Resilient Hills & Coasts

A Climate Change Adaptation Plan for the Adelaide Hills, Fleurieu & Kangaroo Island

Knowledge Audit

Australian Government
Attorney-General's Department

Adelaide Hills Council

Alexandrina

Kangaroo Island Council

District Council of Mount Barker

city of Victor Harbor

District Council Yankalilla

Government of South Australia
South Australian Fire and Emergency Services Commission

Regional Development Australia
Adelaide Hills Fleurieu & Kangaroo Island

Local Government Association of South Australia

Government of South Australia
Department of Environment, Water and Natural Resources

Contact for enquiries: C/- Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island.
Phone (08) 8536 9200.

Title: Knowledge audit for the Adelaide Hills, Fleurieu and Kangaroo Island RDA Climate Change Adaptation Plan

This report should be cited as: Resilient Hills and Coasts (2014). Knowledge audit for the Adelaide Hills, Fleurieu and Kangaroo Island RDA Climate Change Adaptation Plan, prepared by Seed Consulting Services for Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island. September 2014.

Contributors:

Siebentritt, M.A. and Garden, J. – Seed Consulting Services

The following stakeholders were actively involved in the project: RDA Adelaide Hills, Fleurieu and Kangaroo Island, Adelaide Hills Council, District Council of Mount Barker, Alexandrina Council, City of Victor Harbor, District of Yankalilla, Kangaroo Island Council, Southern and Hills Local Government Association, Adelaide Mount Lofty Ranges NRM Board, Kangaroo Island NRM Board and the South Australian Department of Water, Environment and Natural Resources.

Acknowledgements: Thanks go to stakeholders from across the region who participated in interviews and a workshop which provided valuable input into better understanding the impacts of climate change in the region. The direction and guidance provided in the development of this knowledge audit by the Steering Committee was greatly appreciated as was the support given to the project team by the Chair, Terry Lee and Project Managers Sarah Nankivell and Dilrini Pathirana.

Table of Contents

Table of Tables

Executive summary

This knowledge audit has been designed to inform the development of a climate change adaptation plan for the Adelaide Hills, Fleurieu and Kangaroo Island RDA (Regional Development Australia) region in accordance with the State government's South Australian Adaptation Framework. The audit:

- provides an overview of the current state of the human, social, financial, physical, and environmental capitals for the region;
- outlines regional climate change projections; and
- discusses the sensitivity and adaptive capacity of key sectors in the region to climate change.

Relevant information was collated from multiple sources including, but not limited to government plans and policies, consultant reports, scientific literature, and interviews with key stakeholders in the region.

The Adelaide Hills, Fleurieu and Kangaroo Island RDA region comprises six local councils (Adelaide Hills Council, District Council of Mount Barker, Alexandrina Council, City of Victor Harbor, District of Yankalilla, Kangaroo Island Council) covering an area of 8,752km^2. It includes the entire Kangaroo Island natural resource management (NRM) region and parts of the Adelaide and Mount Lofty Ranges and South Australian Murray-Darling Basin NRM regions.

The projected trend across South Australia is for a hotter and drier climate by 2070. However, the region's current climate is already inherently much wetter and, in certain locations cooler, than other areas of the State, and so the projected drying and warming changes are not expected to be as severe compared to other areas in the State. Although not as severe as other regions in the State, a response to a warming and drying climate in the region will still be important. Sea level rise, increased storm surges and associated coastal flooding will be a particular challenge for the region's coastal townships and Kangaroo Island. Increasing risk of bushfires will also be a particular concern for the more inland, hilly areas of the region.

The growing population is changing the region's demographics, though not consistently across all local Council areas. For example, population growth rates between 2006 and 2011 were just over 15% in Victor Harbor yet only 2% in the Adelaide Hills. Overall the population is aging, though particularly so in coastal townships on the Fleurieu Peninsula, which present particularly attractive retirement destinations. Other areas however, such as Mount Barker, are experiencing a growing younger population, due largely to population growth from inland migration by working-aged people and young families. The region tends to be physically healthier, on average, compared to the State; though the health of people in the region also varies geographically. Given increasing climate changes can further negatively impact people's

health, maintaining and improving the health of people in the region will be an important action for addressing climate change impacts.

The region's population is generally well educated and highly qualified and unemployment is lower than the State average. However, there are again differing geographic trends across the region, with distinct concentrations of more or less affluent communities and higher or lower unemployment rates. For example, compared to the rest of the region, the Adelaide Hills had the lowest unemployment rates as well as the highest proportion of high school and post-school education graduates. On the mainland, almost half of the region's large workforce commutes to areas outside of the region for work, which is facilitated through good connections to the Adelaide Metropolitan Area, with additional future improvements being recently approved.

Due to its geographic isolation by sea, Kangaroo Island's workforce is largely contained on the island. This physical isolation also places the Island at increased risk of social disconnectedness with limited access options to the mainland and the larger metropolitan areas. However, the residents of Kangaroo Island maintain a community with a high level of social connectedness, as is evident from their rate of volunteering which is the highest in the region, and nearly double the average rate for the whole State. A major challenge on the Island, and also in the mainland's coastal townships, will be ensuring energy, water and communications infrastructure, as well as emergency services, are able to withstand climate change impacts, particularly sea level rise and storm surges.

Predicted increasing tourism to the region's mainland coastal townships and Kangaroo Island, will likely facilitate this challenge by acting as a catalyst for the creation and upgrading of essential services, facilities and infrastructure. The predicted tourism influx also presents one of the best opportunities for future job creation in the region, which is likely to help decrease unemployment rates and also decrease the need for some workers to commute outside of the region for work.

The region's horticulture, agriculture, fisheries and aquaculture, and forestry industries will also face significant challenges, particularly from increasing temperatures, decreasing water availability, and increasing bushfire risk. However, carefully considered mitigation and adaptation actions (e.g. establishing alternative water resources and shifting to more climate-resilient products) implemented now can help to minimise the impacts on the primary production sector. Such climate change impacts will also have important implications for the security of environmental assets within the region, which include a diversity of flora and fauna species (including threatened species) as well as a number of threatened plant communities and nationally and internationally recognized significant wetlands.

Careful consideration will need to be given to how to minimise the impact of potential increased pests and predators, which will pose a risk not only to the primary production sector, but also

the region's natural environment assets and services. The physical isolation of Kangaroo Island from the mainland, although presenting challenges, may also offer a key opportunity for the region to improve potential biosecurity impacts. For example, efforts employed to maintain Kangaroo Island's current pest and disease free status, will allow opportunities for the Island to supply the mainland industries with a disease and pest free product source, and also act as a climate change refuge for certain species and habitats.

There is no doubt that the region will be impacted by climate change. However, the key to adapting to inevitable climate change is predicting the specific changes likely to occur, recognising the impacts these changes may have on various sectors, and identifying ways in which the region can increase its adaptive capacity. Accordingly, although the region will face a number of climate change challenges, there is also substantial scope to capitalise on a range of opportunities. Doing so will reinforce the region as a vibrant and prosperous place to live and work.

1. Introduction

1.1 Background

The Adelaide Hills, Fleurieu Peninsula and Kangaroo Island has a diverse range of natural and human made landscapes that are nationally and internationally recognised and celebrated. The region is:

- a major sea change and tree change (lifestyle) destination for greater Adelaide and South Australia;
- contains major tourism destinations for intra and interstate as well as international visitors (e.g. Kangaroo Island, Victor Harbor);
- contains significant environmental areas (e.g. Adelaide Hills Watershed, Murray Mouth and Coorong, Flinders Chase National park and other Coastal fringe areas). Indeed the greater Adelaide area is considered a biodiversity hotspot; and
- highly productive and recognised primary production areas (e.g. Kangaroo Island honey, Fleurieu Dairy) (Southern and Hills LGA 2012).

Compared to other parts of South Australia, the region is characterised by moderate to high rainfall and cooler summers. Interaction between the land and sea along the coast shapes much of the landscape.

Seasonal variability in temperature and rainfall is common in the region as it is across all of South Australia. Despite this, climate change is modifying the underlying climatic conditions. Southern Australia has already experienced nearly 1.0℃ of warming since the 1950s and a reduction in average rainfall. A warming and drying trend is projected to continue into the future and will lead to changes in the environment, economy and community. The importance of the coastal zone in the region means that changing ocean conditions will also have an impact, for example, through rising sea levels.

Planning for climate change has already commenced in the region by a variety of sectors, and includes work by the natural resource management organisations, local government and agriculture. While this has proven useful for identifying impacts and potential actions within sectors, a coordinated regional approach to adapting to climate change has not previously existed.

1.2 Purpose

Under South Australia's Strategic Plan (target 62) and the South Australian Climate Change Adaptation Framework (DEWNR 2012), areas across the State are required to develop a Regional Climate Change Adaptation Plan. In the Adelaide Hills, Fleurieu and Kangaroo Island

region (Figure 1) this is being progressed by RDA (Regional Development Australia) Adelaide Hills, Fleurieu and Kangaroo Island, Adelaide Hills Council, District Council of Mount Barker, Alexandrina Council, City of Victor Harbor, District of Yankalilla, Kangaroo Island Council, Southern and Hills Local Government Association, Adelaide Mount Lofty Ranges NRM Board, Kangaroo Island NRM Board and the South Australian Department of Water, Environment and Natural Resources

Development of a climate change plan requires an understanding of the potential impacts of climate change on important assets, values or services from across key sectors and then identification and assessment of adaptation options. Adaptation plans must be informed by best available information from either published reports, scientific papers or local knowledge.
This knowledge audit provides a review of:

- information regarding important features of the region that relate to key sectors (Section 2);
- regional climate change projections (Section 3); and
- sensitivity and adaptive capacity of sectors to climate change (Section 4).

Information was derived from a desktop review of available documents and literature and interviews with key stakeholders representing the region's different sectors.

The objective of this audit is to provide the foundation for the integrated vulnerability assessment for the region and as such the sensitivity or adaptive capacity of key features is described where applicable. Exposure, which is an important element of a vulnerability assessment, can be understood from climate projections (Chapter 3). The paper also presents information against the five capitals (i.e. human, social, physical, financial, environmental), to ensure that all sectors are considered.

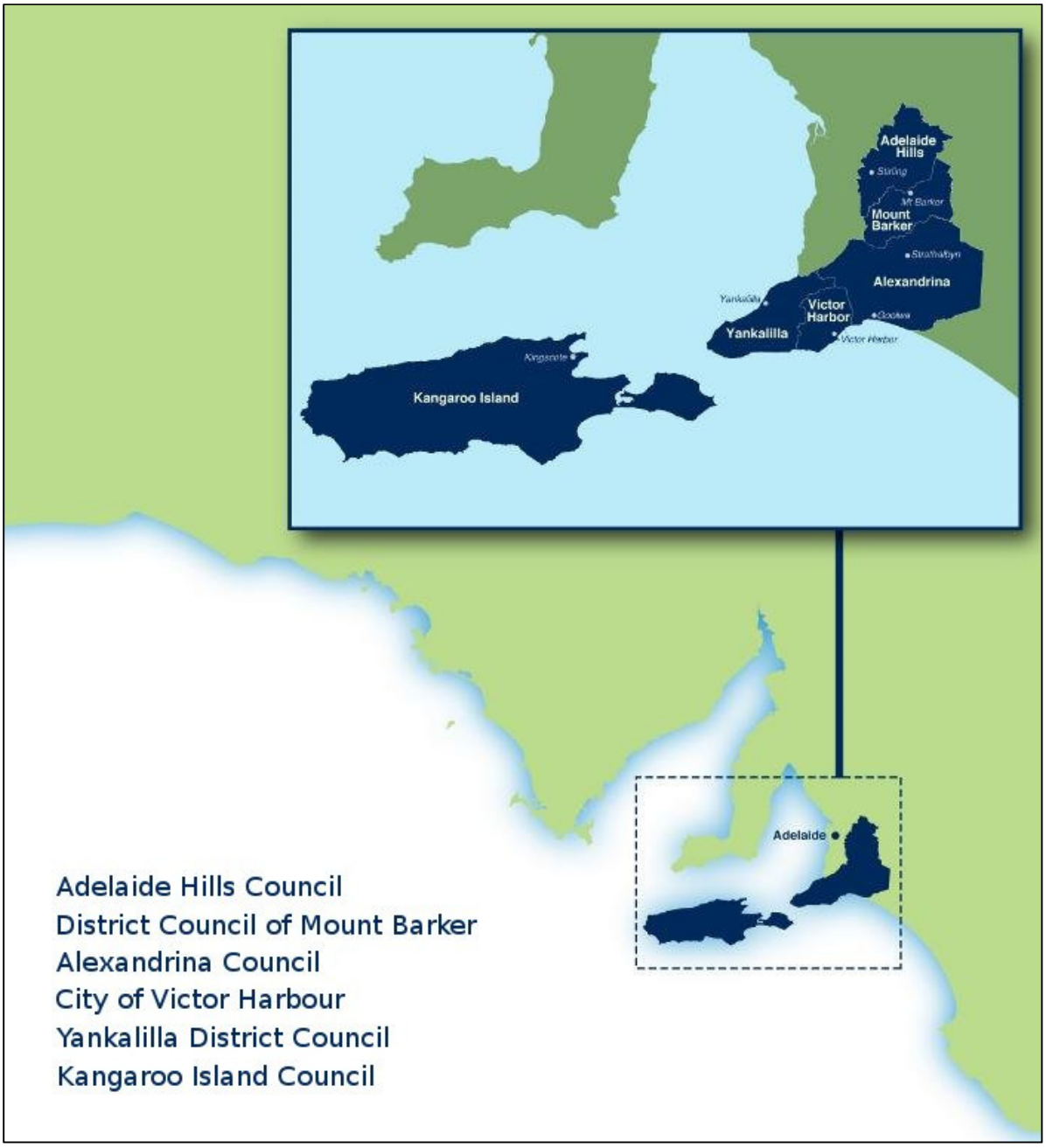

Figure 1. Location of Adelaide Hills, Fleurieu and Kangaroo Island areas comprising the Adelaide Hills, Fleurieu and Kangaroo Island region (Source http://www.rdahc.com.au).

