THE UNIVERSITY OF ADELAIDE AUSTRALIA

The Environment Institute, University of Adelaide

Strengthening Basin Communities Program – Planning Component Consultancy SBC033A.1/2 Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region

MILESTONE 1 REPORT

TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Climate variability and climate change

Climate change refers to a change in the state of the climate identified by changes in the average and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2007a). Climate change can be due to natural or human induced processes. This is in contrast to the weather, which is variable but follows a well established seasonal trend. Taken over a year the annual trends in temperature, rainfall, humidity and cloudiness are referred to as climate indicators. The year to year climate indicators are variable. But now, over and above this quite normal variability the measurements are showing persistent trends that indicate that our climate is changing.

The best projections of the climate indicators for the South Australian Murray-Darling Basin Natural Resource Management region indicate that conditions will generally be warmer and drier. Measurements from the last 50 years indicate that this warmer, drying trend is already evident particularly in the most recent 10 to 15 years. The expectation is that during the next 20 years, annual temperature will increase by another 0.8°C and over the next 60 years by 1.8°C compared with temperatures during the 1990's. Projections for rainfall indicate a decrease of 3.5% in the next 20 years and 10% less in the 60 year period. This means that areas that normally expect say, 350 mm will by 2030 receive 337 mm on average, a small but perhaps significant reduction particularly if the reduction occurs during winter and spring.

The important message from the climate analysis is that measureable changes and trends are occurring. Projections of future trends are not certain but it is extremely prudent that plans and actions be implemented now since business as usual will not be a viable option for the future.

One useful method for planning in the face of potentially significant but uncertain change is to develop robust management responses to a set of plausible future scenarios. In the case of climate change studies, scenarios can be used to describe future emission scenarios (e.g. low, medium and high - see Chapter 2 for further details on emission scenarios); emission scenarios can then be used to develop climate projections defined by variables such as temperature, rainfall and evapo-transpiration. To make best use of scenario planning it is important to decide on the content and range of scenarios to be developed. It is also important to decide on which stakeholders should be part of the consultation process in forming up the scenarios. The involvement of stakeholders in the process of scenario development can enable them to take their newly acquired understanding of plausible scenarios into their day-to-day roles and responsibilities so that they are able to respond to climate changes as they occur.

Effects of climate change and relevance to local government

Local government works closely with the community and therefore has a broad range of responsibilities that are and will be effected by local climate conditions. These are considered and described along with broad discussion of impacts on agriculture.

Notably, attempting to consider all of the possible effects at once can be bewildering. So this review proposes a framework to help understand and provide a systematic way of working through the possible effects and in turn the possible responses. The framework helps identify the most "sensitive" or "vulnerable" activities and hence provides a way of prioritising where to focus work on adapting to climate change.

All activities of local government will be influenced by climate change. This will continue to occur for the foreseeable future and so planning and actions will need ongoing monitoring, evaluation and revision where required. It will be important to develop a process that can be used to assess priorities associated with infrastructure and community obligations

Adapting to and exploring opportunities with climate change

There are many adaptation options and opportunities that will be of interest to local government and communities. These may relate to the specific adaptation measures by councils or emerging opportunities in relation to agriculture through, for example, biofuels agriculture and biomass agriculture. The most important first step is identifying the possible effect and considering the adaptation options.

As a general approach to adaptation it will be important to identify those actions that increase the resilience of the services and community to withstand and bounce back from increased extreme events. Identifying those actions will need a set of processes embedded in planning, prioritising and actions that checks and considers if resilience has been improved.

1 INTRODUCTION

1.1 South Australian Murray-Darling Basin Natural Resource Management Region

The South Australian Murray-Darling Basin (SA MDB) Natural Resource Management region [1]supports a population of approximately 126,000 people and extends over more than 5.6 million hectares, from the Victorian and New South Wales' borders to the catchment boundary along the Mount Lofty Ranges, to the Murray Mouth and up to 14 kilometres into the Southern Ocean (Figure 1).

This is one of South Australia's most ecologically diverse and agriculturally productive regions. It supports a wide range of flora, fauna, natural environments and human activities. The SA MDB is in the rain shadow of the Mount Lofty Ranges, resulting in a marked reduction in rainfall compared to the country to the west. Even over short distances, a large reduction in rainfall can occur. Annual rainfall ranges from an unreliable 260 mm at Renmark in the northern part of the SA MDB, to 387 mm at Lameroo, near the south-eastern corner of the SA MDB, to 768 mm at Mount Barker near the western edge of the SA MDB.

The SA MDB's natural resources support a wide range of human activity including irrigated and dryland agriculture, tourism and recreation and various manufacturing industries (notably food products, wine and beverages). Many South Australian towns and urban centres, including Adelaide, rely heavily on the River Murray for a large proportion of their annual potable water supply needs. The SA MDB also faces significant urban growth pressures around some of its major towns, most notably Mount Barker, Murray Bridge and Goolwa, placing increased pressure on natural resources in these localities.

Primary production utilises about 82% of the land area of the SA MDB consisting mostly of pastoral lands (43%) and dryland cropping and higher rainfall pasture areas (38%). Grazing of the rangelands is a major land use north of the River Murray. Adjacent to the River Murray, within part of the Mallee and along the Eastern Mt Lofty Ranges, horticulture is a major land use consisting of wine grapes, citrus, stone fruit and vegetables. There are also areas of dairy production on the Lower Murray Reclaimed Irrigation Areas and around the Lower Lakes. In the agricultural areas, broadacre farming is largely mixed cereal and livestock grazing, although pulse and oilseed crops are increasing as cropping intensifies, particularly in the more reliable rainfall areas to the south.

The SA MDB has been gripped by severe drought in recent years, with whole of River Murray system inflows during the past two years being the lowest on record. Particularly dry winter seasons throughout the Murray-Darling Basin have resulted in low inflows, as well as declining river and groundwater levels in many areas. The impact of drought is particularly evident at the downstream end of the River Murray

[1] Information on the governance structure and responbsilies of the South Australan Murray-Darling Basin Natural Resources Management Board can be found at http://www.samdbnrm.sa.gov.au/

system and other catchments, including the Eastern Mount Lofty Ranges, Burra and the Marne and Saunders.

Reductions in allocations, limited water access and worsening water quality have significantly affected horticultural, agricultural and dairy industry output and, in turn, have had wider impacts on local communities and economies. Whilst irrigators along the River Murray system have been hit hard with reduced water allocations since 2006/2007 (e.g. closing allocations of 60% in 2006/2007 and 32% in 2007/2008), water users in other areas have also been impacted by either reduced access to water and/or poor water quality. Little improvement is expected without significant rainfall and runoff.

Major threats to the natural resources of the SA MDB arise from past and current uses or from broader global processes. Some arise from decisions and actions made within the SA MDB while others arise from the decisions and actions of upstream states or from global processes (e.g. climate change). Of particular note are:

- the impact of introduced pest plant and animals;
- the continued fragmentation and decline of remnant native ecosystems;
- ongoing land degradation processes such as dryland salinity and soil acidity;
- the allocation, capture and non-licensed extraction of water resources beyond sustainable limits;
- altered quantity and timing of flows within river systems;
- declining water quality due to increasing salinity, nutrients and pollution; and
- inappropriate development practices.

Many of these threats are further compounded by the risk of a warmer, drier region under climate change predictions[2].

[2] Extract from SA MDB Regional NRM Plan: State of the Region.
http://www.SAMDBnrm.sa.gov.au/OurPlans/ TheRegionalNRMPlan.aspx#1

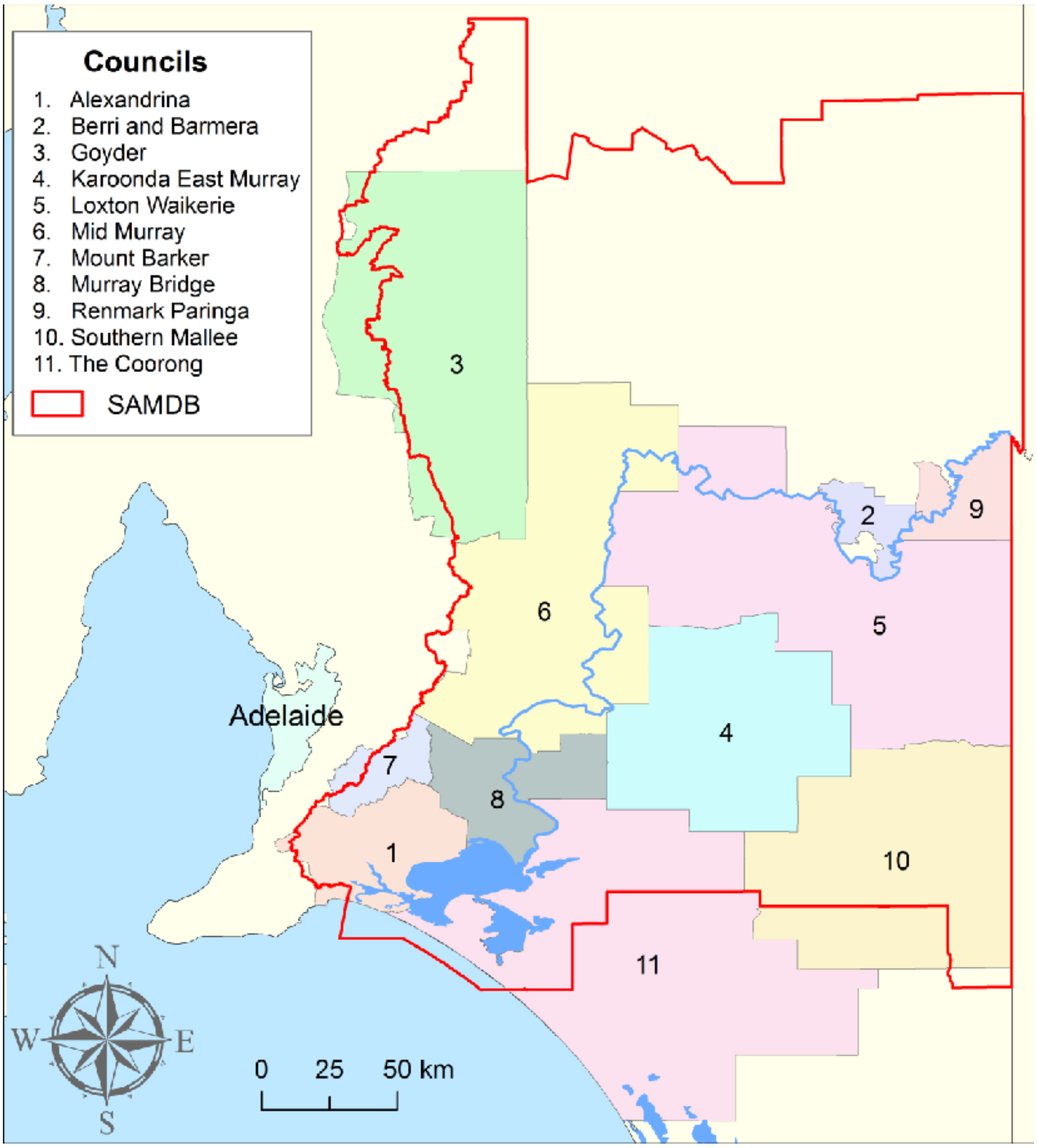

Figure 1. The South Australian Murray-Darling Basin showing overlay of local government boundaries relevant to this project.

1.2 Evidence from Australia that Climate is Changing

There is much information available providing evidence that Australia's climate is changing beyond the bounds of normal variability. A useful summary of this information, which will be referred to throughout this project and be used during the consultation process, was produced by CSIRO and the Bureau of Meteorology (2010) and draws the following conclusions[3]:

[3] Another summary of the science of climate change can also be found in "The Science of Climate Change: Questions and Answers", Australian Academy of Science, Canberra. http://www.science.org.au/policy/climatechange.html

Concentrations of greenhouse gases in the atmosphere are increasing

Concentrations of greenhouse gases in the atmosphere have increased significantly over the last 100 years. For the past 800,000 years and possibly the past 20 million years, levels of just one greenhouse gas, carbon dioxide, have been between 180 and 300 parts per million (ppm). The level in 2009 of 386 ppm is much higher than the natural average.

Australia is getting hotter

All of Australia has experienced warming over the last five decades and some areas have experienced an increase in average temperature by 1.5 - 2°C. Also, the number of record hot days per annum has been increasing each decade since the 1960's and the number of record cold days per annum has been decreasing over the same time period.

There is less rainfall where most Australians live

Over the last five decades, rainfall has increased in northern and central Australia and decreased in eastern and southern Australia. The decrease varies from between 5 and 50 mm/year.

Sea surface temperatures are rising

Sea surface temperatures in the Australasian region have increased by about 0.4°C over the last 50 years.

The sea level is rising

The global mean sea level has risen by about 200mm since 1870. Since 1993, sea level rise, mostly resulting from thermal expansion has been 1.5 to 3 mm/year in southern and eastern Australia and 7 to 10 mm/year in northern and western Australia.

1.3 Defining the Language of Responding to Climate Change: Vulnerability, Resilience and Adaptive Capacity

The ability for a community, industry, organisation or even a crop or human being to cope with a stress or hazard - such as climate change – can been viewed through the concept of vulnerability. If someone or something has high vulnerability it is more susceptible and less able to cope with the adverse impacts of climate change and vice versa.

Vulnerability of a system (e.g. geophysical, biological, agricultural, socio-economic) can be seen as a function of the potential impact that stress or hazards can have on the system combined with the system's adaptive capacity. In the case of climate change, mitigation of stresses and hazards will most likely be managed at national and international scales, beyond the reach of individual councils. However, adaptive capacity is well within the grasp of communities and local governments.

'Adaptive capacity', or a 'system's ability to cope with change', comes through building resilience into people and systems and is found in many shapes and forms. For example, social resilience can relate to concepts of wealth and education; and biophysical resilience can be built into crops and soil through more drought tolerant root stocks or higher soil organic content which improves ability to retain soil moisture.

The core themes of vulnerability and adaptive capacity are introduced in the introduction to this Milestone 1 report so as to outline a central framework that will be drawn on throughout this project. Importantly, approaches to dealing with vulnerability differ across various disciplines from risk management and social sciences to ecology. In the first instance this project will highlight the different approaches to working with vulnerability, but then as the project evolves, it will work toward a consistent approach that best matches the needs of the local government areas upon which this project is based.

Concepts of vulnerability, resilience and adaptive capacity and further expanded on in Chapter 3.

1.4 Report Structure

The *Climate Change impact assessment, adaptation and emerging opportunities for the SA Murray-Darling region* project is the umbrella project in a suite of 21 projects being undertaking as part of the Strengthening Basin Communities program funded by the Australian Government. The funding was provided to the following eleven councils within the South Australian Murray-Darling Basin Natural Resources Management Region to undertake this work:

- Berri Barmera Council
- Regional Council of Goyder
- District Council of Karoonda East Murray
- District Council of Loxton Waikerie
- Renmark Paringa Council
- Southern Mallee District Council
- Alexandrina Council
- The Coorong District Council

- Mid Murray Council
- District Council of Mount Barker
- Rural City of Murray Bridge

Findings from the project will assist the region to plan for a climate change driven future with less water through addressing risk and implications and identifying options for adaptation (including emerging industries and associated socio demographic patterns).

The key deliverables for the project are:

1) Climate Change Scenarios;
2) Climate Change Impact Assessment Report;
3) Adaptation and Emerging Opportunities Plan; and
4) Horticultural/Rural Lands Review.

