress with increased body temperature, increased respiration, changed metabolic rate and maintenance requirements, increased water intake, increased evaporative water loss, reduced feed intake and changed blood hormone content. The result of these changes is decreased production. In dairy cows, temperatures above 27°C will reduce milk yields. A 1°C increase in global average temperature may mean that passively ventilated or free range pig production units may no longer be viable (Dwyer et al. 2009).

Adaptations livestock and pasture

The GrassGro model could be used to test various adaptation options for the livestock industry in the SA MDB Region as was done for the Central Local Government Region (Balston et al. 2012). At Angaston (a higher rainfall area just outside the SA MDB Region), we examined the optimum stocking rates at for a future climate change scenario in 2030 using the NCAR CCSM3 Global Climate change model (Figure 41).

![Figure 41: Gross margins for varying stocking rate and calving times at Angaston for 2030 using the NCAR CCSM3 model with the A1F1 scenario and a CO2 concentration of 450 ppm. The pasture is sub-clover, annual weeds, cocksfoot and phalaris. The soil type is an acidic sandy loam (300 mm) on sandy clay loam with gravel (900mm). Self-replacing Angus cow herd. The cows are 550 kg standard reference weight. 1 cow/ha = 13 dse/ha. Cows were weaned at 42 weeks. Heifers mated at 15 months. Hay is fed in paddock to maintain weight of average animal and ground cover. All steers and surplus heifers sold at 350 kg or 44 weeks. NB: dse = dry sheep equivalents.](image)

The highest gross margins for the modelled Angus cow system at Angaston for 2030 is a March calving at a high stocking rate of 1.3 cows/ha. The Grass Gro model can also simulate the impact on ground cover, stocking rate and calculate viable pasture options. This modelling is yet to be undertaken in the SA MDB Region.
In other regions across SA under a changing climate it has been found that there is much room for changes to lambing and calving times. Stocking rates can be increased in many cases as pasture is under-utilised. Producers can increase the flexibility in their systems as the season progresses by varying their sale times/rules, confinement feeding, movement, more animal trading (core breeding) and agisting stock (Rebbeck 2012). Other adaptation options identified by Rebbeck (2012) indicated that there is a good opportunity for improved pasture utilisation by grazing management systems including:

- Control cell, rotational, confinement, and movement of stock;
- Having larger mobs for shorter periods of time;
- Matching livestock feed demand to pasture production;
- Maintaining high pasture quality by adequate fertiliser; and
- Maintaining pasture in growth stage two (a lower growth stage with higher carbohydrate content).

By improving pasture utilisation, stocking rates could be increased and because stock are eating pasture at higher carbohydrate content and will put on weight faster, they can be removed from the land faster resulting in reduced methane outputs.

Other adaptations to climate change by 2030 for the southern livestock industry include (MLA 2012):

- Feedbase modifications;
- Reduce periods of low ground cover;
- Higher soil fertility;
- Include a summer-growing perennial; and
- Feedlot in poor summers.

There is also a capacity to increase production by genetic gains such as:

- Increased size of sires;
- More wool at same body size; and
- Increased conception rates.

These changes would also allow stock to be turned off the pasture faster, would increase stocking rates and production and reduce methane emissions (Rebbeck 2012).

The majority of the impact of projected climate change to pasture and wool production by 2030 can be offset by the adaptations described above. However, multiple adaptations and flexibility are likely to be needed. The best combinations depend on location and enterprise. Figure 42 below shows how multiple adaptation actions help recover from the impact of climate change by 2030 at a range of locations across southern Australia.

![Figure 42: Multiple adaptations help recover a merino ewe enterprise from the impact of climate change by 2030 at a range of locations across southern Australia (MLA 2012).](image-url)
The results highlighted the differences in projections of rainfall and thus pasture biomass between global climate models. Therefore sensitivity based analyses can be more useful. Recent studies have also shown that recent climate trends are useful for getting producers to think about what they may do in a climate with 10% less rainfall and 2°C higher average temperatures (Rebbeck 2012). Most producers in the SA MDB Region would have experienced these conditions in 2006/7.

Livestock and pasture production will be adversely affected by climate change in the short-term unless adaptations are incorporated into management. There are many adaptation options available for the region, and multiple adaptations will be essential. Livestock is a viable alternative to cropping in the marginal regions.

6.2.5 Identified gaps for livestock and pasture

Some more detailed modeling is recommended for the SA MDB Region using GrassGro and SGS to investigate the impact of climate change on specific livestock enterprises. For example, work has been carried out looking at the wool quality using GrassGro in other regions, but not in the SA MDB Region. The GrassGro model can also be used to simulate adaptation strategies. Adaptations tested can include, optimum stocking rates, pasture species mix, animal weaning dates, calving and lambing optimums, supplementary feed required, gross margins and more.

The modelling shows that deep rooted perennials may be more viable than continuous grazing alone. However, although perennials produce more biomass, the challenge will be to improve pasture use efficiency. It is also important to know when the pasture is in its highest carbohydrate form for animal fat conversion and when it is most palatable and available to animals.

In dryland areas, precision irrigation systems have been introduced for vegetables, and despite best management practice, have led to a change in soil structure and chemistry, increased silt loads (affecting drip irrigation), and increased sodicity (particularly of subsoil and groundwater). These aspects of the farming system need to be better understood (Sylvia and Skewes 2006).

6.2.6 Irrigated agriculture

Irrigated agriculture in the SA MDB Region is dominated by viticulture and horticulture. The irrigation community will be more severely impacted by climate change both in the short- and long-term than dryland farming. Temperature rises in the short-term will shorten the ripening periods and compress harvest times of irrigators and lead to increased demand for labour, fruit storage and support services (Siebentritt and Sharley 2010). Warming and drying (and reduced water allocations for irrigation) will reduce productivity (Summers et al. 2011) and will reduce the total area under irrigation and force a change to an alternative land use (Seibentritt and Sharley 2010).

Water will be traded from lower to higher value production systems. However, total productivity from irrigated activities need not decline and could potentially increase with greater productivity and better adapted practices and varieties from a smaller total area (Summers et al. 2011). The profitability of irrigated agriculture is directly linked to the availability of water. Figure 43 shows that the profitability of irrigation industries is heavily dependant upon water allocations. Profits may be as low as 13% of baseline (Conner et al. 2009a, Summers 2011). Figure 43 also shows that as water allocations fall below an annual average of 30% irrigation industries in the SA MDB Region become unprofitable.

![Figure 43: Estimated revenue, cost and profit of reduced water allocation for the South Australian lower Murray irrigation sectors (Connor et al. 2009 in Summers et al. 2011).](image)
Another economic analysis by the Australian Institute of Social Research (Summers et al. 2011) reported on two hypothetical water restriction scenarios. The first scenario looked at the impact of a 25% reduction in water availability in the Riverland. This scenario found that GRP would be expected to fall by almost $30 million or approximately 2.0% of total Riverland GRP (approximately 1.5 billion in 2009/10). The second scenario assumed both a short and long term 25% reduction in water availability. The results showed a 4.7% decline in GRP and a 4% decline in employment.

6.2.6.1 Grapes and wine production

The Riverland is Australia’s largest winegrape producing region in Australia. In terms of annual crush it accounts for about half of South Australia’s production and about a quarter of Australia’s production (Figure 44). Viticulture is the number one producing commodity for the SA MDB Region. The total crush of South Australian winegrapes in 2011 was 682,671 tonnes. The top producing area was the Riverland at 56% (382,223 tonnes crushed) and its estimated total value was $105 million. The Langhorne Creek Region produced $23 million and McLaren Vale $48 million (Figure 44) (Pheloxara and Grape Industry Board of SA 2011). Winemaking and grape production directly account for 3.5% of GRP in the SA MDB Region in the 2006/07 financial year (EconSearch 2009a). The contribution to the local economy is even larger when one takes into account indirect economic impacts associated with manufacturing, approximately 4.5% of the GRP.

Figure 44: Proportion of wine crush per region in 2011 (Source: SA Winegrape Utilisation and Pricing Survey 2011 Phylloxera and Grape Industry Board of SA).

The total crush of wine grapes sourced from the Riverland over recent years has generally been well below the peak levels achieved in 2004 and 2005 (Figure 45) due to unfavourable seasonal conditions, pest and disease pressures, cooler growing conditions, above average summer rainfall and heatwaves. Furthermore, drought and water restrictions have also reduced the wine crush. Grape responses to climate variability and drought can be a good indicator of what may occur in the future if the rainfall decline continue as expected. It is important to note that the total wine grape crush can include wine grapes sourced from the region that are crushed outside the region (Pheloxera and Grape and Industry Board of South Australia 2011).
Vineyards will be affected by climate variability and change, most particularly as the variety of wine is determined by the climate. The year to year variability in climate is the major determinant of the quality and quantity of each vintage. If the region is too cool for the variety there are problems with even ripening. However, if conditions are too warm there is the risk of over ripe flavours (Hayman et al. 2009 and Balston et al. 2012). In addition, the vine life cycle can be altered by heat stress and moisture stress (Hayman et al. 2009). Rising temperatures will cause a shift in budburst dates and earlier harvest dates. Expected increases in temperature may mean it will be too warm to produce balanced wines from some varieties (Webb et al. 2011b) resulting in decreased grape quality and gross margins (Webb et al. 2011a). Higher temperatures have also been found to alter the flavour and aroma of wine grapes with subsequent consequences for the wine (Summers et al. 2011). Frosts are likely to reduce in the long-term but possibly increase in the short-term in response to drier conditions in spring (Hayman et al. 2009). Increases in mean temperature will also change pest and disease pressures.

Modelled effects of temperature increases show that grape quality could be reduced in some regions by 12 to 57 per cent compared to current conditions – if no adaptive measures are implemented (Jones and Webb 2010, Balston et al. 2012). Data from Foster’s Wine Estates shows that over the 13 years to 2006, maturity advanced by about seven days per degree increase in temperature. These changes vary by variety, regional influences and irrigation regimes (Hayman et al. 2009) (Figure 46). Increases in the frequency of extreme high or low temperatures will also have an effect on plant physiology and water use.

Changes to the timing and intensity of rainfall will influence the water balance in the soil, alter irrigation demands and have an impact on pests and diseases and fruit quality (Hayman et al. 2009). Dependence on water from the Murray-Darling Basin will be at risk in a hotter and drier future as demands on the river increase and water yields decrease and there are changes to water policy across the Basin. Most grape pests and diseases (e.g. powdery mildew, Light Brown Apple Moth) are sensitive to changes in humidity, rainfall and temperature (Hayman et al. 2009, Balston et al. 2012).

Various analyses have been completed around Australia to identify the optimum temperature for high to premium quality wine production. Results vary for each grape variety. Table 11 below shows the optimum growing season temperature for benchmark locations in the
northern hemisphere. The new world wine
regions in general and Australia in particular,
tend to break these rules (Balston et al.
2012). As a comparison, the median growing
season temperature at McLaren Vale is 18°C.

Southern Fleurieu is 16.9°C and Langhorne
Creek is 18.9°C. The projected growing season
temperatures for the same regions are shown in
Table 12 and for southern Australia in Figure 47.

Table 11: The range of growing season temperatures for quality wine production in benchmark regions of the northern
hemisphere (Jones et al. 2005).

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<tr>
<td>Tempranillo</td>
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<tr>
<td>Merlot</td>
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<tr>
<td>Malbec</td>
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<tr>
<td>Viognier</td>
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<tr>
<td>Shiraz</td>
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<td>X</td>
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<tr>
<td>Table Grapes</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Cabernet Sauvignon</td>
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<tr>
<td>Grenache</td>
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<tr>
<td>Cearignane</td>
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<tr>
<td>Zinfandel</td>
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<td>X</td>
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<tr>
<td>Nebbiolo</td>
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<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Raisins</td>
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<td></td>
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<td>X</td>
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</tbody>
</table>

Table 12: Index summaries of the pixel sets inside the listed wine regions for the base period (1971-2000) and the
projection in years of 2030, 2050 and 2070. Projections are derived from the CSIRO Mk3.0 GCM SRES Emission Scenario:
A1B (Source: Hall and Jones, 2008).

<table>
<thead>
<tr>
<th>Region</th>
<th>Base</th>
<th>2030</th>
<th>2050</th>
<th>2070</th>
</tr>
</thead>
<tbody>
<tr>
<td>Langhorne Creek</td>
<td>18.7</td>
<td>19.4</td>
<td>19.9</td>
<td>20.5</td>
</tr>
<tr>
<td>South Fleurieu</td>
<td>16.9</td>
<td>17.5</td>
<td>18.1</td>
<td>18.6</td>
</tr>
<tr>
<td>McLaren Vale</td>
<td>18</td>
<td>18.6</td>
<td>19.1</td>
<td>19.6</td>
</tr>
</tbody>
</table>
Figure 47: Mean growing season temperature for vines for the period 1 October to 30 April, for the base period 1971-2000 and projected for 2030, 2050 and 2070. Projections are derived from the global climate model CSIRO Mk3.0 GCM SRES Emission Scenario: A1B (Source: Hall and Jones 2008).

Vine growth, fruit ripening, growth of cover crops and soil biota will all be affected by increases in atmospheric levels of CO2. These and other changes are detailed in Table 13 on the following page (Hayman et.al. 2009).
Table 13: Summary of climate changes, confidence from climate science in that change and the likely impacts to viticulture (Source: Hayman et al. 2009).

<table>
<thead>
<tr>
<th>Climate factor</th>
<th>Confidence from climate science</th>
<th>Impact of climate factor on viticulture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in mean temperature</td>
<td>High confidence in general warming</td>
<td>A major impact of temperature is likely to be advanced phenology, which, in most cases, will shift ripening to warmer periods (Webb et al. 2007). Recent anecdotal evidence for earlier maturity and compressed vintages (observed throughout South-east Australia in 2006, 07 and 08) is supported by analysis of Foster’s Wine Estates’ ripening data collected over 13 years to 2006 (Peirie and Sardars 2006).</td>
</tr>
<tr>
<td></td>
<td>High confidence that warming will be greater for inland regions than coastal regions</td>
<td>Although subject to varietal and regional influence, maturity advanced by about 7 days per degree.</td>
</tr>
<tr>
<td></td>
<td>High confidence that warming will be greater at higher latitudes than tropics</td>
<td>A number of studies link regions and varieties to different temperature indices on a global scale (Jones 2008) and Australia (Webb 2005). However, the information on the temperature elasticity of different varieties under Australian conditions is limited (Smart 2006). Important interactions between varieties, temperature and irrigation regimes are</td>
</tr>
<tr>
<td></td>
<td>High confidence that higher altitudes are likely to warm faster than lower altitudes.</td>
<td>There are many climatic indices that attempt to quantify the impact of temperature on viticulture.</td>
</tr>
<tr>
<td></td>
<td>There is lower confidence in the seasonal pattern of warming and although nights have warmed more than days, it is not clear that this will be a strong trend in the future.</td>
<td>Simulation models such as Vins logic (Godwin et al. 2002) which use daily climate files rather than a single seasonal measurement are potentially powerful tools.</td>
</tr>
<tr>
<td>Changes in extreme temperature</td>
<td>Moderate confidence of general increase in frequency and intensity of heatwaves in summer.</td>
<td>Considerable circumstantial evidence exists on the impact of heatwaves on phenology and quality, but there is little controlled experimental data on heat stress. Current projects funded by GWRDC will provide valuable information.</td>
</tr>
<tr>
<td></td>
<td>Lower confidence in the timing of individual synoptic events such as heat waves and frosts.</td>
<td>Bushfires are a climate related risk due primarily to the smoke taint in wine (Webb and Barlow 2003). The frequency and severity of bushfires are likely to increase (Lucas et al. 2007).</td>
</tr>
<tr>
<td></td>
<td>Although warming at night will reduce risk of frost, increased drying may counter this trend.</td>
<td>Even if frequency of frost stays the same or decreases, changes in phenology may increase frost risk due to earlier flowering.</td>
</tr>
<tr>
<td>Changes in rainfall (including seasonal patterns and water balance)</td>
<td>Low to medium confidence in rainfall projections. Generally anticipating drier winters and springs with lower confidence in projections for summer.</td>
<td>There is a large body of scientific work on the impact and management of water stress on viticulture in Australia. A number of experiments are both planned and are being conducted which explore the impact of extreme deficits in a given season and the subsequent seasons. The response of different varieties and rootstocks are also being explored in current and planned projects (see GWRDC website for soil and water initiative).</td>
</tr>
<tr>
<td></td>
<td>Medium to high confidence in an increase in evaporative demand with rising temperatures.</td>
<td>Most grapevine pests and diseases are very sensitive to rainfall, humidity and temperature (both day and night temperature). Some simple models exist and could be run under climate change projections (eg powdery mildew, mildew. Light</td>
</tr>
</tbody>
</table>
Over the 2009 and 2010 period, the Grape and Wine Research and Development Corporation (RDC) arranged for a range of wine grape growers to identify issues of concern. The information collected from all regions indicated that the regions are similar and so the information should relate to the SA MDB Region. The growing regions identified five major issues of concern for the next three to five years:

1. Water;
2. Economic sustainability;
3. Climate change;
4. Pests and diseases; and
5. Best management practices.

The full report is available from GWRDC (2010) and highlights that water and climate change are significant issues but there is also pressure on economic survival and managing immediate threats such as pests and disease.

Tactical management of the season will be important, however, it will be compromised by water supply reductions and unknown policy on future allocations. Managing the time of maturity by pruning vines harder will be important to slow the shift of early ripening (Webb et al. 2011a). It will also be important to look at projected temperatures and assess the long term suitability of current varieties as temperatures rise.

6.2.7 Identified gaps for Grapes and Wine production

- Analyses on the impacts of climate change on various grape varieties and specific adaptations to suit these varieties in the region; and
- Unknown policy for future water allocations means adaptation planning is difficult.

6.2.8 Horticulture

Horticulture in the SA MDB Region is dominated by fruit (e.g. citrus, stone and pome), nuts and vegetables with an annual gross value of more than $260 million over an area of approximately 14,500 ha (ABS 2007). With the exception of vegetables these are all largely high value perennial tree crops that take many years to establish and are dependent on irrigation water for their viability in the semi-arid climate of the region (Summers et al. 2011).

Increased temperature and water deficit stress will adversely affect fruit set, taste, colour and the rate of ripening for fruit crops and spread the risk of some diseases. For irrigated crops where the water is not limited, the increase in CO2 and temperature may open new opportunities. For example, drier, less humid conditions may reduce fungal diseases and insect pests (Webb and Whetton 2010, Summers 2011).

For many horticultural crops, a warmer climate will result in a faster progression of the phenological and fruiting stages and result in an early season (Webb et al. 2008a). For some vegetable crops (e.g. lettuce) it may be possible to achieve two crops within the timeframe of one under current climatic conditions (Pearson et al. 1997, Summers et al. 2010). However, increased water and heat stress may also cause some vegetable crops (e.g. lettuce, parsley, spinach) to bolt (premature flowering) and may reduce the viability of these crops in the region (Webb et al. 2008a, Webb and Whetton 2010). Higher temperatures may also be a threat to crops that require chilling for setting fruit (e.g. stone and pome fruit) and may reduce the area suitable for these crops (Webb and Whetton 2010, Summers, 2011).

Some crops that were not previously suitable to the SA MDB Region may become suitable, e.g. tropical fruits that require higher temperatures or fewer frost days (e.g. avocados, pecan nuts, bananas) (Webb et al. 2008a, Webb and Whetton 2010, Summers et al. 2011).

Murray River flows are projected to reduce by between 12 and 25% by 2050 depending on the scenario and the catchment. The resultant reduction in economic returns for horticultural crops may be between $0.8 billion and $1.2 billion depending on the scenario (ABARE 2011).

Some horticultural crops in the SA MDB Region are grown in controlled environments. Costs of inputs will rise as energy costs associated with pumping of water, fertilizers, heating greenhouses, transport and storage of produce or disposal of waste increase. Pests and diseases are also increasing (Deuter et al. 2006) and will result in increased costs for management. Hail and flooding has also affected horticultural crops in the region in recent times.

6.2.9 Vegetables

In the 2009/10 financial year, vegetables accounted for 3.3 per cent ($147 million) and fruit and nuts 2.5 per cent ($110 million) of the gross regional product in the SA MDB Region (Econosearch 2010) and are together the largest earner of the agricultural commodities in the SA MDB Region. In the 2000-01 financial
year, total vegetable production in SA earned $280 million. The largest farm gate production of vegetables was potatoes which earned the SA MDB Region $55 million in GRP followed by onions at $37 million (Table 14). Other vegetables grown in the region include carrots, melons, pumpkins, sweet com, lettuce, capsicum, leeks, tomatoes, broccoli, watermelons, cauliflower, beetroot, cabbages, cucumbers, snow peas, green peas and zucchini (Sylvia and Skewes 2006).

Table 14: Farm Gate Gross Value $ of Production of Vegetables in the SA MDB Region in 2001 (Sylvia and Skewes 2006).