2 Regional profile

The Adelaide Hills, Fleurieu and Kangaroo Island region covers a land area of 8,752km^2 (~0.9% of the State) and comprises six local council areas: Adelaide Hills Council, Alexandrina Council, City of Victor Harbor, District Council of Mount Barker, District Council of Yankalilla, and Kangaroo Island Council (hereafter referred to either by their geographic namesake or collectively as "areas") (Figure 1). The region coincides with three natural resource management regions: all of the Kangaroo Island region, as well as portions of the Adelaide and Mount Lofty Ranges region and the South Australian Murray-Darling Basin region.

The following sub-sections provide an overview of the current state of the region with regard to the human, social, physical, financial, and environmental capitals, a concept developed by Forum for the Future (a British not-for profit) in the early 1990s. Information has been selected for this section based on what is typically of interest in conducting a vulnerability assessment.

2.1 Human capital

Human capital incorporates the health, knowledge, skills, intellectual outputs, motivation and capacity for relationships of individuals (Forum for the Future 2014). Key features of human capital in the region are:

- the number of people living in the region will continue to rise, with growth of approximately 27% over the next decade, especially in coastal areas like Victor Harbor and Goolwa, as well as the inland town of Mt Barker;
- average annual rates of access to general practitioners are slightly below State averages; and
- secondary and tertiary education enrolments are above the State average.

<u>Population</u>

In 2011, the region's resident population was estimated at over 118,700 (~7.2% of State population), representing an increase of about 8.7% since 2006. The highest population densities per square kilometre occurred in Mount Barker and the Adelaide Hills (51.2 and 50.1 persons/km^2, respectively), and the lowest on Kangaroo Island (1 person/km^2) (ABS 2011).

The majority of the region's population (~64%) were considered to be of working age (15-64 years old), with the remaining 36% split evenly between young people (0-14 yo) and retirees (>65 yo) (EconSearch 2013). Compared to the State's overall average age distribution, the region is approximately consistent in terms of youth age, slightly less than average for working age, and more than average for retiree age (EconSearch 2013).

An additional population increase of approximately 27% is projected for the region over the next 12 years to 2026. Population growth on the Fleurieu Peninsula will be concentrated around retirement centres of Victor Harbor and Goolwa. This will also mean that the predominantly older population's demand for health and recreation services will require a shift away from a male dominated low skilled agricultural workforce to a female dominated qualified workforce (SACES 2012).

Physical and mental health

In 2009/10, the average annual rate of access to general practitioners in the region was approximately 524 per 1000 persons, which is just lower than that for the whole State (540). Access rates were highest in Yankalilla (622) and lowest on Kangaroo Island and in the Adelaide Hills (474 and 475, respectively). In the same time period, the average annual rate of mental health care plans prepared by general practitioners was approximately 14 per 100 persons, which was nearly double that for the State as a whole (7.9 per 100 persons) (EconSearch 2013; URPS 2014).

Just under half (41%) of the region's residents had at least one of four health risk factors (smoking, harmful use of alcohol, physical inactivity, obesity). This was slightly lower than the State average (45%) (EconSearch 2013).

Education

Between 1996 and 2011, primary school enrolments decreased across the State by 10%, though the region experienced only one-tenth of these declines (1%). Comparatively, increases in secondary school enrollments in the region were more than double that of the State average (21% compared to 9%). Enrolments in tertiary institutes by people living in the region increased by 47% compared to a 39% increase in the State as a whole (EconSearch 2013).

Although enrolment levels generally increased more within the region compared to the State, in 2011 the average percentage of people completing secondary school within the region was just lower than the average for the State (40% compared to 43%). Despite this, the region's resident population (aged 15 years or over) maintained a relatively equal level of education and formal qualification compared to the State overall, with an average of 53% of the region's population being classified as graduates (i.e. holding some form of post-school qualification such as a degree, certificate, or diploma), compared to 52% for the whole State (EconSearch 2013). In 2011, 56% of the region's population (aged over 15 years) also held some form of non-school qualification, up from 43% in 1996, and higher than the State's average of 45% (EconSearch 2013).

2.2 Social Capital

Social capital is any value added to the activities and economic outputs of an organisation or community by human relationships, partnerships and co-operation (Forum for the Future 2012). Key features of social capital in the region are:

- community connectedness is relatively strong with personal mobility and volunteering rates well above the State average and internet access and the number of people requiring assistance with core activities on par with the State average;
- unemployment rates have been low compared with the remainder of the State over the past decade; and
- income support levels are below the State average, although the percentage of people receiving an aged pension is above the State average in Victor Harbor (25%) and Alexandrina and Yankalilla (18% each) reflecting the high number of retirees.

Community connectedness

Community connectedness can be assessed using a number of measures including personal mobility, community participation and social connectedness. Measures of personal mobility include motor vehicle ownership and the number of people requiring assistance with self-care, mobility and communication activities (URPS 2014). In 2011, only 4.5% of dwellings within the region had no motor vehicle, which is less than half of that for the State as a whole (9.6%) (ABS 2012). Within the region, the percentage of dwellings with a motor vehicle ranged from 97.6% (Adelaide Hills) to 92.9% (Victor Harbor) (URPS 2014; ABS 2012).

The percentage of the region's population requiring assistance with core activities, is approximately the same as that for the State as a whole (5.3% and 5.6%, respectively). Within the region, Victor Harbor area had the highest proportion of their population requiring assistance, and Adelaide Hills area the lowest (ABS 2012). These personal mobility statistics likely reflect the higher percentage of working age residents in the Adelaide Hills that commute to work, compared to a higher percentage of retirees in Victor Harbor.

The average rate of volunteering across the region was more than 1.5 times higher than the State average, 29.4% compared to 17.4%, respectively (URPS 2014; ABS 2012). The region's composite areas each have higher rates than the State as a whole, with Kangaroo Island having the highest rate (38.5%).

The number of dwellings with internet access increased in the region by 34% from 2006 to 2011; equal to the increase reported across the State as a whole (EconSearch 2013). In 2011, the average number of dwellings in the region lacking internet access was approximately equal to the average across the State (20% compared to 23%). Within the region, dwellings with internet access ranged from 86.2% in the Adelaide Hills) to 73.5% in Yankalilla (ABS 2012).

Employment and labour force

The labour force in the region increased by approximately 20% in the period 2003-2013 which was higher than the 15% increase for the State as a whole (EconSearch 2013). The highest increase occurred in the Mount Barker area (31%) reflecting general population increases in this district. The unemployment rate in the region fluctuated over the period 2003-2013, from just above 2% to an estimated 5% in Mach 2013. Over this time period the region maintained employment rates above the State average (4.5 to 7%).

Income support

The proportion of people receiving income support is another measure used to indicate the wellbeing of a region's resident population. In 2008/09, approximately 13% of the region's population claimed an age benefit, 3% a disability pension 1% an unemployment benefit (EconSearch 2013). For all measures, the region has averages below that of the State. Within the region, the percentage of people claiming an aged benefit was highest in Victor Harbor (25%) followed by Alexandrina and Yankalilla (18% each).

Housing

In the decade to 2012, the region's housing industry experienced a decline in approvals and an increase in the average value per approval, consistent with State trends over the same time period (EconSearch 2013). The Adelaide Hills consistently recorded the highest average value per approval during the decade (EconSearch 2013).

2.3 Physical Capital

Physical capital is the material goods and infrastructure owned, leased or controlled by an organisation or community that contributes to production or service provision (Forum for the Future 2014). Key features of physical capital in the region include:

- Vast areas of public open spaces that support community health and wellbeing, much of which is managed by Councils in the region;
- Substantial built infrastructure including buildings and roads, that underpin the region's economy and functioning of the community; and
- Growing demand for physical capital like new transport infrastructure and community facilities especially in areas such as Mount Barker, Goolwa and Victor Harbor where population growth increases demand for services and facilities.

Open space and community facilities

Public open spaces and facilities are important in supporting community health and wellbeing, and also for facilitating connectedness through direct social interactions (URPS 2014). A number of open spaces and community facilities occur within the region including: formal parks, playgrounds and reserves (some with amenities); sporting clubs and infrastructure (e.g. tennis

and netball courts, soccer and hockey fields, equestrian facilities, lawn bowls greens and cricket ovals); recreation tracks and trails; designated skateboarding areas; libraries, child care centers, and emergency services buildings; and community centers and meeting halls (for community programs such as scouts, guides, and Returned Service League) (URPS 2014).

Buildings

The region contains a number of public and private buildings and associated infrastructure (URPS 2014) including:

- 5 public hospitals (Victor Harbor, Kingscote, Strathalbyn, Mount Barker, Gumeracha) and 1 private hospital (Stirling);
- 119 public childcare centres, preschools and schools, 3 TAFE SA campuses (Victor Harbor, Kingscote, Mount Barker), and 47 non-government childcare centres, preschools and schools;
- a number of council assets, including: offices, libraries, depots, reserves, community and recreation centres, halls, car parks, and heritage sites.
- emergency services facilities (e.g. 5 SES units located at Mt Barker, Kangaroo Island, South Coast, Strathalbyn and Yankalilla);
- private owned buildings and infrastructure (private); and
- coastal assets such as jetties, ports, wharves and boat ramps.

Demand for new infrastructure is especially strong in areas like Mt Barker, Goolwa and Victor Harbor because of their rapidly growing populations.

Transport and service networks

The region contains a large number of transport networks and associated infrastructure that services major towns and growing urban centers as well as the large areas of farming and public conservation lands. This infrastructure incldes (URPS 2014):

- arterial roads managed by State government (e.g. South Eastern Freeway) and local roads managed by local councils;
- footpaths, shared paths, street lighting, and traffic safety and control assets;
- a railway line between Mount Barker and Victor Harbor (traverses the Mount Barker, Alexandrina and Victor Harbor LGAs), and the Adelaide-Melbourne rail line (traverses Adelaide Hills and Mount Barker LGAs);
- one airport, located at Kingscote and operated by Kangaroo Island Council; and,
- 10 coastal jetties and 28 coastal boat ramps that are State government owned, (though some are constructed on local council-owned land and managed by local councils) (e.g. Second Valley jetty, Rapid Bay jetty, Cape Jervis jetty and boat ramp, Wirrina Cove Marina, the Bluff jetty and boat ramp, Granite Island causeway and jetty, Port Elliot jetty, Goolwa wharf, Barrages) and numerous private jetties; and
- three marinas (Goolwa, Hindmarsh Island and St Vincent/Wirrina Cove).

The importance of transport networks in rapidly growing parts of the region is highlighted by the Adelaide Hills, where approximately 60% of residents work outside the region mainly in metropolitan Adelaide because of proximity to the Adelaide Hills and accessibility via the South Eastern Freeway.