This report addresses the first milestone of the project, which is the provision of scoping papers and literature reviews for the first three of these items. As such the methodology for this first milestone is primarily a desktop literature review. The remaining milestones include:

- Completion of climate change scenarios and community consultation (Milestone 2 – 15 November 2010);
- Final Impact Assessment and Draft Adaptation and Emerging Opportunities Plan (Milestone 3 - 16 May 2011); and
- Final Adaptation and Emerging Opportunities Plan (5 December 2011).

It is envisaged that as this project continues, the background information contained within this report will be further elaborated on from additional regional studies, current studies underway elsewhere in Australia and the experience of the community within the SA MDB.

This milestone report has been prepared by the:

- Environment Institute, University of Adelaide;
- The Australian Institute for Social Research, University of Adelaide;
- CSIRO Sustainable Ecosystems; and
- South Australian Research and Development Institute.

A technical report such as this encounters many acronyms and thus to assist the reader a list of the most commonly used acronyms and their meaning is provided at Attachment A.

2 CLIMATE CHANGE SCENARIOS

2.1 OVERVIEW OF CLIMATE PROJECTIONS [4]

The SA MDB, like most of southern Australia, is expected to be warmer and drier in coming decades. Compared to the base period of 1980 to 1999, the best (median) estimate from a suite of global climate models for the two decades centred on 2030 is a warming of 0.8 degrees C and a range between models of 0.5 to 1.3 degrees C (Table 1). By 2070 the best estimate under medium emissions is 1.8 degrees warmer (range 1.3 to 2.8). Under high emissions the best estimate is a warming of 2.3 degrees with some models predicting up to 3.5 degrees warming (Table 2).

The best estimate is for a 3.5% reduction of rainfall in 2030 with the driest 1 in 10 models estimating a 7.5% drying and the wettest one in 10 a 3.5% increase in rainfall. By 2070 the best estimate under medium emissions is a 10% reduction in rainfall (range of -30% to + 5%) and under high emissions a 15% reduction (range of -30% to +7.5%). Although there is little difference between seasons in projected warming, most of the drying is in winter and spring. Consistent with drying and warming there is expected to be a decrease in relative humidity and potential pan evaporation although the impact of these changes on the water balance are relatively small compared to possible changes in rainfall. Projected changes in solar radiation and wind are not expected to be large but generally solar radiation will increase especially if there is less rainfall and wind is projected to decrease in winter and show modest increase in summer.

Applying climate change science to decision making and planning is essentially a problem of information management. Given the objective of this project on capacity building and encouraging the combination of local knowledge with climate information, this paper outlines three guiding principles for the use of climate change projections in adaptation studies. These guiding principles can be summarised as the 'three As': Climate change projections need to be **a**uthoritative, they must **a**cknowledge the uncertainty and be **a**ction orientated. Prior to addressing these guiding principles, a series of definitions are given and the difference between climate variability and climate change is discussed.

[4] The data for this section is drawn primarily from Tables 1 and 2, which are based on information contained in CSIRO and BoM 2007.

Variable	Season	Low emissions			Medium emissions			High emissions		
		10p	**50p**	**90p**	**10p**	**50p**	**90p**	**10p**	**50p**	**90p**
Temperature Degrees C	Annual	0.5	**0.8**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Summer	0.5	**0.8**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Autumn	0.8	**0.8**	0.8	0.8	**0.8**	1.3	0.8	**0.8**	1.3
	Winter	0.5	**0.5**	0.8	0.5	**0.8**	1.3	0.5	**0.8**	1.3
	Spring	0.5	**0.8**	1.3	0.5	**0.8**	1.3	0.5	**0.8**	1.3
Rainfall %	Annual	-7.5	**-3.5**	0.0	-15	**-3.5**	3.5	-15	**-3.5**	3.5
	Summer	-15.	**0.0**	7.5	-15	**-2.0**	10.0	-15	**-2.0**	10.0
	Autumn	-7.5	**0.0**	7.5	-10	**0.0**	7.5	-10.	**0.0**	7.5
	Winter	-15	**-3.5**	0.0	-15	**-7.5**	0.0	- 15	**-7.5**	0.0
	Spring	-15	**-7.5**	2.0	-15	**-7.5**	2.0	-15	**-7.5**	2.0
Potential Evapo-Transpiration %	Annual	0.0	**0.0**	3.0	0.0	**3.0**	6.0	0.0	**3.0**	6.0
	Summer	0.0	**0.0**	3.0	0.0	**0.0**	6.0	0.0	**0.0**	6.0
	Autumn	0.0	**3.0**	6.0	0.0	**3.0**	6.0	0.0	**3.0**	6.0
	Winter	0.0	**6.0**	10.0	0.0	**6.0**	10.0	0.0	**6.0**	10.0
	Spring	0.0	**0.0**	3.0	0.0	**0.0**	3.0	0.0	**0.0**	3.0
Relative Humidity %	Annual	-1.5	**-0.8**	0.0	-1.5	**-0.8**	0.0	-1.5	**-0.8**	0.0
	Summer	-1.5	**0.0**	0.0	-1.5	**-0.8**	0.0	-1.5	**0.0**	0.0
	Autumn	-1.5	**0.0**	0.0	-1.5	**0.0**	0.5	-1.5	**0.0**	0.5
	Winter	-2.0	**-0.5**	0.0	-2.5	**-0.8**	0.0	-2.5	**-0.8**	0.0
	Spring	-1.5	**-0.8**	0.0	-2.5	**-1.5**	0.0	-1.5	**-1.0**	0.0
Downward Solar Radiation %	Annual	0.0	**0.0**	1.5	0.0	**0.0**	1.5	0.0	**0.0**	1.5
	Summer	0.0	**0.0**	0.0	0.0	**0.0**	0.0	0.0	**0.0**	0.0
	Autumn	0.0	**0.0**	0.0	0.0	**0.0**	1.5	0.0	**0.0**	1.5
	Winter	0.0	**1.5**	3.5	0.0	**1.5**	3.5	0.0	**1.5**	3.5
	Spring	0.0	**0.0**	1.5	0.0	**0.0**	1.5	0.0	**0.0**	1.5
Wind Speed %	Annual	-3.5	**0.0**	3.5	-3.5	**0.0**	3.5	-3.5	**0.0**	3.5
	Summer	0.0	**0.0**	7.5	0.0	**3.5**	7.5	0.0	**3.5**	7.5
	Autumn	-5.0	**0.0**	3.5	-7.5	**0.0**	3.5	-7.5	**0.0**	3.5
	Winter	-12	**0.0**	3.5	-12	**0.0**	3.5	-12	**0.0**	3.5
	Spring	-5.0	**0.0**	3.5	-7.5	**0.0**	3.5	-7.5	**0.0**	3.5

Table 1. Climate projections for the SA Murray Darling Basin region. Projections for 2030 are given relative to the period 1980-1999. Individual years will show variation from this average. The 50th percentile (50p; the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (10p and 90p; 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 where low emissions is the B1 scenario, Medium is A1B and high is A1FI. Projections from CSIRO and BoM 2007.

Variable	Season	Low			Medium			High		
		10p	50p	90p	10p	50p	90p	10p	50p	90p
Temperature Degrees C	Annual	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.8	**2.3**	3.5
	Summer	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Autumn	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Winter	0.8	**1.3**	1.8	1.3	**1.8**	2.8	1.3	**2.3**	3.5
	Spring	0.8	**1.3**	2.3	1.3	**1.8**	2.8	1.8	**2.8**	3.5
Rainfall %	Annual	-15	**-7.5**	3.5	-30	**-10**	5.0	-30	**-15**	7.5
	Summer	-30	**-3.5**	15	-30	**-3.5**	30	-30	**-7.5**	30
	Autumn	-15	**-3.5**	15	-30	**-3.5**	20	-30	**-3.5**	25
	Winter	-30	**-7.5**	3.5	-30	**-15**	3.5	-30	**-15**	5
	Spring	-30	**-15**	3.5	-30	**-15**	3.5	-60	**-30**	5
Potential Evapo-Transpiration %	Annual	0.0	**3.0**	6.0	0.0	**6.0**	10.0	0.0	**6.0**	14.0
	Summer	0.0	**3.0**	6.0	0.0	**6.0**	10.0	0.0	**6.0**	14.0
	Autumn	2.0	**6.0**	10.0	3.0	**6.0**	14.0	4.0	**10.0**	18.0
	Winter	2.0	**10.0**	18.0	3.0	**12.0**	18.0	4.0	**16.0**	18.0
	Spring	-2.0	**2.0**	6.0	-2.0	**3.0**	10.0	-3.0	**4.0**	10.0
Relative Humidity %	Annual	-2.5	**-1.5**	0.0	-3.5	**-1.5**	0.0	-4.5	**-2.5**	0.0
	Summer	-2.5	**-0.8**	0.0	-2.5	**-1.5**	0.8	-4.5	**-1.5**	0.8
	Autumn	-2.5	**-0.8**	0.8	-3.5	**-1.5**	1.5	-4.5	**-1.5**	1.5
	Winter	-4.0	**-1.0**	0.8	-4.5	**-1.5**	1.5	-4.5	**-1.5**	1.5
	Spring	-3.5	**-1.5**	0.0	-4.5	**-2.5**	-0.5	-4.5	**-3.5**	-0.8
Downward Solar Radiation %	Annual	0.0	**0.0**	2.5	0.0	**1.0**	2.5	0.0	**1.5**	2.5
	Summer	0.0	**0.0**	1.5	-1.0	**0.0**	2.5	-1.5	**0.0**	3.5
	Autumn	-1.5	**0.0**	1.5	-2.0	**0.0**	3.5	-3.5	**0.0**	3.5
	Winter	-1.0	**3.5**	7.5	-1.5	**3.5**	10.0	-2.0	**3.5**	15.0
	Spring	0.0	**1.0**	3.5	0.0	**1.5**	3.5	0.0	**2.0**	5.0
Wind Speed %	Annual	-7.5	**0.0**	7.5	-7.5	**0.0**	7.5	- 12	**0.0**	12.5
	Summer	-3.5	**3.5**	10.0	-3.5	**7.5**	12.5	-5.0	**7.5**	17.5
	Autumn	-10	**0.0**	7.5	-12	**-2.0**	10	-17	**-2.0**	12.5
	Winter	-12	**-2.0**	7.5	-17	**-3.5**	7.5	-17	**-5.0**	12.5
	Spring	-10	**0.0**	7.5	-15	**0.0**	12.5	-17	**0.0**	17.5

Table 2. Climate projections for the SA Murray Darling Basin region. Projections for 2070 are given relative to the period 1980-1999. Individual years will show variation from this average. The 50th percentile (50p; the mid-point of the spread of model results) provides a best estimate result. The 10th and 90th percentiles (10p and 90p; 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 where Low emissions is the B1 scenario, Medium is A1B and high is A1FI. Projections from CSIRO and BoM 2007. As for Table 1 but time period of 2070. Note that by 2070 there is a wider range in all parameters at any emission level and there is a significant difference between emissions.

2.2 DEFINITIONS AND SOURCES OF INFORMATION ON CLIMATE CHANGE SCIENCE

Global warming is usually used to describe the gradual increase in global average surface temperature as one of the consequences of increased greenhouse gases. The term climate change is more commonly used than global warming because there are also non-temperature related changes such as rainfall, wind and evaporation. The changes to temperature, rainfall, potential evaporation, wind and solar radiation for the SA MDB NRM region are shown for 2030 in Table 1 and 2070 in Table 2 these tables summarise data from the Climate Change in Australia report (CSIRO and BoM 2007).

A climate change projection is the response of the climate system to levels of greenhouse gases. A climate change projection should have a date (e.g. 2030 or 2070) and an emission scenario (low, medium or high). The emission scenario can be a level of carbon dioxide in the atmosphere (e.g. 550 ppm) or from the special report on emissions scenarios (SRES). The term scenario in this context refers to "a coherent, internally consistent and plausible description of possible future states of the world" (IPCC 2007).

Climate change is a much discussed and often contentious topic. It is not the purpose of this short paper, or the project, to engage in a debate on climate science. It assumes an acceptance of the basic science of human induced climate change. Nevertheless, it is naïve to ignore the fact that incorporating climate change when planning for local councils will involve a diversity of views and some challenges to the basic climate science.

There are numerous books and pamphlets designed to explain the basics of climate science. The Commonwealth Department of Climate Change has a section of frequently asked questions on a website[5] that deals with questions such as whether global warming has stopped, the emails stolen from the Climate Research Unit of the University of East Anglia, the Himalayan Glaciers and the reliability of climate models. The popular science magazine New Scientist website[6] addresses the 18 most common climate change questions. The Intergovernmental Panel on Climate Change summary for policy makers is also an excellent summary of the basic science.

2.3 CLIMATE VARIABILITY AND CLIMATE CHANGE

For this project a key question is how the internal climate variability will interact with human induced change over a planning period. The relationship between climate

[5] http://www.climatechange.gov.au/climate-change/science.aspx
[6] http://www.newscientist.com/article/dn9913-faq-climate-change.html

variability and change is usefully explained in Figure 3. The contrast is between variability within a stationary climate and variability within a changing climate. For any system, such as a vineyard, dryland farm or council infrastructure there is a degree of variability that can be managed and this is labelled the coping range. Beyond that range the system is vulnerable. In a changing climate, the damage to a system is most likely to come from the extremes and runs of extreme events rather than the mean.

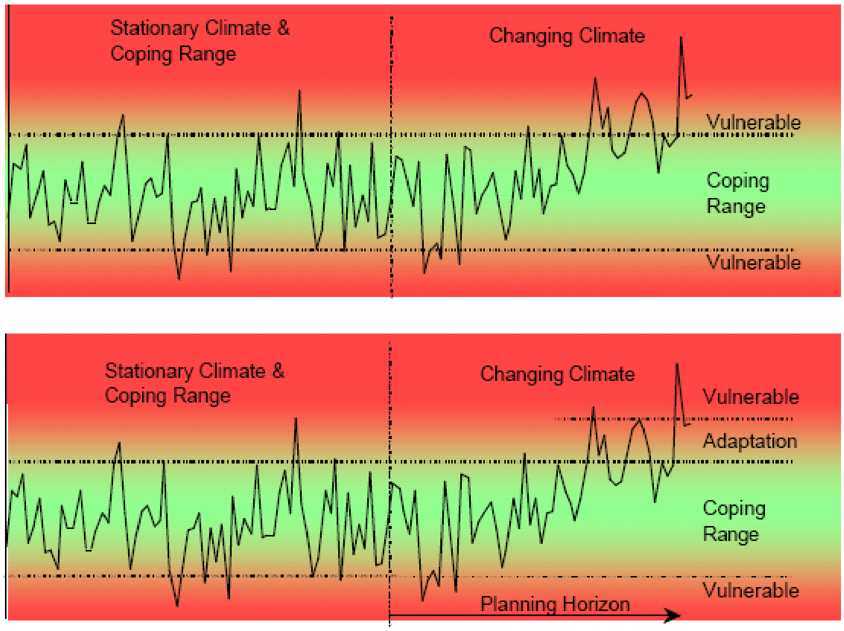

Figure 3. Relationship between climate variability and change. Roger Jones in Suppiah *et al* 2006).

This diagram also shows that the coping range can be widened with adaptation. For example more heat tolerant and water use efficient crops and cropping systems will have a wider coping rage. The diagram also shows how the planning horizon is relevant to any discussion of climate change. Climate change is going to feature less in a decision of planting an annual crop than a perennial crop like viticulture or decisions about whether children come back to take over management of the farm.