<table>
<thead>
<tr>
<th>Crop</th>
<th>2001 Farm Gate Gross Value of Production ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>55,221,895</td>
</tr>
<tr>
<td>Onions</td>
<td>37,206,675</td>
</tr>
<tr>
<td>Carrots</td>
<td>21,497,800</td>
</tr>
<tr>
<td>Melons</td>
<td>3,844,275</td>
</tr>
<tr>
<td>Pumpkins</td>
<td>3,279,265</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>1,702,754</td>
</tr>
<tr>
<td>Lettuce</td>
<td>1,067,314</td>
</tr>
<tr>
<td>Capsicum, chillies, peppers</td>
<td>660,389</td>
</tr>
<tr>
<td>Leeks</td>
<td>578,375</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>568,684</td>
</tr>
<tr>
<td>Broccoli</td>
<td>349,049</td>
</tr>
<tr>
<td>Water Melons</td>
<td>217,973</td>
</tr>
<tr>
<td>Melons-other</td>
<td>156,552</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>76,693</td>
</tr>
<tr>
<td>Beetroot</td>
<td>41,072</td>
</tr>
<tr>
<td>Cabbages</td>
<td>31,633</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>13,240</td>
</tr>
<tr>
<td>Snow peas</td>
<td>10,985</td>
</tr>
<tr>
<td>Green peas</td>
<td>2,127</td>
</tr>
<tr>
<td>Zucchini</td>
<td>90</td>
</tr>
</tbody>
</table>

Water use
A moderate increase in the rate of global warming is projected to result in a substantial decline in Murray River flows and economic returns (ABARE 2011). The vegetable industry in the SA MDB Region is dependent upon irrigation and water availability. Vegetable growing is largely restricted to southern regions with access to surface irrigation water (e.g. the Murray River), underground (of adequate quantity and quality), or recycled sources. In South Australia the gross margin per ML of water for the main vegetable crops were $271 per ML and $306 per ML for potatoes and onions respectively, up to $9,264 per ML for glasshouse cucumbers. The South Australian vegetable industry used 86,747 ML of water, in 2003–04 (Sylvia and Skewes 2006).

The lettuce aphid (Nasonovia ribisnign) is one example of pest that can increase in large numbers under the correct temperature thresholds (Deuter et.al. 2011). The temperature thresholds identified by Deuter et.al. (2011) indicate the temperature at which the production of a commodity becomes unviable due to identifiable change in a production variable due as a result of changes in a critical biological climate indicator – in this case temperature (Table 15). The impacts for some horticultural crops are listed below (Kenney et.al. 2000) (Table 16).

Table 15: Temperature thresholds for selected horticultural crops. Productivity and or quality will be significantly affected above these thresholds (Deuter et.al., 2011).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Development Phase</th>
<th>Critical Temperature Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce</td>
<td>Hearting</td>
<td>28°C – mean maximum</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Curd Induction</td>
<td>22°C</td>
</tr>
<tr>
<td>Sweet com</td>
<td>3-4 weeks post flowering</td>
<td>32°C</td>
</tr>
<tr>
<td>Citrus</td>
<td>Fruit Set (near end of bloom)</td>
<td>27°C</td>
</tr>
<tr>
<td>Tomato</td>
<td>2 week period Pre-anthesis</td>
<td>29°C</td>
</tr>
<tr>
<td>Capsicum</td>
<td>Flowering</td>
<td>32°C</td>
</tr>
<tr>
<td>Avocado</td>
<td>Flowering and fruit development</td>
<td>33°C</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Flowering</td>
<td>&gt;32°C</td>
</tr>
</tbody>
</table>
In the SA MDB Region, producers need to become more aware of the temperature sensitive periods for horticultural crops. They can then avoid production during these periods by changing planting and harvest dates or using more adaptable vegetable cultivars or rootstocks. The changes in production times that result from increased temperatures will need to be taken into account with changes to production and marketing plans for most crops. Suitable site selection, diversification of orchard locations and spreading the harvest seasons will also help minimise climate change exposure (Balston et al. 2011).

Cooling with overhead irrigation, strategic applications of nitrogen and irrigation may need to increase as temperature increases. Many horticultural growers have adopted more efficient irrigation technologies that are providing significant water-use efficiencies. These changes will need to continue, together with an increased understanding of crop water requirements and tightened irrigation management practices including monitoring, scheduling and maintenance (Deuter et al. 2011).

Other on farm adaptations also include managing heat through use of mulching and soil moisture, maintaining a strong focus on soil health and structure, maintaining high organic matter content and high soil biodiversity. Minimizing evaporation or seepage from on-farm storage will also be more important. Integrated Pest and Disease Management (IPDM) practices are common in all horticultural regions and commodities, and continuous improvement in these systems, and their adoption, will also be an important part of adapting to a changing climate (Deuter et al. 2011). More vulnerabilities, impacts and adaptations to the horticultural industry are described in Table 17.
Table 17: An assessment of adaptive capacity and vulnerability in relation to selected climate change impacts on horticultural crops in Australia (Deuter et al. 2011).

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Adaptive Capacity</th>
<th>Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production Timing and Location</strong> (crops mature earlier and take less time from planting or fruit set to harvest).</td>
<td>Growers are already making the following adaptations: changing marketing plans to account for these changes; moving some of their production to more favourable locations and using more ‘adaptable’ crops/cultivars. Growers in some regions (summer season) may be able to take advantage of extending production into winter. Growers in other regions (winter season) will have their production season shortened.</td>
<td>Currently not vulnerable. This will change to vulnerable if crops/cultivars are unable to cope with increasing temperatures (i.e. thresholds are reached). All vegetable growers and regions are vulnerable if more adaptable cultivars are not available. Depending on the crop and location, those crops which are close to temperature thresholds will be very vulnerable.</td>
</tr>
<tr>
<td><strong>Product Quality</strong> (quality affected by increasing heat stress days)</td>
<td>There is a need for more adaptable cultivars for the vegetable industry. The decision makers are the seed companies who currently source the majority of cultivars from overseas breeding programs. Increasing number of heat stress days will result in a narrowing of production windows, and the potential for production to shift to more suitable (coolier) regions.</td>
<td>Currently vulnerable as a market for new vegetable cultivars which might be specifically adapted to the Australian environment is quite small in comparison to the overseas market. Likely to increase in vulnerability. Growers are currently adapting well. All industries are increasing in vulnerability, especially as the critical temperature thresholds for available crops/cultivars are approached or extended.</td>
</tr>
<tr>
<td><strong>Inputs</strong> (availability and costs of water and fuel)</td>
<td>Drought has been a driver of decisions involving access and use of irrigation water. Some vegetable growers have moved production to areas where water is available. Fuel costs will increase (as will all other inputs derived from fossil fuels – fertilisers and pesticides)</td>
<td>Some growers and some industries (especially permanent fruit crops) are very vulnerable (currently and into the future). All industries and growers are very vulnerable as they have limited ability to reduce costs and / or pass on increased costs.</td>
</tr>
<tr>
<td><strong>Pest and Disease Effects</strong> (increasing activity of pests and diseases)</td>
<td>Current (and future) Integrated Pest and Disease Management Systems (IPDM) will make a significant contribution to overcoming these impacts.</td>
<td>All industries are vulnerable to increased pest and disease activity (continually improving IPDM systems will be one mechanism to delay and reduce the impacts). All industries are vulnerable to the effects of new pests and diseases (new to Australia and/or new to production regions).</td>
</tr>
</tbody>
</table>

Potential adaptation options include increased water use efficiency and development of water trading markets. Regional development opportunities combined with user, State and Commonwealth government funding have enabled significant infrastructure developments that benefit the vegetable industry. Examples of these developments include Murray River salt-interception schemes and pressurised delivery schemes.

6.2.10 Identified gaps for horticulture

As suggested by Sylvia and Skewes (2006), irrigation benchmarking studies with vegetable focus groups are needed to identify the potential for optimum performance parameters for each vegetable growing region, and identify further research, extension and training needs.

Best management practices for fertiliser application and water use is needed. This should aim to prevent toxic build up or drainage...
of salinity nutrients, focus on crop yield and quality, and improve water use efficiency.

Deuter et al. (2011) found that there is lack of direct research into the effects of climate change on specific horticultural commodities.

Further gaps identified by Sylvia and Skewes (2006) include:

- Understanding of the impacts and options with less water allocations;
- Improved understanding of soil chemical analyses and subsequent timely recommendations to improve drainage and nutrient retention (e.g. addition of gypsum, organic matter or deep ripping);
- Increased promotion and support of vegetable grower irrigation training is needed; and
- Development of a culture of irrigation scheduling, recording and monitoring water and fertiliser inputs to manage on-farm and regional water tables.

Little literature on fruit impacts and adaptation was found.

6.2.11 Identified gaps for agriculture

Workshop participants at the stakeholder engagement meeting in July identified knowledge and data gaps in terms of the potential impact of climate change on:

- specific native grazing species (i.e. grasses, bushes, trees);
- relationships between pastures and crop production with livestock production; and
- animal health (e.g. pink eye in sheep, increased dust production).

Siebentritt et al. (2011) recommend that the region:

- Build on the existing consortium of Councils and the SA Murray-Darling Basin NRM Board;
- Present a coordinated vision of climate change adaptation for the SA Murray-Darling Basin that encourages investment in the region;
- Reduce potential duplication of effort;
- Acquire funding to support diversification of the region’s economy;
- Prepare a climate change adaptation action, monitoring and evaluation plan;
- Prepare an adaptive communities research and development priorities strategy;
- Establish an adaptive communities web portal for knowledge sharing, skill development and networking; and
- Develop and adaptive communities’ capacity building program (Siebentritt et al. 2011).

Maiorano (2011) coordinated a policy direction paper, “Strengthening Basin Communities Program: Climate Change Adaptation Project. Horticultural and Rural Lands Review Policy Direction. Discussion Paper that contains many recommendations for the future direction of the region and these would need to be considered and discussed as part of a full IVA.

Kellet et al. (2011) reviewed climate change adaptation initiatives within SA. These include the South Australian Local Government Adaptation Program and State Government programs such as the Vulnerability assessment of the Northern and York NRM region and the Climate change Communities Program looking at the vulnerability in the Eyre Peninsula and SA MDB Regions. There are also sustainability initiatives these include the Developing Landholder Capability to Adapt program and the Sustainable Dryland Agriculture Initiative. Programs to monitor land and environmental condition in the face of climate change such as the Climate Change and Land Capability program aims to reduce the potential risk of wind erosion. Each of these studies would need to be assessed in full as part of an IVA.

Research from the National Climate Change Adaptation Research Facility (NCCARF) Primary Industries Adaptation Research Network (PIARN) has developed a variety of tools to assist in climate change adaptation such as the Environmental Management System (EAMS), and life cycle assessment tools – all of which may be useful as part of an IVA.

6.3 SECONDARY INDUSTRIES

6.3.1 Manufacturing

Manufacturing accounted for approximately 12 per cent ($518 million) of gross regional product in 2009/10 for the Murray and Mallee LGA regional economy (EconSearch 2011). The most significant contributors to manufacturing output include wine, meat and meat processing and dairy processing.

Limited research on the potential effects of climate change on manufacturing within the SA MDB Region currently exists. Balston et al. (2011) considered the potential implications of future climate change for manufacturing
in the Central Local Government Region in a qualitative sense. The report states:

“Manufacturing activities that rely on produce grown in the region (e.g., food products manufacturing) may be adversely affected by the impacts of climate change on production in these supplying sectors. Manufacturers may be able to adapt by importing supplies from other regions although this may lead to an increase in cost structures.

Impacts on the total supply and reliability of energy and water supplies may represent a significant risk for manufacturing activities to the extent these resources are significant inputs.” (Balston et.al. 2011).

Feedback obtained during the Central Local Government Region IVA would be relevant to the SA MDB Region given the similarities between the two regional economies in terms of reliance on agriculture and food processing activities (especially winemaking). Participants in the regional workshop for the Central Local Government Region noted that ‘stable temperature environments are often required for food and other manufacturing activities, and makes these activities sensitive to changes in heat and temperature’ (Balston et.al. 2011). In addition to increasing energy demand and costs, workshop participants noted that higher temperatures and more frequent heatwaves would present occupational health and safety risks for employees working in warm environments (Balston et.al. 2011).

Uncertainties remain in predicting the likely future long-term impact of climate change on supplying industries such as agriculture. Nonetheless, given the importance of irrigation to the regional economy, any increase in temperature and/or reduction in water availability will likely have significant implications for manufacturing activities in terms of the negative impacts on supply sectors.

6.3.2 Construction

Construction, which is comprised of residential building, construction trade services and other construction, contributed $227.3 million in gross value added (5.1 per cent) to the Murray and Mallee LGA regional economy in 2009/10 (EconSearch 2011).

Research on the effects of climate change on the construction industry in the SA MDB Region is limited. Studies for other regions have identified potential negative impacts in terms of interruptions to construction activity due to occupational health and safety issues for workers and reduced reliability of energy supplies as a consequence of an increase in the frequency and duration of heatwaves (Balston et al. 2011). The Central Local Government Region IVA concluded that ‘the most significant risks to construction are probably indirect: negative production impacts for key primary industries in the region such as broadacre cropping, wine, viticulture and tourism will flow to some extent into activity levels in the construction sector’. A similar scenario would apply for the SA MDB Region given the large extent to which it is composed of small regional communities that are narrowly based on primary activities and that may be sensitive to climate change impacts.

For the limited coastal areas in the south west of the SA MDB Region, rising sea levels would also pose a risk to construction activity.

6.3.3 Identified gaps for secondary industries excluding agriculture

There is limited research on the effects of climate change on manufacturing and construction in the SA MDB Region. Further research is needed into:

- Impact of reduced supplies from the agricultural sector on manufacturing;
- Reliability of energy and water supplies for use in manufacturing;
- Impact on health and safety in the construction sector; and
- Effects of reduced activity in the broad acre cropping, wine, viticulture and tourism industry on the construction sector.

6.4 TERTIARY INDUSTRIES

6.4.1 Retail trade.

Retail trade accounted for 5.2 per cent ($231.6 million) of gross regional product for the Murray and Mallee LGA regional economy in 2009/10 (EconSearch 2011). Retail trade is an important source of employment and approximately 8,500 people in the region were employed in the sector in 2009/10, close to almost 16 per cent of total employment in the region (EconSearch 2011).

There is minimal literature considering the impacts of climate change on retail trade in general which would reflect that the direct impacts are likely to be quite limited. However, the Victorian Employers’ Chamber of Commerce and Industry (2010) identifies the following potential climate change impacts on businesses in retail and wholesale trade:
• Upward pressure on energy prices, which would raise costs for energy intensive inputs;
• Reductions in water availability and associated increases in water prices, which would be particularly relevant for retailers and wholesalers of food and agricultural products; and
• Changes in customer preferences toward more environmentally friendly products and services.

Participants in the Central Local Government Region IVA workshop noted that an increased frequency of heatwaves would have implications for storage of produce, affect visitation and could compromise the reliability of energy supplies during peak periods, while drought could affect the supply of produce for food retailing (Balston et al. 2011).

The greatest risks posed by climate change to the retail trade sector are probably indirect. Retail trade is highly dependent on population size and broader macroeconomic trends. For small regional economies that are heavily based on primary activities, negative climate change impacts on these primary activities could be expected to flow through to the retail trade sector. For example, the Central Local Government IVA report states that:

“The main impact of climate change on retail trade will therefore be indirect via its impact on the performance of key industry sectors in the region e.g. agriculture, manufacturing and tourism. To the extent that climate change has an adverse impact on these sectors with negative outcomes for unemployment and/or real incomes, impacts will flow through to retail trade. Given the importance of farming and primary production to the region’s economy and the prospects for climate change to disrupt these activities, the prospect for disruption to the local retail trade sector is probably higher relative to retail trade located in metropolitan areas.” (Balston et al. 2011).

A similar rationale would apply for the SA MDB Region given the importance of agriculture and water supply to many parts of the agricultural base in the region.

6.4.2 Tourism

Tourism in the study region is centred on recreational activities along the Murray River and nature based experiences at Monarto Zoological Park, Banrock Station and a number of nature reserves (RDA Murraylands and Riverland Regional Roadmap, 2011-2013). In 2011 total expenditure by overnight visitors was $81 million, followed by day trippers who spent $74 million; total visitors to the region over this period was 422,000 (SACES regional fact sheet for RDA Murraylands and Riverland). Besides recreation on the Murray River, tourists also visit the region to see family and friends, visit restaurants, go sightseeing, visit pubs and clubs and for pleasure shopping. According to Tourism Research Australia (2011), the two most popular visitor experiences in the Riverland and Murraylands are “food and wine” and “nature based”.

Threats posed to tourism in the SA MDB Region from climate change include reduced food and wine production due to lower rainfall which would adversely affect wine based tourism, increased frequency of bushfires and increased frequency and intensity of heatwaves, and reductions in environmental flows and river levels, which together would adversely affect the quality and quantity of native attractions.

Looking at Australia as a whole, climate change may have potential negative and positive implications for tourism. Forsyth, Dwyer and Spurr (2007) identify the following potential impacts:

• Loss of attractions – changes in climate may effectively destroy natural attractions and environments (e.g. coral reefs and ski fields);
• Loss of quality attractions – while the attraction may continue to exist, the quality of the attraction and therefore visitor experience may be diminished by changes in climate and other physical conditions;
• Costs of adaptation – some attractions may be able to be preserved through various adaptation strategies which will have associated cost implications;
• Costs of replacing tourism capital – some attractions may be able to be relocated following changes in regional climate (e.g. beaches and ski fields), which may require new facilities and amenities to be established; and
• New or better attractions – changes in climate may make certain locations more attractive (e.g. existing cold locations may become more attractive under a warmer climate).

Since weather conditions have an important bearing on the attractiveness of a region from a visitor’s perspective, changes in climate and extreme weather events have the potential to alter existing visitor patterns. Changes in future visitor patterns due to climate change have been modelled at a global level. Balston et al.
(2011) summarised that outcomes from an example of such modelling:

“Bigano et. al., (2006) modelled the impact of climate change (in terms of temperature change and sea level rise) and economic development on total tourism demand for most countries up to 2100. The results indicated that climate change would shift patterns of tourism towards higher altitudes and latitudes. In terms of domestic tourism, warmer countries are likely to see a reduction in domestic tourism of up to 20% relative to the baseline scenario without climate change, while tourism in colder countries may double. International tourism would also shift towards countries with cooler climates as climate change increases the attractiveness of cooler countries. Tourists in hotter countries would prefer international over domestic travel. However, the modelling also indicated that the impact of climate change is small compared to effects of population and economic growth on overall tourism patterns (Bigano et al. 2006).

Workshop participants at the Central Local Government IVA workshop argued that more frequent and intense heatwaves would have a negative impact on tourism in the region as visitation drops during periods of extreme temperature. There were also concerns expressed about the impact of carbon pricing on tourism given higher cost implications for car travel and airfares that may discourage travel to the region.

Siebentritt et.al. (2011) briefly identified some of the potential impacts of climate change on tourism for the SA MDB Region. The authors note that the regional economy must diversify given the expected harmful impact of climate change on primary production, and that tourism has an “important role” to play in this respect. However, tourism itself will face challenges associated with climate change. While a warmer and drier climate would make summer visitation less attractive to visitors (which may be offset to some extent by increased visitation during winter periods), it is the potential for an “increased frequency of drought and conditions of extreme heat that pose the greatest challenge” (Siebentritt et al. 2011). Drier and warmer conditions combined with extreme weather events would lead to reductions in river and lake levels and consequently erode natural attractions.

The impact of the most recent drought on tourism in the SA MDB Region provides insight into the potential impact of climate change on tourism. For example, the total number of domestic overnight visitors to the Riverland in 2010 was down 36 per cent compared to 2000 – a relatively larger decline compared to Adelaide (down 21 per cent) and South Australia as a whole (down 22 per cent) over this period (Advance Tourism 2011). Furthermore, the occupancy of houseboat accommodation fell from 62 per cent in 2005 to 35 per cent in 2009/10 (Summers et al. 2011).

While the prolonged drought followed by floods had a serious impact on visitor demand, Advance Tourism (2011) argues that a lack of “counter-measures to combat the decline in visitors” and market demand strategies to generate new visitor demand also contributed to the poor performance. It is interesting to note that while the Riverland Tourism Development Plan aims in part to provide a strategic direction to “achieve sustainability for the industry by 2015 so that never again does the industry suffer such a serious downturn in its economic performance”, no mention is made in the plan with respect to potential risks associated with climate change. In contrast, Siebentritt et al. (2011) recommend that the region prepare for the future by developing a Blueprint for Tourism in a Variable Climate to build resilience in the local tourism industry. They also recommend that a Nature Based Tourism Action Plan be developed to “determine how to best leverage off of future investment in natural assets across the SA Murray-Darling Basin”.

Apart from recent studies that have considered the impact of the recent drought on tourism in the Murray-Darling Basin Region (for example, see Tourism Research Australia 2010), we were unable to identify any detailed studies specifically addressing climate change impacts for the SA MDB Region. However, case studies have been conducted for other regions in SA. For example, a study for the Barossa found a strong link between tourism and climate change given:

- the potential impact of changes in climate on the sustainability of viticulture;
- the strong existing relationship between wine and tourism; and
- lack of alternative tourism products in the region (Sustainable Tourism CRC 2009).