Water resources infrastructure

A variety of water resource management and treatment infrastructure occurs within the region (URPS 2014; BOM 2014a; SA Water 2013; DEWNR 2013), including:

- stormwater pipes, culverts, pits and channels;
- a number of council operated waste-water treatment plants/systems
- SA Water operated country waste-water treatment plants (Bird-in-Hand, Gumeracha, Hahndorf, Heathfield, Myponga, Victor Harbor);
- a desalination plant located at Penneshaw on Kangaroo Island;
- surface water pipes primarily used for urban and irrigation uses, including two of the State's five major pipelines which bisect the region (Murray Bridge-Onkaparinga and Mannum-Adelaide pipelines);
- three of the five barrages comprising the "Goolwa Barrages" near the River Murray mouth; and
- six reservoirs – four contained entirely within the region (including one on Kangaroo Island) and two partially coinciding with the region.

2.4 Financial Capital

Financial capital reflects the productive power of other types of capital (Forum for the Future 2014) and is taken here to be those sectors that contribute to employment and the gross regional product in the region. Key features of financial capital in the region are that:

- health and community services, agriculture, forestry and fishing, and property and business services are major contributors to both employment and gross regional product;
- agriculture is central to the character of the region with a diverse range of produce generated; and
- significant tourism expenditure occurs in the region, with primarily domestic visitors on the mainland but a higher proportion of international visitors on Kangaroo Island.

Contribution to the region economy

In 2011, the region supported 11,132 businesses spanning a wide range of professions. It was estimated that these business employed 32,000 people accounting for 4.4% of total state employment. The region contributed about 3.7% of the State's overall economy (EconSearch 2013). The top five sectors in terms of people employed were retail trade (14.6%), health and community services (12.6%), agriculture, forestry and fishing (10.8%), property and business services (9.1%) and education and training (9.0%). In comparison, the top five according to %

share of gross regional product (excluding ownership and purchase of dwellings) were property and business services (8.1%), manufacturing (8.0%), agriculture, forestry and fishing (7.5%), building and construction (7.2%) and health and community services (6.7%).

Agriculture, forestry and fishing

A diverse range of activities make up the primary production sector, which although is not necessarily the highest employer in the region or contributor to gross regional product, shapes much of the character of both the mainland parts of the region and Kangaroo Island. Major produce from the region includes:

- livestock farming to produce meat, fibre and products;
- fresh food such as fruit (e.g. apples, pears, cherries, berries), vegetables (e.g. brassicas, seed potatoes) and broad-acre crops (e.g. wheat, barley);
- wine, such as cool climate wines, from the Adelaide Hills and Kangaroo Island;
- aquaculture and seafood products like shellfish, abalone, marron, and yabbies from Kangaroo Island. Marron and yabbies are produced on the Fleurieu Peninsula but at a much smaller scale than Kangaroo Island (EconSearch 2013);

Other land-based primary industries within the region include forestry and equine ventures (e.g. horse racing, show and Olympic, and recreation) (EconSearch 2013). Forestry occurs in a number of locations in the Mount Lofty Ranges (e.g. Kuitpo, Mount Crawford, Second Valley). Significant private forestry plantings have also been established on Kangaroo Island over the past decade funded by managed investment schemes.

Tourism

The region supports a prosperous tourism industry comprised predominantly of domestic visitors. Spending by tourists ($397 million) contributes approximately 23% of the total value of exports from the region in 2011/12 and approximately 8% of total South Australia based tourist expenditure in 2011/12 (EconSearch 2013).

The Fleurieu Peninsula reported the highest number of tourists, predominantly domestic visitors, with most visiting Victor Harbor (197,000 visitors) and Goolwa-Port Elliot (196,000 visitors) (Tourism Research Australia 2013). The top three most visited locations within the Adelaide Hills were: Hahndorf-Echunga (44,000 visitors), Mount Barker (37,000 visitors), and Aldgate-Stirling (25,000 visitors) (Tourism Research Australia 2013). Although Kangaroo Island receives fewer visitors than the Adelaide Hills and Fleurieu Peninsula, it has the highest number of international visitors.

The main tourist experiences reported for 2012/13 were food and wine, nature based, indigenous, and culture and heritage (Tourism Research Australia 2013).

Energy

Energy within the region is predominantly from conventional sources (EconSearch 2013). Renewable energy sources in the region include:

- Starfish Hill Wind Farm – the State's first wind farm, and now one of 15 wind farms operating in the State (owned by Tarong Energy) located near Cape Jervois in Yankalilla District Council (Tarong Energy n.d.); and
- A dual-axis solar array system installed at the Kangaroo Island Airport plus a 14kW solar system installed at the Kingscote Town Hall, as part of the Island's Visible Solar Project (KI Council 2014).

In addition to solar energy, biomass energy generation is considered to provide the most potential as renewable energy sources within the region (EconSearch 2013).

2.5 Environmental Capital

Environmental capital (sometimes referred to as natural or ecological capital) is the natural resources and processes needed by organisations or communities to produce products and deliver services (Forum for the Future 2014). Key features of the environmental capital in the region are:

- substantial amounts of remnant vegetation with approximately one-third of the region mapped as remnant, with Kangaroo Island containing over 50% as remnant. However, there are some localities that are more heavily cleared than others, such as Woodchester in Alexandrina Council where the proportion of remnant vegetation remaining is very low;
- the internationally important (RAMSAR listed) Coorong and Lakes Alexandrina and Albert;
- 7 ecological communities listed as critically endangered, endangered or vulnerable under the EPBC Act; and
- significant water resources, providing major potable supplies and supporting important water dependent ecosystems.

Comprised of a highly variable topography and geology, from coastal dunes and rocky escarpments to inland fertile hills and pasturelands, the region supports a range of natural assets, including terrestrial, coastal, aquatic and marine communities, as well as geological phenomena (e.g. Remarkable Rocks on Kangaroo Island). These natural environmental assets support high flora and fauna diversity (including significant species and communities) and together provide a range of ecosystem services, as well as playing a key role in supporting the region's tourism industry (URPS 2014).

In the Adelaide and Mount Lofty Ranges Natural Resources Management region, which covers the majority of the mainland part of this project area, two natural landscape types exist:

- Coastal – includes areas along the Fleurieu Peninsula and Kangaroo Island coastline, including sandy beaches, rocky shores and samphire communities;

- Hills – predominant part of the region with a mixture of private land dominated by agricultural uses and native vegetation on public lands. This landscape type contains significant topographic and microclimatic diversity.

While this terminology has only recently been applied to the Adelaide and Mount Lofty Ranges Natural Resources Management region, the coastal and hills landscape types equally apply to Kangaroo Island.

Terrestrial, marine, and aquatic ecosystems

Remnant vegetation is important for supporting a range of ecosystem services as well as native flora and fauna species. On average, approximately one-third of the region is mapped as remnant vegetation (URPS 2014).

Kangaroo Island differs significantly from the regional average as more than half of the land area (51.7%, 229,860ha) is mapped as remnant vegetation (URPS 2014), the highest percentage of any area comprising the region. In comparison, Mount Barker has the lowest percentage of remnant vegetation, covering only 8.1% (4,818ha) of its area (URPS 2014).

Less than half (44%) (URPS 2014) of the remnant vegetation in the region is formally protected by State or National legislation (e.g. conservation parks, national parks, conservation reserves, wildlife reserves). The large majority (>90%) of these reserved areas occur on Kangaroo Island (URPS 2014), where 30% of the remnant vegetation is formally protected (DEWNR 2013), mostly in State Wilderness Protection Areas such as Revine des Casoars, Cape Gantheaume and Cape Bouger (URPS 2014). On the mainland, Deep Creek Conservation Park is the largest formally protected remnant vegetation area (URPS 2014).

Together, the region's protected areas include some of the State's most frequented and well known parks, such as: Cleland Wildlife Park and Morialta Conservation Park in the Adelaide Hills area, Granite Island Recreation Park in the Victor Harbor area, Deep Creek Conservation Park in the Yankalilla area, and Flinders Chase National Park and Seal Bay Conservation Park on Kangaroo Island (Government of South Australia 2014). The region also contains aquatic reserves, including four marine parks, three of which are associated with Kangaroo Island, and one which spans between Kangaroo Island and the mainland (DEWNR 2014; RDAB AHFKI 2013).

Remnant vegetation, together with the range of other natural assets within the region (e.g. wetlands and coastal beaches), play a critical role in supporting numerous environmental features of significance at local, State, Federal, and international levels. These include, but are

not limited to: native flora and fauna species (including 5 critically endangered species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and 63 endangered species listed under State legislation (URPS 2014), various ecological communities (including seven listed as critically endangered, endangered or vulnerable under the EPBC Act (URPS 2014; Department of the Environment 2013a), internationally important migratory species (terrestrial and marine); nationally and internationally significant wetlands; Commonwealth heritage places; natural, indigenous and historic places on the register of the national estate; and numerous state and territory reserves (Table 1).

Table 1. Count of environmental features listed under the *Environment Protection and Biodiversity Conservation Act 1999* for each local government area comprising the Adelaide Hills, Fleurieu and Kangaroo Island region (Department of the Environment 2013a).

	Adelaide Hills	Alexandrina	Kangaroo Island	Mount Barker	Victor Harbor	Yankalilla
Matters of Environmental Significance						
National Heritage Places	0	1	0	0	0	0
Wetlands of International Significance	1	1	0	1	1	1
Threatened Ecological Communities	3	6	1	3	3	2
Threatened Species	31	68	45	37	54	52
Migratory Species	10	54	48	10	34	34
Other Matters						
Commonwealth lands	4	0	2	3	1	1
Commonwealth Heritage Places	0	1	2	0	0	0
Listed Marine Species	11	92	88	11	66	59
Whales and Other Cetaceans	0	11	12	0	12	11
Extra Information						
Places on the Register of the National Estate	110	137	66	86	40	49
State and Territory Reserves	103	70	149	13	61	37
Invasive Species	47	41	48	48	37	40
Nationally Important Wetlands	2	3	15	0	1	6

Of particular note within the region are:

- the internationally important (RAMSAR listed) Coorong and Lakes Alexandrina and Albert;
- five federally listed threatened ecological communities (URPS 2014; Department of the Environment 2013a):
    - Grey box (*Eucalyptus microcarpa*) Grassy Woodlands and Derived Native Grasslands of South-Eastern Australia (listed as occurring in the Adelaide Hills local council area);
    - Peppermint Box (*Eucalyptus odorata*) Grassy Woodland of South Australia (listed as occurring in the Adelaide Hills, Alexandrina, and Mount Barker local council areas);
    - Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions (listed as occurring in the Alexandrina local council area);
    - Iron-grass Natural Temperate Grassland of South Australia (listed as occurring in Alexandrina, Mount Barker local council areas);
    - Sub-tropical and Temperate Coastal Saltmarsh (listed as occurring in Alexandrina, Kangaroo Island, and Victor Harbor local council areas) –note though that only temperate (not sub-tropical) coastal saltmarshes occur within the region; and
    - Swamps of the Fleurieu Peninsula (listed occurring within Alexandrina, Victor Harbor, and Yankalilla local council areas); and
- the large number of terrestrial, aquatic, and marine birds, mammals, amphibians, reptiles, and fishes listed as threatened, migratory, or other protected matters under the EPBC Act, as well as many others listed as significant at State or local levels.

<u>Water resources</u>

Surface water in the region includes: numerous minor natural watercourses (e.g. streams and rivers), man-made watercourses and natural and man-made water bodies (e.g. lakes, wetlands, reservoirs). The region includes either partially or completely six main river basins: Torrens River, Onkaparinga River, Myponga River, Fleurieu Peninsula, Lower Murray River, and Kangaroo Island (BOM 2014b). These are divided into a number of smaller river catchment areas; 10 on the mainland and 53 on Kangaroo Island (Department of Environment 2013a; AMLR NRM Board 2013).

The main watercourses in the mainland catchment areas feed several large reservoirs, natural wetlands (including some of Federal and international significance), several minor watercourses, and numerous dams on private and public lands (URPS 2014). The terrain and river networks within much of the mainland region form part of the Mount Lofty Ranges Watershed, which provides much of Adelaide's potable water supply (SACES 2012).