Nicholls (2006) reviewed the evidence for climate change in Australian records which is essentially trying to disentangle climate variability from climate change. He emphasised the importance of the two verbs – to *detect* a trend and to *attribute* the cause of the trend. Detection is finding a change and showing that it is something beyond what we might expect by random chance due to internal, natural climate variability. Attribution is the process of establishing the most likely causes for the detected change – for example human induced climate change. According to Nicholls' review, detection and attribution studies of Australian climate indicate that:

- The widespread warming is very likely to be due to increased greenhouse gas concentrations.

- The rainfall decrease in southwest Western Australia is likely due to a combination of increased greenhouse gas concentrations, natural climate variability, and land use change.
- The increased summer rainfall in northwest Australia may be due to increased aerosols resulting from human activity, especially in Asia.
- The apparent decline in pan evaporation is mainly due to changes in instrumental exposure.
- No study has attributed a cause to the rainfall decrease along the east coast.

In the period since Nicholls' (2006) review there has been substantial scientific study on the causes of the current drought in southern Australia (Nicholls 2009, Timbal 2009, Verdon-Kidd and Kiem 2009, Ummenhofer *et al*. 2009). Although there is increased evidence of some degree of human induced change on rainfall, it is much harder to detect changes in rainfall due to the high degree of annual and decadal variability and even harder to attribute these changes to climate change. A summary of the work undertaken by the Bureau of Meteorology on detection and attribution of the rainfall decline in the southern Murray Darling Basin as part of the South East Australian Climate Initiative (SEACI) is summarised by Timbal *et al* (2010). This report identifies an increase in the intensity of the sub tropical ridge as a major source of rainfall decline. It also summarises research with a global climate model run that showed no trend in the intensity of the subtropical ridge due to natural variability but an increase in the intensity towards the end of the 20th Century with greenhouse gasses. The report concludes that some of the recent drought is due to global warming.

Temperature will have a direct impact on the water budget but this is relatively small compared to rainfall. The increase in potential evapo-transpiration is about 2 to 3 % per degree of warming (Lockwood 1999). As recent seasons have shown, runoff is very sensitive to changes in rainfall. The "rainfall elasticity for runoff" for most of mainland Australia is 2 to 3 (Chiew 2006); this means that a 10 decline in rainfall may result in a 20% to 30% reduction in runoff and a 30% decline in rainfall can lead to a 60% to 90% reduction in runoff. For many catchments there is a threshold amount of rainfall required before there is any runoff and the seasonal timing of the rainfall is crucial. The decline in autumn rainfall has been particularly detrimental to runoff in the Murray Darling Basin (Timbal et al 2009). The complex relationship between rainfall and runoff are the intensity of rainfall, changes in landuse such as improved pasture and the impact of climate change on vegetation (warmer and drier and higher carbon dioxide). The overriding factor remains the change in rainfall.

2.4 PRINCIPLES OF CLIMATE CHANGE PROJECTIONS FOR USE IN PLANNING: AUTHORITATIVE, ACKNOWLEDGING THE UNCERTAINTY AND ACTION ORIENTATED.

2.4.1 THE NEED FOR AUTHORITATIVE CONSISTENT CLIMATE CHANGE PROJECTIONS

Planning for climate change can be made unnecessarily complex by the many sources offering guidance on what the future climate might be. The IPCC was established in 1988 by the World Meteorological Society and the United Nations' Environment Programme to provide authoritative advice on climate change. It has produced four major assessment reports in 1990, 1995, 2001 and 2007. A fifth assessment will be released in 2011. Further details on the IPCC are provided at Attachment B.

South Australia has two complementary sources of climate change projections, Suppiah *et al*. (2006) CSIRO report Climate Change Under Enhanced Greenhouse Conditions in South Australia and the CSIRO and Bureau of Meteorology Climate Change in Australia Technical Report 2007. Both of these reports are based on global climate models prepared for the 4th Assessment Round of IPCC (2007) and are readily available on the internet.[7] In November 2009 there was a science update for the climate change in Australia report. The emphasis of the update was that emissions were tracking at the higher level of the envelope of projections and the scientific community in Australia and internationally continue to document changes in the climate system such as ocean warming, sea-level rise, continental-average temperatures, temperature extremes and wind patterns. Discussion with Dr Penny Whetton (pers comm. 2010) Climate Impacts and Risk Research Leader, CSIRO earlier this year has confirmed that future climate modelling will be done for the 5th Assessment Report of IPCC, but that this will not be available for another 1 to 2 years. It was confirmed that the models chosen for the Suppiah (2006) report should still be considered valid.

SARDI climate applications and the climate policy section of DWLBC have worked with the DPC and PIRSA to summarise the climate change projections for the eight NRM regions for these reports. The first two regions are Eyre Peninsula NRM region and the SA MDB NRM region. Feedback from this project will be valuable for use in other NRM regions. This milestone report is based on the same information and presentation of climate change projections as the report prepared by South Australian state government departments. It is expected that the SA MDB NRM region report from state government will be available at the end of August.

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[7] http://www.climatechange.sa.gov.au/index, http://www.climatechangeinaustralia.gov.au/resources.php

The emphasis in this milestone report and the report that will be issued by the state government is to summarise existing information. This is not to dismiss new science or downscaling analysis that may become available for the region. Rather it is to use the existing projections as a foundation for decision makers. If, for example, a new study found that the likely rainfall reduction was 20% by say 2030 it is worth knowing that this is much more severe than the most likely projections for 2030.

In addition to rainfall, temperature, radiation, humidity and wind, the key issues for councils in the region are flow in the River Murray and sea level rise. The authoritative source of information on flows in the Murray-Darling Basin is the Murray-Darling Basin Sustainable Yields Project[8] that was released in July 2008. It estimates the current and likely future (2030) water availability in each catchment and aquifer for the entire MDB, considering climate change and other risks, and surface-groundwater interactions. Three global warming scenarios were used, with 15 global climate models, and modelled future development including commercial forestry, farm dams and groundwater extractions.

Figure 4 summarises some of the results. The best estimate is that in 2030 water availability in the Murray will be 14% less than the 1895 to 2006 period (Black bar). The 10 years shown as the red bar (1997-2006) have seen a 30% decline. Under the driest modelled conditions (Brown bar) water availability would decline by 40% and under the wettest extreme it would increase by 7%. This is an active area of research and reports that include the ongoing drought of 2007 and 2008 are likely to show an even more worrying situation. The modelling exercise also shows that under current policy the greatest impact of a changed climate will be end of system flow.

The authoritative source for sea level rise is the Coastal Protection Board within the South Australian Department of Environment and Heritage. Conversations with Dr Murray Townsend on 29th of April 2010 identified the current sea level rise policy of site/floor levels to allow for 0.3m rise to 2050 and a further 0.7m in the following 50 years. These numbers should take into account local land subsidence. There are a number of key uncertainties about sea level rise, but the uncertainty is all one sided; that is the contribution of catastrophic effects such as ice caps melting will add to the more modest rises predicted by the models. There are no expected processes that will lead to a reduction in sea level rise.

[8] http://www.csiro.au/partnerships/MDBSY.html

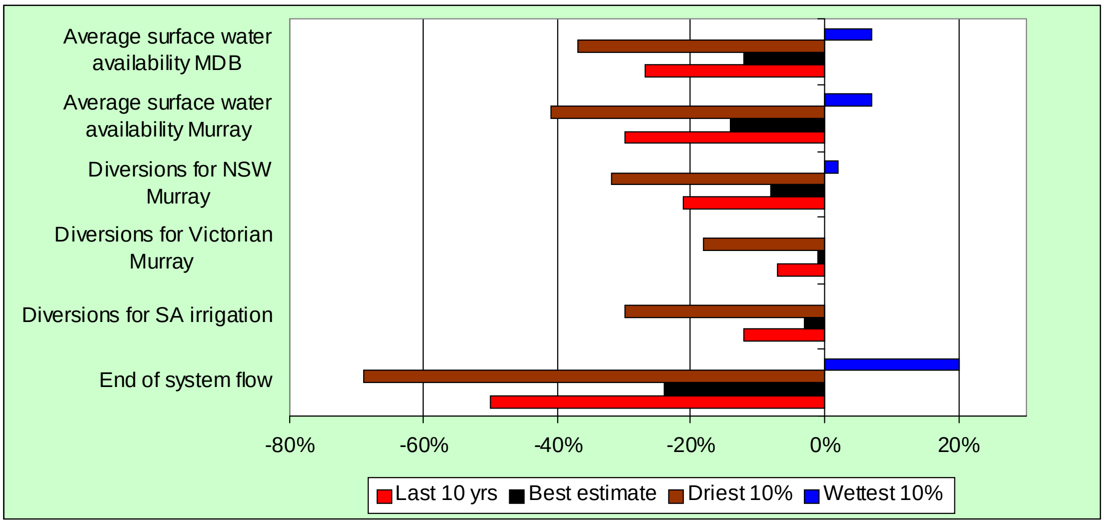

Figure 4. Changes in water availability. Figure drawn from data in CSIRO sustainable yields project (http://www.csiro.au/partnerships/MDBSY.html). * see supplementary milestone report for more detail

2.4.2 The Need for Climate Change Projections to Acknowledge the Uncertainty

It is important that users of climate change information acknowledge that there is uncertainty in the projections. Simply put, no one can supply a single map of what the climate will look like in the SA MDB in 2030. Ideally as shown in Figure 5, there should be a series of maps that represent the two sources of uncertainty (emissions as columns and different models as rows). The percentiles are found by ranking the models from the warmest to the coolest or driest to the wettest. The 10th percentile is the one in 10 coolest and the 90th percentile is the one in 10 warmest. The 50th percentile is the median or mid ranked model also referred to as the best estimate. There is very little difference between high and low emissions in 2030. Figure 6 shows the different sources of uncertainty for mean global warming. In a broad sense, South Australian future changes to temperature are similar to global changes with coastal regions a bit cooler and inland a bit warmer (see Figure 18 Suppiah *et al* 2006).

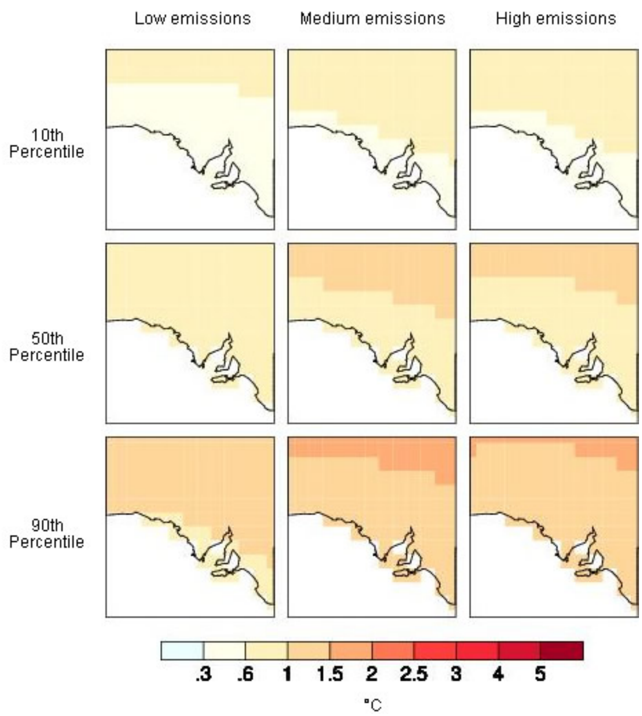

Figure 5. Temperature projections for South Australia for 2030 from CSIRO and BoM 2007.

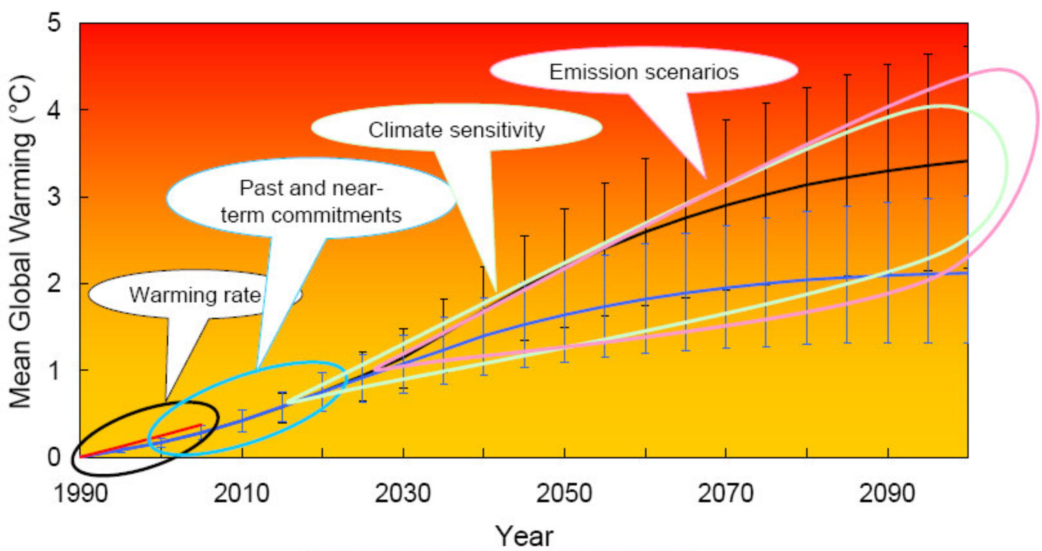

Figure 6. Different sources of uncertainty for mean global warming in coming decades (IPCC 2007)

The range of expected warming in the coming 10 to 15 years is relatively small and can be estimated from recent trends in temperature and past and current emissions. The recent trends in temperature indicate that there will be year to year variability, but each decade is warmer than the previous decade. The range of global temperatures in 2030 or 2040 is larger but the main source of uncertainty is the question of how sensitive the climate is to greenhouse gases (not whether we are on a medium, high or very high emission pathway). At 2070 the range is much larger and this is because of the combined uncertainty of different emission pathways and the climate sensitivity. The news that emissions are tracking higher than what was thought likely by IPCC is worrying news, however, the *main* impact of these higher emission scenarios will be expected in the latter part of the century.

The level of confidence in warmer temperatures and increased heatwaves is much higher than the confidence about rainfall. Although there is a general consistency between models on drying in winter and spring in southern Australia, there is a wide range in the extent of the drying. The IPCC 4th Assessment Round Summary for Policy Makers states "On scales smaller than 50 years, natural climate variability is relatively larger than human influences, making it harder to distinguish changes expected due to external e.g. man-made forcings" (IPCC 2007). This is especially true of parameters such as rainfall. A number of extreme events associated with storm events are localised and can occur in short time periods. These events that are much smaller than the grid scale of the models are difficult to assess in climate change projections. Effective ways of modelling changes in extreme events is a focus of the Australian Climate Change program. SARDI climate applications is working on the climatology of heatwaves in the region (Grace *et al.* 2009) and involved with a Managing Climate Variability Program project led by CSIRO sustainable ecosystems on changes in meteorological processes that lead to frost events.

2.4.3 The Need for Climate Change Projections that are Action Orientated

The uncertainty in climate change predictions should not be a reason to delay planning for a warmer and water constrained future with rising sea levels. In recent times adapting to climate change has become less reliant on climate change projections. That is not to say that it is unimportant to get the latest projections, but there has been a switch from "top down" impact studies which take climate change projections and then model what the impact will be on human and natural systems to more closely studying the climate sensitivity and sources of vulnerability of local systems. This 'bottom up" approach equips end users to make more sense of what a 10% decline in rainfall means for their system. Sarawitz (2010) a researcher who has worked in the application of predictive science in seasonal climate forecasts, nuclear reactor planning, emergency planning and earthquakes notes in the context of climate change predictions that *"predictions are not instructions that people simply follow to make better decisions. They are part of an intricate puzzle that may sometimes contribute to a better decision".*

The approach taken in the Lower Murray Landscape Futures project was to use a set of scenarios of mild, moderate and severe warming with associated drying and a mild warming with a small increase in rainfall. These future scenarios are designed to stretch the thinking and assumptions of planners. A major advantage of these scenarios is that they provide a range of possible futures that can be considered rather than focussing on a single future that is the average of many models or being confronted with a bewildering range of models.