Other potential negative impacts for the region include “the impact of drier conditions on heritage buildings and repair costs, reduced water availability for parks and gardens, the impact of drought on native flora and fauna, and increased prevalence of weeds.” (Balston et al. 2011).
Wine tourism in the SA MDB Region is also likely to be negatively affected by climate change although tourism would arguably be less sensitive than the Barossa given the former is not as reliant on wine tourism. Detrimental impacts on water availability and environmental flows are likely to be more important for tourism in the SA MDB Region and/or particular sub-regions. For instance, taking a counter example, the CSIRO estimated that the annual incremental recreational benefits associated by recovering 2800 GL/year of water for the environment in the Murray-Darling Basin was worth $124 million in the Murray-Lower Region (Coorong) (CSIRO 2012). Reductions in environmental flows due to climate change would prevent such recreational benefits from being realised or reduce the existing level of tourism related benefits.

6.4.3 Identified gaps for tertiary industries
There is limited research on the effects of climate change on retail trade and tourism in the SA MDB Region. Based on the likely impacts of climate change identified in the broader literature, further research concerning impacts of climate change in the SA MDB Region is needed into:

- Assessing the impact climate change on manufacturing, tourism and agricultural sectors and likely flow on effects to retail trade;
- Effect of increased input prices of energy and water on retail trade;
- Effects on tourist visitation due to increased temperatures, heatwaves, higher fuel prices and, most significantly, changes in environmental flows due to likely future climate change scenarios.

The latter needs to take into consideration environmental flows returned to the system as part of any final Murray-Darling Basin Plan. At the time of writing, the revised draft basin plan stipulated that the long-term average sustainable diversion limit for Basin water resources be reduced by 2,750 GL per year to 10,873 GL per year (Murray-Darling Basin Authority 2012).

Participants in the stakeholder workshop as part of this study noted a need to identify industries, manufacturing opportunities and crops – including new varieties that are resilient and suitable to low rainfall – that that may be applied under a changing environment. Such needs reflect knowledge gaps with respect to adaptation options to climate change rather than rather than gaps with respect to climate change impacts.

6.5 Quaternary sector

The quaternary sector comprises intellectual activities, government, culture, libraries, scientific research, education, information technologies and gross regional income from government support or aid. There were insufficient resources available to consider the literature for these activities. However, it is likely that there is very limited information available that specifically addresses climate change impacts on these activities in the SA MDB Region. Furthermore, by definition, the threats posed by climate change to quaternary activities are probably relatively less significant compared to other financial activities considered elsewhere in this report.

It is possible to make some speculative comments on what the potential impacts on quaternary activities from climate change may be. For most quaternary economic activities, the most substantive risks are probably indirect in terms of adverse flow on or multiplier effects stemming from negative impacts on primary activities in the region. Most communities in the SA MDB Region are dependent on agricultural activities, either directly or indirectly, and these may be quite vulnerable to changes in climate over the long term. In the absence of adaptive response and/or diversification of regional communities, a lack of employment opportunities may encourage emigration and population decline in certain regional communities. Such an outcome may generate a negative feedback loop through reduced economies of scale (i.e. a smaller population/economy makes certain activities or opportunities unviable). Under such circumstances there would be an increase in demand for government income support and assistance.

6.6 Summary gap analysis of financial capital for the Murray-Darling Basin region of South Australia

As one would expect for a diverse regional economy such as this, there are gaps in the literature concerning the impacts of climate change on primary industries, secondary industries and tertiary industries. The Environment Institute’s Climate Change Impact Assessment, Adaptation and Emerging Opportunities for the SA MDB Region Milestone 3 report (Summer et al. 2011) briefly mentions that insufficient water supplies due to a drying climate will reduce availability for the mining industry but does not provide detailed impacts on the forestry, manufacturing, construction, retail trade or tourism industries.
For the primary industries excluding agriculture sector further research is required to determine the effects of climate change on energy availability, efficiency of equipment and health and safety implications for workers in the mining sector. For forestry, findings of the Pinkard and Bruce study (2011) summarise the effects of climate change for South Australian plantations and would be relevant to the existing (limited) forestry activity in the SA MDB Region.

Much of the cropping area in the SA MDB Region is low rainfall and so long-term, transformational change is eminent. Support for producers to undertake long-term planning for transformational change would be beneficial.

Under the SA Murray-Darling Basin Landscape Futures Program reports, biofuels are considered as a long-term plan for the drier parts of the region, but we need to consider their long term viability since opportunity crops such as canola are often cut from a rotation in drier years as they do not perform as well under a warmer and drier future. New projects are emerging to support producers to take advantage of the carbon market. However, support for the long-term triple bottom line viability needs to be provided.

Some more detailed modeling is recommended for the SA MDB Region using Grass Gro and SGS to investigate the impact of climate change on specific livestock enterprises. For example, work has been carried out looking at the wool quality using Grass Gro in other regions, but not in the SA MDB Region. The Grass Gro model can also be used to simulate adaptation strategies. Adaptations tested can include, optimum stocking rates, pasture species mix, animal weaning dates, calving and lambing optimums, supplementary feed required, gross margins and more.

Pasture modelling shows that deep rooted perennials may be more viable than continuous grazing alone. However, although perennials produce more biomass, the challenge will be to improve pasture use efficiency. It is also important to know when the pasture is in its highest carbohydrate form for animal fat conversion and when it is most palatable and available to animals.

In dryland areas, precision irrigation systems have been introduced for vegetables, and despite best management practice, have led to a change in soil structure and chemistry, increased silt loads (affecting drip irrigation), and increased sodicity (particularly of subsoil and groundwater). These aspects of the farming system need to be better understood (Sylvia and Skewes 2006). As suggested by Sylvia and Skewes (2006), irrigation benchmarking studies with vegetable focus groups are needed to identify the potential for optimum performance parameters for each vegetable growing region and identify further research, extension and training needs.

Best management practices for fertiliser application and water use is needed to prevent toxic build up or drainage of salinity nutrients, improve crop yield and quality, and improve water use efficiency.

Deuter et.al. (2011) found that there is lack of direct research into the effects of climate change on specific horticultural commodities.

Further gaps recommended by Sylvia and Skewes (2006) to address include:

- Improved understanding of the impacts and options with less water allocations;
- Improved understanding of soil chemical analyses and subsequent timely recommendations to improve drainage and nutrient retention (e.g. addition of gypsum, organic matter or deep ripping);
- Increased promotion and support of vegetable grower irrigation training is needed; and
- Development of a culture of irrigation scheduling, recording and monitoring water and fertiliser inputs to manage on-farm and regional water tables.

Little literature was found on climate change impacts and adaptation for fruit in the Region.

Workshop participants at the stakeholder engagement meeting in July identified knowledge and data gaps in terms of the potential impact of climate change for:

- specific native grazing species (i.e. grasses, bushes, trees);
- relationships between pastures and crop production with livestock production; and
- animal health (e.g. pink eye in sheep, increased dust production).

Siebentritt et.al. (2011) recommend that the region:

- Build on the existing consortium of Councils and the SA Murray-Darling Basin NRM Board;
- Present a coordinated vision of climate change adaptation for the SA MDB Region that encourages investment in the region;
- Reduce potential duplication of effort;
• Acquire funding to support diversification of the region’s economy;
• Prepare a climate change adaptation action, monitoring and evaluation plan;
• Prepare an adaptive communities research and development priorities strategy;
• Establish an adaptive communities web portal for knowledge sharing, skill development and networking; and
• Develop and adaptive communities’ capacity building program (Siebentritt et al. 2011).

For secondary industries, further research is required on the effects that climate change will have on the manufacturing sector in the SA MDB Region. Climate change has implications for food processing and grape and wine processing as the supply of agricultural products is likely to be adversely affected by reduced rainfall and higher temperatures. Further research is required to assess the magnitude of the impact that reduced agricultural productivity would have on manufacturing in the context of likely future climate change scenarios for the region and reductions in water diversions. Further research is also required to establish the effects of climate change on the health and safety of workers in the construction sector and potential flow on effects due to productivity impacts on agricultural activities.

For tertiary industries further research is needed to determine the effect of climate change on retail trade which is influenced by output from the primary production and farming sectors. Input prices for energy and water are likely to increase as a result of climate change; further research is needed to determine the degree to which this will impact on retail trade. Tourism is likely to decline with the effects of hotter temperatures and increased heatwaves due to climate change, but further research is required to establish the likely effects on visitation to the SA MDB Region.
7 The social capital of the region

“There are many changes occurring in rural and regional communities in the Murray-Darling Basin as a result of climate change, water availability, water trading, global markets, population movements and ongoing social changes. Basin communities will respond to, and be affected by, a range of these drivers in combination with their adaptive capacity, resilience and vulnerability.” (Australian Bureau of Agricultural and Resource Economics and Sciences 2010).

The term social capital relates to the social make-up of a community and the associated community services. “Aspects of social capital include families, communities, businesses, clubs, social networks, communication channels, institutions such as religious institutions and governments, and also the prevailing social and cultural norms. It is the social capital that enables a community to maintain and develop its human and other capitals and therefore the social capital is a key determinant of adaptive capacity within a region.” (Stanley 2010).

As climatic risks increase as a result of more extreme events driven by climate change, so will the level of ambiguity in the community arising from the fact that our understanding of changes in climatic patterns remains limited, particularly at regional and catchment levels (Adamson et.al. 2009). Modelling undertaken by Adamson et.al. (2009) shows that the reduction in social value due to climate change is likely to occur mainly in downstream regions, such as the SA MDB Region due to reduced environmental flows and lower water quality. The SA MDB Region is an area constantly in the spotlight due to its position at the mouth of the river and is posed be highly sensitive to drought, changes in water allocations and impacts to the Murray River further upstream.

A report by ABARE (2010) shows that community vulnerability to changes in water availability varies widely across the SA MDB Region depending on the differing adaptive capacities and sensitivities of particular communities. The report identified two large regions in the MDB with high to very high community vulnerability to changes in water availability. One of these regions is in the MDB southern Basin (ABARE 2010) and therefore is within the study area of this assessment.

There is a range of catchment and regional level organisations working to secure the future prosperity of the SA MDB Region on environmental, economic and community levels. The Murray-Darling Basin Authority (MDBA) (2012) said in describing the MDB Plan (the Plan) that they:

“fundamentally believe that local communities need to be engaged in the management of their part of the river system. That will require support from government. Localism is about using local people to find localised solutions to achieve the objectives of the Basin Plan. Opportunities for local input have been built into the Plan to ensure that communities are given the chance to have their say over the next seven years and beyond in the ongoing development and implementation, including the management of environmental water.”

Referring to the politics of community in the Murray-Darling Basin, Boully and Dovers (2002, p.106, cited in Winkworth 2008) argue “there is no such thing as a catchment or basin community, but rather a highly complex, interacting set of communities.” Some factors that may limit the adaptability of communities to the effects of climate change include:

- social isolation or socially excluded individuals;
- people who lack possible sources of assistance;
• the social stability of a community; and
• access to and availability of resources.

The ABARE (2010) climate change community vulnerability report on the MDB (focusing on irrigation and agriculture) found that sensitivity is highest for communities including the southern Basin communities within the MDB Plan regions of Lachlan, Murrumbidgee, Murray, Wimmera-Avoca and Loddon-Campaspe. According to ABARE (2010) these areas have a combination of high dependence on water for agriculture at the farm level and a high proportion of people in the community who are employed in agriculture and downstream agricultural industries (food processing plants, abattoirs, canneries, etc.).

ABARE (2010) also found that adaptive capacity is lowest for communities including the Lower Darling, Murray and Eastern Mt Lofty Ranges and stated that areas that demonstrate low adaptive capacity are those that show signs of general social and economic disadvantage. Even though the ABARE (2010) study was focused on community vulnerability in relation to irrigation in agriculture, the adaptive capacity measure can be more generally applied as it is an indication of the wider community’s general vulnerability to stressors, including climate change, changes in rainfall reliability, diversion limits or other socio-economic changes. In models run by Adamson et.al. (2009), farmers commonly incur losses in the “drought state.” The results suggest that improvements in the function of water markets could support adaptation to climate change, at least if change takes the form of a proportional reduction in state-contingent inflows. This conclusion is supported by the ABARE (2010) study which found that due to the low adaptive capacity and high sensitivity, some communities in areas of the SA MDB Region were considered to be highly vulnerable to changes in water availability (Figure 48).

Hogan et.al. (2011) investigated farmer adaptation to climate change by categorising farmers on the basis of specific attributes (health, values, belief about climate change, sense of responsibility for climate change, desire to change, social, human and financial capitals and farmer demographics) and by considering social aspects of the contextualised capacity to adapt. The study was based on a nationally representative sample of nearly 4,000 farmers concerned with farmer adaptation to climate risks. The results identified farmers on the basis of belief in climate change, desire for financial assistance and advice, social connectedness, information seeking and adverse farm conditions. Of those sampled, 55% recognised the effects of drought and drying and were actively engaged in adaptive practices, despite the fact that they had little income and poor farm resources. The findings suggest...
that it is the intent to adapt, starting from where people are at in a given moment (i.e. social connectedness, knowledge of climate change and level of health) that is a more important indicator of the capacity to work towards sustainable practices than an asset tests alone (Hogan et al. 2011).

All of these studies conclude with a common message – engagement with the social capital is vital to reduce a region’s vulnerability to climate change and to facilitate successful adaptation. This chapter defines the social capital in the SA MDB Region, considers the potential impacts of climate change and identifies gaps in existing knowledge.

7.1 EXISTING SOCIAL CAPITAL

“Many larger communities in the Basin have grown significantly. Analysis by the ABS has shown that 10 major urban centers in the MDB grew by more than 30 per cent over the period 1976-2012. However, some smaller rural communities have grown relatively slowly, or may even have experienced population decline. This is symptomatic of a long term trend, since the beginning of the twentieth century, for the proportion of the population living in rural areas of the MDB to decline.” (ABS/ABARE/BRS 2009).

According to ABS data (2010) there are approximately 125,000 people residing in the SA MDB study region. In line with State trends for regional areas, the larger towns in the SA MDB Region are growing in population while the population in the majority of smaller towns, including Waikerie, Tailem Bend, Meningie, Pinnaroo and Lameroo is decreasing (Murray and Mallee Zone Emergency Management Committee, Unpublished). Table 18 below shows the area and population totals for each of the Councils in the SA MDB Region. These figures do not take into account homeless people within the zone. According to LGA in 2006 this group numbered 126; however, this figure is based on 2006 Census information and so may not be accurate (Murray and Mallee Zone Emergency Management Committee, Unpublished). Exclusion of homeless data in population figures demonstrates existing social exclusion within the community.

Table 18: Area of and population within Councils of the SA MDB Region (ABS 2010).

<table>
<thead>
<tr>
<th>Local Government Area</th>
<th>Population*</th>
<th>Area km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>District Council of Mount Barker</td>
<td>30,540</td>
<td>597</td>
</tr>
<tr>
<td>Alexandrina Council</td>
<td>23,868</td>
<td>1,800</td>
</tr>
<tr>
<td>Rural City of Murray Bridge</td>
<td>18,402</td>
<td>1,832</td>
</tr>
<tr>
<td>Loxton Waikerie Council</td>
<td>12,062</td>
<td>7,957</td>
</tr>
<tr>
<td>Berri Barmera Council</td>
<td>11,391</td>
<td>508</td>
</tr>
<tr>
<td>Renmark Paringa Council</td>
<td>9,820</td>
<td>921</td>
</tr>
<tr>
<td>Mid Murray Council</td>
<td>8,326</td>
<td>6,266</td>
</tr>
<tr>
<td>Coorong District Council</td>
<td>5,916</td>
<td>8,836</td>
</tr>
<tr>
<td>Southern Mallee Council</td>
<td>2,216</td>
<td>5,695</td>
</tr>
<tr>
<td>District Council of Karoonda East Murray</td>
<td>1,205</td>
<td>4,404</td>
</tr>
<tr>
<td>Gerard Community Council</td>
<td>96</td>
<td>85</td>
</tr>
<tr>
<td>Unincorporated Land</td>
<td>n/a</td>
<td>17,595</td>
</tr>
</tbody>
</table>

The indigenous population makes up over 3.1% of the SA MDB Region population and the largest community is located at Murray Bridge (Murray and Mallee Zone Emergency Management Committee, Unpublished). Ten major indigenous nations maintain their traditional lands within the southern SA MDB Region and are represented by the Murray Lower Darling Rivers Indigenous Nations. The SA MDB Region’s waters, waterways and wetlands remain significant places for indigenous people (Murray–Darling Basin Authority 2010). In the past, the indigenous population in the study area has changed at slightly higher rates than the state average. However, the most recently available figures show that in 2009 the indigenous percentage population change in the study area was equal to that of the State (ABS 2009).
Mount Barker was the fastest growing urban centre in the SA MDB Region. Its population almost tripled from 3,204 in 1976 to 9,153 in 2001. Murray Bridge was the 5th fastest growing town in the same time frame – its population grew from 8,740 in 1976 to 13,017 in 2001 (ABS/ABARE/BRS 2009). To meet the SA Strategic Plan Target 5.9 “Maintain regional SA’s share (18%) of state population” the Murray and Mallee Region (this is the same as the SA MDB Region excluding the Alexandria and Mount Barker Council areas) must continue to grow by at least 864 persons per year (Department of Planning and Local Government 2011).

“Only 15 per cent of the population of the Murray and Mallee live in towns of less than 1000 people and 48 per cent live on farms or settlements of fewer than 200 people” (Department of Planning and Local Government 2011).

Murray Bridge Urban Growth Plan (2006) sets a vision for planned and staged growth (including community, social and infrastructure) over a 30 year period, comprising:

- 15,000 additional people to the year 2030;
- 7,500 new homes; and
- Employment lands identification.

The Rural City of Murray Bridge Plan sets a vision for much stronger growth targets than the 30 Year Plan for Greater Adelaide (RDA 2010).

Population changes impact the ability for communities to respond to climate change. This is particularly prominent in regions where populations are growing smaller at the same time as they are growing older. From the Central Region Integrated Vulnerability Assessment Study:

“It is typically the younger, more vigorous and outward looking individuals that leave rural regions. There is a propensity for rural people to become more geographically mobile in times of drought as they search for alternative sources of income. Those with more responsibility – for example, senior land managers – may tend to stay, while others in their household with fewer responsibilities, or reduced roles, may tend to move (Edwards, Gray et.al.. 2009). This change in household composition may mean that while the individuals who remain are very capable, they may also be highly engaged in their existing responsibilities and consequently lack spare capacity with which to address challenges introduced by climate change. In practical terms it may be that there is a labour shortage to address climate change issues, both in regard to planning (community meetings, group activities) and participation, as people – particularly those in the smaller centres – find themselves stretched thinly between their traditional responsibilities and new ones that may emerge.” (Balston et.al. 2011).
7.1.1 Identified gaps for existing social capital

- The Public Health Information Development Unit (PHIDU) has compiled a thorough set of data for all local government regions in SA. The Social Health Atlas of South Australian Local Government Areas (2011) includes data on a range of population characteristics, including demography, socioeconomic status, health status and risk factors and use of health and welfare services. Some of the data is old, with a large proportion derived from the 2006 Census. The 2011 Census data is due to be released soon and will fill this gap. However, data could benefit from refining for use in interpretation of climate change impacts.

- Detailed information on smaller towns within local government regions would provide greater refinement of future vulnerability studies results.

- Studies have been done in the SA MDB Region on the vulnerability to climate change of the social capital with a focus on irrigation, agriculture and water allocations (drought). Studies are lacking that focus on other predicted impacts of climate change such as extreme weather events (e.g. heat waves, fire), sea level rise, ocean acidification and other threats such as biosecurity.

- Climate change studies to date do not always provide specific information for the SA MDB Region.

- The Regional Development Australia (Murraylands and Riverland) commented on the draft Murray and Mallee Region Plan that it “needs to acknowledge that the region suffers from external factors, such as droughts, water restrictions to commercial irrigators, and a variety of social issues – the Plan needs to help deliver a stronger government focus on the needs of regional communities and the demand (current and future) for services, infrastructure and funding that facilitates growth, but also addresses the social and human impacts facing the region” (RDA 2010). This consideration for climate change impacts on the social and human capitals is lacking in most literature on the SA MDB Region.

7.2 COMMUNITY PLANNING AND DEVELOPMENT

“Rural communities affected by drought suffer place based disadvantage which constrains their capacity to access the opportunity to secure a job; access services; connect with family, friends, work, personal interests and neighbours; deal with personal crisis such as ill health, bereavement or the loss of a job; and have their voice heard.” (Winkworth 2008)

7.2.1 Internet and Communication

Communication methods are an important part of a community’s ability to access information and thus to strengthen their social capital. The use of information channels that enable access to information that is physically and/ or institutionally remote is particularly important for establishing and maintaining linking bonds, specifically bonds between individuals, governments and institutions. Linking bonds are important to a community that may be seeking new technologies and new adaptive approaches in response to climate change (Mowling et al. 2009).