On Kangaroo Island, surface water also provides the major resource for potable supplies. Most watercourses on the Island tend to terminate in coastal estuaries, with only a smaller number feeding inland lakes and lagoons, as well as reservoirs and private dams (DEWNR 2013). Most

of the Island's watercourses are ephemeral in nature, tending to flow in winter and dry either completely or to fragmented shallow pools in summer, resulting in increased salinity in these waters until they are flushed by winter rainfall; saline surface water is particularly evident in the Island's eastern waterways and bodies, which tend to be saline year-round due to a combination of lower annual rainfall, geology, soils, and groundwater (DEWNR 2013).

Surface water resources across the region are generally considered to be "abundant and reliable" (SACES 2012; KI NRM Board 2009), although variations in the security of supply exist. Much of the Adelaide Hills area, for example, lack mains water and wastewater treatment infrastructure meaning that residents must rely instead on water capture, bore water, and septic tanks systems (SACES 2012).

Impacts on surface water quality and flow regimes within the region include expanding land-use (e.g. farming, forestry plantation, development), increasing residential populations and tourism, limited water storage infrastructure (e.g. dams and reservoirs), native vegetation clearing, pollution, flooding, and poor land management practices (e.g. overgrazing and inappropriate fertilizer and pesticide application) (URPS 2014; DEWNR 2013; KI NRM Board 2009).

Groundwater resources within the region are important for a variety of purposes, particularly horticulture, viticulture and irrigation of open space (Hayman et al. 2009), as well as residential use within towns such as Uraidla and Summertown, which lack mains water supply and so rely on bore water supplies (*sensu* stakeholder interviews 2014). On Kangaroo Island, groundwater supplies are generally saline with low yielding wells (URPS 2014; KI NRM Board 2009).

Licensed extractions on the mainland occur from aquifers within the region, and a recent survey of the status of such aquifers (i.e. Murray Group Limestone aquifer in the Angas-Bremer Prescribed Wells Area; Permian Sands and Tertiary limestone aquifers on the Fleurieu Peninsula; and fractured rock aquifers in the Mount Lofty Ranges) described the condition of the Murray Group, Tertiary Limestone, and Fractured Rock aquifers as showing "no adverse trends, indicating negligible risk to the resource", and of the Permian Sands aquifer as "gradual adverse trends indicating a low risk to the resource in the medium term" due to declining groundwater levels (URPS 2014).

3 How will climate change affect the region?

3.1 Overview

Climate change is occurring as a consequence of the release of greenhouse gases like carbon dioxide, methane and nitrous oxide into the Earth's atmosphere. These gases come from a range of sources including the stationary energy, transport, industrial processing, waste management, agriculture, and land management sectors. Increasing concentrations of greenhouse gases act to trap more of the sun's energy in the Earth's atmosphere leading to changes in the global climate.

Since 1990, the Intergovernmental Panel on Climate Change (IPCC) – the world's leading international organisation for the assessment of climate change – has released five comprehensive reports which review and synthesise global climate science, build on the knowledge and developments from previous reports, and provide refined greenhouse gas emissions scenarios and related global warming projections.

Global Circulation Models (GCMs) are the basic tool used to predict climate change and have been developed for different parts of the world. The models are run over long time periods and are based on well-established laws of physics regarding interactions between the physical processes in the atmosphere, ocean, cryosphere, and land surface, and predict climate change by solving numerical equations relating to these interactions. In addition, other factors applied when using GCMs are emissions scenarios which consider the concentration of greenhouse gases in the atmosphere under different conditions, and timeframes over which greenhouse gas concentrations are generally expected to increase. As such, predictions for an area can vary depending on the GCM, emissions scenario, and timeframe selected.

The scale of resolution can also influence climate change predictions. GCMs use a coarse [horizontal] scale of resolution (e.g. 200x200km up to 600x600km), and so will not capture fine-scale variations in climate, which occur more so in topographically diverse regions. To assist regional scale planning, a number of finer-scaled regional models have been developed for some regions around the world. These regional climate models apply the information from GCMs to regional and local level climate data. However, the higher variability captured using regional climate models also results in higher variability in the model outputs.

3.2 Projections for the region

The impacts of climate change are already being experience around the world, including Australia. For example, the nation's annual average surface air temperature has risen since 1910 (CSIRO and BoM 2007), with warming occurring at nearly 0.2ºC per decade since 1950. Annual rainfall, on the other hand, has shown a variable but gradual decline in southern Australia since 1950. Sea levels have risen across the globe in response to thermal expansion because of warming of the world's oceans, by 21 cm from 1880 to 2009 (CSIRO 2011). Locally, sea levels have been rising at about 2 mm/year at Outer Harbor since about 1940 (DEH 2005).

Region specific projections are based on Regional Climate Change Projection reports for different regions of South Australia published in 2010 by the Department of Environment and Natural Resources. Specifically, the reports used here are for the Kangaroo Island (DENR 2010a) and the Adelaide Hills and Mount Lofty Ranges (DENR 2010b) areas[1]. In addition to generally informing the development of the Plan and raising awareness about climate change amongst stakeholders in the region, the projections information presented below and in Table 2 will be used to assist in undertaking the integrated vulnerability assessment, specifically to inform scoring of "exposure".

The two reports provide data and climate change projections (DENR 2010a,b) from regional climate models developed by CSIRO and the Bureau of Meteorology. The regional climate models presented are at a scale of resolution of 100kmx100km, based on 23 global climate models (CSIRO 2007), at the 2030 and 2070 time periods, and assuming high, medium and low emissions scenarios (IPCC 2000). For the purposes of this report, information is largely presented in relation to projections for the 2070 time period under a medium emissions scenario (called "A1B" in the Fourth Assessment Report). It should be noted though that current trajectories of fossil fuel emissions are consistent with the high emissions pathway (RCP 8.5) presented in recent reports by the IPCC (Global Carbon Project 2014).

While South Australia is the nation's driest state, the region is arguably the wettest in South Australia, comprising 16 of the top 20 wettest towns in the State, including the top nine wettest towns (Digital Atlas 2014). The region also comprises some of the coldest towns in the State, including Kingscote on Kangaroo Island and several towns in the Mount Lofty Ranges area of the Adelaide Hills Council. Under climate change, the region is expected to experience a warmer and drier climate by 2070, though Kangaroo Island will be slightly less impacted than the mainland portion of the region (Table 3) (DENR 2010a,b).

Compared to the rest of the State, temperature increases will be less severe in the region (CSIRO 2007), yet rainfall decline (particularly significant in winter and spring) will be greater

[1] Projections for the region need to be reviewed at the end of 2014 following release of modelling from a national scale project by CSIRO and BoM and state level project by the Goyder Institute.

than is projected for the central region of the State, though approximately equivalent to projections for the north of the State (CSIRO 2007). Given the region's current wetter and cooler conditions, however, the impacts of a drying and warming climate are likely to be less severe compared to projections for the rest of the State.

There is no specific information on the changing risk of extreme events in the region such as heatwaves, bushfires and intense rainfall. However, some of this information can be inferred from studies in other regions or from more general trends, for example:

- projections for Adelaide suggest (a) the frequency of 2 or more days greater than 40℃ will increase from 0.09 times per year to 0.7 to 1.3 per year and (b) 3 or more days with temperatures greater than an average of 32℃ will increase from 0.02 times per year to 0.2 to 0.65 per year (Resilient South 2014). For contrast, in Murray Bridge in the SA MDB NRM region, the frequency of 2 or more days greater than 40℃ is projected to increase from 1 per year to 1.8-2.4 to per year by 2070 (SKM 2013);

- the incidence of extreme fire days (forest fire danger index or FFDI ≥ 50), based on Adelaide Airport's weather is projected to increase from 2 per year in 1980-1999 to 6-10 per year in 2070 (Resilient South 2014). At Murray Bridge, extreme FFDI days are projected to increase from 0.3 per year to 2.1-6.7 days per year by 2070 (SKM 2013); and

- climate models suggest that for each degree of global warming, extreme daily rainfall may increase by 7%, although this may not apply in every circumstance (SKM 2013).

It is interesting to note that weather events are already aligning with projected trends, with 2013 being the State's warmest year on record, several record high temperatures occurring through the year, extensive heatwave conditions at the start of the year, a highly variable rainfall differing from average records through the year (with the first half of the year being wetter and the second half of the year drier, than average), and several severe and destructive storms and associated flooding experienced (BOM 2014c).

Table 2. Climate change projections for selected variables for the Adelaide Hills, Fleurieu and Kangaroo Island region for 2070 (unless stated otherwise). Projections are given relative to the period 1980-1999. Information is from DENR (2010a,b) unless indicated otherwise.

Climate variable	Description
Temperature increases: Winter-spring	Mainland and Kangaroo Island: An increase of 1.8℃ (1.3-2.8℃) is projected in winter-spring across the region.
Temperature increases: Summer-autumn	Mainland and Kangaroo Island: An increase of 1.8℃ (1.3-3.5℃) is projected in summer-autumn across the region.
Rainfall Reduction: Winter-spring	Mainland: Winter-spring rainfall predicted to decrease by 15% (+4.5% to -30%). Kangaroo Island: Winter-spring rainfall predicted to decrease by 15% (no change to -30%).
Rainfall Reduction: Summer-autumn	Mainland: Summer-autumn rainfall predicted to decrease by between 4.5% and 8% (+15% to -30% for autumn). Kangaroo Island: Summer-autumn rainfall predicted to decrease by 8% (+15% to -30% for autumn).
Sea level rise	Sea level has been rising at about 4.5 mm/year in South Australia since the 1990s. The recent IPCC 5th Assessment Report suggests global mean sea level rise for 2046–2065 relative to 1986–2005 could be 0.26 m for more moderate emissions outlooks and up to 0.48 m by 2081–2100 (IPCC 2013).
Increased ocean temperatures	During 2010, the sea surface temperatures in the Australian region were 0.54℃ above the 1990 baseline average. Annual sea surface temperatures may increase by 1.5-2.0℃ around southern Australia (0.6℃ to 2.0℃) (CSIRO 2003-2014).
Increased ocean acidity	Projections for decreasing pH range from 0.06 to 0.32 by 2100, with a best estimate more likely to be in the order of a 0.2 pH unit decrease. This compares with a 0.1 pH unit decrease since the beginning of the industrial era about 250 years ago (IPCC 2013).
CO2 Increases	Atmospheric CO2 is currently at 395.2 ppm (CSIRO 2014). Under a medium emissions outlook CO2 concentrations in the atmosphere will likely increase to 700 ppm by 2070.
Potential evapotranspiration	Mainland: Annual potential evapotranspiration is projected to increase by 6.5% in summer and autumn, 3% in sprig and 10% in winter. Kangaroo Island: Annual potential evapotranspiration is projected to increase by 6.5% in summer, autumn and spring and 10.5% in winter.

4 Sensitivity and adaptive capacity

This section describes the sensitivity and adaptive capacity for key measures under the five capitals described in Section 2. Together with exposure, these factors form the basis of a vulnerability assessment. Sensitivity reflects the responsiveness of a system to climatic influences and the degree to which changes in climate might affect that system in its current form whereas adaptive capacity is the ability of a system to respond to climate change (e.g. Allen Consulting Group 2005).

Adaptive capacity can be autonomous (natural) or planned (managed). Autonomous adaptation does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Planned adaptation is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

The information used in this has been derived from both a review of the literature as well as interviews with stakeholders in the region. Local scale sensitivity and adaptive capacity was particularly informed by local level climate change adaptation plans that had been developed for Alexandrina Council and the City of Victor Harbor.

3.1 Human capital

Climate change will likely influence population growth and settlement patterns especially within the mainland part of the region. Current population growth in the region is currently higher than the State average, with such growth likely to bolster the adaptive capacity of specific locales, as well as the region overall. Growth in the region is largely driven by inward migration (RDAB AHFKI 2013), with this trend potentially increasing under climate change due to increased temperatures and heat waves causing people to seek out cooler areas in the hills in which to live. For example, areas such as the Adelaide Hills and Mount Barker may be attractive for people commuting to metropolitan Adelaide as higher temperatures are likely to be experienced in the Adelaide plains and CBD. Countering this, however, will be the increased bushfire risk which may act as a disincentive for people to move to the area.

Coastal communities may also experience increasing population growth under climate change given the cooling influence of water and coastal breezes, together with the popularity of coastal towns as retirement destinations (SACES 2012). However, population growth in coastal areas may be countered by increasing risk from sea level rise and storm surges. Such growth may also have repercussions for the adaptive capacity of other sectors (e.g. being able to provide adequate services within the social sector) which, without careful consideration and planning, may counteract any adaptive capacity benefits.