The figures below are a graphical representation of Table 1 and 2. In each case the grey bar represents the range of the 10^{th} and 90^{th} percentile and the black bar the median or best estimate.

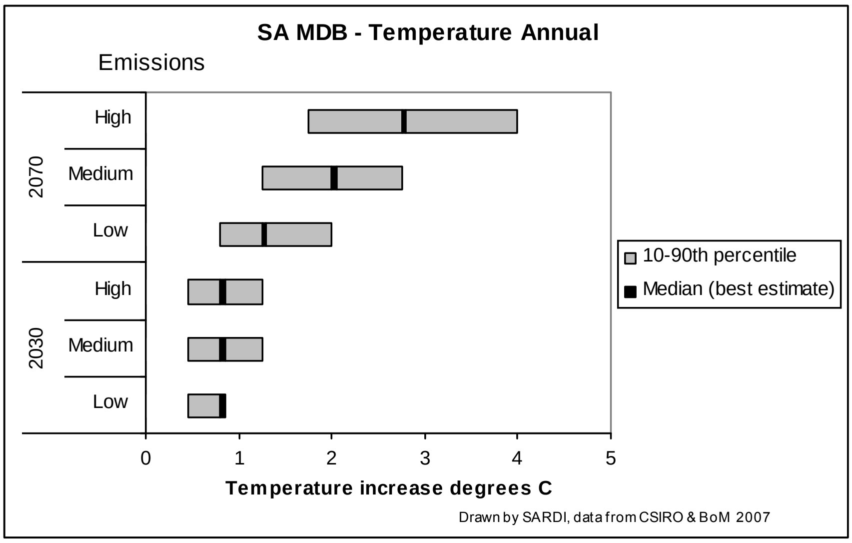

Figure 7. 2030 and 2070 annual temperature change for SA MDB.

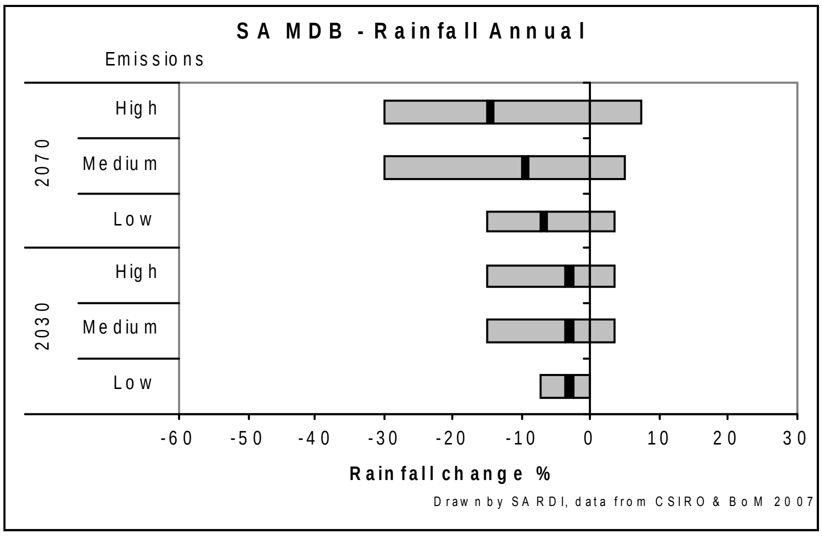

Figure 8. 2030 and 2070 annual rainfall changes for SA MDB.

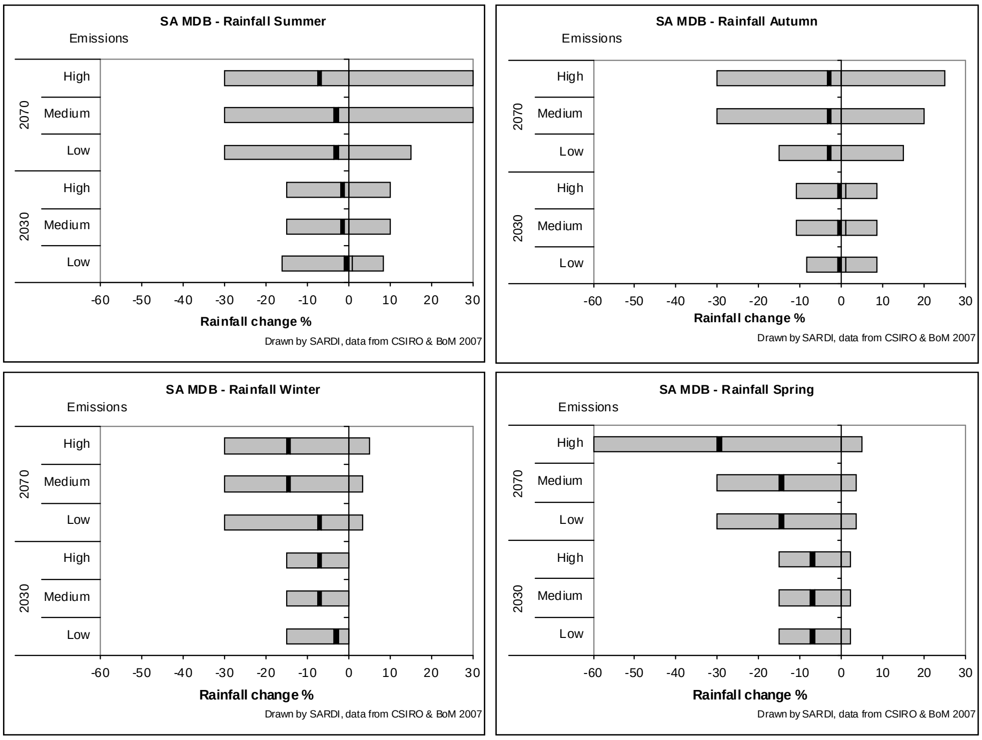

Figure 9. Seasonal rainfall changes showing the greater rainfall change in winter and spring compared to summer and autumn. Care should be taken in interpreting the increase in summer rainfall as the base amount of summer rainfall is very low.

In the case of constructing a scenario of a future climate, it is problematic to combine the 1 in 10 warmest outcome and the 1 in 10 driest outcome as they are unlikely to be the same model. An alternative approach is to take the 13 GCMs that were identified by Suppiah (2006) as performing the best in predicting the 1960 to 1990 rainfall, temperature and mean sea level pressure for South Australia. These are listed in Table 3.

Legend	Abbreviation	Climate Modelling Group	Country
Dark Green	BCCR	Bjerknes Centre Climate Research	Norway
Red	GFDL	Geophysics Fluid Dynamics	USA
Purple	IAP	Institute of Atmospheric Physics	China
Pink	Miroc	Centre for Climate Research	Japan
Black	MIUB	Met Inst of University of Bonn	Germany
Grey	MK3	CSIRO	Aust
Dark Blue	MPI-ECAHM5	Max Plank Institute	Germany
Light Green	MRI	Meteorological Research Institute	Japan
Orange	CC50	CSIRO	Aust
Yellow	UK met office	Hadley Centre	UK
Light Blue	NCAR	National Centre for Atmospheric Res	USA

Table 3. Global climate models from Suppiah *et al* (2006). The colour scheme from this table is used in the following figures.

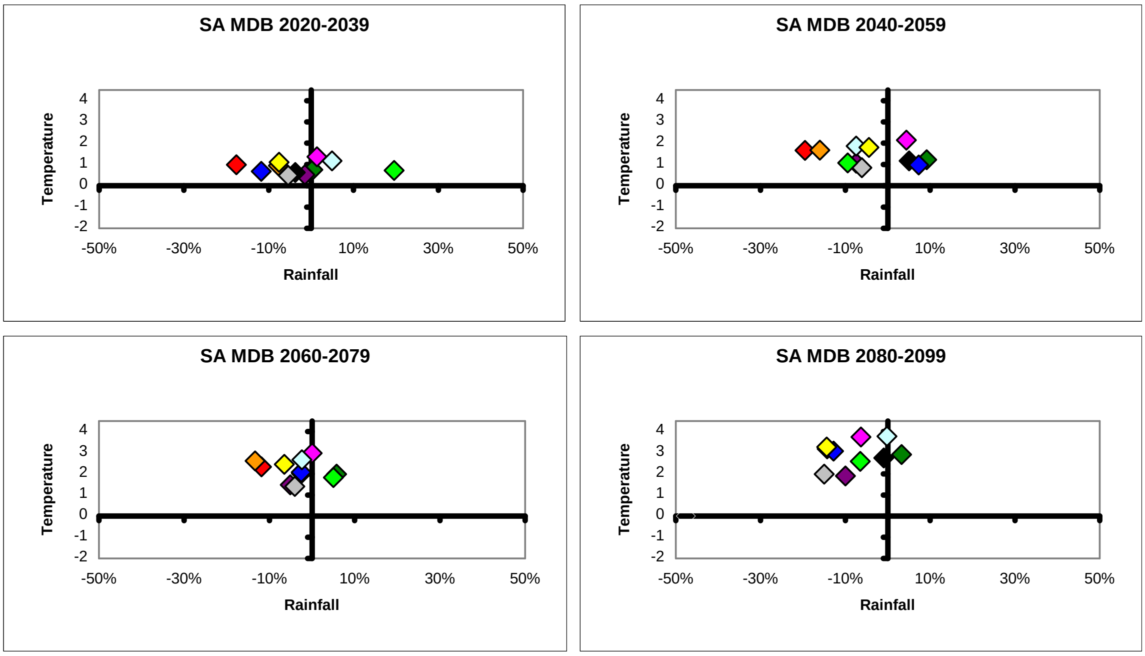

Figure 10. The 13 global climate change models from Suppiah (2006) for the SA MDB. Colour scheme as per Table 3. In later decades there is a strong confidence in warming and a general trend towards drying, i.e. a move towards the top left hand quadrant. The scenarios used in the Lower Murray Landscapes Futures project of mild warming/drying (1°C warming and 5% drying); moderate warming/drying (2°C warming and 15% drying); severe warming/drying (4°C warming and 25% drying), and mild warming/wetting (1°C warming and 5% wetting) are plausible and capture the spread of the points.

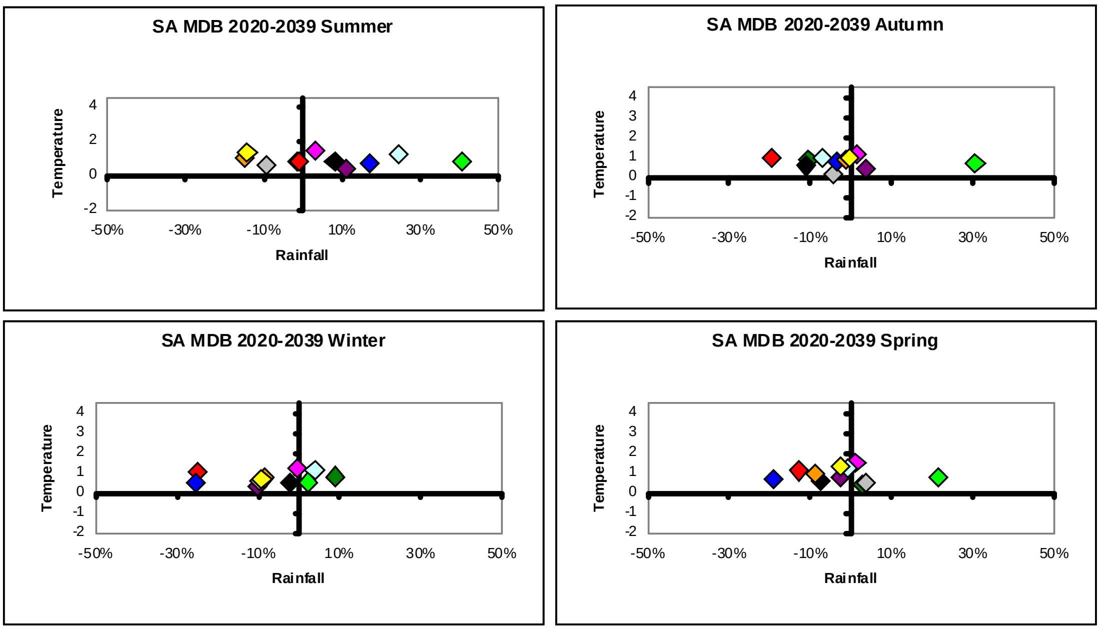

Figure 11. Rainfall and temperature changes in the two decades centred on 2030 from the 13 global climate models from Suppiah *et al* 2006. Colour scheme as per Table 3.

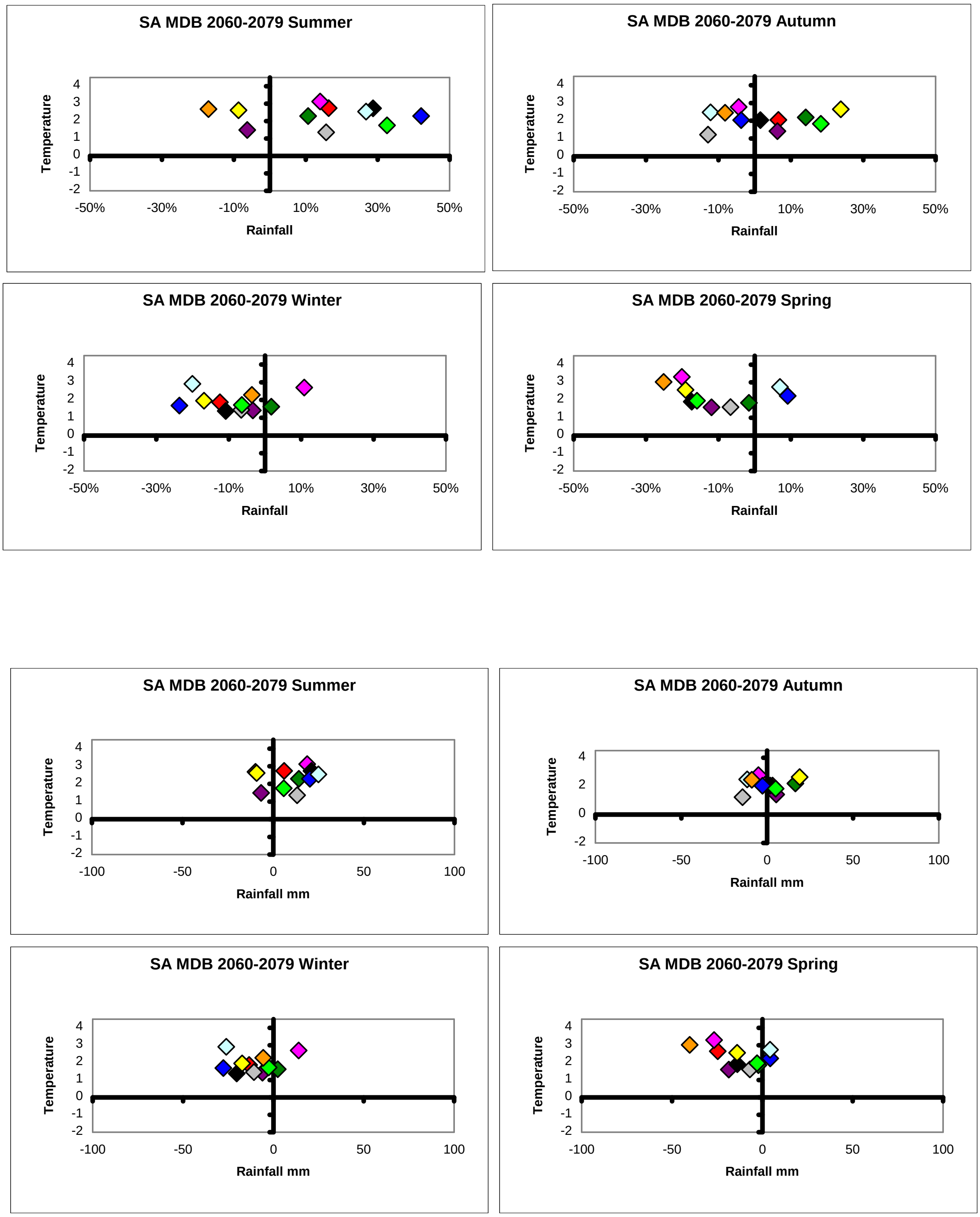

Figure 12. Rainfall and temperature changes in the two decades centred on 2070 from the 13 GCMs from Suppiah *et al* 2006 and A1 scenario. Colour scheme as per Table 3. The top panel shows the four seasons with the x axis as a percentage and the bottom axis shows the same data but as mm. This highlights the point that the increase in summer rain is high in percentage terms but low in mm of rainfall, especially considering the high potential evaporation rate (often over 10 mm per day) in summer.