In 2006 a higher percentage of houses within the SA MDB Region were without internet connection compared to the percentage without internet connection in the state (Figure 50) and a lower percentage of houses have broadband connection – most still use a dial-up connection. The Department of Planning and Local Government reported (2011) that the SA MDB Region has broadband services in the major urban centres but there have been problems installing systems for the rural areas. They stated that the “Murraylands is the state’s poorest served broadband region.” This situation puts a community already challenged by distance at a significant disadvantage when adapting to climate change.
In February 2010 a new project to provide improved broadband services to the Southern Mallee Region and south of Loxton was announced (Department of Planning and Local Government 2011). The project leverages off projects already established in the Riverland, Murraylands and Coorong and will result in the provision of improved broadband services to around 50,000 rural premises. Altogether, over $6 million in new broadband infrastructure was planned to be invested in the region prior to 2011. As part of the National Broadband Network (NBN), a new optical fibre backbone will be built between Renmark and Gawler to serve townships along the route, including Berri and Waikerie. The network will also provide new optical fibre connections into homes and businesses at data rates of 100 Mbps and new wireless and satellite connections at data rates of 12 Mbps (Department of Planning and Local Government 2011). The NBN website (http://www.nbn.com.au) shows that work to commence in 2015 will bring fibre and fixed wireless broadband networks to some key centres in the SA MDB Region. It is unclear from the NBN rollout maps if the service will cover key areas such as Renmark, and the smaller surrounding communities within the study area. A three year delay in the commencement of works in identified areas reduces the ability for the SA MDB Region communities to be engaged now.

The eventual increase in internet coverage has the capacity to substitute for other resources and overcome the barriers of distance for health, educational and social purposes. As each of these three factors is critical for enhancing adaptive capacity, internet usage has the potential to provide excellent value to the communities within the study region by strengthening community bonds internally, and by enabling individuals to access resources external to the local community more readily.

"Internet access, particularly broadband will ensure better information delivery and coordination between health care providers and lead to improved health services, instant access to specialist diagnosis and patient management information for local medical practitioners. This information is imperative for the increased demand that climate change will place on the health system and during disaster situations where specialist knowledge and additional advice will be required. It is in these times, however, that the internet is least reliable." (Balston et.al. 2011).

Mobile phone coverage in the Murray and Mallee Region is reasonably effective, however, there are still areas without mobile phone reception. Figure 51 shows the coverage in the study region of Telstra’s Next G network – one of the networks with the highest current regional coverage.
Workshop participants in the Central Region IVA (Balston et al. 2011) stated that services are severely hampered during heat waves and the infrastructure is threatened by fire. There are few people available to repair the facilities, so when the system goes down, it can take long periods of time to repair it. There is an obvious need for more service personnel to be available for repair work, and improved infrastructure to cope with heatwaves (Balston et al. 2011). Similar challenges are likely to apply to the SA MDB Region.

The internet engages individuals and can overcome space and time limitations. Given the lack of public transport available within the study area, and the limited social interaction outlets in some of the more rural areas of the study region, the internet can assist greatly in helping networks form and interactions take place and so lead to a better informed population and increased sense of belonging and identity.

Effective internet connectivity has the potential to be an important factor in enhancing climate change adaptation. The enhanced communication that high speed internet access brings will assist information flows in times of crisis (healthcare management, fire front movements), and will also be equally helpful in ensuring that information regarding long-term climate change mitigation (passive solar building design, new crop management methods, detailed regional weather information) can be accessed and implemented on a daily basis.

The RDA (2010) responses to the Murray and Mallee Regional Plan state that future planning needs to consider current demands of the community for improved facilities and social services, whilst at the same time demanding new and emerging services to meet modern day trends and needs. This identified requirement within an influencing organisation is a positive step forward towards planning for positive outcomes such as improved internet and phone coverage in the SA MDB Region.

7.2.2 Household size

The most common household composition for the study region is ‘couple with no children’, closely followed by ‘couple with children’ and then ‘lone person’ households (Figure 52). Most households in the study region consist of two or more people, a fact that significantly contributes to their adaptive capacity. Multiple occupant households are more likely to be sustained by more than one income stream, and also have wider social networks. They are therefore less vulnerable to sudden changes in financial status and are also more likely to be well placed to access social support in difficult times. In times of change, larger households also have a greater chance for one of the occupants to find an alternative career path if employment options become limited, or in the instance of farming, an off-farm income. Alternative employment options are an important resource for dealing with climate change shocks (Bryan et al. 2010).

Many living expenses in two plus person households are shared and so households with more people are often more likely to be able to maintain a higher standard of living and afford measures to adapt to climate change (Department of Climate Change and Energy Efficiency 2010). One person households are often lower income households and are therefore less able to quickly respond to changing needs. Around 25% of households in the study region report that they are living alone or are a one parent family (ABS 2006). This proportion was slightly below the state average in 2006. In the 2006 Census, 52.0% of persons aged 15 years and over usually resident in Murray Mallee (Statistical Subdivision) were married, 28.5% never married, 12.1% separated or divorced and 7.4% widowed.
Of the occupied private dwellings currently rented in the Murray Mallee area, 30.1% were rented from a real estate agent, 26.6% were rented from a State or Territory housing authority, and 37.1% were rented from other landlord type. In comparison, in Australia, 50.5% were rented from a real estate agent and 14.9% from a State or Territory housing authority (ABS 2006). The data shows almost double the number of houses are rented from housing authorities in the Murray Mallee compared to the average across Australia. In alignment with this, of the home owners surveyed in the 2006 census, 10.3% of households in the Murray Mallee reported mortgage stress compared to the state percentage of only 7.1% (ABS 2006). These figures illustrate heightened household resourcing stress, particularly monetary stress.

Generally, however, across the study region, most households consist of two or more people suggesting that they have a greater range of access to information sources and networks to assist with adaptation to climate change.

7.2.3 Employment

The main industries for employment in the SA MDB Region in 2006 were agriculture, education, health services, and supermarkets (Figure 53). These figures have changed over the longer-term as the proportion of those employed in agriculture in the Region has declined. The 2006 Census figures show that between 1996 and 2006, the number of people identifying themselves as ‘farmer’ or ‘farm manager’ in the SA MDB Region declined by 10 percent, from 74,000 to 67,000 (ABS various years).
The previously low unemployment rate in the SA MDB Region compared to the rest of SA has now changed, as there has been a sharp rise in unemployment recorded since March 2010 (Figure 54). The unemployed residents may be considered a vulnerable community and their access to adequate resourcing to respond in an emergency needs to be considered. As the unemployment rate has increased quite dramatically, it may mean that it will continue to become an increasingly important factor in maintaining a fully functional social capital in the future.
Figure 54: Unemployment rates from March 2008 to June 2010 in the SA MDB Region compared to the State (ABS 2009).

“Communities living in remote and very remote areas tend to have some different characteristics relative to those in the more densely populated inner and outer regional areas. For example, in 2006, there were higher labour force participation rates in remote and very remote areas of Australia. In remote and very remote areas of Australia and the age of the labour force was older and a greater proportion worked over 49 hours.” (ABS/ABARE/BRS 2009).

It has been identified that unemployment is a generational problem in some areas of the state and it is likely these people will also be unwilling to act as volunteers within their communities (Murray and Mallee Zone Emergency Management Committee, Unpublished). As a result these individuals become a burden on social and other networks, while at the same time refraining from contributing to those networks themselves. As mentioned above, the increase in unemployment rates may be due to the change over time of various industries, or due to a reduction in industries from the drought (Murray and Mallee Zone Emergency Management Committee, Unpublished).

7.2.4 Household income

Poverty and low socio-economic status are frequently linked with social exclusion in Australia. The barriers that social exclusion create make it difficult or impossible for people to participate fully in society or to obtain a decent standard of living (Stanley 2010).

There is also a close relationship between people’s socio-economic status and their health – both mental and physical. There is a strong correlation between people with good mental health and those who have a strong sense of community, the presence of social capital, a trust in people and medium to high income. People who experience low income levels or sit at the lowest socio-economic level often experience the highest rate of illness and death. Research also shows that often when a person’s socio-economic status improves, so does their health (Australian Institute of Health and Welfare 2011).

The Murray and Mallee Region Median Household Income (Figure 55) is much lower than the state, and this is likely to carry significant negative implications for the health and wellbeing of those living in this area.
This situation is also the case for Personal Income (Figure 56) which is consistently lower than the State average. This data fits with the general trend for the entire MDB where personal income and average wages are recorded as being lower than the Australian average (Murray-Darling Basin Authority 2010).

In 2006 the dependency ratio in the whole MDB was 55, which means that there were 55 ‘dependents’ for every 100 people of working age. This ratio is higher than for the rest of Australia, where there are 49 dependents for every 100 people (ABS/ABARE/BRS 2009). The added level of dependents for each working age person in the MDB together with lower incomes suggests that the people in the study area are under financial stress. This assumption is supported by the data showing a higher proportion of households under mortgage stress in the SA MDB Region compared to the State (Figure 57).
Research shows that indigenous Australians experience much higher levels of disadvantage than non-indigenous Australians. Given the disadvantage evidenced for indigenous Australians in general, it is very likely that areas with more indigenous people will also show significant disadvantage relative to other areas of the Basin.

“When analysing indicators of disadvantage such as unemployment rates, or people on low incomes, it is useful to compare the Indigenous and non-Indigenous populations. Aggregate population data can mask profound differences in these two population groups.” (ABS/ABARE/BRS 2009)

Socio-economic circumstances can be determined by measuring how easily a person can access services provided by cities and towns. Being close to health and education services can make a large difference to people’s lives, as can the proximity of a diverse job market. Even though there have been many innovations in the delivery of services to more remote areas as a result of improved technology and communications networks, people living in more remote areas tend to have less access to a range of goods and services. Businesses in remote areas tend to have greater transport costs and reduced access to markets (ABS/ABARE/BRS 2009).

The whole MDB showed some declines in the average annual growth of own unincorporated business income and business owners’ income for the period 2001-02 to 2003-04, at a time when most of the rest of Australia showed some growth in these areas. During the period 2001-2006, there was an increase in the agricultural areas of the MDB that were declared as “Exceptional Circumstances” due to the drought (ABS/ABARE/BRS 2009, Murray–Darling Basin Authority 2010).

Building economic diversification in the SA MDB Region will provide better resilience to climate change by reducing the reliance on agricultural and other water dependent industries. The Department of Regional Australia, Regional Development and Local Government are working in partnership with the Department and the Murray and Riverina RDA Boards in New South Wales in a ground-up partnership with communities affected by the MDB Plan to identify a range of opportunities for growth and diversification (Crean 2011). The project involves identifying potential options that build on existing competitive advantages like the natural resource base, local skills, the knowledge of regional universities with input from affected communities, government agencies and the RDA network. The project will involve working with the RDA Boards and affected communities to identify practical solutions for economic diversification from the ground up (Crean...
Emergent industries may provide new employment opportunities in the areas of carbon sequestration and alternate energies (biomass, biofuels etc.).

A South Australian survey showed that households with higher incomes were more likely to implement water saving devices, such as efficient washing machines or dual flush toilets (ABS/ABARE/BRS 2009). This finding is logical. However, a study by Hogan et.al. (2011) found that it is the intent to adapt, starting from a recognised baseline of education, an understanding of climate change, health, community and other social measures, that is a more important indicator of the capacity to work towards sustainable practices than assets tests alone. This finding highlights the need for the social and human capital to be strengthened as a primary function of climate change adaptation and as a critical building block to growing economic, physical and environmental capital within the study region.

The study region has a significantly lower than average income when compared with the rest of the state. This fact will need to be recognised, and if considered important, compensated for, by local agencies and institutions – particularly in regions where income is exceptionally low (Balston et.al. 2009).

7.2.5 Identified gaps for community planning and development

- Regional internet service coverage maps (for all providers) and NBN rollout information is either not available or poorly documented;
- Further information could be gathered on the required services of communities in the study area and possibilities for hastening upgrades (funding sources);
- Data is lacking for the Gerard Community Council area;
- There is little information available about regional occupations and industries and how climate change impacts on communities who are reliant on one or two major industries only;
- Data for the median household income per week for the study region is not readily available (including the Murray and Mallee, Alexandrina and Mount Barker Council areas);
- Data for each Council area is lacking on personal incomes;
- Separate population data for Indigenous and non-Indigenous populations;
- Incentives or other methods for retaining/retrieving the educated youth who leave the region are not clearly understood and would be valuable to know;
- What programs/projects have been working and which have not? e.g. Riverland drought task force, Aboriginal Learning on Country;
- Why do we have an angry reaction to stress? How will society respond to different climate change stresses in the short term and long term?
- What is the ideal size for a community?
- How do we build close families/communities?
- How do we increase situational awareness (education) and how do we act on this to make good decisions?

7.3 Emergency Management

There are a number of emergency situations expected to increase in frequency and intensity as a result of climate change including bushfires, heat waves and possible outbreaks of vector borne and plant / animal diseases. Emergency management considerations for regional areas include the number of people living on farms or in small towns and the distances between residents, the time needed to respond to emergencies and the availability of services (Murray and Mallee Zone Emergency Management Committee, Unpublished). The growth and decline in the population of towns is also important. Growth of a town could mean that there may be new residents who are not aware of the best emergency procedures and emergency contacts. The decline of a town’s population may lead to a lack of available volunteers or knowledge.

7.3.1 Emergency services

The Murray and Mallee Region is primarily protected by the Country Fire Service (CFS), State Emergency Services (SES), SA Police (SAPOL), Metropolitan Fire Services (MFS) and SA Ambulance Services. Local Councils also have the capacity to provide assistance within Council areas (Murray and Mallee Zone Emergency Management Committee, Unpublished).

The State Emergency Service (SES) and the Country Fire Service (CFS) are volunteer based fire and emergency services. There are 55 CFS brigades in the area, and the CFS currently has 1611 volunteers in the region (CFS 2012). The SES gives immediate assistance during emergencies and disasters, and is the hazard leader and control agency for extreme weather. The
SES has more than 1,600 volunteers who are members within 67 units across South Australia. There are seven units in the SA MDB Region including at Murray Bridge, Loxton, Mount Barker and Renmark.

The Municipal Fire Service (MFS) is tasked with responding to fire, chemical incidents and other emergencies. There are four MFS stations in the Murray and Mallee region, located at Berri, Loxton, Murray Bridge and Renmark, and they are operational 24 hours a day. The South Australian Police (SAPOL) regional headquarters is in Berri. There are 17 police stations in the region (nine multi-member stations and eight single person stations). Berri, Renmark and Murray Bridge provide 24/7 services to the community and both have dedicated patrols, CIB, crime prevention, criminal justice, intelligence, highway patrol, and training officer sections (Murray and Mallee Zone Emergency Management Committee, Unpublished).

The SA Ambulance Service has six career stations and 12 volunteer stations in the Murray and Mallee Region (Murray and Mallee Zone Emergency Management Committee, Unpublished). In the regional areas of South Australia there are more than 1400 volunteers that make up a network of over 70 country volunteer teams for the SA Ambulance Service. There is a Community Emergency Response Team proposed for Blanchetown. Recent changes in training requirements have required all ambulance volunteers to undertake extensive paramedical training. Anecdotally this policy has resulted in a loss of volunteer drivers, some of whom are unwilling to undertake the extensive training for activities for which they do not feel they are suited. “Volunteers provide professional emergency ambulance and patient-transfer services within their communities” (SA Ambulance Service 2011).

The spirit and nature of volunteering is readily illustrated through the extensive network of emergency management volunteers who operate throughout the SA MDB Region. 26.49% of the SA MDB Region population had volunteered in the 12 months prior to the 2006 Census (ABS 2006). This figure is high compared to the state’s average of 20.38% (Figure 58). However, the Murray and Mallee Zone Emergency Management Committee believe that this rate has declined since 2006 and that a trend is developing for more people to volunteer but for fewer hours per person (Murray and Mallee Zone Emergency Management Committee, Unpublished). The Murray and Mallee Zone Emergency Management Committee also showed that of these volunteers only 3% are volunteering in frontline emergency management while 20% are volunteering in committees and management roles and 20% in admin/clerical/recruitment roles. In the face of an emergency a higher percentage of volunteers may participate in frontline emergency management, however, the capacity for these spontaneous volunteers to cope well with physical duties and unexpected psychological demands is questionable.

7.3.2 Volunteerism and the volunteer population

As in the Central LGA Region, volunteers are of particular importance to the SA MDB Region as resources are scarce and volunteers represent an effective means of managing intermittent service needs.

“Volunteers are also a critical part of maintaining local social networks. It is possible that the aging population and other social changes will result in a reduced pool of potential volunteers. This situation will result in the reallocation of responsibilities to agencies such as local councils and other paid service providers.” (Balston et.al. 2011).
Due to the aging population the need for volunteers in the area is likely to increase. Winkworth (2008) identified that levels of civic participation, self-help and volunteering are under threat – especially in rural communities suffering the long term impacts of drought. This increased need due to aging population together with an increased need due to climate change may cause an increasing undersupply of volunteers.

It is possible, however, that the baby boomer bulge will result in an absolute increase in volunteer numbers, even if the proportion of volunteers drops. Finlay and Murray (2005) caution, however, that in order to benefit from the pool of potential volunteers as baby boomers reach retirement age, strategies will need to be in place to attract retirees, and volunteering agencies will need to be responsive and provide opportunities for meaningful participation in the types of activities these people choose.

Major General Hori Howard (Howard 2009) provided a succinct overview of the effects of climate change and the emergency volunteer sector and grouped influential factors into several key issues that can be considered in two groups. The first group included external pressures, such as an ageing population, sea and tree changes, rural restructuring, and community and political restructuring. The second group included more subjective or personal pressures such as time commitments, costs, the threat of legal action, and recognition (or the lack of it). While the external pressures are principally within the scope of this report, the subjective or personal pressures should not be ignored as they are an important part of the maintenance of a healthy emergency management sector for the region. These factors would include consideration for increasing costs of volunteering including travel expenses. It also needs to be remembered that existing pressures in this sector are likely to be amplified due to the increasing frequency and/or intensity of emergency events that climate change will bring.

As can be seen in Figure 58, at present the study region is relatively well served by volunteers. These volunteers are a valuable resource for the community in the region, and must be supported and encouraged. Volunteers are much more than convenient unpaid workers – they are also the nurturers of community networks and the cultivators of trust and a sense of belonging in their communities (Balston et al. 2011). It is possible that the SA MDB Region may experience significant falls in the number of available volunteers in future years, in keeping with national patterns of falling volunteer hours.

7.3.3 Identified gaps for emergency management

Emergency management information was generally out of date. Further research is needed to establish whether or not volunteer levels will rise or fall locally. Specific areas that could benefit from further information:

The capacity of local businesses to assist in an incident also needs to be considered (e.g. supermarket, op shop providing goods during and after an incident). There does not appear to be any available statistics in relation to businesses providing this type of...
assistance (Murray and Mallee Zone Emergency Management Committee, Unpublished);

Research into the possibility for organised corporate volunteering;

Detailed information on service provisions to smaller towns and remote areas;

Data on hospital admissions in times of heat waves and the consequential possible strain on emergency transport needs to be assessed for the likely increase in cases with climate change; and

Information on impacts of carbon pricing or fuel pricing on volunteers (increased cost of fuel may reduce the rural community’s capacity to volunteer as the cost of travel increases).

7.4 SOCIAL INCLUSION / EXCLUSION

7.4.1 Sense of belonging to community

“A sense of belonging is one of the key social assets of rural communities and can reduce vulnerability to any change that disrupts social fabric, as drought and other climate change-related phenomena can. However, a sense of belonging can also be a very strong element of successful community-based adaptive responses and needs to be nurtured and maintained to preserve the informal support networks it underpins.” (Balston et.al. 2011)

Social capital involves emphasis on collective action and social networks, the bonding of similar people and bridging between diverse people with norms of reciprocity (Claridge 2004). The distribution and actions of networks and groups, internal dynamics and interaction between people acknowledges important informal social networks within communities and organisations. These interactions create a framework for information flow and empower communities and organisations to analyse risks and implement adaptation procedures without reliance on top-down directives (Pelling 2004).

Three distinct forms of connections are necessary for the formation of healthy social capital:

• Bonding social capital – denotes ties between people in similar situations, such as immediate family, close friends and neighbours;

• Bridging social capital – encompasses more distant ties of like persons, such as loose friendships and workmates; and

• Linking social capital – reaches out to unlike people in dissimilar situations, such as those who are entirely outside of the community, thus enabling members to leverage a far wider range of resources than are available in the community (McMillan and Chavis-George 1986).

If any one of these three connections is weak or absent, the community concerned will have a less secure social capital, and so will be more vulnerable to the effects of change (Mowling et.al. 2009). People with low incomes, people who are unemployed, have a disability, the aged, young and people who live in isolated areas are examples of individuals that may be at risk of social exclusion (Balston et.al. 2011).

According to the 2006 Census 56.4% of the SA MDB Region were members of an organised sport or church or community group in their local area compared to 39.1% in the state. The strong membership base apparent across the region fosters a strong sense of belonging within individuals. A sense of belonging is a vital component of a healthy community and generates the ‘bonding’ aspect of social capital. A sense of belonging stems from the feeling that an individual is within the boundaries of their community, and gives them a sense of security and identity (McMillan and Chavis-George 1986).