Climate change will also impact the physical and mental wellbeing of people, with the elderly identified as being at particularly high risk. General expected impacts on human physical health identified for the State, include increasing mortality (heat-related and also due to bushfires and floods), incidence of diseases (water, food, and vector-born), and frequency of respiratory diseases and allergies (e.g. from dust and bushfire smoke) (DEWNR 2012; Department of Environment 2013b). A decline in mental health is also anticipated, particularly due to the increased stress associated with the flow-on effects of climate change impacts on elements associated with other capitals (e.g. extreme event impacts) (DEWNR 2012).

A number of specific impacts on physical health identified within the region align with the general State-level impacts. Increasing temperatures are expected to be the most significant potential impact on human health (Tonkin 2010), though decreasing rainfall together with increasing extreme events (particularly frequency and intensity of hot days, bushfires, and floods) are also of concern (Davis et al. 2010; DEWNR 2012; Davis et al. 2009). On Kangaroo Island, heat-related illnesses (e.g. food poisoning) have been specifically identified as the most likely climate change-induced threat to human health (Tonkin 2010). However, it should also be noted that the region is likely to be generally less impacted compared to the rest of the State, given the inherent higher rainfall and lower temperatures.

Some local councils have identified specific impacts that they consider may be significant in their area, such as increasing European wasp activity (as a result of increasing temperatures) in Alexandrina (Davis et al. 2010), and algal blooms affecting water bodies (due to decreasing rainfall) in Victor Harbor (Davis et al. 2009). There is also concern at the local council level that impacts on human health may increase demands on council resources and services related to mitigating and managing impacts, as well as treating individuals (Davis et al 2010; Davis et al. 2009).

One way to help address resource pressures, and already recognised by some councils in the region, involves increasing the education of community members (particularly at risk groups) regarding specific risks (e.g. bushfire risk) and necessary actions. Currently, however, there appears to be opposing information being delivered to people across the region. For example, some councils promote and encourage the use of public buildings as extreme event refuges, whilst others recommend people prepare their own response plans and not rely on council buildings as “safe houses”. Regional public health plans currently being developed are a mechanism to address these issues and help improve adaptive capacity across the region.

Opportunities for improving education regarding climate change impacts on human health are not limited to community members, with the region’s health service also calling for increased information to help mitigate and manage climate change related health issues. A number of

studies have been published on the impacts of climate change on human health (McMichael et al. 2006; AMA 2008; Patz et al. 2005; de'Donato & Michelozzi 2014; Pinkerton & Rom 2014; Goudie 2014; Webb et al. 2014; Burge et al. 2014), and there is a clear opportunity to increase the region's human health adaptive capacity by facilitating the transfer of knowledge from scientific studies to the local and regional health services so that they may be better prepared and able to respond proactively, rather than reactively. For example, Country Health SA Local Health Network has implemented proactive strategies aimed at identifying and protecting at-risk individuals from increasing temperatures and associated bushfires.

The region's adaptive capacity is bolstered by maintaining unemployment rates lower than the State average (RDAB AHFKI 2013); though many people are reported to commute outside of the region (mainly to Adelaide) for work (RDAB AHFKI 2013). Creating opportunities for additional jobs within the region will need to be considered particularly in some Southern Fleurieu coastal townships where unemployment rates are higher than the State average (RDAB AHFKI 2013). Ironically, climate change may, in part, help address unemployment, as projected residential population and tourism influxes in the coastal townships are likely to require additional facilities and services, which may in turn create additional job opportunities.

Understanding the adaptive capacity of human capital in the region can be further informed by considering the number of graduates and school finishers, proportion of the population over 65, one-parent households, lone-person households, and women in non-routine jobs (Table 3). Regions are considered to have a greater human capital adaptive capacity when the measures of these indicators are more favorable than State averages. In this regard, two local council areas (Adelaide Hills and Mount Barker) had all indicator measures comparing favourably to State averages (Table 3), and so are likely to be the areas within the region with the highest human capital adaptive capacity.

Opportunities exist to improve the human capital adaptive capacity of the region by focusing on establishing mechanisms for improving or mitigating indicator measures. For example, incentives could be provided to complete high school and attain a post-school qualification, and facilities, appropriate opportunities and support may be enhanced to encourage more women into non-routine occupations. Other options include increasing community strength (social capital) and ensuring emergency services (social capital), and buildings and infrastructure (physical capital) are adequately equipped to deal with climate change impacts and the likely increased community need,

Table 3. Indicators of human capital adaptive capacity (EconSearch 2013). Shaded cells indicate local council areas with greater adaptive capacity when compared to the State average.

		Local Council Area Averages					
Indicator measure	**State**	**Adelaide Hills**	**Alexandrina**	**Kangaroo Island**	**Mount Barker**	**Victor Harbor**	**Yankalilla**
% population completing high school	43	54	36	37	46	31	35
% post-school graduates	52	62	51	49	55	51	50
% population ≥ 65 years	16	13	25	17	12	35	25
% single-parent households	16	10	13	15	11	12	12
% lone-person households	28	18	26	32	22	30	30
% women in non-routine jobs	23	30	21	27	25	17	21

3.2 Social Capital

Climate change is expected to impact on emergency, recreation and community services, industry and economic activity, and social connectedness. Impacts of climate change on extreme events will be relevant for many communities. As well as their direct impact on property and infrastructure, they can also impact the ability for critical emergency services to function adequately, for example, through delayed response times due to communication network damage or access routes being limited (e.g. damaged or blocked). Bushfire is likely to be particularly important in the region, as recognised the by the State's Country Fire Service.

The interactions between bushfire and climate changes are likely to complicate the identification and adoption of clear management and mitigation procedures, as is already apparent in existing documents. For example, although changes have been made to the State's bushfire risk management process (including a pilot project on Kangaroo Island), the impacts of climate change are yet to be incorporated into process revisions. The ability for State and local governments to comply with existing bushfire regulations is also likely to be challenged under increasing extreme events, and may be compounded by increasing public pressure to protect, maintain and recover life and property under risk from extreme events (Davis et al. 2010; Davis et al. 2009), potentially resulting in increasing liability claims (Davis et al. 2010).

Damage to community and recreation infrastructure and facilities (e.g. from bushfire or sea level rise) could negatively influence local industries and economic activity, and will further compound increasing demands placed on public buildings, transport and support services by at-risk communities and individuals seeking refuge from heat waves or bushfires (Davis et al. 2010;

Davis et al. 2009). Public pressure on local councils to replace lost, or repair damaged, infrastructure and facilities are also likely to increase. For example, the City of Victor Harbor notes that increasing pressures may result in a loss of sporting clubs if associated increasing costs are passed on through increasing facility use costs (Davis et al. 2009). Alexandrina Council has also identified declining home ownership along river and coastal foreshores as a concern due to decreasing rainfall negatively affecting environments and, subsequently, property values (Davis et al. 2010).

From a cultural perspective, there is some concern that indigenous stories and laws may be lost as a result of the on flow-on effects of climate change impacts. For example, many of the laws of the Peramangk people within the Mount Barker area are based on Eucalypt trees, yet Eucalypt trees are being lost in the area either by direct removal by councils and developers, or by loss of essential groundwater supplies.

Adaptive capacity can be further explored for social capital by considering voluntary work and community strength. Regions are considered to have a greater social capital adaptive capacity when the measures (EconSearch 2013) of these indicators compare higher than State averages. All local council areas within the region have volunteer percentages higher than the State average, yet community strength percentages just under the State average (Table 4).

Kangaroo Island has the highest proportion of their population contributing to volunteer work, which will help mitigate potential negative impacts on social disconnectedness due to geographic isolation. Comparatively, Mount Barker has the lowest proportion of population in volunteer work, yet it was still higher than the State average. The social adaptive capacity of the region could be increased by focusing on increasing community strength in all local council areas. For example, through increasing social networking among individuals (e.g. ensuring help can be sought from friends, family or neighbours when needed), promoting and encouraging memberships in organised clubs and groups (e.g. sports, church, community groups), and further encouraging parent's involvement in school activities.

Table 4. Indicators of social capital adaptive capacity (EconSearch 2013). Shaded cells indicate local council areas with greater adaptive capacity when compared to State average.

		Local Council Area Averages					
Indicator measure	**State**	**Adelaide Hills**	**Alexandrina**	**Kangaroo Island**	**Mount Barker**	**Victor Harbor**	**Yankalilla**
% population volunteering	20	30	27	38	26	27	29
% community strength	70	67	67	67	67	67	67

3.3 Physical Capital

With the exception of Kangaroo Island, the region is in close proximity and generally well connected to the Adelaide metropolitan area (RDAB AHFKI 2013). Climate change elements of particular importance to physical capital within the region are increasing temperatures and extreme events, such as heat waves, sea level rise and storm surges, as well as decreasing rainfall. Increasing temperatures and extreme events will particularly cause direct impacts on the structural integrity of infrastructure (including water, sewer and storm water) within the region, with additional impacts on the local community and the ability for local councils to adequately comply with existing regulations and meet increasing public demands.

Direct impacts to infrastructure will include:

- melting bitumen on sealed roads and buckling of railway lines (DEWNR 2012; Davis et al. 2009);
- cracking and displacement of footpaths (Davis et al. 2009);
- increasing damage and failure of river levees (Davis et al. 2009); and
- destruction of reserves and other public green space areas, including loss of street trees and parklands (Davis et al. 2010; Davis et al. 2009), as well as damage from falling limbs of trees under water stress.

Infrastructure located in coastal areas will be particularly vulnerable across the State, with estimates of 60,000 buildings being impacted along the State's coastline (DEWNR 2012). Within the region, such impacts on infrastructure (and also reserves) will have particular relevance to Alexandrina, Yankalilla, Kangaroo Island, and Victor Harbor local council areas. For example, within Victor Harbor, concerns regarding sea-level rise include damage to infrastructure and reserves from associated rising water tables and salinity, as well as the potential for inundation of parts of the CBD and civic center due to associated storm surges (Davis et al. 2009).

Non-coastal areas may also be at increased risk of infrastructure damage due to flooding, with towns such as Balhannah and Aldgate in the Adelaide Hills local government area already affected by 1 in 100 year flood events (*sensu* stakeholder interviews), and community wastewater management systems at Kersbrook and Birdwood (also in the Adelaide Hills area) having a tendency to overflow under current heavy rainfall (*sensu* stakeholder interviews); additional or improved storm-water infrastructure will be critical in helping to address such climate change impacts.

Climate change may also increase stress on energy generation, transmission, and distribution systems in a number of ways. For example, power distribution may be interrupted as the network is shut down for periods during extreme bushfire risk days (as per current operating practices). At the same time, however, energy demands for cooling are likely to increase under

similar conditions (DEWNR 2012; Davis et al. 2009). The need for increasing cooling will place additional demands on local council resources such as:

- public facilities will require upgrading to meet thermal comfort standards (Davis et al. 2009);
- additional shade structures will need to be established (particularly in car parks) (Davis et al. 2010); and
- increased monitoring, mitigation, and maintenance (including increasing irrigation) of infrastructure, public open spaces, and street trees will be required (Davis et al. 2010; Davis et al. 2009).

The ability for local councils to appropriately manage and plan urban development, including meeting regulation compliance may also be compromised, leading to increasing costs and resource requirements, and potential public liability claims. For example:

- increasing extreme events will require buildings to meet higher levels of application, structural, and green rating compliance (Davis et al. 2010; Davis et al. 2009);
- decreased rainfall will limit opportunities to seal roads resulting in longer periods of poor conditions and access (Davis et al. 2010);
- new open space areas at risk from bushfires will require appropriate fire prevention conditions included in management plans (Davis et al. 2010); and
- increasing temperatures and decreasing rainfall will necessitate management and development planning to potentially reconsider construction projects (e.g. appropriate urban development patterns, open space designs, and water security) (Davis et al. 2009).

Adaptive capacity for physical capital can be further explored for social capital by considering remoteness (using the ARIA index, which is a measure of community remoteness from service centres and populated areas), population size, population change, and household internet access. Regions are considered to have a greater physical capital adaptive capacity when the measures (EconSearch 2013) of these indicators compare favourably to State averages as is described below.