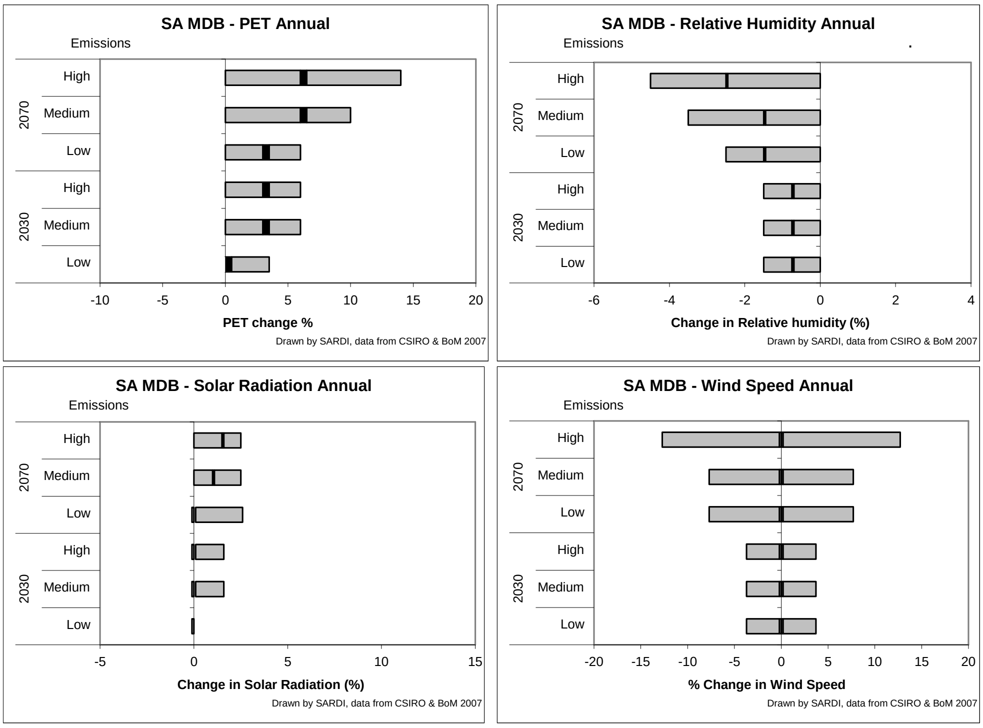

Figure 13. Changes in potential evapotranspiration, relative humidity, solar radiation and wind speed for 2030 and 2070 under low, medium and high emission scenarios. Note the change in scale. The general trend towards increased evapotranspiration, decreased relative humidity and increased incoming solar radiation is consistent with warmer and drier conditions. However at 2030 these changes are relatively minor compared to the rainfall and temperature changes. There is no clear signal with wind.

3 CLIMATE CHANGE IMPACT ASSESSMENT

3.1 Overview

In this section we provide a framework for examining climate change vulnerability. We then look at the expected impacts of climate change for the major agricultural activities in the SA MDB and provide some discussion of adaptation options.

Vulnerability analysis is broadly seen as a way of estimating the ability of a system (natural or anthropogenic) to cope with an external stress or hazard. It has become an increasingly popular tool to understand the possible effects of climate change with applications in social, economic and biophysical systems (Adger 2006, Nelson *et al*. 2010, Young *et al*. 2010).

The IPCC defines vulnerability as 'the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change' (Schneider *et al*. 2007). Within this context, the vulnerability of a system can be thought of as the combination of exposure to a stress, the sensitivity of the system to the stress and the ability of the system to respond or adapt to the stress.

Figure 14 illustrates one possible vulnerability framework. A hazard event, such as climate change, has a certain magnitude and likelihood. The system is exposed to the hazard in the form of reduced rainfall and increased temperature as well as greater incidence of extreme events such as storms and droughts. The sensitivity of the system is determined by the thresholds past which it cannot cope with the changed conditions. The exposure and sensitivity together determine the potential impact of the hazard event. On the other side of the framework is the system's ability to cope which is called its adaptive capacity. The adaptive capacity depends on many social (e.g. wealth or policy) and biophysical factors (e.g. climate or crops) that combine to determine the systems resilience. The potential impact and the resilience determine the systems climate vulnerability. While we do not present a complete vulnerability analysis here, such a framework assists in framing the issues involved with climate change.

3.2 Impacts on Local Government Business

Exposure to climate change can have an impact on a range of factors that influence the operation of local government, and more directly on communities within these local government areas.

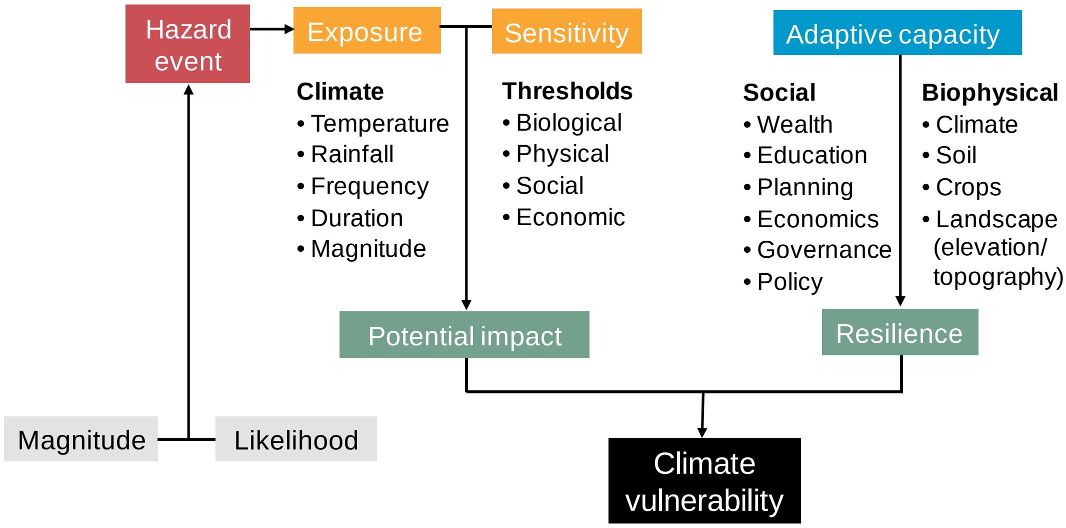

Figure 14. Vulnerability framework (adapted from Preston *et al*. 2009, Adger 2006 and Turner 2003)

A preliminary review of literature on the direct and indirect impacts of climate change on local communities is summarised in Table 4 (Hawke Research Institute 2004; Australian Greenhouse Office 2006; Baum, Horton et al. 2009; SGS Economics and Planning and Water Research Laboratory (UNSW) 2009; SMEC Australia 2009; Halifax Regional Municipality September 2006). This review is not exhaustive and will be built on further using the results of community consultation and additional research. Drawing on this review conducted to date, issues of direct relevance and interest to SA MDB Councils will include:

- changes in rates of road deterioration - increased frequency and magnitude of storm events, higher temperatures and increased solar radiation will increase deterioration, alternatively, reduced rainfall will decrease deterioration rates;
- changes in emergency response operations – e.g. bushfire intensity and frequency likely do change due to less rainfall. Potentially lower fuel load, which would be expected to reduce fire incidence, but likely dryer plant material which would be expected to increase fire incidence; and
- health impacts due to exposure to extreme weather such as heatwaves.

Of course the actual impacts of relevance to local government in the SA MDB will vary in accordance with:

- differing environmental and socio-economic conditions that prevail throughout the region;
- each Councils' culture, stakeholders and ability to respond;
- the service delivery roles they have to play, which can be different when comparing urban and rural councils.

Table 4. Likely climate change-related challenges for local councils (Direct impacts on socio-economic wellbeing of local communities).

Road/pavement construction and maintenance	• 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. • rail tracks buckling during heatwaves
Buildings	• Changes in frequency of wind, rain, hail, flood, storm events and damage, potentially resulting in destruction. • Changes in building heating/cooling costs • Increased risk of damage from bushfires.
Community/workplace health	• Increase in geographical range and seasonality of vector-borne diseases and the possibility for an expansion of receptive zones. • High temperatures increasing incidence of food and water-borne diseases. • Risk of increased cryptosporidium infections during open water swimming in summer. • Health impacts due to exposure to extreme weather, e.g. heatwaves. • Extreme rainfall events transporting contaminants into waterways and drinking water supplies. • Increased pressure on drinking water supplies.
Emergency/bushfire management	• Increased emergency response and recovery operations. • Risks to public safety and tourism and longer term impacts on regional economies.
Biodiversity	• Shifts in distributions of plant and animal species. • Increased risk of population and species extinctions. • Reduced ecosystem resilience to stress. • Increased ecosystem and species heat stress. • Increases in ecological disturbances.
Wastewater	• Changes in intensity of rainfall events impacting inflow and infiltration to wastewater network. • Potential for blockages and dry weather overflows during dry spells.
Water supply	• Changes in mean and peak stream and river flows. • Uncertain water availability. • Insufficient water supply in some areas. • Increased potential for water contamination. • Salination of surface and groundwater supplies. • Changes in availability of groundwater available for irrigation. • Impact on public open space and ovals

Beyond the completion of this first phase of the project (i.e. Milestone 1), a community and stakeholder consultation process along with further review of past and current regional studies will be used to refine our understanding of impacts, shedding light on those that are common to the region and those that are relevant to each council.

3.3 Impacts on Agriculture and Rural Enterprises

Modern Australian history has been a story of rapid landscape change. It has been a triumph of human will and ingenuity and has forged our myths and our sense of identity. The rapid and dramatic change has brought great wealth to Australia but also left a sobering legacy of extinction debt, over-allocated water resources, soil loss and communities in constant flux and stress. The future presents even greater challenges to us than the past: shifting climates, rapid population growth, resources at their limits and global competition for resources and markets.

Current climate change projections indicate an increase in temperatures and a decrease in rainfall over the SA MDB and a higher frequency of extreme weather events (Suppiah *et al*. 2006). These conditions will have significant effects on current production systems whether dryland agriculture or in the case of irrigated agriculture through reduced river flows and water allocations.

There is general concern about the possible reduced income base for regional councils that could hamper the adaptation to the many issues within the different council areas. The economic viability of maintaining infrastructure, which supports all aspects of the economy from agriculture and industry, to tourism, may be compromised. Similarly, rural centres and towns could become unviable and find themselves stranded as the economic activity that supports them diminishes. For the councils in the SA MDB NRM region a major part of this economic activity is driven by the agriculture sector. The total gross value of agriculture in the SA MDB NRM region exceeds $1.2 billion (ABS 2007) from a diverse range of broadacre cropping and grazing to irrigated horticulture and viticulture.

Most broadacre agriculture has been preceded by large scale clearing of deep rooted perennial native vegetation and replacement by shallow rooted annual systems. This change in land use has resulted in substantial degradation in the biological, nutritional and water resources in the landscape. Climate change has the potential to exacerbate these changes in our landscape functions. Reduced rainfall and increased temperature are known to reduce agricultural yields and increase the risk of environmental problems such as wind erosion (Stokes *et al*. 2008). Similarly, remnant vegetation and biodiversity will be effected with some ecosystems

Table 5. Summary of potential impacts for dominant land uses in the SA MDB.

POTENTIAL IMPACTS	
Cropping	Shortened crop season length and reduced yield potential Increased variability Reduced frost due to warming and changing weather patterns Increased risk of wind and water erosion
Pasture and grazing	Declines in pasture productivity and reduced forage quality Livestock heat stress Increase risk of wind and water erosion Increased threat from weeds and disease better adapted to warmer conditions
Viticulture	Faster progression of phonological (development) stages Reduced/poor budburst due to insufficient chilling over winter Heat damage and poor grape quality resulting in poor wine quality Shorter, more intense vintages due to early and more rapid ripening Reduced threat from frost damage Impacts on grape quality due to bushfire smoke
Horticulture	Likely reduction in areas suitable for stone– and pome– fruits that require chilling for setting fruit Likely increase in suitable areas for sub-tropical fruits Reduced threat from frost damage but Increase in sunburn, colourisation and other yield quality. Potential problems with flowering and pollination Increase in water stress and potential decrease in water use efficiency Potential decrease in fungal pathogens Potential decrease in cold season suppression of some pests/diseases

benefiting and others suffering as changes occur. While new opportunities may arise for these systems, establishing them in a damaged and fragmented landscape will likely be more difficult.

Warmer and dryer climates are likely to increase the vulnerability of farming systems and result in lower yields for most crops simply through reduced water availability. The positive growth effects of increased carbon dioxide in the atmosphere are mostly offset by the more rapid development of annual species with warmer average temperatures. Dryland cropping and pasture will be effected by shortened growing season duration with higher temperatures while reduced rainfall will almost always reduce yield potential. Similarly, higher temperatures will increase the stress imposed on livestock and reduce the abundance and quality of their feed. Irrigated crops will also be affected; decreased rainfall will result in less river flow and likely reduced water allocations, insufficient cold will reduce seed set for some fruit crops (Hennessy and Clayton-Green, 1995) and higher temperatures will affect fruit quality for other crops. The reduced risk of frost will be advantageous for some crops but these benefits can be quickly overshadowed by the prospect of lower rainfall amounts. Below we give detailed examples of the impacts on the major farming systems in the SA MDB.