Partnerships have been formed between indigenous groups in the area and the SA State government to work on environmental projects funded by the Federal Government. DEWNR’s Coorong, Lower Lakes and Murray Mouth (CLLMM) Program’s Ngarrindjeri Partnerships Project is one of 18 key CLLMM Program projects aimed at helping the region to continue its recovery from the impacts of drought, and to ensure the region and its communities can better cope with future droughts and floods. The Ngarrindjeri Partnerships Project aims to build the capacity of the Ngarrindjeri community to manage the Ngarrindjeri’s cultural and environmental resources throughout the lakes and Coorong region. It will also enable the Ngarrindjeri to continue their broader role in many of the CLLMM Program’s projects, especially in the provision of heritage services, for the benefit of the entire CLLMM community (Government of South Australia 2012). These kinds of affiliations are important for strengthening communities and enhance knowledge sharing and acknowledgment of indigenous heritage.
7.4.2 Leadership and Linking

“Within the Murray-Darling Basin context ‘linking social capital’ refers to directly engaging with government officials, joining political advocacy groups set up to lobby for additional resources and planning decisions, working in partnership with the non government sector and/or business to create new structures and new possibilities. Direct access to and positive interactions with powerful institutions can provide a sense of renewed hope, efficacy and optimism for the future.” (Winkworth, G. 2008).

Effective leadership is a critically important adaptive strength, and for this reason strong community leadership must be supported throughout the study region. Strong leaders who are well accepted by the community will enable informal networks to overcome vulnerabilities much more swiftly. They will also support other sectors of the community (such as volunteers) in their endeavours, to ensure greater resource efficiencies (Balston et al. 2011).

The extent of leadership across the study region is not well documented, but it never-the-less forms an important component of the social capital because leaders engage, empower and encourage others. Powerful community leadership through change is of vital importance in the effective identification, harnessing and utilisation of resources available to a community. Avant and Copeland (2005) have noted that as challenges in rural areas have increased in frequency, complexity and intensity, the quest for rural leadership has become one of the greatest issues facing rural communities. As one might intuitively suspect, effective leadership is central to the effectiveness of communities achieving their goals and positive outcomes. Furthermore, leadership, and how people feel about their leaders, is related to overall community success (Mowling et al. 2009).

The social capital of the SA MDB Region includes well-structured and well informed groups or organisations that concentrate primarily on the vitality of the region with a focus on agriculture and water. Much of the literature that considers climate change is on a basin scale and therefore lacks detail on the smaller towns within the study region. The Lower Murray Landscape Futures (LMLF) (Bryan et al. 2007) reports are produced from a tri-state, multi-organisation and multi-region research collaboration within the lower Murray-Darling Basin, Australia. The collaborative approach and high level of association in the study provides for a strong, adaptable community if continued. However, despite the strong emphasis on leadership throughout the study region, it is not well documented how well leadership initiatives are progressing and how strong uptake is on leadership programs.

The ageing population across the study region suggests that leadership succession could become a problem as there is not a large base of people to effectively take up leadership roles.

“Research highlights that when a critical local institution is threatened – as may happen in the case of climate change – communities become most active in finding innovative and collaborative solutions to ensure that local service are preserved. Leaders are integral to bringing together disparate sections of the community, particularly in times of crisis or significant change when participation by the wider community is needed to resolve the problem. Leaders bring together the community both to keep them informed and to work together to facilitate a plan of action. Public forums have proven to be one of the most important opportunities for information transfer and learning in rural communities, and social relationships are the key to ensure that learning and leadership is effective” (Balston et al. 2011).

Leadership is vital to the adaptive capacity of the SA MDB Region due to the importance of mentoring young leaders and succession planning. However, with the population ageing, and younger people less willing to become leaders, there is concern that communities may lose the ability to achieve their goals.

7.4.3 Crime perceived / real

Crime is a threat to social capital and areas of high social capital are rarely areas of high crime. Similarly, a pervasive theme in the study of social capital is that as social capital declines, crime increases. For these reasons it is important to assess the levels of crime in a region, along with the perceived levels of crime. This information can provide insight into the state of the local social capital (Mowling et al. 2009).

Reduced levels of crime and better health have been associated with resulting social benefits for the local area (ABARE 2010). Therefore levels of crime and perceived levels of crime are strong indicators of the strength and health of community networks. As in the Central Region IVA, crime levels in the SA MDB Region are low at present (Figure 59), suggesting a high level of social capital. However:
“Disasters and other events precipitated by climate change are likely to cause increases in specific types of crime. These must be anticipated and countered to maintain the existing high levels of social capital in affected communities.” (Balston et al. 2011)

Climate change stressors such as heatwaves, are likely to be associated with an increase in personal violence (associated with increased alcohol intake, increased stress and increased levels of mental health disturbance). Disasters are likely to be associated with increased levels of property offences, as opportunistic individuals loot the damaged or unattended property. These changes in crime patterns need to be anticipated and prepared for (Balston et al. 2011).

In 2007 two Murraylands organisations received funding under the Small Grants initiative of the National Community Crime Prevention Programme (Secker 2012). Amy Ambagtsheer, Regional Coordinator of the Murraylands Victim Support Service said, in December of 2011, that “One of the areas of crime that has been highlighted in my area (Murraylands) has been that of serious assaults, in particular offences against, and by, young people. This has included home invasions, aggravated assaults, vehicular assaults and gangs assaulting individuals, and client numbers in these areas have escalated in recent times. I am currently planning to provide training and awareness in combination with other organisations who address this type of violence, and am looking at providing training to school-aged people and identifying the need to address crime as a community.” This finding suggests that crime rates in some parts of the study area are of concern and further information is needed to bring data up to date and into perspective with the rest of the study area and the state.

Statistics from the Office of Crime Statistics and Research (2008) show the crime rates in the SA MDB Region are well below the State average, a finding that would suggest that social capital is high. However, the level of perceived crime is unknown, data on crime rates is relatively out of date and variations between towns within the SA MDB Region would be important considering the focus in the media on the Murray Bridge area.

7.4.4 Multiculturalism

The proportion of overseas-born residents in all regions of the whole MDB is consistently lower than in the rest of Australia (Murray-Darling Basin Authority 2010). In 2006 there were 201,355 people residing in the MDB who were born overseas – 10.7% of the Basin population (ABS/ABARE/BRS 2009). There are approximately 50 different nationalities represented in the Murray Mallee Region (Murray and Mallee Zone Emergency Management Committee, Unpublished). The majority of residents of the MDB Region who were born outside of Australia were born in England, New Zealand, Germany, Netherlands and Scotland. The most widely spoken language in the region, other than English, is Greek. Other frequently spoken languages include Italian, German, Punjabi and Mandarin (ABS 2006). In recent times there has been an increase in residents who were born in Afghanistan and Korea (Murray and Mallee...
Zone Emergency Management Committee, Unpublished). The numbers of residents who speak Greek and Italian may be declining as this group get older. The majority of their children are expected to be bilingual, although numbers are expected to decrease with each generation.

“The region has benefited from skilled migration, and local communities have been welcoming of different cultures with Chinese, Afghan, Uzbek, Bhutanese and Sudanese communities now well established, and both Murraylands and Riverland regions are positioning as a preferred region for inward migration of refugees and skilled migrants” (RDA Murraylands and Riverland 2012).

There are a large number of multicultural transient workers who reside within the SA MDB Region at certain times of the year predominantly to obtain seasonal farm work. These numbers are declining as automation of industries (such as viticulture) reduces employment opportunities (Murray and Mallee Zone Emergency Management Committee, Unpublished).

7.4.5 Identified gaps for social inclusion / exclusion

Additional information would be useful, including:

• Need further research to establish level of memberships across the region in different sectors (i.e. sport and recreation, art groups, church groups including data on involvement in nature conservation groups such as “save the Murray” groups);

• No localised information available about the potential climate change impacts on indigenous people residing in the study region;

• Crime data was often out of date and did not provide enough information on individual towns;

• Data not available on crime/domestic violence and livestock theft and the changes in levels of these crimes that could be expected with climate change.

• Little information has been documented about perceived crime in the area. If people are complacent this could lead to an increase in crime across the region, particularly after disaster situations. Data collected could include the number of persons involved in community watch programs etc.;

• Data on the number of leaders, how well engaged they are and resources available to them, are all unknown or not documented;

• How do we support early adopters/leaders?

• How do we empower communities and enhance citizen centric decision making?

7.5 SUMMARY GAP ANALYSIS OF SOCIAL CAPITAL FOR THE MURRAY-DARLING BASIN REGION OF SOUTH AUSTRALIA

Data analysis could benefit from collection or segregation of data into a range of groups so that it can be analysed in a variety of ways i.e. indigenous and non-indigenous data separated out, youth and adult health data separated out, incomes shown as an average for part time and full time workers separately etc. This data would allow some conclusions to be drawn, for example; is the variance in personal or household income in some areas due to the high proportion of part time workers or are there actually lower incomes for full time workers? Some of this information may become available with the release of data from the Australian Health Survey 2011-13 (ABS 2012). Data from this survey is still being collected and the date of data release is unconfirmed.

Limited recent information is available in detail for the SA MDB Region. Release of the 2011 Census data later this year will address the age of some data.

Vulnerability studies to date usually have an environmental or water focus and therefore studies with a focus on the effect of the complete range of predicted climate change impacts on the social capital would be highly valuable.

Study into the causes of happiness in the region would be beneficial to ensure community satisfaction in the future. Adaptation will need to have a focus on achieving positive outcomes instead of avoiding negative outcomes.

What are the opportunities arising from climate change and how can they be identified and achieved?
8 The human capital of the region

“The human capital involves health, knowledge, skills and motivation and can be enhanced by education and training and life experience. All communities depend on healthy, well-resourced individuals to enable them to function in an efficient and sustainable manner. In rural areas, the successful self-management of human capital, that is often significantly scarcer than in comparable urban areas, is crucial.” (Mowling et.al. 2009).

As stated in the Central Local Government Region IVA:

“Education is a significant determinant of individual health, regional development and the sustainability of rural communities and therefore an important tool in adapting to change and mitigating the potential challenges of climate change (National Rural Health Alliance Incorporated 2009). Educational attainment can impact on employability by increasing employment prospects, financial capacity by providing an income due to job prospects and social wellbeing. The higher an individual’s level of education and literacy, the better their health is likely to be (National Rural Health Alliance Inc 2009). Education provides people with knowledge and confidence and can decrease social exclusion by removing barriers such as lack of educational opportunity, low social capital and connection to the community, low income and unemployment. People facing disadvantage and social exclusion are more likely to have difficulty in adapting to climate change, predominantly because they have fewer resources available to deal with the challenges (Stanley 2010)” (Balston et.al. 2011).

Human capital is an integral part of every individual’s life, but is often understated or even overlooked entirely by those outside the sphere of the social sciences, as it is so well incorporated into our daily experience. All communities depend on healthy, well-resourced individuals to enable them to function in an efficient and sustainable manner. In rural areas, the successful self-management of human capital, which is significantly scarcer than in urban areas, is crucial (Balston et.al. 2011).

Human capital is composed of people’s health, knowledge, skills, relationships and motivation. Indicators that measure the human aspects of a community usually include health and wellbeing, population age structure and education. Factors that may limit the human adaptability of communities to the effects of climate change include:

- Education – people who lack knowledge about climate change;
- Age – the age structure of the population;
- Health – both that of individuals and the overall existing health care system.

Each of these measures is examined in this chapter and discussed with particular relevance to climate change.

8.1 EDUCATION

The Murray and Mallee Region comprises 29 childcare facilities, 93 government schools, 10 non-government schools, and TAFE campuses located at Murray Bridge, Berri, Waikerie and Renmark (Murray and Mallee Zone Emergency Management Committee, Unpublished).
focused community can be severely hampered by a lack of ability to access and apply the information they need (Mowling et al. 2009). Students in rural areas are less likely to be enrolled in school, more likely to have absences, less likely to complete the compulsory school years, less likely to complete Year 12 and less likely to participate in tertiary education and training (Australian Human Rights Commission 2000). This finding holds true in the SA MDB Region which has much lower percentage of people completing year 12 or equivalent than State average (Figure 60). The Murraylands and Riverland have approximately 23,300 people whose highest level of educational attainment was year 11 or lower in 2006 (RDA 2010). The figures also show that a larger portion of people in the study region are finishing their schooling in years 8-11 compared to the State average. Conclusions could be drawn that school leavers are entering into work on farms in the study region and as the farms are family businesses that are passed on from generation to generation (Australian Government 2011) training required may be done on the job without any formal qualifications.

The perception that tertiary education is of lesser importance in rural areas (James 2000) restricts job options in the face of reductions in on-farm work, reduces capacity for income generation and limits economic diversity required for adaptable communities. Lower educational levels can also limit the ability of a community to fully engage their social capital and subsequently makes them more vulnerable to climate change (Mowling et al. 2009).

While costs are predicted to increase due to mitigation and adaptation to climate change, along with declining industry production, there is a risk that household funding previously allocated to education will reduce (National Rural Health Alliance Inc. 2010). In low socio-economic regional groups, especially where living away from home is required for study, the accessibility of obtaining a qualification is likely to decrease.

The Murraylands and Riverland Regional Roadmap and Strategic Plan highlights that the region “has among the poorest levels of educational attainment in South Australia” (RDA 2010). Of the people residing in the study region that have gained non-school qualifications and stated a qualification they have attained, the highest percentage (17.71%) is in engineering and related technologies (Figure 61). This proportion is similar to the percentage of people who have qualifications in this field of expertise at a state level. Of note is that the proportion of non-school qualifications undertaken in Agriculture, Environmental and Related studies is substantially higher than the State average. This finding aligns with the primary industries of the region that include agriculture, manufacturing, fishing and mining (ABS 2010).
Qualifications in agriculture, environmental and other related studies also reflect the main industry of employment by occupation (Figure 62) for the SA MDB Region – Farmers and Farm Managers. A noticeable lack of mining or engineering occupations in the region may be due to the fact that the data is old (2006) or may highlight a mismatch in acquired qualifications and job availability. The RDA acknowledges that “people with low educational attainment are more vulnerable to periods of unstable employment, unemployment or being out of the labour force altogether, unless they are able to improve their foundation skills. Increasing workforce participation requires improved access to training and improving the attainment of qualifications” (RDA Murraylands and Riverland 2012).

Challenges presented by climate change, potential global food shortages and the increasing skills needed in agricultural industries, particularly due to advancements in technology, highlight an increasing need for people to be appropriately skilled to effectively overcome challenges. With few non-school qualifications in agriculture, environmental and related studies in the study region, it arguably does not place the industry in a favourable position to improve productivity and address issues such as sustainability and climate change (Industries Development Committee Workforce – Training and Skills Working Group 2009).
The lack of literacy and numeracy skills associated with low educational attainment was highlighted as a major issue during the stakeholder forum session undertaken in the Murraylands Network Region in March 2011. The Murraylands South Australia Works Network has identified for 2011-14 the need for career development services and foundation skills programs to address low levels of regional educational attainment, and post school qualifications to increase workforce participation (RDA 2012).

The RDA is partnering with the ‘South Australia Works’ program and will partner with networks, employers and local organisations to deliver career development services and targeted projects in response to local labour market needs. Career development services are planned for each region to support individuals to make sound career choices that respond to local labour demands, encourage workforce participation by providing an entry point for people not participating in the labour market, unemployed people and jobseekers. Career development services will incorporate skills recognition services to boost qualifications and enable local people to meet local skill shortages (RDA Murraylands and Riverland 2012).

A lack of education implies a disadvantage in both information and financial resources and therefore increases the vulnerability of a region to climate change. A lack of either information or money will slow the ability of a community to respond to a challenge significantly, but a lack of both may be extremely serious both in the long- and the short-term (Balston et.al. 2011).

Access to educational opportunities is more difficult for potential students in the Region due to distance to and lack of facilities offering a full range of courses. Medicine was highlighted at a forum in Murray Bridge on the 24th of July as being one discipline not available in the study region (pers. comm. Donna Sell, SA Murray-Darling Basin NRM Board). This constraint would be a barrier to the full uptake of educational opportunities available and hinders the development of an educationally linked network amongst younger people. The effects on climate adaptation are most likely to be observed in a reduced ability to acquire and transmit both learning skills and information directly related to the mitigation of climate change impacts. Reduced access
to educational facilities may also hinder full
development of social networks amongst the
educated youth (Balston et al. 2011).

Education is a significant determinant of
individual health, regional development and
the sustainability of rural communities, and
therefore is an important tool in adapting to
change and mitigating the challenges of
climate change. The SA MDB Region has a
much lower than state average percentage
of people completing year 12 or equivalent. In
addition, of those people who have completed
non-school qualifications, the majority are not in
the main fields of employment within the study
region. These factors indicate a miss-match
between local educational opportunities and
local needs that hopefully will be addressed,
at least in part, by the ‘South Australia Works’
program.

8.1.2 Identified gaps for Education

• Research into the potential changes in
  education facilities, course offerings or
  job matching assistance that may lead to
  retention of young people in the region;

• The impact of climate change on education
  systems (attendance, school closures due to
  heatwaves/bushfires);

• Data to show if there is a link between the
  lower income households in the region and
  the effect this has on education level and
  qualification types achieved; and

• Education awareness may be low due to
  lack of service providers in the region. How
  can this be increased?

8.2 AGE

“The total population of Australia is ageing,
and this trend is slightly more pronounced in
the Murray-Darling Basin. In 2001, 13.1% of the
Basin population was aged over 65, and this
increased to 14.5% in 2006. Not only is there a
smaller proportion of younger people in the
Basin, but the proportion is particularly low in
the 25-34 age group.” (Murray-Darling Basin
Authority 2010).

Age has a direct impact on the human and
social capitals. The very young and the very old
are most vulnerable to a number of hazards,
ranging from poverty through to health-
based vulnerabilities. Individuals in these age
brackets are more likely to have special care
needs, and tend not to be very productive
in terms of generating economic capital for
the community. Thus, the age structure of a
community is of considerable importance
when assessing its resilience and adaptability
(Mowling et al. 2009). Figure 63 shows the age
structure of the population in the whole MDB in
2009 (ABS 2009).

Figure 63: Age of the population in the MDB in 2009 (ABS 2009)

The highest proportion of people within the SA
MDB Region fall within the 45-59 age bracket.
There is a reduction in population in the age
groups from 20-34, as young people leave the
region to study or work in urban areas (ABS/
ABARE/BRS 2009). Of all the people living in
the SA MDB Region, 23% are aged over 60.
The Murray and Mallee Zone Emergency
Management Committee (Unpublished)
noted that between 1996 and 2006 there was
an increase of 26% in the number of people
aged 60-69, a 16% increase in those aged
70-79 and a 49% increase in those aged more
than 80. Ian Yates, CEO of the Council of the
Aging SA (COTA SA) said (April 2012) that there
are currently about 185,000 people over the
age of 70 in South Australia – a number that is
predicted to increase over the next 15 years
to more than 313,368, and that will place a
huge pressure on an already struggling aged
care system. The SA MDB Region is expected
to be strongly affected by this trend, due to
the tendency for retirees to move back into the region or to remain in the region (Murray and Mallee Zone Emergency Management Committee, Unpublished). Mr Yates stated that South Australia will need an almost eighty percent increase in the number of aged care beds and community care places by 2027 or see a crisis for the state’s older residents (SeniorAu 2012).

Figure 64 shows that there are slightly less females than males in the SA MDB Region in the younger age groups. This imbalance eves out somewhat after the 30-34 year age bracket, and remains balanced until the over 70 cohort, where there are more females than males.

![Figure 64: Population by age and sex in the SA MDB Region Compared to the State (ABS 2009)](image)

Population growth in the Murray and Mallee Region over the ten years from 1996 to 2006 was predominantly recorded in the 40-59 age group (Figure 65), and the number of people in the under 14 and 25-39 age groups declined significantly.

![Figure 65: Population growth in the Murray and Mallee Region by age group (ABS 1996, 2001, 2006).](image)

The age population profile for indigenous Australians is younger, and they have a lower life expectancy compared to the non-indigenous population (Steering Committee for the Review of Government Service Provision, 2009). In 2006, at the Australia level only 8.7% of indigenous Australians were aged 55 years or over across the whole MDB compared to 26.7% of the non-indigenous population (ABS/ABARE/BRS 2009).
The make-up of the state’s population is also changing dramatically – it is ageing at a faster rate than the other Australian states and this will bring significant challenges for planning, particularly in terms of the type and location of housing and its proximity to services (Department of Planning and Local Government 2011).

8.2.1 Identified gaps for Age

More information is needed about the ageing population and how this will impact on the study region. Special consideration needs to be given to the health sector as it is expected the demands will increase with climate change stressors.

8.3 Physical Health

“Human mental and physical health is vulnerable to climate change. Direct effects of this vulnerability can range from life-threatening heat stroke in the very young and the very old, and a significant reduction in productive capacity in people of intermediate age, through to greatly increased expressions of heat-induced confusion and dementia, and episodes of mental instability in vulnerable individuals. Indirect effects can include depression and suicide amongst those affected by drought, increased vector borne disease (e.g. Ross River virus) and food borne disease caused by heat induced breakdown of the food storage and handling cool-chain. Other direct effects include dust menace, and indirect effects such as the exacerbation of existing poor health conditions. Ill health is costly as it increases the drain on the medical system, reduces productivity and has a negative effect on social support networks. People suffering from poor health are significantly more vulnerable to any additional change, including climate change, and have a lower adaptive capacity. Climate change impacts may have physical or mental health consequences, and those in rural areas are more likely to be affected” (Balston et al. 2011).