Across the region, half of the indicator measures compare favourably to the State averages (Table 5). Mount Barker fairs particularly well, being the only local government area in which all indicator measures are better than State averages, suggesting that Mount Barker has the greatest expected physical capital adaptive capacity within the region. Comparatively, Kangaroo Island has no indicator measures above the State averages, though many of these measures are likely to be significantly biased by the inherent island nature.

Improving the physical capital adaptive capacity of Kangaroo Island is likely to be difficult given its physical isolation from the mainland which imposes a number of inherent constraints. Increasing the percentage of households with internet connection, however, is one indicator that could be more readily improved on the Island, as well as within Alexandrina, Victor Harbor and Yankalilla.

Table 5. Indicators of physical capital adaptive capacity (EconSearch 2013). Shaded cells indicate local council areas with greater adaptive capacity when compared to the State average.

		Local Council Area Averages					
Indicator measure	**State Avg.**	**Adelaide Hills**	**Alexandrina**	**Kangaroo Island**	**Mount Barker**	**Victor Harbor**	**Yankalilla**
ARIA index (transformed) (i.e. remoteness)	0.00	0.91	0.71	-0.75	0.85	0.88	0.70
Local government area population size	22,444	38,628	23,699	4,417	29,766	13,841	4,396
% population change	5	2	14	4	13	15	6
% households with internet	76	86	75	71	83	71	72

3.4 Financial Capital

Agriculture

Agriculture is a critical component of the State's economy, particularly the State's viticulture industry which provides nearly half of the nation's wine grapes, and almost 60% of national wine exports (Department of Environment 2013b; Hayman et al. 2009). Although a large amount of research has been conducted on climate change impacts on various sectors in the region, and also on the impacts of climate change generally on various agricultural activities, more focused work is required which investigates climate change impacts on the agricultural activities specifically within the region (Hayman unpublished). Hayman's (unpublished) review of climate change impacts on primary industries within the region helps to address this knowledge gap, though Hayman notes that it is difficult to assess specific impacts and adaptive capacities of agricultural activities within the region given the variety of responses likely among different agricultural activities, and even potentially within individual properties. Nonetheless, it is generally agreed that direct impacts of climate change on the region's agriculture will primarily be linked to altered rainfall patterns and increasing temperatures.

Decreased rainfall is known to increase vineyard disease and death and decrease fruit yield (Davis et al. 2010). It may also decrease pasture quality and availability and quality of drinking water which will have negative impacts on livestock (DEWNR 2012) and may also result in a reduction in irrigated areas (DEWNR 2012) as well as decreased water quality available for irrigation with subsequent impacts on plant growth and soil condition (Dwyer et al. 2009). It may also decrease the suitability of farm areas, requiring a change in crop types or sowing and harvesting practices (Dwyer et al. 2009). Water security and associated reduced yields were additionally identified as key issues in the Fleurieu's olive-culture industry, together with

concerns regarding emerging soil salinity, rising water tables, and increased pest and disease outbreaks (James & Liddicoat 2008).

Increasing temperature is also identified as a key impact on primary production industries within the region (e.g. Hayman unpublished). Direct losses of livestock and damage to agricultural lands and crops are expected to increase as a result of increases in average temperatures (e.g. Hayman unpublished), as well as increases in extreme events, such as heat waves, droughts and bushfires (DEWNR 2012). Extreme events, together with associated high winds, will not only cause direct damage, but will also impact on erosion, salinity, nutrient leaching and denitrification of soils, and decreasing water quality through increasing sedimentation of waterways (DEWNR 2012; Dwyer et al. 2009). There is also the potential for heat waves to cause negative physiological responses, such as reduced livestock growth and increased trauma (Tonkin 2010; Dwyer et al. 2009), and interruptions to bee pollination due to heat stress days during flowering (Dwyer et al. 2009; Hayman unpublished).

Climate change has been directly implicated in bee population (and other pollinator) declines (Potts et al. 2010), with likely detrimental consequences for agriculture industries reliant on bees as pollinators, as well as apiaries, such as those based on Kangaroo Island. Crop and pasture growth have also been specifically identified as at risk agricultural sectors on Kangaroo Island, though the impacts are likely to be lower compared to the mainland, given the generally cooler, wetter conditions on the Island (Tonkin 2010).

Heat waves will place additional demands on energy supply to maintain favourable thermal conditions for climate-controlled indoor farming on the mainland (Dwyer et al. 2009). Furthermore, fruits grown in the region such as apples, pears, and some grapes varieties are heavily reliant on cold weather conditions occurring at the right time of year, with increasing temperatures and altered timings impacting the flowering, pollination and fruiting times, leading to earlier ripening (up to a month (Department of Environment 2013b), decreased winter chilling, and shorter growing seasons (DEWNR 2012), as well as decreasing yield and quality (e.g. nutritional content) (*sensu* stakeholder interviews, and DEWNR 2012; Department of Environment 2013b). Warmer temperatures may also increase the likelihood of bolting in certain vegetable crops (Dwyer et al. 2009).

Livestock and cropping will be further negatively impacted by increasing temperatures through associated increasing abundance and distribution of invasive pest and weed species which will present additional competitive challenges and herbivory for native species, and decrease pasture quality for livestock (DEWNR 2012; Dwyer et al. 2009; Hayman unpublished). Some pests and diseases will increase, with this being particularly problematic for cropping given produce vulnerability to diseases is also likely to increase (DEWNR 2012; Dwyer et al. 2009; Hayman unpublished). The impacts of pests, weeds, and diseases on Kangaroo Island's primary production industries may be somewhat less than that experienced on the mainland

given the generally cooler, wetter conditions of Kangaroo Island together with the Island's oceanic isolation presenting a natural barrier to movement and spread of diseases and pests (Tonkin 2010).

The combined impacts of increasing temperature and decreasing rainfall are likely to interact creating specific complexities for agriculture within the region. For example, the combined impacts may alter soil carbon levels and increase the susceptibility of some soil types to wind and water erosion, leading to an overall decreasing suitability of farmlands, particularly those located in the drier marginal areas of the region DEWNR 2012; Dwyer et al. 2009). Warmer conditions will also increase evapotranspiration (which will influence crop growth) and with decreased rainfall will place additional pressure on water availability for irrigation[49]. The impacts are not necessarily always negative, with crop yields and produce quality potentially increasing in the medium-term due to warmer temperatures and increasing CO^2 concentrations; however any potential benefit to various produce may be counteracted by increasing temperatures and decreasing water availability (Tonkin 2010), if nitrogen supplies are not adequately maintained[49], or if concurrently boosted weed growth is not appropriately managed (Dwyer et al. 2009).

Overall, the impacts of climate change are generally expected to increase financial hardship for agricultural industries across the State, due in part to increasing costs associated with: decreasing productivity and quality; adapting agricultural practices and capabilities, including changing crop types and irrigation efficiency (Hayman unpublished), as well as harvesting times (Dwyer et al. 2009); seeking, establishing and maintaining alternative water and energy supplies (DEWNR 2012); altered soil conservation practices[52]; and shifts in national and international markets due to changing consumer requirements and altered produce quality and availability (Dwyer et al. 2009).

Despite some of the negative effects, some agricultural opportunities may also exist. For example, warmer temperatures may result in generally higher overnight temperatures which may reduce the risk of frost damage in fruiting plants (Hayman unpublished). Kangaroo Island's geographic isolation may also provide a key opportunity for maintaining biosecurity, which is likely to be an issue on the mainland where it is less easily controlled. Accordingly, under future climates, Kangaroo Island may become a critical supplier of high quality, disease and pest free, produce; it is already recognised for its pure honey strains and as a supplier of high quality seed potatoes. Furthermore, a mainland trend over the years for larger agricultural properties in the hilly mainland areas to be subdivided and sold to hobby farming ventures may potentially increase under climate change as the hills become a more attractive climate in which to live. Although such subdivision could potentially limit productivity across the region, it may potentially boost tourism to the region through an increase in boutique farms and guesthouses.

Forestry

The forestry industry faces significant negative impacts from climate change, with forestry growth and wood production, as well as flowering and reproduction (important for breeding programs that aim to improving certain traits, such as wood quality and insect resistance) being highly sensitive to changes in climate. Of particular importance to the forestry industry will be changes in: average and extreme temperatures, timing and amount of rainfall, wind speed, and atmospheric CO^2 concentrations (ABARES 2011; Pinkard & Bruce 2011).

There is little reported on climate change impacts on forestry within the region specifically, but known impacts from a State perspective are similar to those identified for agriculture, including: direct mortality and increased water and heat stress, altered growing seasons and productivity, and increasing pest damage, competition and susceptibility, as well as flow-on effects to costs and communities reliant on a forestry-based economy (DEWNR 2012; ABARES 2011). Furthermore, areas considered commercially viable may shift (geographically), shrink, or expand, with the Mount Lofty Ranges and Kangaroo Island areas (which support one of the three main plantation regions in the State[53] considered particularly vulnerable (DEWNR 2012).

Radiata pine, one of the main tree species comprising the plantations with the region (ABARES 2011), has been identified as one of the species likely to be particularly susceptible to decreasing productivity under warmer and drier climate conditions (ABARES 2011). The impacts of climate change on the forestry industry will be further exacerbated by existing pressures from salinity, fragmentation, and competing demands for inputs.

Fisheries and aquaculture

Increasing climate change impacts on oceans (e.g. increasing oceanic temperatures, acidity, and sedimentation) will cause changes to species' distribution and migration patterns, breeding and growth rates, and physiology. Southern-ranged species in South Australian waters are most likely to be affected by ocean warming and strengthening boundary currents, with prawn, western rock lobster, salmon and estuarine species being particularly vulnerable (DEWNR 2012). Marine biosecurity will become an increasing issue, with the spread of pests and diseases increasing under a changing climate.

Impacts on first order consumers such as zooplankton communities (i.e. decreased productivity and diversity) will additionally create flow-on impacts higher up the marine food chains, though the magnitude of such flow-on effects are as yet unclear. Climate changes such as sea level rise, storm surges and altered water chemistry will also cause a degradation of littoral zone habitats (e.g. samphire and mangrove communities) that provide important shelter, breeding and feeding niches for a range of commercially and recreationally important marine species (DEWNR 2012). Alexandrina Council notes that recreational fishing may further be negatively impacted by decreased stream flows in the River Murray and channel depths resulting from decreasing rainfall (Davis et al. 2010).

For aquaculture industries, sea level rise and oceanic warming may result in decreased suitability of some aquaculture locations (DEWNR 2012). Land-based aquaculture operations may also be impacted if freshwater supplies on which they are reliant are limited due to declining rainfall and water availability, and the supply and quality of feed ingredients may also be compromised (DEWNR 2012).

Tourism

Climate change will likely impact tourism in the region through a direct loss of attractions, as well as a decreasing quality of attractions, with associated increasing costs for repair, maintenance, and replacement of infrastructure and creation of new, alternative attractions (DEWNR 2012). However, summer conditions that are likely to last longer under climate change may also boost the tourism season.

Both the Fleurieu Peninsula and Kangaroo Island represent major eco-tourism draw-cards within the region; Kangaroo Island in particular has an advantage given its unique natural assets. The impacts of climate change on tourism though remain unclear. On one hand, climate change could affect tourism to the region through: decreased aesthetic value as a result of damaged/degraded natural assets; increasing damage to infrastructure and transport systems; increasing safety risks from extreme events; and decreasing water availability. For example, wildflower tourism on Kangaroo Island will be impacted as flowering seasons begin and finish earlier with increasing temperatures (Tonkin 2010). On the other hand, warmer conditions on the mainland could make Kangaroo Island a more attractive holiday destination.

The proposed doubling by 2022 of Kangaroo Island's current 185,000 tourists (SACES 2012) will need to be carefully considered in order to balance the benefits associated with increased income with potentially impacts associated with increased demand on already limited water resources, and additional strain on the island's infrastructure and resources (SACES 2012). Other eco-tourism destinations within the region, such as the Adelaide Hills, could also face negative effects due to extreme events (e.g. heat waves, bushfire) increasing risk to human life and also causing destruction of tourism destinations and infrastructure (DEWNR 2012). However, as for Kangaroo Island, the heat refuge nature of the region may mean that more people visit.

Coastal areas are also likely to lose a certain level of tourist appeal as a result of increasing sea levels, coastal instability, and storm events (DEWNR 2012); Alexandrina council further note that caravan parks and marinas in their area may experience declining tourism activity as a result of decreasing aesthetics and amenities resulting from decreasing rainfall and associated water restrictions (Davis et al., 2010).