3.3.1 Broadacre Cropping

Broadacre cropping in the SA MDB is dominated by cereals, legumes and oilseeds. The gross value of production is approximately $900 million and covers an area of 1 million ha (ABS 2007). Broadacre cropping will suffer from reduced rainfall and increased temperature (heat shock) over most of the SA MDB which will adversely affect crop growth and yields (Stokes *et al*. 2008). Bryan *et al*. (2007) modelled the impact of climate change on agricultural production in and around the SA MDB. They looked at various crops including wheat, lupins, canola and lucerne under traditional and conservation (minimum tillage) management systems. They also examined various rotations including continuous cropping, crop-crop rotations and crop-grazing rotations with the different crops and pastures, where applicable, and found each of these had reduced yield estimates with warming and drying climate scenarios. For example, under the most severe warming (4^{o} C hotter) and drying (25% less rain) they found a wheat yield decreased by one third (Bryan *et al*. 2007). They also examined the impact of these changes on environmental issues and found a reduced risk of dryland salinity through reduced deep drainage but dramatic increases in the risk of erosion due to reduced crop growth and vegetative cover. For example, under severe warming and drying the area of land at risk of dryland salinity decreased by 74% and the area at risk of wind erosion increased by more than 10 times (Bryan *et al*. 2010).

Other more subtle changes will also be felt. Seasonal shifts, for example may result in changes in the timing and duration of the growing season and increased variability require the adoption of and greater reliance on opportunistic cropping (Stokes *et al*. 2008).

There is the potential to sow earlier in the season with higher temperatures and reduced frost risk during colder seasons.

3.3.2 Broadacre Grazing

Pasture and grazing in the SA MDB is dominated by sheep and cattle farming with a gross value of $230 million in primary products alone (ABS 2007). The grazing systems range from semi-arid in the north of the region to temperate in the south. The main impacts of warming and drying on broadacre grazing will be a decline in pasture productivity and quality, and livestock heat stress. Changes in pastoral productivity are likely to be driven by rainfall both through changes in the total rainfall and the timing and intensity of rainfall events (Crimp *et al.* 2002, Stokes *et al*. 2008). A higher frequency of summer rainfall events, for example, will change the growth patterns of pastures and the available forage. Similarly, potential increases in the growth of pastures during the cooler months, due to higher minimums, may also reduce the ongoing plant available water and reduce spring pasture vigour. Rangeland areas may be particularly sensitive to changes in climate with studies indicating that small variations in climate have magnified effects on livestock carrying capacity (Stokes *et al*. 2008).

Forage quality will also be affected through increased CO_2 concentration in the atmosphere which has been shown to increase growth but reduce pasture protein content (Wand *et al.* 1999, Stokes *et al*. 2008). Also there is some risk that changes in the distribution of pests, feral animals, disease and weeds may follow changing climate. For example, desirable forage plants may be out competed by less suitable and palatable species that are less suited to the changing climate (Stokes *et al*. 2008, Stokes *et al*. 2010).

Increased heat stress reduces animal productivity and reproductive rates. In southern areas such as the SA MDB there may be opportunities to exploit the hardier northern (sub tropical) breeds that are more heat tolerant. However, these breeds are generally less productive, have a lower fecundity and produce poorer quality meat.

Increased frequency of extreme weather events, such as high rainfall or wind intensity, will also increase the risk of soil erosion. This may be exacerbated by reduced pasture growth due to general warming and drying. In such a situation, the erosion of small amounts of top soils can remove a large amount of soil nutrients having a significant effect on overall soil fertility.

3.3.3 Viticulture

Viticulture in the SA MDB has an approximate gross value of $280 million and covers an area of 30,000 ha (ABS 2007). Like most horticulture in the region, vineyards are irrigated and generally take some years to establish.

Vineyards will suffer from reduced water allocations and accompanying increased water deficit stress and increased temperatures. A warmer climate will likely result in a faster progression of the phenological and fruiting states resulting in an early season, although reduced chilling over the winter dormancy may impact on budburst. The increased temperature and water deficit stress will also adversely affect grape quality and colour attributes which will have flow on effects for the wine industry (Stokes *et al*. 2008, Webb *et al*. 2010). A positive impact of the increased temperature will be the likely reduction in the number of frost days which will decrease the risk of frost damage on canopy and fruit development (Hennessy and Clayton-Green, 1995).

Adaption options include grafting and planting new varieties that are better suited to the 'new climates' or that have longer seasons which may compensate for the expected changes. Another option is to move production into other areas, within or outside the SAMDB, whose climates become more suitable due to the expected changes. Improvements in vineyard management may also alleviate some of the expected changes (Webb *et al*. 2010). For example, the use of wind breaks may reduce the drying effects from dry hot winds over summer, although this will also have consequences for water balance and pest management in the vineyard.

3.3.4 HORTICULTURE

Horticulture in the SA MDB is dominated by fruit (citrus, stone, pome and berry etc), nuts and vegetables with an annual gross value of more than $260 million over an area of approximately 14,500 ha (ABS 2007). Most of these are high value, perennial crops that are dependent on irrigation and can take many years to establish. Reduced river flows and unreliable water allocations have the potential to dramatically change the risk profile of these production systems. This may be exacerbated by higher demand for water from crops in response to increased temperatures and heat stress. An increase in the demand on water combined with decrease in supply will place greater pressure on water use efficiency. Higher temperatures also pose a substantial threat to those 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). Similarly, the increased water and heat stress may cause vegetable crops to bolt (premature flowering) and reduce the viability of these crops in the region (Stokes *et al*. 2008). There is also the potential for increased sunburn, colourisation and other yield quality issues that would affect the market value of crops once they leave the farm gate.

There are some potential positive outcomes for these industries as well. Increased CO_2 concentrations in the atmosphere are known to increase photosynthesis and water use efficiency. Warmer atmospheric temperatures are also mostly associated with drier (less humid) conditions that tend to reduce yield losses due to fungal diseases and some insect pests (Webb and Whetton 2010). It is also possible that crops previously not suitable to the SA MDB may benefit from changes in climate, for example, tropical fruits that require higher temperatures (Stokes *et al*. 2008).

4 ADAPTATION AND EMERGING OPPPORTUNITIES

4.1 Overview

This section of the Milestone 1 report focuses on adaptation and emerging opportunities from two different perspectives. First, it considers institutional adaptation approaches and issues that are relevant to local government, giving some 11 examples of approaches adopted by other councils across Australia to the challenges posed by climate change impacts. Second, an overview is given of the considerations for adaption and emerging opportunities with respect to agriculture.

4.2 Institutional and Local Government Adaptation

4.2.1 Climate Change Vulnerability, Risk and Adaptive Capacity for South Australian Murray-Darling Councils

Local government is well placed to play a key role in the development and implementation of strategies and plans designed to mitigate and adapt to the likely impacts of climate change. Important lessons can be learnt from recent local government experience.

The role of local government in assessing climate change vulnerability, risk and adaptive capacity has been the focus of considerable attention in Australia over the last few years. The International Council for Local Environmental Initiatives OCEANIA (ICLEI) has acted as a catalyst for this through the 'Cities for Climate Protection Australia Adaptation Initiative' which prepared the *Local Government Climate Change Adaptation Toolkit* (2008) to assist councils to better understand and respond to the challenges presented by climate change over decades to come. It is important to note that in 2008 around 220 Australian councils were engaged in strategies designed to reduce greenhouse gas emissions as part of the 'Cities for Climate Protection' (CCP) program – a joint venture between the Australian Government and ICLEI.

The engagement of local government in assessing climate change vulnerability, risk and adaptive capacity is intensifying as substantial funding opportunities become available to develop adaptation strategies and plans. The Australian Government, particularly through the Department of Climate Change and Energy Efficiency (DCCEE) has financed a wide range of local government initiatives. More broadly the DCCEE commissioned an important study on 'Climate Change Adaptation Actions for Local Government', released in 2009. It identified a wide range of possible implications of climate change for local government and adaptation options that might be considered in response to climate change. The key findings from this study are summarised later in this report.

Understanding and responding to climate change is a multi-dimensional challenge that is subject to considerable uncertainty as our knowledge about climate change is refined with the benefit of new observations and insights. What we do know is that climate change will have differential spatial impacts, requiring localised responses that seek to both limit and adapt to the impacts of climate change. Local government is beginning to play a key role in this through the systematic assessment of climate change vulnerability, risk and adaptive capacity.

4.2.2 Approaches to Assessing Vulnerability, Risk and Adaptive Capacity

While we can learn a great deal from the substantial body of experience assessing climate change vulnerability, risk and adaptive capacity in Australia it is important to note that the complexity and comprehensiveness of the approach to adaptation planning that is adopted needs to be tempered by the human and financial resources available. In a diverse region such as the SA MDB it will be necessary to establish priorities for detailed vulnerability and adaptive capacity assessments that can be implemented as resources become available.

The literature identifies a range of possible adaptation measures that might be undertaken at a local level (Kinrade and Justus 2008):

1. **Structural and technological** – focus on engineering solutions and changes in related practices.

2. **Planning and legislation-related** – focus on revising planning regulations to take into account existing and potential climate change risks.

3. **Internal management** – focus on reviewing councils' internal practices with regard to community engagement, environmental assessment and extending planning horizons to incorporate long-term socio-economic and ecological changes due to climatic events.

4. **Research** – focus on improved understanding of climate change as a process, resulting challenges and opportunities, knowledge and a better assessment of existing local capacities to cope with these challenges and identify a future course of action with a focus on both 'what' and 'how' aspects of climate change risks and adaptation options.

5. **Educational/behavioural/cognitive** – focus on engaging community in decision making and improving its awareness and preparedness to collaborate with other groups – internal and external – to address climate change risks.

The choice of the most suitable measures in addressing risks and developing adaptation options can be made on the basis of a number of factors, including but not limited to economic and political viability, concurrence and compatibility with other measures (including the development of 'no-regrets' measures[9]), public acceptance and socio-cultural sensitivity.

In a community workshop conducted in the Western port region in Victoria (Kinrade and Justus 2008), three issues of particular significance were identified by stakeholders in considering how to approach climate change adaptation. These were: a) general anxiety within the community with respect to climate change and potential impacts on socio-economic wellbeing; b) heightened pressure on volunteer services to deal with climate change-related emergency events; and c) loss of community wellbeing, particularly for disadvantaged or vulnerable groups of elderly and indigenous people, as a result of direct climate change impacts. An all-encompassing method of engaging communities – through councils, NGOs and locally-based widely representative coordinating bodies was identified as crucial to enhancing the flow of information on climate change to the community, which is in turn a pre-requisite to successful climate change adaptation locally. A preliminary review of literature on the direct and indirect impacts of climate change on local communities is provided in Section 2.2.

4.2.3 Focusing on Resilience

The concept of resilience was first introduced in Section IV. Communities exhibit a great deal of resilience in the face of considerable threats and challenges Resilience refers to the ability to recover from ongoing internal or external stresses in an informed transformative, adaptive manner (Maguire and Cartwright 2008). In the context of climate change it requires an understanding of the inter-relationship between:

- the nature and extent of the region's exposure to climate change;
- residents' awareness and perceptions of potential climate change impacts;
- the existing stock of socio-economic, ecological, institutional and technological capacities within the system; and
- the degree of inherent sensitivity to short and long-term changes in natural climatic conditions.

In light of the significant degree of uncertainty associated with climate change, the application of a community resilience approach to adaptation is likely to be particularly useful in that it "accepts that change is inevitable and unpredictable. Rather than focusing on the potential points of weakness, [it] identifies the resources and adaptive capacities that a community can utilise to overcome any problems that may result from change" (Maguire and Cartwright 2008, p3).

[9] In climate change parlance, 'no-regrets' measures are those that have wider socio-cultural, economic, ecological and institutional merits to the community/ region independent of their role in addressing climate change-related challenges and risks.

4.2.4 Community Engagement and Participation

Central to effective climate change adaptation is community engagement and participation in strategic planning and implementation of action plans. Key lessons from the literature include that:

- community-initiated climate change actions and other grassroots initiatives such as Save the Murray can be important (place-based networks/cyber communities etc.) (Hawke Research Institute 2004; Bond 2009).

- self-audits of local communities can play a useful role to identify a) potential measures to address climate change-related impacts in the area, and b) existing capacities (individual and social capital) to operationalise measures outlined in a) above (Maguire and Cartwright 2008).

- emphasis on individuals and businesses can yield positive results (Agrawal 2008) because they are often better placed to manage local risks. Given the diversity of socio-economic conditions often observed in a study region, developing a blueprint guide to adaptation is neither feasible nor advisable. Context-specific micro-level adaptation measures developed in collaboration with the community may be most effective (Hawke Research Institute 2004; Department of Climate Change 2010).

4.2.5 Spatially and Socio-Economically Sensitive Approaches

It is vital that climate change adaptation strategies are informed by an understanding of physical and socio-economic diversity. Key lessons from the literature include the importance of:

- spatial planning *in* climate change which recognises the need for planning and developing regions, towns and communities that are better adapted to changing climatic conditions (Steele and Gleeson 2009); and

- an emphasis on the socio-spatial dimensions of climate change vulnerability as a function of exposure and social sensitivity to risk (as influenced by age, income and other socio-economic and cultural characteristics) (Baum, Horton *et al*. 2009).

4.2.6 Collaboration and Partnerships

A co-ordinated and collaborative approach to tackling climate change requires a commitment to collaboration and the development of partnerships at the national and local level. Key lessons from the literature include:

- Effective collaboration between key stakeholders, ongoing learning through established groups of organisations and/or individuals and strong leadership are key characteristics of a successful adaptation plan at the local level (ICLEI (Oceania) 2008). In addition, the 'whole of government approach' that ensures greater and well-coordinated interaction between the three tiers of government is another vital component of a successful adaptation framework (Kinrade and Justus 2008).

- Effective inter-agency engagement that pro-actively situates climate change risk assessment and adaptation management within the council's broader strategic planning process (Australian Greenhouse Office 2006).

4.2.7 Responsibility of Local Government and Potential Roles

Local Government provide vital social, economic and environmental support to communities and operate under the Constitution Act 1934 (SA), the Local Government Act 1999 (SA), and the Local Government (Elections) Act 1999 (SA). Some of this support is required by legislation, including for example planning and development services, some environmental health services, fire prevention, dog and cat management and some administrative requirements such as preparing strategic plans (LGA SA, 2010). There are many other forms of support that are provided by choice, such as stormwater drainage and parks and gardens (LGA SA, 2010).

The Planning Institute of Australia identify that local government has a duty of care to manage the impact of climate change on local communities. In the future Local Government may be subject to claims for compensation or common law negligence cases (Planning Institute of Australia, 2004). These legal risks can be reduced through proactive approaches based on consulting communities and coordinating efforts with other organisations.

The scope of potential climate change impacts and adaptation actions is extremely large and is not limited to the jurisdiction of Local Government or other individual organisations. Support for communities to navigate changes in climate will be more effective through collaboration with other levels of government and organisations. While costs may be saved through collaboration, overlapping efforts and multiple similar projects will reduce the risk of failure to adapt to change and increase confidence that adaptation is achievable.

4.2.8 Local Government Adaptation Tools

The ICLEI local government climate change adaptation toolkit provides a framework for addressing the socio-economic, institutional and ecological implications of climate change (ICLEI Oceania 2008). The adaptation toolkit details an approach to risk management and the development of adaptation options at the local level (Australian Greenhouse Office 2006; ICLEI (Oceania) 2008) as illustrated in Figure 15. A similar report has been developed by the Local Government Association of South Australia and is called the Local Government Climate Adaptation Program (Local Governments Association of South Australia 2010). This report is in the interim stages but relies upon similar methodologies to those discussed here.