The SA Department of Health is undertaking research to support adaptation of the South Australian population to the effects of climate change – particularly extreme heat events and has developed a booklet and fact sheet outlining strategies to identify the effects of extreme heat in the individual and a manage extreme heat events. An extreme heat action plan has also been developed for public health providers in the State. Ongoing research with Adelaide University Discipline of Public Health will examine the impacts of heatwave to identify risk factors for individuals including thresholds and triggers of heat collapse.

The study region has poor indigenous health (the highest level of ‘years of life lost’ outside of remote South Australia), and high rates of obesity, smoking, substance abuse and psychological distress (RDA Murraylands and Riverland 2011). Access to health facilities, availability of professional health care staff and the range of health treatments available in the study region is limited compared to urban areas.

8.3.1 Access to Medical Care

The Murray and Mallee Region has 12 main health facilities (Figure 66) with six outreach clinics. Barmera, Berri, Karoonda, Loxton, Mannum, Meningie, Murray Bridge, Pinnaroo, Renmark, Tailem Bend and Waikerie all have hospitals. Berri Hospital is currently being upgraded and Renmark Hospital is protected by levee banks. Karoonda and Pinnaroo do not currently have doctors in residence (Pinnaroo also provides health services to Murrayville in Victoria). Despite this, health services within the SA MDB Region are more difficult to access than in the city (RDA Murraylands and Riverland 2011). The SA MDB Region also has a lower proportion of health workers than the average for rural South Australia, and retention of health workers is an on-going issue (RDA Murraylands and Riverland 2011).

![Country Health SA](source: Country Health SA 2012)

Many towns also have residential care facilities that may not be located within the hospital complex. There are also several facilities...
within the SA MDB Region for those with disabilities including Orana at Loxton, Shiralee House in Renmark and several facilities run by Community Lifestyles Incorporated and Cara at Murray Bridge (Murray and Mallee Zone Emergency Management Committee, Unpublished).

The heightened potential for bushfire or heat related illnesses and other life threatening occurrences as a result of climate change reinforces the need for an expanded emergency response in the region, particularly ambulance. The SA Ambulance Service (SAAS) currently has stations dispersed across the study region, with a large proportion of these relying solely on volunteers to enable responses (Figure 67). As noted in the section on Emergency Services, the Murray Bridge, Mount Barker, Berri, Loxton, Renmark, Barmera and Wakerie Stations are staffed by paid officers and the remainder are volunteer stations. There is a proposed community emergency response team for Blanchetown. For more life threatening cases, SA Health (MedSTAR Emergency Medical Retrieval Service) and the SA Ambulance Service rely on MAC Rescue helicopters to transport critically injured and ill patients from regional South Australia to major hospitals. The helicopters are also used for policing, bushfire management and search and rescue tasks (Motor Accident Commission 2011).

![Figure 67: Location of ambulance services across the study region (SA Ambulance Service 2011).](image)

Figure 68 shows that in 2006 there was a lower number of aged care places per 1000 persons aged 70 or older in the SA MDB Region (78) compared to the State (93). The coverage of these facilities fails to meet the health needs of the ageing population and statistics show current coverage of aged care places in the study region is lower than the state average (Department of Trade and Economic Development 2011).

![Figure 68: Number of aged care places per 1,000 persons aged 70 or older in the SA MDB Region compared to the State (Public Health Information Development Unit 2008)](image)
Given the reliance on volunteers for emergency response across the study region, volunteer numbers are integral for upkeep of services and to ensure the community is serviced in times of need (refer Emergency Management section). The SAAS, like many other community organisations, “faces the challenges of high volunteer attrition rates, diminishing regional resources, continual changes in community profiles and competition from other community agencies for volunteers” (Marshall 2003). With an ageing population and low youth retention in the study region, volunteer numbers can be expected to plateau or decline in future years. This trend presents a number of issues for ambulances responding to a potential increase in call-outs due to climate change stressors such as heat waves. The regional area is therefore at greater disadvantage when compared to their metropolitan counterpart as stations within Adelaide are “career stations” where people are paid to staff ambulance stations full time and respond to call-outs.

8.3.2 Identified gaps for Physical Health

- Obesity data needs to be analysed and considered as a relevant indicator of health in the study region;
- Health services analysed in the region should be expanded include Eastern, Western and Alternative medicines;
- What is planned through the funding of the Wellbeing program in Murray Bridge ($700,000 fund) and how may this improve physical and mental health in the study region?

8.4 MENTAL HEALTH

“Rural regions suffer from higher incidences of mental health problems, partly due to specific physical, economic and social circumstances and partly due to the barriers encountered when seeking effective care. Climate change is likely to make many of these factors more pronounced” (Balston et.al. 2011)

“The Murraylands and Riverland region has higher incidents of mental illness (exacerbated by the cessation of Exceptional Circumstances payments outside of the River corridor and of the Rural Solutions Drought Counselling Service)” (RDA Murraylands and Riverland 2011).

Recently released research shows that 17% of farmers in drought affected areas of Australia suffer from mental health problems such as anxiety and depression, compared with eight percent in non-drought affected areas (Edwards et.al. 2009). Up to 10% of land managers in drought affected areas are taking anti-depressant medication, compared with fewer than three percent in non-drought areas. Rates of medication are even higher for the unemployed and reach levels of almost 25%. Overall, the findings indicate that mental health problems approximately double in drought affected regions (Edwards et.al. 2009).

“The forecasted increases in temperature and heatwaves and reduced rainfall as a result of climate change have the potential to severely impact on people’s livelihoods across the study region, particularly those reliant on agricultural systems that need rain to support many of their industries (agriculture, viticulture etc.). With these impacts comes the possibility of increased mental strain due to loss of stock/production (and hence income), and increased isolation (due to a subsequent decrease in participation in community networks)” (Balston et.al. 2011).

Unfortunately, if mental health issues go undetected or are not treated, the outcomes can be devastating and lead to self-harm. The South Australian suicide rate per 100,000 people for the years 2005-2009 was higher than the Australian average (Figure 69). Suicide rates are higher in rural areas when compared to urban areas in general (Page and Fragar 2002). Findings of the Australian Institute of Health and Welfare (2008) report on rural, regional and remote health showed that rates of death by suicide in regional Australia were about 20–30% higher than in major metropolitan areas (25–40% higher for males). In remote and very remote Australia, male rates of death by suicide were observed to be 1.7 and 2.6 times higher respectively (Commonwealth of Australia 2010).
There is a demonstrated link between living in rural areas and higher incidences of mental health problems (Australian Government 2010). The problem lies in accessing help and services to counteract the issues faced by those suffering from mental health difficulties. A lack of information and access to mental health facilities exacerbates the problem regionally, as do factors such as isolation, fewer networks to seek help from or to recognise when a problem exists, and reluctance amongst regional people to discuss personal issues with acquaintances from rural services. Men are more at risk of long-term effects from mental health. The literature suggests that they are estimated to access mental health services provided by General Practitioners at only 50 per cent of the rate women do (National Rural Health Alliance Incorporated 2009).

While the region does have an established mental health network, it is not clear if those who will need it in the future will be able to access it readily enough. An analysis of population health data identified youth health as a significant problem in rural South Australia, and in particular for the Murray Mallee (Murray and Mallee General Practice Network 2012). Mental Health Support for Drought Affected Communities provides community outreach and crisis counseling for distressed individuals, families and communities in drought affected rural and remote areas including the SA MDB Region. Community awareness activities and training and support for clinicians and community leaders are also provided (Murray and Mallee General Practice Network 2012).

As drought events and more extreme weather events such as heatwaves and bushfires are predicted to increase with climate change, the mental health of individuals, and consequently communities, is likely to decline if adequate intervention and support is not available. On-going drought can also cause feelings of loss, grief and hopelessness, all of which can contribute to an increased risk of subsequent psychiatric morbidity. The farming profession is especially vulnerable as it is associated with a unique set of stressors such as reliance on environmental conditions, that are somewhat unpredictable, and financial or business related pressures. These stressors can have flow-on effects throughout rural communities dependent on farming, particularly those that suffer isolation, economic disadvantage and limited services (Balston et.al. 2011).

8.4.1 Identified gaps for Mental Health

- The impacts of climate change on mental health is not well documented in the SA MDB Region, however studies on the impact of drought highlight some;
- Suicide amongst children under 15 is not recorded, but this is also an age group that may also raise concern;
- Regional suicide rates need to be assessed;
- Information on social dislocation after a climate change event is not well researched;
- Consider other indicators and strategies to improve mental health by linking in with Beyond Blue and other mental health organisations; and
- Consider findings in “Kicking the Dust – The Past, Present and Future of Young Farmers in the Mid North and Southern Mallee of South Australia” by Ann Clarke and Bradley Morgan (2008) and how their research may inform adaptation planning.
8.5 SUMMARY GAP ANALYSIS OF HUMAN CAPITAL FOR THE MURRAY-DARLING BASIN REGION OF SOUTH AUSTRALIA

A range of useful data exists for some local government areas especially those included in the “Murray and Mallee” region. As some data is only available by Council Region this made it hard to include additional Council areas into an assessment. For example, Mount Barker Council data is often lumped in with the Adelaide Hills Council data as Adelaide Hills regional data. In general then there is a lack of recent, consistent data sets, covering the entire study area in enough detail to allow analysis.

Further information broken down by individual Council areas that would be of significant use includes:

- Level of climate change knowledge and acceptance within the community;
- Mental health – levels, perception, treatments, recovery;
- Ageing population and the effects of climate change; and
- Ageing population and the effects on health services.
9 Stakeholder Workshop

An important part of undertaking an IVA is to ensure that stakeholders from a wide range of sectors are involved in the process from the beginning to capture the varied perspectives and skills that they have and to create a sense of ownership in the outcomes.

As the end product of an IVA is a regional Adaptation Plan, the more diverse and engaged the Region is in the process the more likely the adaptation plan will be supported and enacted.

To this end, a stakeholder workshop was held at the Murray Bridge Natural Resources Centre on the 24TH July 2012 to brief them on the project and progress to date and to provide them with the preliminary findings of the review (Appendix 2). Stakeholders then had the opportunity to identify any outstanding gaps in the research that had been missed (Appendix 3), provide additional references and explore the types of decisions that they will have to make in the face of climate change within their sector. Knowing what the decisions are that need to be made and the timeframe over which actions need to be implemented provides guidance to the selection of climate change scenarios and the types of data that may need to be sourced to inform the IVA.

As described in the LGA SA guidelines for undertaking an IVA “Some decisions have shorter lead times and short-term consequences and so are more flexible and can be implemented incrementally over time (e.g. planting annual crops). Other decisions have a longer lead time and long-lived consequences that may be hard to reverse and so are less flexible and need to be considered within in a more strategic time frame (e.g. construction of a dam or planned location of a coastal suburb).... determining the key decisions that need to be made at this stage in the process identifies the time lines that are important, and therefore the climate change scenario to select.”

Feedback was provided on the day in workshop sheets (Appendix 4) and collated after the day (Appendix 5). Workshop handouts were sent out to participants after the day and additional feedback was captured using an online survey. Results from the online survey were added to those collated on the day (Appendix 5). An evaluation of the day was also undertaken and results are provided in Appendix 6.

The workshop was well attended and included a presentation by each of the review team and representatives of other key sectors in the Region including agriculture, tourism, emergency services, coastal management and local government. References missed and gaps not identified in the desktop review were then included to ensure as much of the local knowledge was included in the report.

Key decisions that were identified as important in the short term (< 5 years) included decisions pertaining to water management and long-lived trees. Those that will need to be addressed in the coming 5-10 years included short lived vegetation decisions, infrastructure, utilities (water infrastructure, roads) and buildings. Decisions for the longer term (>10 years) that were identified included land use planning rail and gas infrastructure. Many other decisions did not have time frames specified – in particular the social and human dimensions that present less tangible and arguably more complex problems. It will be important to consider all of these decisions in the next phase of the IVA prior to determining the climate change scenarios and key sectors to include.
10 Conclusions and next steps

This review was undertaken as part of Phase 1 of an integrated climate change vulnerability assessment of the SA MDB Region. The review provides a thorough analysis of all relevant climate change research of relevance to the Region and includes input from key stakeholders. The gaps identified for each of the indicators assessed appear in the main text of the report and are summarised here.

10.1 CLIMATE SCIENCE AND PROJECTIONS

There has been a significant amount of work done to quantify the current and expected changes to the climate across the whole MDB and SA MDB Regions. Coarse resolution maps at a state scale are available for most climate parameters (temperature, rainfall, evaporation, wind, and sea surface temperature) from the Bureau of Meteorology. High resolution maps of annual climate changes are available for the Lower MDB area for temperature, rainfall and a rainfall index for four selected scenarios that span the range of IPCC scenario projections for the Region but that are independent of time (Bryan et al. 2007). Future climate change projections for the SA MDB Region are available in table format for seasonal and annual temperature, rainfall, evaporation and wind (Hayman et al. 2011) for the years 2030 and 2070 for a low (B1), medium (A1B) and high (A1FI) emissions scenario but not in map format.

Projections of extreme events are for individual locations (heatwave at Strathalbyn) and extreme rainfall at Murray Bridge, Langhome Creek, Swan Reach, Eudunda and Australia Plains and bushfire index at Adelaide. Projected changes in temperature, rainfall, evaporation and wind for the SA MDB Region do not appear in the literature for the years 2050 or 2100 but could be extracted from a number of sources. Projections for future heat wave and rainfall intensity and frequency are limited for centres within the SA MDB region. Projected changes to the Forest Fire Danger Index (FFDI) have not been done for locations in the region.

10.2 ENVIRONMENTAL CAPITAL

There is a large amount of relevant data and highly useful conceptual models to support an IVA for the Environmental Capital. Furthermore, there are well-defined targets for environmental condition across many components of the Environmental Capital that will be extremely useful thresholds against which to assess possible impacts of climate change.

The assessment will, however, be constrained by factors such as: a lack of fine-detail and/or relevant mapping products (e.g. locations of refugia); limited understanding of how individual species may be affected by climate change; and our poor understanding of how population dynamics, trophic interactions, indirect effects of stressors (e.g. temperature, salinity, moisture availability) and dispersal mechanisms will be affected by climate change. Gaps such as the lack of foundational reports specific to the study region (e.g. assessment of the effects of climate change on terrestrial vegetation) are likely to take considerable resources and time to fill, therefore the use of surrogate or indicator species that we have a good understanding of and the development of conceptual models of key ecosystem processes and services will be essential.

For the SA MDB Region the most important gap in our knowledge, by far, is our very poor capacity to predict River Murray inflows and water demand and thus determine how much water is likely to be available for the different components of the Environmental Capital dependent on water. It will be possible to interrogate available data and models to develop a tight set of climate based scenarios for an IVA but there will need to be explicit assumptions made about how water will...
be differentially allocated between human and environmental users by policy makers under different climate conditions in order to proportion water to the environment.

Quantifying the governments and community ability to adapt under given climate change scenarios will be challenging. Actions that occurred during the Millennium drought provide an indication of historic adaptive capacity under extreme climate conditions, but also suggest that society have a limited capacity to predicted future actions that may be required.

10.3 PHYSICAL CAPITAL

There are significant gaps in literature regarding the effects of climate change on transport infrastructure, service networks, communication networks and buildings in the SA MDB Region. Some climate change effects relating to buildings, roads and renewable energy infrastructure are described briefly in the Environment Institute’s Climate Change Impact Assessment, Adaption and Emerging Opportunities for the SA MDB Region Milestone reports but they do not provide detailed descriptions of the broad effects of climate change on all types of SA MDB Region infrastructure. Typical for regional areas, quantitative estimates of potential impacts are sparse to date.

For transport networks further research is required into the amount of road (sealed and unsealed) and rail at risk from climate change and its degree of vulnerability to climate change stressors. It is also necessary to investigate whether there are any roads and/or rail at risk in the Alexandrina and Coorong Region from coastal inundation. Airport services and public transport services are limited in the SA MDB Region and so the effects of climate change are likely to limited to the impact of the carbon price on air travel and cost of fuel but further investigation would be required.

For service networks further research is required into the effects of climate change on electricity networks (i.e. the amount of traditional energy and renewable energy assets at risk from bushfires, heatwaves, extreme temperatures and other climate change stressors) and the likely impacts of climate change on energy demand and supply. It is also necessary to investigate the possible growth in renewable energy generation as the region tries to adopt a low carbon emission approach. Water network infrastructure and their condition throughout the SA MDB Region needs further research such as the likely impact of reduced rainfall and river inflows on the region. For telecommunications networks further research is required into the effects of climate change on telecommunications infrastructure including cables, trunk routes and telecommunications towers at risk from climate stressors.

The Environment Institute’s Milestone 1 report provides limited discussion of the general effects of climate change on buildings in the SA MDB Region, but does not provide specific impacts on houses, schools and hospitals. Further research is needed into the number of houses and public buildings at risk from bushfires.

The First Pass National Assessment of Climate Change Risks to Australia’s Coasts provides an estimate of the number of existing residential buildings at risk of inundation in the Alexandrina LGA, but notes that further research is required to understand coastal dynamics at the Murray mouth in The Coorong LGA.

10.4 FINANCIAL CAPITAL

As one would expect for a diverse regional economy such as this, there are gaps in the literature concerning the impacts of climate change on primary industries, secondary industries and tertiary industries. The Environment Institute’s Climate Change Impact Assessment, Adaption and Emerging Opportunities for the SA MDB Region Milestone 3 report briefly mentions that insufficient water supplies due to a drying climate will reduce availability for the mining industry but does not provide any likely impacts on the forestry, manufacturing, construction, retail trade or tourism industries.

For the primary industries excluding agriculture sector further research is required to determine the effects of climate change on energy availability, efficiency of equipment and health and safety implications for workers in the mining sector. For forestry, findings of the Pinkard and Bruce study (2011) summarise the effects of climate change for South Australian plantations and would be relevant to the existing (limited) forestry activity in the SA MDB Region.

Much of the cropping area in the SA MDB Region is low rainfall and so long-term, transformational change is eminent. Support for producers to undertake long-term planning for transformational change would be beneficial.

Under the SA Murray-Darling Basin Landscape Futures Program reports, biofuels are considered as a long-term plan for the drier parts of the region, but we need to consider their long term viability since opportunity crops such as canola are often cut from a rotation in drier years as they do not perform as well under a warmer and drier future. New projects are emerging
to support producers to take advantage of the carbon market. However, support for the long-term triple bottom line viability needs to be provided.

Some more detailed modeling is recommended for the SA MDB Region using Grass Gro and SGS to investigate the impact of climate change on specific livestock enterprises. For example, work has been carried out looking at the wool quality using Grass Gro in other regions, but not in the SA MDB Region. The Grass Gro model can also be used to simulate adaptation strategies. Adaptations tested can include, optimum stocking rates, pasture species mix, animal weaning dates, calving and lambing optimums, supplementary feed required, gross margins and more.

Pasture modelling shows that deep rooted perennials may be more viable than continuous grazing alone. However, although perennials produce more biomass, the challenge will be to improve pasture use efficiency. It is also important to know when the pasture is in its highest carbohydrate form for animal fat conversion and when it is most palatable and available to animals.

In dryland areas, precision irrigation systems have been introduced for vegetables, and despite best management practice, have led to a change in soil structure and chemistry, increased silt loads (affecting drip irrigation), and increased sodicity (particularly of subsoil and groundwater). These aspects of the farming system need to be better understood (Sylvia and Skewes 2006). As suggested by Sylvia and Skewes (2006), irrigation benchmarking studies with vegetable focus groups are needed to identify the potential for optimum performance parameters for each vegetable growing region and identify further research, extension and training needs.

Best management practices for fertiliser application and water use is needed to prevent toxic build up or drainage of salinity nutrients, improve crop yield and quality, and improve water use efficiency.

Deuter et al. (2011) found that there is lack of direct research into the effects of climate change on specific horticultural commodities. Further gaps recommended by Sylvia and Skewes (2006) to address include:

- Improved understanding of the impacts and options with less water allocations;
- Improved understanding of soil chemical analyses and subsequent timely recommendations to improve drainage and nutrient retention (e.g. addition of gypsum, organic matter or deep ripping);
- Increased promotion and support of vegetable grower irrigation training is needed; and
- Development of a culture of irrigation scheduling, recording and monitoring water and fertiliser inputs to manage on-farm and regional water tables.

Little literature was found on climate change impacts and adaptation for fruit in the Region.

Workshop participants at the stakeholder engagement meeting in July identified knowledge and data gaps in terms of the potential impact of climate change for:

- specific native grazing species (i.e. grasses, bushes, trees);
- relationships between pastures and crop production with livestock production; and
- animal health (e.g. pink eye in sheep, increased dust production).

Siebentritt et al. (2011) recommend that the region:

- Build on the existing consortium of Councils and the SA Murray-Darling Basin NRM Board;
- Present a coordinated vision of climate change adaptation for the SA MDB Region that encourages investment in the region;
- Reduce potential duplication of effort;
- Acquire funding to support diversification of the region’s economy;
- Prepare a climate change adaption action, monitoring and evaluation plan;
- Prepare an adaptive communities research and development priorities strategy;
- Establish an adaptive communities web portal for knowledge sharing, skill development and networking; and
- Develop and adaptive communities’ capacity building program (Siebentritt et al. 2011).