The region's iconic wine-growing areas also attract substantial tourism activity, and as such, negative impacts to these areas from increasing temperatures and decreasing rainfall will have flow-on effects to tourism, both in regards to decreasing product yield and quality impacting consumer activity and tourism businesses reliant on such produce (e.g. restaurants), as well as general decreasing aesthetic appeal (Davis et al. 2010; DEWNR 2012; Department of Environment 2013b; Hayman et al. 2009). Wine production should continue though, but with different styles of wines being produced e.g. trend away from cool climate wines.

Manufacturing and services

There is currently no information available regarding climate change impacts on manufacturing and services specifically within the region. At a State level, however, the impacts of climate change will result in increasing costs for energy and water supplies as well as for increasing insurance premiums, which are likely to rise given increases in the likelihood of extreme events (DEWNR 2012).

Extreme events will also have a negative impact on manufacturing production if energy, water supplies and transport links are disrupted. Victor Harbor council further note that climate change will place increasing demands on services within the region, including increasing wear and tear management of open spaces, as a result of increasing temperatures (Davis et al. 2009).

Other measures of financial adaptive capacity

Adaptive capacity for financial capital can be further explored by considering the following primary indicators (Table 6) (EconSearch 2013): economic diversity (using the Hachman index), median household income, income to housing cost ratio, unemployment rate, and median household size. Regions are considered to have a greater financial capital adaptive capacity when the measures (see EconSearch 2013) of these indicators compare favourably to State averages as shown in Table 6.

Table 6. Indicators of financial capital adaptive capacity (EconSearch 2013). Shaded cells indicate local council areas with greater adaptive capacity when compared to the State average.

		Local Council Area Averages					
Indicator measure	**State**	**Adelaide Hills**	**Alexandrina**	**Kangaroo Island**	**Mount Barker**	**Victor Harbor**	**Yankalilla**
Hachman index (i.e. economic diversity)	0.5	**0.92**	**0.85**	0.31	**0.95**	**0.83**	**0.54**
Median weekly household income ($)	1,125	**1,750**	900	900	900	700	700
Average income ($) per $1 housing cost	3.91	**4.77**	3.37	**4.23**	**3.93**	2.71	2.71
Unemployment rate (%)	5.7	**3.0**	6.5	**4.3**	**4.0**	8.3	7.5
Median number of persons per household	2.41	2.70	**2.33**	**2.18**	2.62	**2.12**	**2.18**

Overall, half of the indicator measures for the region compare better than State averages. The region as a whole fairs best in terms of economic diversity, with all local government areas, except for Kangaroo Island comparing better than State averages. The low Hachman index for Kangaroo Island is indicative of a large proportion of the island's employment (more than 23.2%) occurring within only a few key industries (i.e. agriculture, forestry and fisheries), with this proportion differing substantially from the State as a whole where these industries account for less than 5% of employment (SACES 2012).

The median household income was the indicator with the least adaptive capacity within the region, with only the Adelaide Hills local Council comparing better than the State median. The Adelaide Hills Council is also the local council area with the highest overall financial capital adaptive capacity within the region. Adaptive capacity within the region could be improved by focusing on decreasing unemployment rates and increasing the availability of affordable homes in order to attract young families and skilled workers into the region and so further fortify economic diversity.

3.5 Environmental capital

Climate change will have a number of impacts on elements of environmental capital in the region. Of particular importance are changes which alter the environmental suitability of areas for flora and fauna species, such as: temperature, rainfall, and extreme events. These climate impacts will most likely interact with existing threats, though the magnitude and direction of such

interactions are likely to be extremely variable and are not well understood. Nonetheless, given that elements of the environmental capital underpin all other capitals within the region, impacts on this capital will have repercussions for all others.

Terrestrial, marine and aquatic ecosystems

Climate change will cause a multitude of complex direct and indirect impacts on biodiversity across all ecosystems. Within the region, climate change impacts on biodiversity have been recognised as an important issue in all council areas. Expected (and observed, in some cases) impacts within the region include changes in: species' distributions (range and extent), community composition, species' abundances, and individual behavior/phenology; with these changes applying to both native and introduced species.

Terrestrial ecosystems and concomitant species located on Kangaroo Island and within the Mount Lofty Ranges are considered to be among the State's most vulnerable to climate change (Department of Environment 2013b). Although recognised as an important issue, the degree to which the impacts of climate change on biodiversity have been considered and addressed varies, possibly due to the extreme complexity involved with this issue.

The magnitude and direction of impacts as well as species' responses will be highly species-specific, with some benefitting from the changes (i.e. expanding distributions and abundance) whilst others being negatively influenced (i.e. contracting distributions, declining abundance, extirpations, and extinctions). Although invasive and weedy species are generally considered to be the "winners" from climate change and native species the "losers", this is not always the case. Further complicating this issue is that climate change impacts are unlikely to occur in isolation, but rather will interact with other existing impacts on species such as: habitat fragmentation or degradation (due to clearing), urbanization and associated infrastructure development, pollution, and other human land-uses (e.g. agriculture).

The way in which these impacts interact will vary substantially, for instance some impacts will interact to have an additive effect on species (i.e. the combined impact equals the sum of each impact independently), some may interact synergistically (i.e. the combined impact is greater than the sum of either independent impact), whilst others may be counteractive (i.e. the combined impacts decrease or neutralize the independent impacts).

Coastal ecosystems, for example, will be highly vulnerable to sea level rise, storm surges, decreased rainfall (Department of Environment 2013b), and erosion (Davis et al. 2010). Alexandrina Council specifically recognise that species in their area may face additional extinction risks resulting from the combined impacts of climate change-related habitat loss and anthropogenic land-use related habitat loss (e.g. for urban development) (Davis et al. 2010). Increasing coastal erosion and altered water chemistry as a result of climate change may also interact with increasing pollution, sedimentation and destruction of habitats as a result of

infrastructure development (e.g. desalination plants) to intensify negative impacts on coastal ecosystems, particularly those in the littoral zones, such as mangroves and seagrasses (AMLR NRM Board 2008).

Established infrastructure may interact with climate changes (e.g. sea level rise) to increase negative impacts on habitats by limiting the potential for landward movements of certain estuarine habitats, such as saltmarshes, with likely flow-on effects to dependent species (AMLR NRM Board 2008). Such impacts on coastal and non-coastal systems, will increase costs associated with managing, protecting, and replacing damaged or lost habitats and areas (Davis et al. 2009), though for some habitats and species, protection or replacement may not be feasible options and so councils will need to carefully consider species, habitats and impacts in their area and plan accordingly in order to minimize losses and prevent futile actions and cost expenditure.

Impacts of climate change on species will also likely have flow-on effects to other elements of the environmental capital as well as to other capitals. For instance, increasing abundances and ranges of pest and weed species are likely to have implications not only for conservation management but also for biosecurity within the region, both on land and in the oceans (DEWNR 2012; AMLR NRM Board 2008). For industries reliant on pollination (e.g. fruit producers and apiaries), changes in species' growth rates (e.g. plant productivity) and phenology (e.g. reproduction times and durations, flowering/fruiting times, migration patterns) will be of particular importance, particularly if such changes and shifts result in phonological mismatches; for example, flowering-pollinator timings may be disrupted if increasing temperatures cause flowering times to advance faster than pollinator emergence times, thereby resulting in decreased pollination. Furthermore, increasing salinity and acidification of oceans (due to increasing temperatures) will negatively impact marine plants, plankton communities, and calcium-carbonate based marine life (e.g. shellfish, corraline red macroalgae) which will create additional negative impacts on carbon cycling abilities and entire marine food chains (AMLR NRM Board 2008).

<u>Water resources</u>

The combination of decreasing rainfall and increasing temperatures and evaporation are likely to be the greatest threats to water resources within the region (DEWNR 2012; AMLR NRM Board 2008). Even a small reduction in rainfall will have large impacts on water resources, through run-off and recharge; for example, research has shown that a 10% decline in rainfall can equate to up to 25% reduction in stream flow or run-off (Chiew & McMahon 2012). Such impacts will result in decreased water availability, including in groundwater systems, and will have flow-on effects to productivity, and operational, maintenance and capital expenditure. Impacts of climate change on groundwater systems will be of particular concern for townships such as Uraidla and Summertown (within Adelaide Hills local council area), which lack mains water supply and so rely on bore water supplies (*sensu* stakeholder interviews).

Climate change impacts will also: decrease surface run-off (AMLR NRM Board 2008), flow and quality of water into storages which will, in turn, negatively impact on reliant aquatic systems and communities (i.e. rivers and wetlands); and increase degradation of estuary and inlet ecosystems (DEWNR 2012). Decreasing water quality may cause an increase in algal blooms, and may be further negatively impacted by increasing sediment loads as a result of native vegetation loss (due to climate change), together with increasing storms and floods, erosion, and build-up of contaminants (Davis et al. 2010), and increasing bushfire events (which increase ash and sediment loads in waterways) (AMLR NRM Board 2008).

Land management

With nearly half of the State's coastlines comprising of sandy beaches, and over half of those backed by soft sediment plains, rising sea level and storm surges will greatly increase the vulnerability of these areas to shoreline recession and fore-dune destabilisation (Department of Environment 2013b). Such impacts will increase the impacts on coastal settlements and infrastructure and so also increase the risk of financial loss to coastal landowners and lenders (DEWNR 2012; Department of Environment 2013b).

Extreme rainfall events and increasing winds will increase demand on soil erosion management, and the likelihood of increasing ranges, abundance and diversity of weed and pest species into both production and reserve lands, will have substantial implications for management of these areas (AMLR NRM Board 2008). Alexandrina local council have also identified an increasing need for council resources to be directed to land management, such as roadside slashing and tree trimming, in order to help manage increasing bushfire risk (Davis et al. 2010).

Adaptive capacity

Unlike the other four capitals, there are currently no suggested indicators of environmental capital adaptive capacity in the literature. This is likely due to the extreme species-specific variability in responses to climate change, together with the difficulty in attaining underlying information and data for measuring such indicators. For example, the higher percentages of remnant vegetation and higher diversity of native species within a local council area when compared to State averages, may be one potential indicator of environmental adaptive capacity, however, mapping of remnant vegetation for the State is currently incomplete, and differences in species composition, and associated species-specific responses, may obscure the adaptive capacity of different regions with equal species diversity.

Another indicator may potentially be topographic variation, which would allow indicators such as refugia potential and climate velocity to be measured. In this sense, refugia refers to habitat areas which retain suitable climatic conditions for species under climate change (e.g. small valley pockets may escape the full impacts of increasing temperatures), and climate velocity refers to the rate and direction at which climate suitability shifts across a landscape in relation to

topographic diversity (Pinsky et al. 2013). For example, the velocity of temperature change is lowest in mountainous areas and highest in flat areas (Loarie et al. 2009). Accordingly, temperature-sensitive species living in topographically diverse regions (e.g. Adelaide Hills) may be expected to be better able to adapt to increasing temperatures as they will have less distance to move (up or down) in order to find suitable habitats; whereas similar species living in topographically simple landscapes (e.g. coastal areas) may be less able to adapt to increasing temperatures as they will need to shift greater distances in order to stay within suitable climatic conditions. However, the information required to measure such indicators are either not consistently available across the region and the State, or are available at a scale of resolution too coarse to be ecologically meaningful.

Therefore, we take a broader approach to discussing adaptive capacity within the region, and assume that natural systems will tend to have a higher adaptive capacity if they contain: diverse and unrestricted gene pools (i.e. increased capacity to evolve or shift), and if they are better protected from degrading impacts such as: excessive land clearing, over extraction of ground or surface water, invasive species, soil erosion, salinity, and environmental pollutants (LGA SA 2012).

Within the region, Kangaroo Island supports the largest area, as well as the highest percentage, of remnant vegetation, with 229,860 ha (51.7% of its land area) being mapped as remnant (Table 7). By comparison, the lowest amount of remnant vegetation occurs in the Mount Barker area (8.1%, 4,818ha) (Table 7). The high percentage of remnant vegetation may also be indicative of high protection of habitats from land conversion and degradation, and may imply a higher adaptive capacity for the island compared to mainland areas. However, any benefits of high species diversity and habitat protection are likely offset by the geographic isolation of the island which significantly limits genetic flow and species movements, and so decreases the ability of species to adapt to climate change. However, this same geographic isolation could result in the Island providing critical habitat refugia for species lost from the mainland.