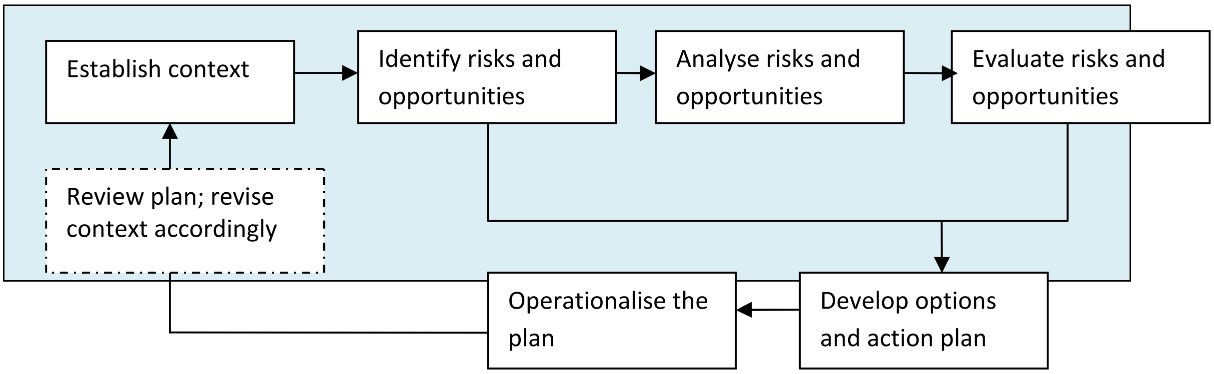

Figure 15. The adaptation toolkit details an approach to risk management and the development of adaptation options at the local level.

This approach involves the identification, analysis and evaluation of potential risks in parallel with the identification of opportunities and adaptive responses at the institutional, individual and community stakeholder level. In this way, local

Table 6. Possible outputs from process of identification, analysis and evaluation (ICLEI (Oceania) 2008).

Stage	Outputs
Establishing the context	• communications brief on the management process • list of existing resources, their potential applicability and availability and gaps • lessons and/or resources database • draft version of a conceptual model that the council will apply to develop context- relevant adaptive management strategies
Identifying risks and opportunities	• common understanding of potential risks and opportunities in the council presented in a scoping brief • draft version of detail on each individual risk • opportunity Conceptual models that situate each risk and opportunity within the council's broad context of climate change adaptation
Analysing and Evaluating risks and opportunities	• set of final briefs on council's risks and opportunities and a detailed prioritisation of each risk and opportunity • prioritised list of top climate change impact-related risks and opportunities in accordance with the council's local context established earlier.
Developing actions and option plan	• comprehensive adaptation action plan or a set of core actions identified through the earlier stages
Operationalising the plan and subsequent reviews and revisions	• results from the field (both institutional and individual/ community related) • lessons learnt about adaptation successes and ongoing and emerging challenges • information on resources – financial, human, social – dedicated to climate change adaptation at the council level

governments can work with stakeholders to share information, debate and deliberate over outcomes. The possible outputs from each stage of the process are detailed in Table 6.

The Australian Government's guide to climate change related risk management provides a useful matrix for assisting with the identification of direct and indirect risks for local authorities (Australian Greenhouse Office 2006). Key scales identified in these examples can be applied with relevant changes to the study region to assess climate change risks to infrastructure and socio-economic capacities of the community more generally. Table 7 provides a snapshot of the matrix presented as part of the evaluation framework in the report.

Table 7. Simplified version of the matrix presented in the Australian Government's guide to climate change related risk management.

Types of direct and indirect risks **for a local authority**					
Impact level	Safety	Economic	Social	Environmental	Institutional
Catastrophic					
Major					
Moderate					
Minor					
Insignificant					
Types of direct and indirect risks **for a public utility**					
Impact level	Service quality	Service delivery	Management with other providers	Administration	Public confidence and opinion
Catastrophic					
Major					
Moderate					
Minor					
Insignificant					

4.2.9 Selecting Adaptation Actions

The vulnerability framework is suggested as a basis for management and more specifically selecting adaptation actions in this report. This framework, also introduced in Section 1, combines understanding of likelihood of a stressor, the magnitude of that stressors' impact and the capacity of the system to adapt. Capacity to adapt can be defined in terms of social, economic, financial, institutional and ecological capital. Vulnerability therefore gives an overall measure, both quantitative and qualitative, to assist planning and management activities of Local Government. When applying the vulnerability framework to select adaptation actions, we should consider the sometimes hidden costs such as reduced water availability from trees planted for carbon benefits.

We identified an extensive range of climate change adaptation actions in the literature. These actions are linked to the impacts identified in the previous section and fall into a number of categories, including general, infrastructure, public health, parks and gardens, water availability and regional economy.

Table 8. Possible impacts of climate change and related adaptation actions. Source: adapted from SMEC (2009).

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
General	
All impacts of climate change	Strengthen profile of climate change within local government, and combine with the sustainability agenda. Raise local community awareness of climate change and adaptation actions that can be implemented at home and that have ancillary benefits in addition to those associated with climate change, e.g. water and energy conservation measures, etc. Establish communication channels between scientists and local government officers. Improve public sector capabilities through capacity building activities for local government staff. Complete climate change risk assessments.
Infrastructure	
All infrastructure related climate change impacts	Showcase best practice in climate sensitive building design in public buildings.
Damage to infrastructure from cracking, moving and subsiding soils	Consider potential for subsidence/ heave in the design of infrastructure foundations.
Infrastructure not suitable to hotter, dryer climate with more extremes	For infrastructure developments with a lifetime greater than 50 years, design for staged construction to allow for future climate change adaptation measures Design council buildings to allow for ease of future adaptation, e.g. have the ability for significant amounts of shade to be added or removed from a facade.
Increase in damage to infrastructure from floods, strong winds and storm surges in coastal areas	Flood-proof or re-site infrastructure and plan transport routes and roads to avoid disruption by flooding activities. Increase monitoring and maintenance activities at embankments and bridge piers, and gully emptying activities. Ensure emergency procedures and equipment are in line with currently available information on local flooding risks.

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
Inundation and erosion of coastal areas from sea level rise	Implement dune restoration programs as appropriate. Protect buffer vegetation in shore zones.
Drainage problems in urban environments from higher intensity rainfall	Provide education of preventative practices prior to and during extreme events, e.g. clearing gutters and drains. Minimise hard surfaces, such as pavements. Include development controls, such as those that promote soft surfaces external to the building footprint. Urban based drainage system should be linked to catchment based flood management to avoid impacting on other areas in the catchment. Development of a stormwater management plan that addresses potential locally-appropriate alternative uses of stormwater and includes measures to reduce peak flows during wet weather, e.g. increased use of stormwater by capturing (such as developing wetlands and aquifer storage and recovery). Ongoing and periodic review of sewerage system strategies and operations to address hydraulic constraints and overflow risks, and sewer rehabilitation and cleaning regimes. Limit growth expansion and/or connections to parts of the system where there are potential capacity constraints.
Increase in bushfires from longer heat spells and higher maximum temperatures	Risk assessment to ensure new infrastructure is not placed in fire-prone areas. For those where location is not flexible, investigate standards of construction that reduce their sensitivity to bushfire. Identify which areas will be more vulnerable to bushfire. Encourage new developments, or changes to existing developments, to include improved protection and adaptations to increased bushfire risk (bushfire management strategies are largely available).
Increase in power consumption for cooling from longer heat spells and higher maximum temperatures	Increase use of insulation in new buildings. Retrofitting existing buildings with addition of insulation materials and effective and efficient cooling systems. Reduce lighting and equipment loads to reduce overheating. Optimise design of cooling systems to provide the best energy efficiency under higher temperature operating loads, i.e. use of passive cooling systems, improved use of thermal properties of building materials, reduce solar heating using recessed windows, roof overhangs and shades. Promote micro power initiatives.
Increase in contamination from open site waste disposal from higher intensity rainfall	Increase community education to reduce waste generation through both sustainable consumption and reducing overall consumption. Maximise kerbside diversion of material from landfill through provision of high performance collection systems. Encourage sorting of waste at source for household, commercial and

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
	construction wastes and promote composting.
Increase is incidence of wastewater overflow from higher intensity rainfall	Design wastewater systems to prevent overflow events from wetter than normal weather, based on climate change scenarios. If costs are prohibitive, plan for regular system reviews to consider climate change effects.
Public Health	
Heat stress and sunburn from exposure to high maximum temperatures and longer heat spells	Review/prepare design guidelines for street furniture, shelters and awnings, and infrastructure to provide protection, e.g. development of a shade and sun protection policy. Conduct shade audits to determine the adequacy of existing shade, whether there is a need for more, if appropriately located and of appropriate size. Include provision of shade structures in design of new council recreational facilities. Ensure sufficient shade, either natural or built, is available or planned for when developing new recreational facilities or centres and in any development plans for picnic areas, playgrounds etc. Adopt heat-emergency contingency plans for recreational/tourism events held within local council area (these plans are generally developed by state/territory governments). Encourage scheduling recreational and sporting events and activities to avoid the hottest part of the day and at shady locations where possible. Utilise demographic profile and social analysis of council area to assess health vulnerability. Identify affected communities and needs. Develop a Public Health Plan that looks at the current health and wellbeing of the communities within the council area and develop Wellbeing Indicators so that the program can be assessed over future years. Increase community education on awareness of dangers of sun exposure/ symptoms of heat stress. Shade audits/provision of more shade in public recreational areas. Reduce the impact of thermal stress via advice on how to stay cool including the use of portable fans, improved ventilation of homes, public buildings, and other residential institutions and workplaces. Development of community heat emergency management plans. Raising awareness of heat-related illness. Provide accessible air-conditioned public facilities. Waive/reduce user fees for swimming pools. Provision of outdoor drinking facilities.
Increase in incidence of contagious, vector-borne and food-borne disease	Improve alert systems for the possibility of vector borne disease outbreaks to be developed with advice from state and Commonwealth health agencies. Surveillance of vector populations, monitoring and reporting of disease

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
from higher temperatures and changes to rainfall	incidence. Control of disease vectors, including elimination of disease vector breeding sites. Educate residents about disease risks, precautions and symptoms. Increase council-run immunisation programs to address any increased threats where possible (should be undertaken in liaison with state health programs/agencies). Increased monitoring for waterborne diseases (such as E. coli, toxic algae, and viruses). Engage in public health education activities (information addressing safer food production and storage processes for local business and communities, food handling guidelines).
Increase in injuries and fatalities from storms and other natural disasters	Review local disaster management plans. Evaluate bushfire risks. Improve community disaster preparedness and response systems.
Increase in depression in regional areas due to unemployment and reduced economic activity in rural sectors	Work with other governments agencies to identify most vulnerable groups. Advertise to increase awareness of mental depression and the services available.
Water Availability	
Less water available from reduced allocations and from less water in on-site storages	Incorporate polices which ensure that the water resource implications of new developments are assessed. Promote water sensitive urban design at the plan-making and development assessment stages of the planning process. Develop water strategies that incorporate grey water reuse. Supplement existing supplies with recycled water where possible. Community education on water efficient garden planting and watering. Promotion of use of Sustainable Urban Design Systems (SUDS) and water efficient installations into new developments. Identification of opportunities to include Sustainable Urban Design Systems in existing developments/ infrastructure. Prepare or review policies to incorporate demand management strategies such as roof water harvesting in residential areas. Identify potential water conservation incentives.
Parks and Gardens	
Less / no water available for	Four main options to consider in reducing irrigation mains water use

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
irrigation from reduced water allocations	i. choosing areas to receive less irrigation ii. efficient irrigation iii. water efficient landscaping iv. using alternative supplies of water such as rainwater tanks, aquifer storage and recovery, grey water and black water, reclaimed effluent and groundwater. Train staff on irrigation system auditing and scheduling. Develop an irrigation plan to identify and reduce existing irrigation levels where possible. Water controls and management be tailored for specific council areas.
Plants and grass dying or damaged from less rainfall, higher temperatures and longer heat spells	Use of plants in parks and open spaces that are indigenous to the local council area. Set aside areas for community gardens to trial plants local to the respective council and their ability to adapt to use in gardens. Increase mowing heights of lawns to decrease lawn water use and stress. Increase application of mulches. Dedicate additional resources to the provision and maintenance of parks, forests and other green areas. Provide for increased regular maintenance of park/green space in council management plans and council budgets.
Increase in incidence of bushfires in parks from less rainfall, higher temperatures and longer heat spells	Take into account the areas at increased risk of bushfire from climate change in the use of prescribed fire as a tool for managing fuel accumulation (recognising that inappropriate fire regimes can potentially threaten the conservation of biodiversity). Use of fire adapted vegetation (much of Australian vegetation is fire adapted). Ensure that 'fire management zones' have been identified. Ensure that clear objectives and the most suitable forms of fire management and mitigation for each zone have been developed, e.g. identification of assets and collation of information on how fire, and fire mitigation, might affect these assets.
Reduced diversity and abundance of native species in reserves and urban areas from less rainfall, higher temperatures and longer heat spells	Develop a Local Biodiversity Plan as a component of the Local Planning Strategy and Town Planning Scheme. Implement conservation management plans for local reserves and other local government lands. Encourage private land conservation, e.g. through incentives. During strategic spatial planning, take into account impact of potential reduced water supply on urban vegetation. The location of water bodies is important, because they can help sustain urban vegetation. Continue to develop roadsides/utility corridors as native vegetation corridors, in consultation with relevant road authorities to ensure road use safety is protected.
Increase in pests and	Develop and implement a pest, weed and invasive species management

POSSIBLE IMPACTS	ACTIONS FOR ADAPTATION
diseases from less rainfall, higher temperatures and longer heat spells	policy/ strategy that takes into account changed climatic conditions (many local government areas have management policies/ strategies in place). Promote awareness to local communities of potential weed risks resulting from climate change in the local area (incorporate into existing awareness programs if appropriate). Revisions to mowing and weed control schedules to take into account changed climatic conditions that affect growth and dispersion.
Regional Economy	
Slowing rural economies in dry land and irrigated areas reducing population and rate revenue.	Work with other levels of government and regional development boards to identify business opportunities. Promote and provide incentives to facilitate new business and industry. Review planning and policy processes to identify undue restrictions on business and economic activity. Concentrate council services in particular areas to make best use of available finances. This may involve identifying areas where infrastructure can be maintained less frequently or at a lower standard.
Urban development encroaching agricultural land in high growth areas.	Work with state government agencies and other relevant organisations to identify and map high value agricultural land. Define and declare areas to be protected for agriculture in strategic plans and town plans.
Increased demand for council services including town planning, building approvals and waste management in high growth areas.	Perform work planning to scope magnitude and timing of demand for council services. Adapt management according to work planning outcomes. Work planning may involve defining priority ratings for different services, allocating resources and monitoring implementation.

4.2.10 What are Other Local Governments Doing?

Local action for climate change is growing across Australia. Here we provide 12 case studies, including those given in SMEC (2009), that highlight different responses to climate change and its potential impacts at a local government level.

1. The City of Melville, Western Australia, developed Sustainable Residential Design Guidelines and a Grey Water Reuse Package. The guidelines provide a checklist and illustrated examples of how to design a dwelling to achieve maximum energy efficiency and water savings. The guidelines have been incorporated into policy and building approval processes. The Grey Water Reuse Package provides information for the selection and installation of systems that take household wastewater and reuse this to irrigate garden areas. The City of Melville also relies heavily on groundwater for irrigation of parks and gardens. Over the last 10 to 15

years, the council has been adding meters to its groundwater bores to collect information for informing water management improvements. The council is also planning to install real time monitoring, which will help community members be more sensitive to urban water use and groundwater levels. Please see www.melville.wa.gov.au for more information on both projects.

2. On the Hunter, Central and Lower North Coast of New South Wales, 14 councils came together on a Regional Climate Change Risk Assessment and Adaptation Planning Initiative. There were two subprojects, one that focussed on rural council areas and one on coastal council areas. The studies identified risks and adaptation options and developed plans for collaboration and action. A case study of impacts on the Hunter Valley Wine Industry was also under taken. Please see http://www.hccrems.com.au/climate_change/index.html for more information.