For secondary industries, further research is required on the effects that climate change will have on the manufacturing sector in the SA MDB Region. Climate change has implications for food processing and grape and wine processing as the supply of agricultural products is likely to be adversely affected by reduced rainfall and higher temperatures. Further research is required to assess the magnitude of the impact that reduced agricultural productivity would have on manufacturing
in the context of likely future climate change scenarios for the region and reductions in water diversions. Further research is also required to establish the effects of climate change on the health and safety of workers in the construction sector and potential flow on effects due to productivity impacts on agricultural activities.

For tertiary industries further research is needed to determine the effect of climate change on retail trade which is influenced by output from the primary production and farming sectors. Input prices for energy and water are likely to increase as a result of climate change; further research is needed to determine the degree to which this will impact on retail trade. Tourism is likely to decline with the effects of hotter temperatures and increased heatwaves due to climate change, but further research is required to establish the likely effects on visitation to the SA MDB Region.

### 10.5 SOCIAL CAPITAL

For the Social Capital, data analysis could benefit from collection or segregation of data into a range of groups so that it can be analysed in a variety of ways. For example, indigenous and non-indigenous data, youth and adult health data, incomes shown as an average for part time and full time workers etc. Some of this information may become available with the release of data from the Australian Health Survey 2011-13 (ABS 2012). Data from this survey is still being collected and the date of data release is unconfirmed.

Vulnerability studies to date usually have an environmental or water focus and therefore studies with a focus on the effect of the complete range of predicted climate change impacts on the social capital would be highly valuable.

Adaptation will need to have a focus on achieving positive outcomes instead of avoiding negative outcomes. For this reason, study into the causes of happiness in the region would be beneficial to ensure community satisfaction in the future.

Very little of the material reviewed identified the opportunities arising from climate change and how can they be identified and achieved within the social context.

### 10.6 HUMAN CAPITAL

A range of useful data for the Human Capital exists for some local government areas especially those included in the “Murray and Mallee” region. As some data is only available by Council Region this made it hard to include additional Council areas into an assessment. For example, Mount Barker Council data is often lumped in with the Adelaide Hills Council data as Adelaide Hills regional data. In general there is a lack of recent, consistent, detailed data for the study area on measures of climate change on the Human Capital.

Additional information at the individual Council level that would be of significant use for the full IVA would include:

- Level of climate change knowledge and acceptance within the community;
- Mental health – levels, perception, treatments, recovery;
- Ageing population and the effects of climate change; and
- Ageing population and the effects on health services.

### 10.7 NEXT STEPS

When considering the next steps in the IVA process, it is important to realise that there will always be gaps in our understanding of the likely impacts of climate change on such a diverse and interconnected Region such as this. Regardless, the wealth of information that is already available surpasses that for many other regions and will be of critical importance in developing a full IVA.

The findings of this review and the stakeholder engagement workshop provide a broad range of identified gaps for each of the five capitals assessed. As part of the next phase of the IVA, the steering committee and key stakeholders will need to determine their priorities based on the key sectors of value and the available funds to address gaps. In addition, consideration of the key decisions that need to be made by each of the sectors as captured in the stakeholder workshop (Appendix 5) should be considered with respect to their data needs and timelines. The identification of timelines should also inform the selection of climate change scenarios to be used in the assessment. Stakeholders are encouraged to build on the existing networks and collaborations already in place and to ensure that as diverse a group as possible has the opportunity to be involved in the steps that follow and ultimately the development of the Regional Adaptation Plan.
ADAPTATION
Adaptations are actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected changes in climate conditions.

BOM
Bureau of Meteorology

CFS
Country Fire Service

CLIMATE
Climate summarises the average, range and variability of weather elements, e.g. precipitation, wind speed, air temperature, humidity, and sunshine hours (solar radiation), observed over many years (typically > 30 years) at a location or across an area (BoM 2009).

CLIMATE VARIABILITY
Climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. Examples of climate variability include extended droughts, floods, and conditions that result from periodic El Niño and La Niña events.

CLIMATE CHANGE (global warming)
Climate change refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer). Contemporary climate change refers to anthropogenically driven changes in the climate as a result of changes to the composition of the atmosphere via the addition of greenhouse gases.

CPRS
Carbon Pollution Reduction Scheme

CSIRO
Commonwealth Scientific and Research Organisation

DEH
Department of Environment and Heritage

DROUGHT
Drought in general means acute water shortage. When dry conditions are not relieved by equally wet periods over a number of years, or when a shorter period of dry is exceptional, it is commonly called drought.

DWLBC
The Department of Water, Land and Biodiversity Conservation, South Australia.

GCM
Global Climate model

GRP
Gross Regional Production

IPCC
Intergovernmental Panel on Climate Change

LITTORAL
In coastal environments, the littoral zone extends from the high water mark, which is rarely inundated, to shoreline areas that are permanently submerged. It always includes the intertidal zone and is often used to mean the same as the intertidal zone. However, the meaning of “littoral zone” can extend well beyond the intertidal zone.

LGA
Local Government Area

MFS
Metropolitan Fire Service

RISK
Risk is the product of consequences and likelihood – what can happen, and what are the odds of it happening. Both of these factors are important in determining whether and how we address specific risks.

RDA
Regional Development Australia

SAAS
South Australian Ambulance Service

SES
State Emergency Service
VULNERABILITY
Vulnerability to the impacts of climate change is a function of exposure to climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes. Vulnerability is typically described to be a function of three overlapping elements – exposure, sensitivity, and adaptive capacity. For example, agricultural vulnerability to climate change is described in terms of not only exposure to elevated temperatures, but also crop yield sensitivity to the elevated temperatures and the ability of farmers to adapt to the effects of that sensitivity, i.e. by planting more heat-resistant cultivars or by ceasing to plant their current crop altogether. Vulnerability is place based – region rather than country, and needs to match the scale of decision-making of the collaborating stakeholders (Schroter, Polsky et al. 2005).

WEATHER
Weather describes atmospheric conditions at a particular place in terms of air temperature, precipitation, wind speed, pressure, and humidity.
12 Bibliography


Bryan, B.A., Connor, et al. (2007). Lower Murray Landscape Futures – Volume 1 Executive Summary, CSIRO Land and Water; Primary Industries Research, Victoria; CSIRO Sustainable Ecosystems; Econsearch Pty. Ltd.; The University of Adelaide; In Fusion Consulting Pty. Ltd.


Department of Environment and Natural Resources (in progress). Provisional List of Threatened Ecosystems of South Australia. (Unpublished and provisional list).


IPCC (2001), Climate change: The scientific basis. Geneva, Switzerland, Intergovernmental Panel on Climate Change: 20.


SA Centre for Economic Studies (2012). Regional Development Australia Murraylands and Riverland, Regional Fact Sheet.


Short, A.D. and P.A. Hesp (2006). Beach and dune morphodynamics of the south east coast of South Australia. Coastal Studies Unit, Department of Geography, University of Sydney, Sydney N.S.W. ISBN 0 909764 14 X.


Four criteria that should be met by climate scenarios if they are to be useful for impact researchers and policy makers are suggested in Smith and Hulme (1998):

**Criterion 1: Consistency with global projections.** They should be consistent with a broad range of global warming projections based on increased concentrations of greenhouse gases. This range is variously cited as 1°C to 3.5°C by 2100 (IPCC, 1996a), or 1.5°C to 4.5°C for a doubling of atmospheric CO2 concentration (otherwise known as the “climate sensitivity” – IPCC, 1990; 1992).

**Criterion 2: Physical plausibility.** They should be physically plausible; that is, they should not violate the basic laws of physics. Hence, changes in one region should be physically consistent with those in another region and globally. In addition, the combination of changes in different variables (which are often correlated with each other) should be physically consistent.

**Criterion 3: Applicability in impact assessments.** They should describe changes in a sufficient number of variables on a spatial and temporal scale that allows for impact assessment. For example, impact models may require input data on variables such as precipitation, solar radiation, temperature, humidity and wind speed at spatial scales ranging from global to site and at temporal scales ranging from annual means to daily or hourly values.

**Criterion 4: Representative.** They should be representative of the potential range of future regional climate change. Only in this way can a realistic range of possible impacts be estimated.

An additional criterion can be added to this list:

**Criterion 5: Accessibility.** They should be straightforward to obtain, interpret and apply for impact assessment. Many impact assessment projects include a separate scenario development component which specifically aims to address this last point. The DDC and this guidance document are also designed to help meet this need.

# Regional Forum and Workshop – An Integrated Vulnerability Assessment for the S.A. Murray Darling Basin

Murray Bridge Natural Resources Centre – 24th July 2012
9:30am for a 10:00am start, Tea and coffee on arrival

<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Discussion Leader</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Welcome and Introductions</td>
<td>Hugo Hopton</td>
<td>10:00</td>
</tr>
<tr>
<td>2. Overview</td>
<td>G. Lundstrom, Senior Project Officer - Climate &amp; Energy Natural Resources, SA Murray-Darling Basin</td>
<td>10:05</td>
</tr>
<tr>
<td>3. Regional Integrated Vulnerability Assessments (IVAs) – “The Central Local Government region experience”</td>
<td>Anita Crisp, Executive Officer - Central Local Government Region of Councils</td>
<td>10:10</td>
</tr>
</tbody>
</table>
| 4. Jacqueline Balston and Associates  
Dr. Jacqui Balston - The project methodology and climate changes for the SA MDOB Region  
Olivia Brodhurst - Social and Human Capitals  
Anthony Kosturjak - Financial and Physical Capitals  
Dr. Kerri Muller - Environment Capital including water | J. Balston | 10:30 |
| 5. Human Capital:  
Community Health and wellbeing | Representative for Health sector (TBA) | 11:45 |
| 6. Environmental Capital:  
Coastal Management; Biodiversity; | | |
| Financial Capital:  
Agriculture  
Regional Development  
Social capital:  
Emergency management  
Tourism | | |
| Physical Capital:  
Infrastructure and urban areas  
Local Government | | |
| Lunch | | 1:05 |
| 6. Workshop Key Studies, Knowledge and Gaps, Key Decisions | All/Workshop | 1:30 |
| 7. Wrap up | | 3:00 |
| Close | | 3:30 |
APPENDIX 3:
DRAFT GAPS provided at the workshop

Gaps identified in the desktop study are summarised here. A draft version of this summary was provided at the workshop and additional points added by stakeholders.

**Climate change**
- Downscaled spatial maps of climate changes (temperature, rainfall, evaporation, wind, sea level rise inundation) for the SA MDB Region;
- Projected changes in temperature for 2050 and 2100 scenarios;
- Projections for heat wave event intensity and frequency in centres within the SA MDB Region;
- Projected changes in rainfall for 2050 and 2100 scenarios;
- Projections for rainfall event intensity and frequency in centres within the SA MDB Region;
- Projected changes in evaporation for 2050 and 2100 scenarios;
- Projected changes to the Forest Fire Danger Index (FFDI) for centres in the region;
- Projected changes in wind for 2050 and 2100 scenarios.

**Environmental Capital**

**Biodiversity**
- Lack of fine-scale vegetation community mapping;
- Lack of condition mapping;
- Lack of mapping of restoration activities;
- Insufficient knowledge of the distribution and ecology of key biota;
- Insufficient monitoring and research data to assess changes in condition and distribution;
- Lack of access to indigenous biodiversity knowledge for managers;
- Lack of knowledge of distribution, abundance and relative importance of threats;
- Insufficient knowledge of fire management practices to protect and restore biodiversity;
- Insufficient knowledge of post-fire recovery of vegetation;
- Impacts of climate change on biodiversity.

**Landscape Fragmentation and Refugia**
- Identification of regional refugia (terrestrial and aquatic);
- Effects of River Murray and wetland water level manipulations on functional connectivity and availability of aquatic refugia.

**Vegetation communities**
- Compiled dataset of current condition and existing threats to terrestrial vegetation;
- Evaluation of DEWNR vegetation mapping layers of the extent, distribution, size and degree of fragmentation of different vegetation community types;
- Knowledge of future watering regimes for wetland vegetation types;
- Knowledge of future water and sediment quality regimes for wetland vegetation types;
- Knowledge of species specific responses to expected climate change impacts, including tolerances of salinity, acidity and other stressors associated with likely changes in water and flow regime.

**Flora and fauna**
- Individual vulnerability assessments for terrestrial flora and fauna following the methodology of Gonzalez et al. (2011);
- Compilation of data of Gillam and Urban (2010) to inform IVA if individual vulnerability assessments are not undertaken;
- Knowledge of ongoing environmental water availability;
- Knowledge of impacts of pollutants (e.g. acid, heavy metals and salinity) on aquatic and water dependent flora.
Threatened species and communities

- individual vulnerability assessments for threatened terrestrial flora and fauna following the methodology of Gonzalez et al. (2011);
- compilation of data of Gillam and Urban (2010) to inform IVA if individual vulnerability assessments are not undertaken;
- knowledge of ongoing environmental water availability;
- knowledge of impacts of pollutants (e.g. acid, heavy metals and salinity) on aquatic and water dependent flora.

Weeds and pest animals

- regional assessment of climate suitability for weed and pest animal species under climate change.
- Environment and bushfire
  - fire management practices to protect and restore biodiversity;
  - post-fire recovery of vegetation.

Water resources

- effects of climate change driven changes to rainfall and evaporation (volumes and patterns) and consequential transfer rates to run-off and recharge (surface and groundwater availability);
- poor capacity to forecast water availability across all water resources (surface and groundwater) even on an annual cycle;
- limited capacity to forecast water demands under different climate scenarios (urban and rural);
- knowledge of the full range of secondary impacts on catchment processes from alterations in rainfall, temperature, evaporation and evapotranspiration under different climate scenarios;
- lack of detailed models for Eastern Mount Lofty Ranges water resources (surface and groundwater) and hence high uncertainty regarding climate change impacts;
- poor capacity to predict cumulative impacts of policy decisions that affect water resources (due to disseminated operational responsibilities and a lack of clear institutional leadership in South Australia and across the Murray-Darling Basin);
- knowledge of feedback effects from changing demand for water under financial and economic capital (surface and groundwater);
- poor capacity to predict potential for the construction of, and operational guidelines for, new water resource management infrastructure (e.g. new off-takes, new weirs or regulators, modified barrages, desalinisation plants, Salt Interception Schemes);
- limited capacity to predict potential for water recycling to meet changing water demands and thus determine resilience of different communities and sectors.

Environmental flows

- Environmental Water Requirements (EWRs) for aquatic flora and fauna species;
- Inconsistent approaches and quantum of EWRs for SA MDB Region assets by different levels of government;
- Knowledge of effectiveness of EWPs for icon and hydrologic indicator sites delivering whole-of-ecosystem EWRs;
- Knowledge of effects of current flora and fauna population status on future vulnerability;
- Poor capacity to forecast River Murray flows and groundwater levels under various water resource management and climate change scenarios;
- Poor capacity to forecast future stream flows and groundwater levels in the Eastern Mount Lofty Ranges;
- Likely pollutant loads under combined climate and policy scenarios.

Ecological impacts of sea level rise

- poor capacity to predict future River Murray flows, lake water levels and degree of Murray Mouth openness;
- knowledge of the differences in sea level changes between Victor Harbor and the Murray Mouth;
- knowledge of whether sea level will change the meteorological response of water levels relative to the mean water level;
- knowledge of the effects of storm surges on water level attenuation within the Murray Mouth and duration of exceedence of given water levels that relate to operating structures and environmental water requirements;
• poor capacity to predict future barrage operating rules and alterations to infrastructure (e.g. raising of barrages, relocation of barrages).
• Knowledge of impacts of climate change on other parts of the SA MDB Region’s coastline.

Ecosystem services
• identification of ecosystem services associated with different SA MDB Region ecosystem types;
• conceptual understanding of linkages between biota, ecosystem health, ecosystem processes and provision of ecosystem services;
• knowledge of impacts of changing ecosystem service provision on social and financial capital.

Physical Capital
Transport networks:
• Kilometres of road and rail at risk of sea level rise and inundation along the coastal regions of Alexandrina and the Coorong
• Kilometres of roads (sealed and unsealed) and rail at risk from bushfire
• Kilometres of roads (sealed and unsealed) and rail at risk from extreme temperatures
• Airport infrastructure at risk
• Public transport infrastructure at risk

Energy and water networks:
• Effect of climate change on energy demand and supply
• Kilometres of energy networks at risk from bushfire
• Per cent of traditional energy assets at risk from bushfire
• Per cent of renewable energy assets at risk from bushfire
• Per cent of water networks at risk from bushfire

Communications infrastructure:
• Per cent of telecommunications networks at risk from bushfire
• Per cent of cables and trunk routes at risk due to erosion by major storms
• Caballing at risk of degradation
• Tower structures and foundations at risk of degradation

Buildings
• Number of houses at risk from bushfire
• Number of public buildings (schools, hospitals, libraries etc) at risk from bushfire
• Number of flood, fire, and heat refuges at risk from bushfire
• Number of houses and public buildings at risk from inundation in the Coorong

Financial Capital
Agriculture
• Modelling of the impact of future rainfall patterns, temperature changes etc on yields for crops, pastures and viticulture in the region
• Impact of climate change on specific grape varieties
• Potential adaptations options based on knowledge from local producers
• Irrigation benchmarking studies with vegetable focus groups to identify potential for optimum performance parameters for each vegetable growing region
• Value of wool production in the region

Mining
• Energy and water availability to mining operations
• Operational effectiveness of equipment and effectiveness of human resources under climate change
• Health and safety of mining employees

Forestry
• Impact of climate stressors on future development of forestry
Manufacturing, Construction
- Impact of reduced supplies from the agricultural sector on food manufacturing
- Reliability of energy and water supplies for use in manufacturing
- Impact on health and safety in the construction sector
- Effects of reduced activity in irrigated agriculture and broad acre cropping on the construction sector

Tourism
- Effects on tourist visitation due to increased temperatures, more frequent heatwaves, higher fuel prices and, most significantly, changes in environmental water flows due to likely future climate change scenarios.

Retail trade, business and personal services
- Extent to which climate change impacts on agriculture, tourism and manufacturing have flow on effects to retail trade and other downstream industry sectors
- Effect of increased input prices for energy and water

Human Capital
Education:
- Research into the potential changes in education facilities, course offerings or job matching assistance that may lead to retention of young people in the region.
- The impact of climate change on education systems (attendance, school closures due to heatwaves/bushfires)
- Data to show if there is a link between the lower income households in the region and the effect this has on education level and qualification types achieved.

Age:
- More information is needed about the ageing population and how this will impact on the study region. Special consideration needs to be given to the health sector as it is expected the demands will increase with climate change stressors.

Health and Wellbeing:
- The impacts of climate change on mental health is not well documented in the SA MDB Region however studies on the impact of drought highlight some
- Regional suicide rates are not available.
- Suicide amongst children under 15 is not recorded, but this is also an age group that may also raise concerns.
- Information on social dislocation after a climate change event is not well researched.

Social Capital
Existing Social Capital:
- Available data (census etc.) could benefit from refining for use in interpretation of climate change impacts.
- Detailed information on smaller towns within local government regions would provide greater refinement of future vulnerability studies results.
- Studies have been done in the MDB on the vulnerability to climate change of the social capital with a focus on irrigation, agriculture and water allocations (drought). Studies are lacking that focus on other predicted impacts of climate change such as extreme weather events (e.g. heat waves, fire), sea level rise, ocean acidification and other threats such as bio-security.
- Climate change studies to date to do not always provide specific information for the SA MDB Region of this study.
- Built in consideration for climate change impacts on the social and human capitals is lacking across the literature in most regions.
Community Planning and Development:
• Regional internet service coverage maps (for all providers) and NBN rollout information is either not available or poorly documented.
• Further information could be gathered on the required services of communities in the study area and possibilities for hastening upgrades (funding sources).
• There is little information available about regional occupations and industries and how climate change impacts on communities who are reliant on one or two major industries only.
• Data for the median household income per week for the study region is not readily available (including the Murray and Mallee, Alexandrina and Mount Barker Council areas).
• Data for each Council area is lacking on personal incomes.
• Separate population data for indigenous and non-indigenous populations.
• Incentives or other methods for retaining/retrieving the educated youth who leave the region are not clearly understood and would be valuable to know.

Emergency Management:
• Emergency management information was generally out of date. Further research is needed to establish whether or not volunteer levels will rise or fall locally;
• The capacity of local businesses to assist in an incident also needs to be considered (e.g. supermarket, op shop providing goods during and after an incident). There does not appear to be any available statistics in relation to businesses providing this type of assistance (Murray and Mallee Zone Emergency Management Committee, Unpublished);
• Research into the possibility for organised corporate volunteering;
• Detailed information on service provisions to smaller towns and remote areas;
• Information on impacts of carbon pricing or fuel pricing on volunteers (increased cost of fuel may be reducing the rural community’s capacity to volunteer as the cost of travel is increasing).