Improving the region's environmental capital adaptive capacity will require rethinking land management actions and infrastructure development so that degrading impacts on ecosystems are minimized and actions are taken to restore habitat areas and increase connectivity between them. Each area will need to develop conservation and management plans specific to the species diversity occurring within their area, and with respect to species-specific responses and sensitivities to climate change. Increasing attention will need to be paid to biosecurity both on land, and in the oceans, and in certain cases, species adaptations may need to be facilitated through anthropogenic species relocations.

Table 7. Area of remnant vegetation in the region, shown as: total area (ha) per local government area, and percent of land area per local council area (URPS 2014). Values are not provided for the State as mapping is currently incomplete.

State	Remnant Vegetation Area (ha)	% Council Area
Adelaide Hills	22,155	27.9
Alexandrina	19,224	10.5
Kangaroo Island	**229,860**	**51.7**
Mount Barker	4,818	8.1
Victor Harbor	6,121	15.8
Yankalilla	13,027	17.2
State	*Mapping incomplete*	

4 References

ABARES (2011) *Potential Effects on Climate Change on Forests and Forestry in Australia*. Commonwealth of Australia, Canberra, Australian Capital Territory.

ABS (2011) *National Regional Profile 2007-2011*. For Adelaide Hills (LGA) + Alexandrina (LGA) + Kangaroo Island (LGA) + Mount Barker (LGA) + Victor Harbor (LGA) + Yankalilla (LGA). Accessed May 2014. URL http://www.ausstats.abs.gov.au/ausstats/nrpmaps.nsf/NEW+GmapPages/national+regional+profile

ABS (2012) *Community Profiles*. Accessed May 2014. URL http://www.abs.gov.au/websitedbs/censushome.nsf/home/communityprofiles?opendocument&navpos=230

Allen Consulting Group (2005). *Climate Change Risk and Vulnerability*. Canberra, Allen Consulting Group: 159.

AMA (2008) *Climate Change and Human Health*. Accessed June 2014. URL https://ama.com.au/position-statement/climate-change-and-human-health-2004-revised-2008

AMLR NRM Board (2008) *Creating a Sustainable Future: An Integrated Natural Resources Management Plan for the Adelaide and Mount Lofty Ranges Region*. Government of South Australia, South Australia.

AMLR NRM Board (2013) *Water Allocation Plan Western Mount Lofty Ranges*. Government of South Australia.

BOM (2014a) *National Water Account*. Australian Government. Accessed June 2014. URL http://www.bom.gov.au/water/nwa/

BOM (2014b) *Topographic Drainage Divisions and River Regions*. Accessed June 2014. URL http://www.bom.gov.au/water/about/riverBasinAuxNav.shtml

BOM (2014c) *South Australia in 2013: A Year of Extreme Heat and Record High Temperatures*. Australian Government. Accessed June 2014. URL http://www.bom.gov.au/climate/current/annual/sa/summary.shtml

Burge C.A., Eakin M., Friedman C.S., Froelich B., Hershberger P.K., Hofmann E.E., Petes L.E., Prager K.C., Weil E., Willis B.L., Ford S.E., Harvell C.D. (2014) Climate change influences on

marine infectious diseases: implications for management and society. *Marine Science*, 6: 249-277.

Chiew F.H.S., McMahon T.A. (2012) Modelling the impacts of climate change on Australia streamflow. *Hydrological Processes*, 16: 1235-1245.

CSIRO (2011) *Sea Level Rise: Understanding the Past - Improving Projections for the Future*. Accessed September 2014. URL http://www.cmar.csiro.au/sealevel/sl_impacts_sea_level.html

CSIRO (2003-2014) *Cape Grim Greenhouse Gas Data*. CSIRO Marine and Atmospheric Research and the Australian Bureau of Meteorology (Cape Grim Baseline Air Pollution Station. Accessed September 2014. URL http://www.climatechangeinaustralia.gov.au/technical_report.php.

CSIRO, Bureau of Meteorology (2007) *Climate Change in Australia.Technical Report 2007*. CSIRO, Melbourne.

Davis T., Morton D., Daly R. (eds) (2009) *City of Victor Harbor: Climate Change Adaptation Report*. Prepared for City of Victor Harbor, South Australia.

Davis T., Morton D., Daly R. (eds) (2010) *Alexandrina Council: Climate Change Adaptation Report*. Prepared for Alexandrina Council, South Australia.

de' Donato F., Michelozzi P. (2014) Climate change, extreme weather events and health effects. P0p 617-624 within: *The Mediterranean Sea* (eds. Goffredo S., Dubinsky Z.). Springer, Netherlands.

DEH (2005) *Adelaide's Living Beaches: A Strategy for 2005–2025*. Technical Report. Government of South Australia, South Australia.

DENR (2010a) *Regional Climate Change Projections: Kangaroo Island*. Department of Environment and Natural Resources, South Australia.

DENR (2010b) *Regional Climate Change Projections: Adelaide Hills and Mount Lofty Ranges*. Department of Environment and Natural Resources, South Australia.

Department of the Environment (2013a) *Protected Matters Search Tool*. Commonwealth of Australia. Accessed June 2014. URL http://www.environment.gov.au/epbc/pmst/

Department of Environment (2013b) *South Australia. Climate Change Impacts in SA*. Australian Government. Accessed June 2014. URL http://www.climatechange.gov.au/climate-change/climate-science/climate-change-impacts/south-australia

DEWNR (2012) *Prospering in a Changing Climate: A Climate Adaptation Framework for South Australia.* Government of South Australia, South Australia.

DEWNR (2013) *Non-prescribed Surface Water Resources Assessment – Kangaroo Island Natural Resources Management Region*. Government of South Australia, through Department of Environment, Water and Natural Resources, South Australia.

DEWNR (2014) *Marine Parks South Australia*. Government of South Australia. Accessed June 2014, URL www.environment.sa.gov.au/marineparks/home

Digital Atlas Pty Ltd (2014) *Bonzle Digital Atlas of Australia*. Accessed July 2014. URL http://www.bonzle.com

Dwyer E., Gunner E., Shepherd K. (2009) *The Changing Climate: Impacts and Adaptation Options for South Australian Primary Producers*. Primary Industries and Resources SA and Rural Solutions SA, South Australia.

EconSearch (2013) Appendix 1: Socio-economic profile for the Adelaide Hills Fleurieu and Kangaroo Island Regional Development Australia Region. Within: *Regional Development Australia Adelaide Hills Fleurieu and Kangaroo Island 2013-2016 Regional Roadmap*. Report prepared for Regional Development Australia Board Adelaide Hills, Fleurieu and Kangaroo Island Regional Development Australia, South Australia.

Forum for the Future (2014) *The Five Capitals Model – A Framework for Sustainability*. Accessed September 2014. URL http://www.forumforthefuture.org/sites/default/files/project/downloads/five-capitals-model.pdf.

Global Carbon Project (2014). Global carbon budget. http://www.globalcarbonproject.org/carbonbudget/index.htm. Accessed 24 September 2014.

Goudie A.S. (2014) Desert dust and human health disorders. *Environment International*, 63: 101-113.

Government of South Australia. *National Parks South Australia*. Accessed June 2014, URL www.environment.sa.gov.au/parks/home

Hayman P.T., Leske P., Nidumolu U. (2009) *Climate Change and Viticulture: Informing Decision Making at a Regional Level*. South Australian Wine Industry Association and South Australian Research and Development Institute. South Australia.

IPCC (2000) *Emissions Scenarios: Special Report of the Intergovernmental Panel on Climate Change*. (eds. Nakicenovic N., Swart R.) 570 pp. Cambridge University Press, UK.

IPCC (2013) Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Stocker T.F., Qin D., Plattner G.-K., Tignor M., Allen S.K., Boschung J., Nauels A., Xia Y., Bex V., Midgley P.M.) Cambridge University Press, Cambridge, UK and New York, NY, USA.

James J., Liddicoat C. (2008) *Developing Industry Climate Change Adaptation Strategies: A Case Study for the McLaren Vale Viticulture and Fleurieu Peninsula Oliveculture Industries*. Report prepared for City on Onkaparinga and Rural Solutions SA, on behalf of Land and Biodiversity Division Department of Water, Land and Biodiversity Conservation, Government of South Australia, South Australia.

KI Council (2014) *Clean and Green Island Gets a $500,000 Solar Boost*. Media Release, 10 February 2014. Visible Solar Project – File 16.15.7. Kangaroo Island Council, South Australia.

KI NRM Board (2009) *Kangaroo Island Natural Resources Management Plan 2009: Volume 1. State of the Region*. Kangaroo Island Council, South Australia.

LGA SA (2012) *Guidelines for Developing a Climate Change Adaptation Plan and Understanding an Integrated Climate Change Vulnerability Assessment: November 2012*. Report prepared by Jacqueline Balston and Associates with input from LGA South Australia, Department Environment Water and Natural Resources, CSIRO Climate Change Adaptation Flagship, Bureau of Meteorology SA, South Australia.

Loarie S.R., Duffy P.B., Hamilton H., Asner G.P., Field C.B., Ackerly D.D. (2009) The velocity of climate change. *Nature*, 462: 1052-1055.

McMichael A.J., Woodruff R.E., Hales S. (2006) Climate change and human health: present and future risks. *Lancet*, 267: 859-869.

Patz J.A., Campbell-Lendrum D., Holloway T., Foley J.A. (2005) Impact of regional climate change on human health. *Nature*, 438: 310-317.

Pinkard L., Bruce J. (2011) *Climate Change and South Australia's Plantations: Impacts, Risks and Options for Adaptation*. CSIRO, Australia.

Pinkerton K.E., Rom W.N. (eds) (2014) *Global Climate Change and Public Hea*lth. Springer, New York.

Pinsky M.L., Worm B., Fogarty M.J., Sarmiento J.L., Levin S.A. (2013) Marine Taxa Track Local Climate Velocities. *Science*. 341.6151: 1239-1242.

Potts S.G., Biesmeijer J.C., Kremen C., Neumann P., Schweiger O., Kunin W.E. (2010) Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution*, 25: 345-353.

RDAB AHFKI (2013) *Regional Roadmap 2013-2016: Growing a healthy, resilient, well connected and prosperous region*. Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island, South Australia.

Resilient South (2014) *Climate Change Scenarios Report – Resilient South.* Prepared by SKM as part of the Resilient South consultancy led by URPS, for the Cities of Onkaparinga, Holdfast Bay, Marion and Mitcham in association with the Government of South Australia and the Australian Government. Sinclair Knight Merz, South Australia.

SA Water (2013) *Reservoirs – Overview*. Government of South Australia. Accessed June 2014. URL http://www.sawater.com.au/SAWater/WhatsNew/WaterDataUpdate/ReservoirData/default.htm

SKM (2013). *Climate change adaptation to vulnerability project South Australian Murray-Darling Basin NRM region - Climate change scenarios report*. Prepared for the South Australian Murray-Darling Basin Natural Resources Management Board, Sinclair Knight Merz, South Australia.

Southern and Hills Local Government Association (2012). *Strategic Plan*. http://www.lga.sa.gov.au/webdata/resources/files/S_HLGA_Strategic_plan_V2_2012.pdf

Tarong Energy (n.d.) *Starfish Hill Wind Farm – Fleurieu Peninsula – South Australia*. Tarong Energy. Accessed July 2014, URL www.energy.edu.au/new-website/pdf/starfish_hill.pdf

The South Australian Centre for Economic Studies (2012) *Regional Development Australia Adelaide Hills, Fleurieu and Kangaroo Island.* Adelaide and Flinders Universities, South Australia.

Tonkin R. (2010) *Potential Impacts of Climate Change on Kangaroo Island Agricultur*e. A report prepared for Agriculture Kangaroo Island Inc, South Australia.

Tourism Research Australia (2013) *Statistics: Regional Overview*. Accessed May 2014. URL http://www.tra.gov.au/statistics/Regional-overview.html

URPS (2014) *Adelaide Hills, Fleurieu and Kangaroo Island Climate Change Adaptation Plan: Regional Profile*. Report prepared for Seed Consulting Services, South Australia.

Webb L., Bambrick H., Tait P., Green D., Alexander L. (2014) Effect of ambient temperature on Australian Northern Territory public hospital admissions for cardiovascular disease among indigenous and non-indigenous populations. *International Journal of Environmental Research and Public Health*, 11: 1942-1959.