3. The Western Port Greenhouse Alliance (WPGA) in Victoria is a regional partnership established in 2004 to coordinate actions to adapt to climate change and implement greenhouse gas abatement projects. A study was commissioned that identified 30 adaptation measures including amendment of local planning schemes to include provisions on the treatment of sea level rise and storm surge projections in relation to land protection. The partnership is based on a memorandum of understanding between five local governments. Please see http://www.wpga.org.au/ppp.asp for more information.

4. Clarence City Council in Tasmania commissioned a vulnerability assessment of coastal areas to sea level rise and storm surges associate with climate change. Council is now implementing a number of actions identified in the study including adding more sand to beaches and dunes, revegetation, raising and reinforcing some roads, installing sewerage systems and developing new standards and planning controls. Please see http://www.ccc.tas.gov.au/site/page.cfm?u=807 for more information.

5. The City of Port Adelaide-Enfield in South Australia commissioned a study of risks associated with sea level rise on the Lefevre Peninsula. The region is very vulnerable because it is low lying and has a population of about 28,000. The project is managed by an interagency steering group and has identified engineering, urban planning and education strategies for climate change adaptation.

6. Ku-ing-gai Council in New South Wales is securing better water supplies for playing fields and public gardens. The first project involved installing a 250,000

litre tank under an oval that collects water from a stormwater network after being treated in a detention base and gross pollutant trap. The council plans to install tanks under another 10 ovals and 2 public gardens. The council also launched a Water Smart Challenge, which is an education campaign for encouraging residents to conserve water by 10% over two years. A garden of drought-tolerant native plants was constructed as a demonstration site to show residents how to achieve the 10% target. Please see www.kmc.nsw.gov.au for more information.

7. A mosquito control program in Mandurah Western Australia is being adapted with understanding of climate variability. The program involves four Local Governments and the WA Department of Health. Mosquitoes are controlled by larviciding by helicopter at regular periods throughout the breeding season. Warmer temperatures and higher tides increase mosquito populations and higher tides reduce the effectiveness of the larvacides due to dilution. Climate sensitive application methods and larvacides are being trialled. Please see www.mandurah.wa.gov.au for more information.

8. The Victorian Coastal Strategy 2008 was launched by the Victorian Government. It presents a long-term management framework of policies and actions for managing climate change impacts on Victorians coasts. The policies identify development constraints, areas that should be conserved, limits to public liability and the use of scientific information.

9. The Guideline Planning for Bushfire Risk Mitigation in the ACT was adopted in 2006. The ACT Planning and Land Authority requires the guideline to be considered in planning decisions, including for development applications. New suburban estates and rural residences within a bushfire prone area must be subject to risk assessments and higher construction standards. The guideline identifies other risk management measures, including making house asset protection zones, using water supply infrastructure with adequate capacity levels, building emergency accesses in the form of an outer ring road, maintaining a clearance of 0.5 metres on both sides of streets, increased verge width to residential blocks and street species selected for low bark flammability. Two FIREWISE information brochures (Home Design and Construction and Home Gardens) were prepared for home owners and builders and provide information on how to reduce risks to homes and gardens. The Guideline is complementary to the ACT Emergency Services Authority's Strategic Bushfire Management Plan, which outlines measures for preventing, preparing for and responding to bushfires.

10. The City of Salisbury in South Australia has developed more than 30 wetlands that cover approximately 250 hectares since 1984. These wetlands receive and purify water, which can be used for irrigation or injected into underground aquifers for later use. The wetlands also reduce flood peaks, harbour plants and animals and improve the appearance of the parks and gardens in which they are located. Over the last 10 years all new residential subdivisions were required to install wetlands to contain stormwater on site. Large industrial developments have also been actively encouraged to develop wetlands. Wetland construction is part of a broader approach to integrated water cycle management. A plan has been developed with strategies for managing rainwater, stormwater, groundwater, waste water and potable water with a key objective of replacing up to 20 GL of mains water per year. Please see www.salisbury.sa.gov.au for more information.

11. The Darwin City Council is developing plans and an atlas to guide environmental and climate adaptation activities and community engagement for a period of 10 years. A number of products will be developed, including separate community and organisation focussed environmental management plans, an environmental management strategy discussion paper, a city atlas of environmental, recreational, cultural and land-use values, as well as a series of action plans as a basis for contributing to four-yearly work programs. Please see www.darcity.nt.gov.au/aboutcouncil/city_planning/EMP_mgmt_plan.htm for more information.

4.3 Agriculture Adapting to Climate Change

The diversity of land uses and production systems within the region present many potential challenges in the face of climate change but also offer many opportunities to adapt and modify. Under climate change there will likely be emerging opportunities as well as challenges. While a changing climate may make some regions less suited to particular industries or pursuits, other land use options may arise.

Many government and non-government policies can have a substantial impact on the opportunities and options available to address the challenges of climate change. For example, the recent proposed Emissions Trading Scheme presented by the Australian Government would have created a carbon market and as such would present landholders with many more opportunities and options. Similarly a biodiversity market, which has been proposed by different groups around the world (e.g. OECD 2003), would provide income generation options not presently available for land holders. Some examples of adaptation options for agricultural and rural communities relevant to the SA MDB are presented below.

4.3.1 *Water Trading*

With growing population and wealth, come growing rates of water diversion for municipal, industrial and irrigation uses. When increasing diversions collide with periods of low inflow, the result is often what Pulido-Velazquez *et al*. (2006) refer to as “operative” drought: a period when supply is insufficient to meet all consumptive and environmental water demands. Climate change predictions for increasing frequency and intensity of such low inflow periods in many of the world’s arid and semi-arid basins (Ragaab and Prudholm, 2002) are likely to increase the frequency of such operative droughts.

The experience with water markets during the current southern MDB drought indicate that they are an efficient means to allocate water during periods of operational drought. In this situation water markets allow water to be easily traded from areas of low value use to areas of high value use. For example, a study of this period (Mallawaarachchi and Foster 2009) found that the South Australian Murray imported 150 GL of water from the Murrumbidgee catchment in New South Wales increasing the level of allocation by 35%. In the Murrumbidgee water use is predominantly on comparatively low value rice, pasture and grain crops where as in South Australia more than 70% of irrigated land is relatively high value permanent horticultural plantings. Mallawaarachchi and Foster (2009) estimated that the benefits of these transactions were approximately $31 million in South Australia and $4 million in New South Wales. Similarly, Connor *et al*. (2009) assess the economic impacts of the ability to trade water in mild, moderate and severe climate changes scenarios for the high value irrigated horticultural and wine Lower Murray region. They find that in a moderate climate change scenario (with a 38% reduction in available water) net returns in Victorian and South Australian agriculture decline 19% and 54% in the absence of water trade but by only 5% and 11%, respectively with the possibility of water trade.

A limitation of all of the above cited studies is that none includes estimates of the potential value of urban to rural water trading. Considering that major cities that could source water from the Murray system through water trade (e.g. Adelaide, Melbourne, and Canberra) are considering major new urban water infrastructure such as desalinisation plants to meet growing demand and as a contingency for drought, the benefits of such trade could be considerable. In any case, it seems reasonable to conclude that, the benefits of water trade during recent MDB droughts have been considerable, likely in the range of several $100 million to over $1 billion per year during the last two to three years of operative drought. This is in comparison to a gross farm gate value of MDB irrigation of $4 billion AUD in 2006-07 (Ashton *et al*., 2009).

The advent of water trading has also led to increased water use efficiency. Available statistics show a dramatic decline in the rate of irrigation water application per hectare for Australia since introduction of water markets (and by inference the MDB as the location of more than half of all Australian irrigation). Water use per hectare declined from 8.7 megalitres per hectare in 1996 to 4.2 megalitres per hectare in 2005 (OECD 2010). As noted by Young (2008) this is a greater increase in irrigation efficiency than is reported for any other OECD country over these years.

However, there are also adverse environmental effects of water trading with greater utilisation of surface water that was previously left in-stream and an increase in the area of land under irrigation. Also increases in irrigation efficiency generally result in less drainage and return flows to the environment. Connor *et al*. (2008) estimate that the incentive created by the introduction of water markets in the Lower Murray region would have been sufficient to induce efficiency savings of 113 GL (11% of regional irrigation diversions) and reduce irrigation drainage and return flows by 50%.

4.3.2 Irrigation Reconfiguration

The historic development of irrigation in the SA MDB NRM region, beginning in the early 1900's, was driven by a desire to promote regional development and was characterised by state subsidised infrastructure development, delivery, operation and maintenance (Musgrave 2007, Crase 2007). Suitable schemes were chosen based on engineering feasibility with the technology of the day and there was little thought given to economic assessments or cost benefit analyses. As a result, these schemes were developed with open channel gravity supply systems that involved minimal pumping. This in turn resulted in the inclusion of areas for irrigation that we now understand to have soils poorly suited to sustainable production. The continued use of these soils for irrigated agriculture has resulted in significant environmental costs such as river and floodplain salinity (Crossman *et al*. 2010). Furthermore, there are now also substantial issues of water over allocation for irrigated agriculture along the river.

Current NRM policy is now aimed at achieving a better balance between water for consumptive uses (irrigation and urban use) and the environment. The availability of modern technologies, concerns about environmental degradation and ongoing water shortages are now providing the impetus for this landscape reconfiguration, in order to reduce environmental degradation and maintain suitable production levels. One example of this is Crossman *et al* (2010) who used spatial targeting within a cost benefit framework and were able to demonstrate a 20% reduction in agricultural water use and an overall 9% increase in the value of agriculture. Other environmental benefits were also recorded including reduced river salinity and increased carbon sequestration.

4.3.3 *Alternative Land Uses*

Recent studies in the SA MDB have looked at the potential of alternative land uses under different climate change scenarios. These studies examined how alternative land use options would be affected by different markets and policy options and what the likely economic and environmental consequences would be. For example, Bryan *et al* (2007) examined the potential of growing crops for biofuel production, trees for biomass and forests for carbon sequestration and biodiversity benefits in the SA MDB.

4.3.3.1 Biofuels agriculture

Biofuels agriculture involves growing crops which are used for the production of liquid fuels such as ethanol and biodiesel instead of food. First generation biofuels, such as those mentioned above are an existing low-carbon alternative for the transport sector (Tilman *et al* 2009).

In this study, the potential costs, benefits and tradeoffs associated with biofuels agriculture under specific climate change and carbon price scenarios were quantified. To do this, the spatial distribution of agricultural production, life cycle carbon emissions, net energy and profitability for food and biofuels agriculture were modelled. The findings indicate that there is some potential for short term benefits in regional development, climate change mitigation and energy security. However, the costs associated with this include a trade off between land used for food as opposed to energy production which raises issues of food security, and it is clear that the biofuel crops are also susceptible to changes in climate (Bryan *et al*. In review).

4.3.3.2 Biomass agriculture

Biomass production involves growing trees that are used as a fuel to generate electricity. There has recently been increased interest in biomass production in response to the threat of climate change and the need to reduce carbon emissions (Bryan *et al*. 2008). Biomass production also has the potential to help achieve environmental objectives. For example, the use of deep rooted species can potentially mitigate problems such as river salinity, wind and water erosion, and may even provide biodiversity benefits. Deep rooted perennials reduce the volume of groundwater and amount of salt passing to the River Murray.

In a couple of studies the economic viability of growing woody species was examined in the South Australian River Murray Corridor and the broadacre areas of the SA

MDB NRM region. The corridor is the area within about 15 km of the floodplain from the Victorian border to Mannum. Results from the River Murray Corridor indicate that more than 350, 000 ha (more than 50% of dryland areas) within the corridor are potentially viable. Income from carbon markets, electricity generation and other by-products make this economically viable but would also provide other benefits such as reduced risk of erosion, a substantial reduction in EC within the River Murray and the reduction of over 1.7 million tonnes of carbon emissions (Bryan *et al*. 2008). In the dryland areas of the SA MDB NRM Region areas were identified that were more profitable under climate change and carbon markets than traditional agriculture. Similar to the River Murray Corridor, these productions systems were also found to provide environmental benefits such as reduced risk of erosion, salinity benefits and carbon sequestration (Bryan *et al*. 2010).

4.3.3.3 Forests for carbon

Forests for carbon are a land use option that is based on the establishment of a carbon trading market. Under such a market there is likely to be substantial demand for carbon dioxide equivalent permits that would allow people to offset carbon dioxide released into the atmosphere with carbon sequestered elsewhere, such as in trees. The introduction of a carbon market could result in substantial demand for conversion of land traditionally used for agricultural into growing trees if it is economically and logistically viable. A study conducted in South Australia indicates that under certain policy scenarios such as a carbon market there are large parts of the state where reforestation would become viable (Crossman *et al* 2010). Other studies have also found that there would be substantial environmental effects, such as reduced deep drainage and salinity, less soil erosion and substantial carbon sequestration and biodiversity benefits (Bryan *et al* 2007). While this is not a reality at the moment, there is substantial potential for opportunities like this in the future.

4.3.3.4 Ecosystem services

Ecosystem services are generally defined as the benefits people obtain directly or indirectly from natural or semi natural ecosystems (Millennium Ecosystem Assessment 2003). The term ecosystem refers to a dynamic complex of plants, animals and microorganisms interacting with the nonliving environment as a functional unit. Ecosystem services include an important range of goods and services provided, directly or indirectly, from surrounding ecosystems. These services can include the production of tangible products such as food, drinking water and raw materials supplied by ecosystems but can also provide less tangible products such as amenity value and as such their economic value is difficult to quantify.

While arguments around environmental flows to the River Murray are often seen as a conflict between the environment and agriculture there is some evidence to suggest that amenity value is also important. Recent studies show that the importance of amenity, which contributes to tourism, recreation and lifestyle, has significant economic value and community support comparable to traditional agricultural pursuits (Howard 2008). Experience from the recent drought in the MDB goes some way to confirm these findings. As media coverage of the drought intensified, tourism along the river was seen to decrease as potential visitors were discouraged by the expectation that the areas amenity value had decreased.

As early as 2006, the Riverland Strategic Tourism Plan (2006), written at a time when water shortages were just coming into play, indicates the potential threat to the regions image, and therefore destination appeal, due to water shortages and reduced flow. This has since occurred and has seriously affected demand for Riverland Tourism products e.g. houseboat holidays.

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Attachment A - List of acronyms

DCCEE – Department of Climate Change and Energy Efficiency

DPC – Department of Premier and Cabinet

DWLBC – Department for Water, Land and Biodiversity Conservation

IPCC - The Intergovernmental Panel on Climate Change

NRM – Natural resources management

PIRSA – Primary Industries and Resources of South Australia

SA MDB – South Australian Murray-Darling Basin

SARDI – South Australian Research and Development Institute

Attachment B -
Background to The Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences.

The IPCC is a scientific body. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. Differing viewpoints existing within the scientific community are reflected in the IPCC reports.

The IPCC is an intergovernmental body, and it is open to all member countries of UN and WMO. Governments are involved in the IPCC work as they can participate in the review process and in the IPCC plenary sessions, where main decisions about the IPCC work programme are taken and reports are accepted, adopted and approved. The IPCC Bureau and Chairperson are also elected in the plenary sessions.

Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge the authority of their scientific content. The work of the organization is therefore policy-relevant and yet policy-neutral, never policy-prescriptive.

Source: http://www.ipcc.ch/organization/organization.htm