Social Inclusion / Exclusion:
• Need further research to establish level of memberships across the region in different sectors (i.e. sport and recreation, art groups, church groups including data on involvement in nature conservation groups such as “save the Murray” groups);
• No localised information available about the potential climate change impacts on Indigenous people residing in the study region;
• Crime data is out of date and did not provide enough information on individual towns;
• Little information has been documented about perceived crime in the area. If people are complacent this could lead to an increase in crime across the region, particularly after disaster situations. Data collected could include the number of persons involved in community watch programs etc.;
• Data on the number of leaders, how well engaged they are and resources available to them, are all unknown or not documented.
<table>
<thead>
<tr>
<th>Key Decisions</th>
<th>Gaps</th>
<th>Key Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the key issues and related decisions that need to be made in the region with respect to climate change and what timeframes do they sit within? Example image by Stanford-Smith et al.</td>
<td>What further information/data do we need to assess climate change sensitivity, impact and adaptive capacity that we don’t yet know?</td>
<td>Are there any other studies that consider climate change, impacts, impacts or adaptive capacity of relevance to the region that do not appear in the bibliography?</td>
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SA MDB Climate Change IVA Gap Analysis Workshop – 24 July 2012
## Appendix 5
### IVA Stakeholder Gap Analysis Workshop – Workshop Feedback

#### CC IVA Workshop – Environmental Capital

**Gaps**

What further information/data do we need to assess climate change sensitivity, impact and adaptive capacity that we don’t yet know?

- Library of adaption actions when hit triggers
  - GAPs:
    1. Overlays that suit landscape planning: Agreed inputs layers climate change impacts/changes
    2. Common sets of data? Downscaling to region? Uncertainties
    3. Lack of good baseline condition data: as climate change issues get worse, then show trends, avoid subjective opinion. Indicators: surrogate track change against water provision
    4. Biosecurity: Identify responses with climate change impacts?
    5. Current fire management plans and decision capability (e.g. Ngarkat vs Kangaroo Island): conceptual understanding of vegetation changes under fire regime → monoculture.
    6. Indigenous fire and water management. 7) Cultural economy with native vegetation and water
    7. Longer seasonal forecasting for agricultural decisions
    8. Risk assessments what if? Consequences of less water, flow-on effects

- Adaptive management across broader scenarios/longer timeframes. E.g. lakes go below sea level
- Indicators and linkages between different water demand, environmental water requirements, future landcape.
- Annual soil protection: targets for climate change, triggers✓✓, forecasted biomass: trigger for harvesting
- Adaption: moving infrastructure to give greater flexibility in water management
- Future portioning of water during low water availability: inter basin transfers. Production versus environmental water requirements, compensation – do this in wet years
  - How to support environmental water requirements under changing climate
  - Thought through implications of worst case
- Coast impacts/SLR: barrages → River Murray, what do we do? Decisions we need to make? Options and scenarios and modelling: now

- Scenario: Pretend it’s 2005: 2009 and no rain; now: options, triggers, risk management, state wide

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#### Key Studies

Are there any other studies that consider climate change sensitivity, impacts or adaptive capacity of relevance to the region that have already been done and have not yet been reviewed/appear on the list?

- What do people in Eyre Peninsula, Yorke Peninsula think about SA MDB planning?
- Whole of MDB, River Murray supply network (e.g. Barossa)
- What – if’s: best option for adaptive capacity
- Allocations for SA water: what if demand increases from other users
- What if we get secure allocations for MM?
- Water trading: SA water (comfort level, security)

Excellent targets: well thought out, based on excellent science

- Risk analysis of worst-case scenarios
  - Integrated
    - Capitals
    - Regions
  - Evaluation and ACTION

- Very poor Governance: States: baseline condition and monitoring agreed indicators
- Poor capacity for forecasting (modelling – baseline condition and monitoring agreed indicators)

Gaps:

- 9) no-one modelling forecasting water available, soil condition, water demand
- 9) modelling worst-case scenarios.
### Key Decisions

What are the key decisions that need to be made in the region with respect to climate change and what timeframes do they sit within? Example image by Stafford-Smith et al.

### WATER

- Lack of capacity to forecast beyond 6 months to 12 months constrains forward planning: DSS critical, adaptability: options, risk: worst case, profiling
- Capacity to foresee droughts: mechanisms in place to respond earlier/co-operatively
- ‘Droughts’: forecasting, lack of storage capacity
- Decision: review (within 2 years) water management operations (e.g. weir pool manipulations, flexibility in levels vs security
  - Flows < 60,000 mld: ‘giving-back’ water to prevent flooding shocks (constraints)
  - Basin Plan: fundamental decisions
- State Policy: 2015 draft position, co-ordination of River Murray water in SA: 2 years: best use of available water and taking opportunities for banking water.
- Timing: B2 2019 adaptive plan
- Disparity between water users/decision makers: stream line approach, DSS – timely decision, governance
- Water management time-constrained: current water-use year, maybe next one. Scenarios: increase 5 years
- On private lands, business decisions that manage risks around increasing season variability...ongoing. Sustainable extractions from the River Murray in the MDB Plan and WAP that will provide some certainty of the extent of change that will be required to irrigate.

### BIODIVERSITY

- Species vulnerability for cut top priority threatened species - or ones in potential decline, ASAP depending on the species

### ENVIRONMENTAL WORKS AND MEASURES:

- Regional Sector agreement - agreement on what we think is going to happen and agreement on which sector is doing what to mitigate and/or adapt A focus on mitigation as we often talk of adaption but there is less focus on mitigation Pod connected wetlands: 5 year plans most realistic climate change impact.

### LANDSCAPE

- Revegetation and restoration guidelines - how to climate proof your plantings be it for restoration, bio sequestration or amenity etc. Rehabilitation to the appropriate Mallee or vegetation association as farm lands are retired and become more marginal - i.e. should a change in Goyders line mean that areas around Wunkar are no longer suitable for cropping how will we transition this land to shrubby Mallee with grassy pockets rather than blowing sand dunes with a huge weed problem?

### BIOHAZARDS

- terrestrial aquatic e.g. tubeworms, mosquitoes.
- State response team: do we have one?

### VEGETATION: long lived trees 150-200 years

- Transitions to different vegetation types: strategic thinking planning 2 years
- Floodplain: Goyder
- CLLLM – options – flow-on effects (e.g. irrigation, towns)
- Transitioning? (5-10 years): barrages effective 20-40 years (storm surges)
- SE drains

### Most plants live <200 years

- Revegetation – minimum 70 years up to 150 years
- Strategic s/d benefit versus more fires, loss crops, less run-off
- Started long time ago.
- Plan within 5 years
- State wide linkages
- Carbon-ready plans: 1 year
- NRM Plan updating 2014-2019
- Risks and benefits (e.g. fire, weeds)
- Fire management
### CC IVA Workshop – PHYSICAL CAPITAL

#### Gaps

**What further information / data do we need to assess climate change sensitivity, impact and adaptive capacity that we don’t yet know?**

- Land – What land will be available for which uses → Productivity + Capability
- Flood impacts on transport, energy and water
- Failure of river infrastructure e.g. dams
- Overtopping of barrages during storm surges.
- Connection with U.S.E reflows
- Consequence of upstream policy and prescription changes  
  - e.g. River operation changes  
  - Basin Plan
  - Basin Agreement
- Operation of CEWH water

#### Key Studies

**Are there any other studies that consider climate change sensitivity, impacts or adaptive capacity of relevance to the region that have already been done and have not yet been reviewed / appear on the list?**

- Community Capacity – Pinnaroo or Paringa by Liberal Hylton Keele – might be unpublished  
  → speak to Greg Cook
- Studies that DCLW have been involved in provided extremely valuable data and will assist with forward planning for Council.

#### Key Decisions

**What are the key decisions that need to be made in the region with respect to climate change and what timeframes do they sit within? Example image by Stafford-Smith et al.**

| Utility | Lead indicators for demographic change  
| Interaction with regional population  
| Roads – seal or not to seal - 5 years → 10 to 40 years  
| Rail  
| Utility – Water  
| Supply and Demand planning  
| No major expansion but regular upgrades only  
| 4 years → 20 years → Irrigation area unlikely to change  
| Desalination of groundwater  
| **Electricity** → 10 years → 20 years → Local Generation?  
| **Renewable**  
| **Gas**  
| Irrigation Networks → 10 years → 20 years  
| Buildings → 1 → 3 years → 20 years → Energy Efficiency and Insulation  
| Demographic changes and total population  
| Land use planning (type) → 10 years → 80 years  
| Land capability |
# CC IVA Workshop – Financial

## Gaps

<table>
<thead>
<tr>
<th>What further information / data do we need to assess climate change sensitivity, impact and adaptive capacity that we don’t yet know?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The extent to which climate change will drive dramatic change to the types of production systems.</td>
</tr>
<tr>
<td>• What alternative industries and manufacturing opportunities, crops may be applied under a changing environment (should be commencing now)</td>
</tr>
<tr>
<td>• New varieties trials → resilience, robust, low rainfall suitability</td>
</tr>
<tr>
<td>• There should be significant research into growing grapes, production according to minimum water requirements, salt tolerance, applying water with AC accounts, changed irrigation practices → this information should be coming through now (would assume that it is also being conducted in respect of grains)</td>
</tr>
<tr>
<td>• Impact of climate change on animal health (pink eye in sheep, increased dust)</td>
</tr>
<tr>
<td>• Relationships between pastures and crop production with livestock production</td>
</tr>
<tr>
<td>• Implications of CC and ageing populations for health and community services (increased demand due to heat stress)</td>
</tr>
<tr>
<td>• Community resilience → how do we educate the community so they can better help themselves (e.g. dealing with heatwaves, bushfires)</td>
</tr>
<tr>
<td>• Implications for government services in terms of education and information interventions</td>
</tr>
<tr>
<td>• Sustainability of groundwater resources over the longer term (e.g. 200/300 years)</td>
</tr>
<tr>
<td>• Water allocation plans based on current allocations. Is climate change taken into account? Is industry taken into account?</td>
</tr>
<tr>
<td>• Impact of climate change on specific native grazing species (i.e. grasses, bush, trees)</td>
</tr>
<tr>
<td>• Lower Murray Swamps → what is the future for this area? (needs work in the short term)</td>
</tr>
<tr>
<td>• Previously used for dairy, what other potential land uses for this area (tourism-water parks)</td>
</tr>
<tr>
<td>• What are the implications of raising the barrages?</td>
</tr>
<tr>
<td>• Current land use for irrigation</td>
</tr>
<tr>
<td>• Infrastructure (water off-takes, ferries, bridges, levies)</td>
</tr>
</tbody>
</table>

## Key Studies

<table>
<thead>
<tr>
<th>Are there any other studies that consider climate change sensitivity, impacts or adaptive capacity of relevance to the region that have already been done and have not yet been reviewed / appear on the list?</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Recent Mallee Water Allocation Plan (Sherlock, Roby and Peake)</td>
</tr>
</tbody>
</table>

## Key Decisions

<table>
<thead>
<tr>
<th>What are the key decisions that need to be made in the region with respect to climate change and what timeframes do they sit within? Example image by Stafford-Smith et al</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What are going to be sustainable industries in the future on the basis of current climate model predictions?</td>
</tr>
<tr>
<td>• Making linkages with local produces that are innovative (e.g. new varieties)</td>
</tr>
<tr>
<td>• How much investment is required/will it be viable given future climate changes</td>
</tr>
<tr>
<td>• Looking at niche markets, use for branding purposes for the region (new industries/varieties</td>
</tr>
<tr>
<td>• Importance of positively identifying the changes that will occur → so that decisions are properly informed</td>
</tr>
<tr>
<td>• Identifying potential changes in land use activity/alternative industries around the lower lakes region under an environment of higher water levels</td>
</tr>
<tr>
<td>• Keeping research up to date to support decision making</td>
</tr>
<tr>
<td>• Determining the difference between seasonal and climate change impacts (i.e. so that people do not subscribe changes to variability rather than climate change)</td>
</tr>
<tr>
<td>• How we are going to mitigate ourselves from future drought events</td>
</tr>
<tr>
<td>• Stormwater management in relation to flash flood events</td>
</tr>
<tr>
<td>• Infrastructure needs to be designed to cope with increased frequency of extreme events (infrastructure built today needs to take such issues into account given long life of these assets)</td>
</tr>
<tr>
<td>• Stormwater drains, dams on public and private property</td>
</tr>
<tr>
<td>• Educating children/broader community about the potential impacts, and strategies for coping (e.g. in extreme events) to build community resilience.</td>
</tr>
<tr>
<td>• Agriculture practise change to hold soil during more extreme climatic events ... the Palmer hills and Mannum areas are at severe risk of water erosion during heavy rainfall as shown in Dec 2010.</td>
</tr>
<tr>
<td>• Opportunities for alternative fuels and energy production that may be sympathetic to farming and conservation outcomes</td>
</tr>
</tbody>
</table>
# CC IVA Workshop – Social Capital

## Gaps
What further information / data do we need to assess climate change sensitivity, impact and adaptive capacity that we don’t yet know?

- What programs/projects have been working? E.g. Riverland drought task force, ALOC?
- Data not available (?) on crime/domestic violence, livestock theft and Climate change links – drought
- Why do we have an angry reaction to stress? How will society respond to different climate change stresses – short term/long term
- What causes/are the causes of happiness and not focus on the negative focus.
- What is the ideal size for a community?
- How do we build family/communities closely
- How do we increase situational awareness (education) and how do we act on this to make good decisions
- How do we support early adopters/leaders
- How do we empower communities – enhance citizen centric decision making
- What are the opportunities and how do we highlight them

## Key Studies
Are there any other studies that consider climate change sensitivity, impacts or adaptive capacity of relevance to the region that have already been done and have not yet been reviewed / appear on the list?

## Key Decisions
What are the key decisions that need to be made in the region with respect to climate change and what timeframes do they sit within?

Example image by Stafford-Smith et al.

- Secondary impacts from climate change – e.g. property value down, $ affordability down, socioeconomic groups, criminals, drug use etc. move into an area
- Suicide (not a crime) – big impact on communities
- Domestic abuse – recorded but not looked at or/climate/heat wave, drought
- Emergency Response – looting (bushfire, storms) change in behaviour
- Hopelessness – disempowering, decrease social interaction. Can we measure
- Volunteers – impact? Less means, decrease mental health. In extreme event increase numbers of volunteers – co-ordinating. Response but maybe not so many if depressed/decrease dollars. Older population decrease number of volunteers.
- Leadership – coordinating, strategic issues not considered, support to institutional arrangements – are there the support, institutional arrangements and resources available?
- Collaboration – necessary to have linkages and collaboration
- Ensure conversation with cross sections to ensure maladaption avoided
- Agree to a “5 year summit” on climate change and adaption – agreed deliverables
- ZEMC developing 2 EM Plans now. Need more information on extreme events to include.
- Is climate change a hazard under the state plan? Would provide excess to dollars, policy, priority, process.
- Climate change changing indigenous culture. Awareness in elders. Youth looking at opportunities.
- How does the community view the world? Do we want to increase cultural, spiritual values and reduce the focus on money. Should we change this view?
- How do we highlight the opportunities of climate change
- How do we strengthen leaders, invest in middle and lower levels of society as well.
- What programs do we invest in? Need to include all groups in the discussion
- How do we show the commonalities/common language
CC IVA Workshop - Human

<table>
<thead>
<tr>
<th>Gaps</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What further information / data do we need to assess climate change</td>
<td>Beyond Blue etc.</td>
</tr>
<tr>
<td>sensitivity, impact and adaptive capacity that we don’t yet know?</td>
<td>Education awareness down due to lack of service providers</td>
</tr>
<tr>
<td></td>
<td>RDA roadmap (check)</td>
</tr>
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<td></td>
<td>Health service – eastern/western/alternative medicines</td>
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<tr>
<td></td>
<td>Obesity issues – Murray Bridge $700,000 for wellbeing</td>
</tr>
<tr>
<td></td>
<td>A/C to be better than are now</td>
</tr>
<tr>
<td></td>
<td>How to be more alert/better than now/what’s important to community</td>
</tr>
</tbody>
</table>

| Key Studies                                                        | None identified                                                  |

<table>
<thead>
<tr>
<th>Key Decisions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the key decisions that need to be made in the region with</td>
<td>Communication (internet) – Importance for Education</td>
</tr>
<tr>
<td>respect to climate change and what timeframes do they sit within?</td>
<td>▶ Information transfer – digital economy strategy 12/13 Financial Year</td>
</tr>
<tr>
<td>Example image by Stafford-Smith et al.</td>
<td>▶ Mobile phone</td>
</tr>
<tr>
<td></td>
<td>▶ Fast reliable internet</td>
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<tr>
<td></td>
<td>Education facilities (communal learning planes)</td>
</tr>
<tr>
<td></td>
<td>▶ Education precinct – Murray Bridge</td>
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<td></td>
<td>▶ TAFE upgrade ok</td>
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<td></td>
<td>▶ Teacher attraction program</td>
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<tr>
<td></td>
<td>▶ On-farm apprenticeship program</td>
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<td></td>
<td>Medical training (DR) – incentives/facilities to make stay</td>
</tr>
<tr>
<td></td>
<td>▶ Rural doctors training program in area already</td>
</tr>
<tr>
<td></td>
<td>▶ Business case for hospital RDA</td>
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<td></td>
<td>▶ Agricultural schools</td>
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<tr>
<td></td>
<td>Services in line with increase in population and increase need</td>
</tr>
<tr>
<td></td>
<td>with Climate Change and population age etc.</td>
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<tr>
<td></td>
<td>RDA this year implemented → Report on issues, succession of 1st production</td>
</tr>
<tr>
<td></td>
<td>Mental health → Community linkage etc</td>
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<tr>
<td></td>
<td>Strathalbyn health and well being workgroups</td>
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<tr>
<td></td>
<td>Water/environment stress → economic</td>
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<td></td>
<td>Future farming/property/1st production look like skills</td>
</tr>
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<td></td>
<td>Retaining youth → mines</td>
</tr>
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<td></td>
<td>Migrants population</td>
</tr>
<tr>
<td></td>
<td>↑ Future 1st Production Planning → engage youth</td>
</tr>
<tr>
<td></td>
<td>↓ Increase yields → health</td>
</tr>
<tr>
<td></td>
<td>‘Dream Australia Program’ – Carbon Pricing Considerations (Fuel/electricity/etc)</td>
</tr>
<tr>
<td></td>
<td>Health → Feds $ now?</td>
</tr>
<tr>
<td></td>
<td>NOW</td>
</tr>
<tr>
<td></td>
<td>Facilities</td>
</tr>
<tr>
<td></td>
<td>AGE → Dwellings – assessments – alone elderly/ill</td>
</tr>
<tr>
<td></td>
<td>Pilot Project 2 years. Start in 3 years</td>
</tr>
<tr>
<td></td>
<td>▶ urban restructuring/education →mobilise → rehouse → lifestyle villages</td>
</tr>
<tr>
<td></td>
<td>▶ education/awareness/trial. Opens housing markets shop together → home start</td>
</tr>
<tr>
<td></td>
<td>*Older workforce – planning</td>
</tr>
</tbody>
</table>
APPENDIX 6:  
IVA Stakeholder Gap Analysis Workshop Evaluation

Feedback from evaluation forms filled in by participants at the workshop were collated. The results are summarised here.

<table>
<thead>
<tr>
<th>Was the Venue suitable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Bit bigger room</td>
</tr>
<tr>
<td>2) A bit “stuffy”</td>
</tr>
<tr>
<td>3) A bit warm</td>
</tr>
<tr>
<td>4) With a full room the projection screen seems a bit low</td>
</tr>
<tr>
<td>5) Temperature fluctuations</td>
</tr>
<tr>
<td>6) A little hot later in the day</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Was the time allowed sufficient to cover each topic?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The presentations were rushed and jumped around quite a bit and I couldn’t grasp what the workshop process was trying to get out.</td>
</tr>
<tr>
<td>2) Good time keeping</td>
</tr>
<tr>
<td>3) Some presentations cut short/rushed</td>
</tr>
<tr>
<td>4) Good time management</td>
</tr>
<tr>
<td>5) Presentations a little rushed, bit too much information</td>
</tr>
<tr>
<td>6) Time was ok, but the morning sessions seemed rushed but had a lot of useful information, particularly background information</td>
</tr>
<tr>
<td>7) More time required to fully grasp the issues, perhaps if information is summarised and sent out prior to workshop.</td>
</tr>
<tr>
<td>8) So much in early presentations, but did need to be contained in time</td>
</tr>
<tr>
<td>9) But need time to read follow up papers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Do you feel that you need more information on IVAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) This was an initial opener</td>
</tr>
<tr>
<td>2) Not at this stage. Will be engaged as it evolves</td>
</tr>
<tr>
<td>3) Looking forward to application of IVA</td>
</tr>
<tr>
<td>4) A progressing report, where to next</td>
</tr>
<tr>
<td>5) Met my need</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Was sufficient time allowed for you to have input to the Forum and to have any questions answered?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Break also versus productivity</td>
</tr>
<tr>
<td>2) Tight timelines</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Were your expectations of the session met?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Interesting to interact with the diverse crowd and get introduced to the project.</td>
</tr>
<tr>
<td>2) I expected various stakeholders to produce more specific decisions which they need to make for which Climate Change impact data is required</td>
</tr>
<tr>
<td>3) Exceeded – Not too much jargon</td>
</tr>
<tr>
<td>4) Wasn’t really sure what to expect coming in. Would like more information in the project.</td>
</tr>
<tr>
<td>5) Just needed more time</td>
</tr>
<tr>
<td>6) Had no expectations (unsure what to expect), but beneficial outcome</td>
</tr>
</tbody>
</table>
Numeric ratings for each of the questions was also provided: