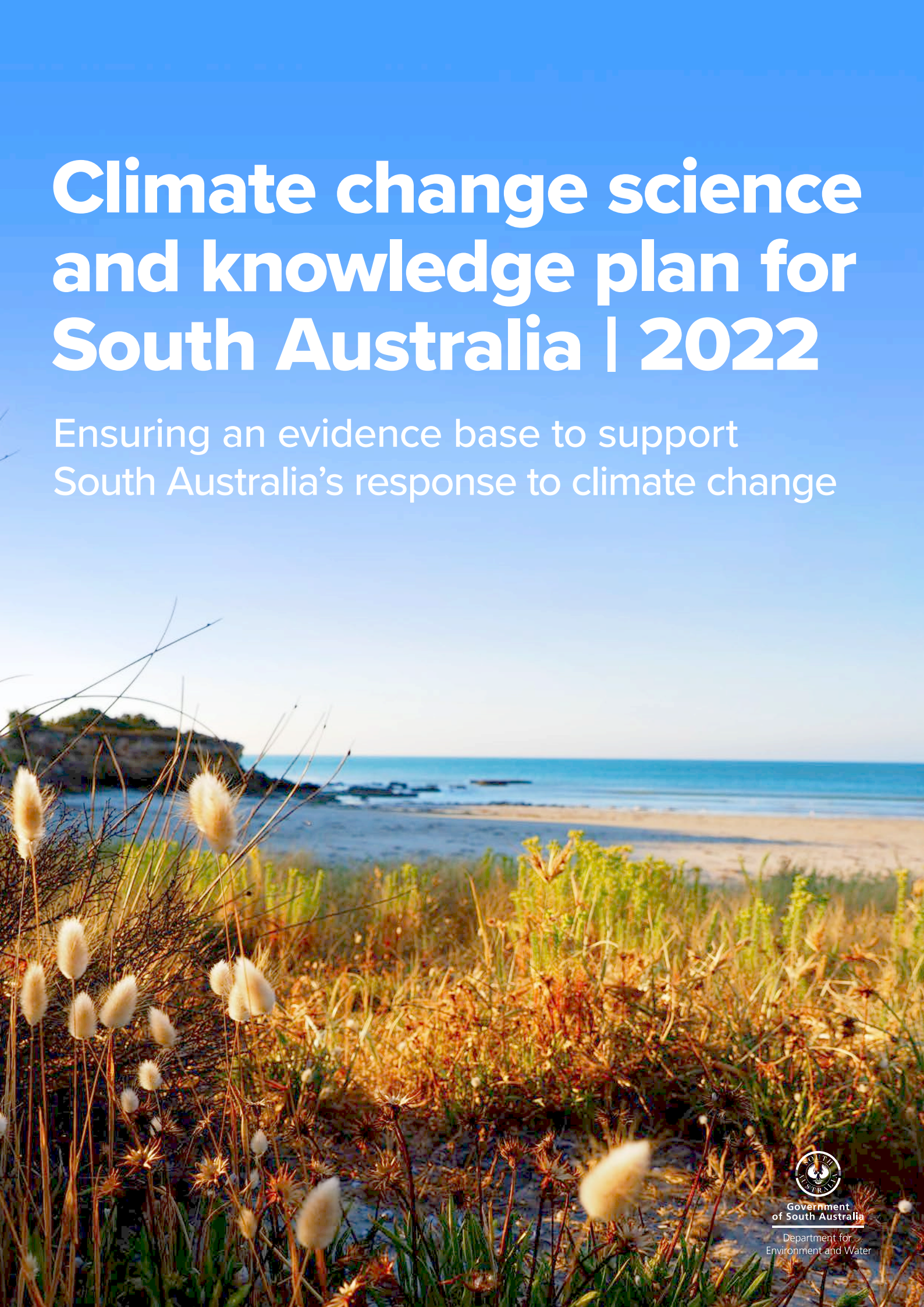
Climate change science and knowledge plan for South Australia | 2022

Ensuring an evidence base to support South Australia's response to climate change



Government of South Australia
Department for Environment and Water

Introduction

The South Australian government is committed to providing accessible information to help prepare our state for a new climate future.

The scientific evidence base shows that the climate of South Australia is changing. Our state is becoming hotter and drier, with rising sea levels and an increased risk of more frequent and intense heatwaves, bushfires, storms, and floods.

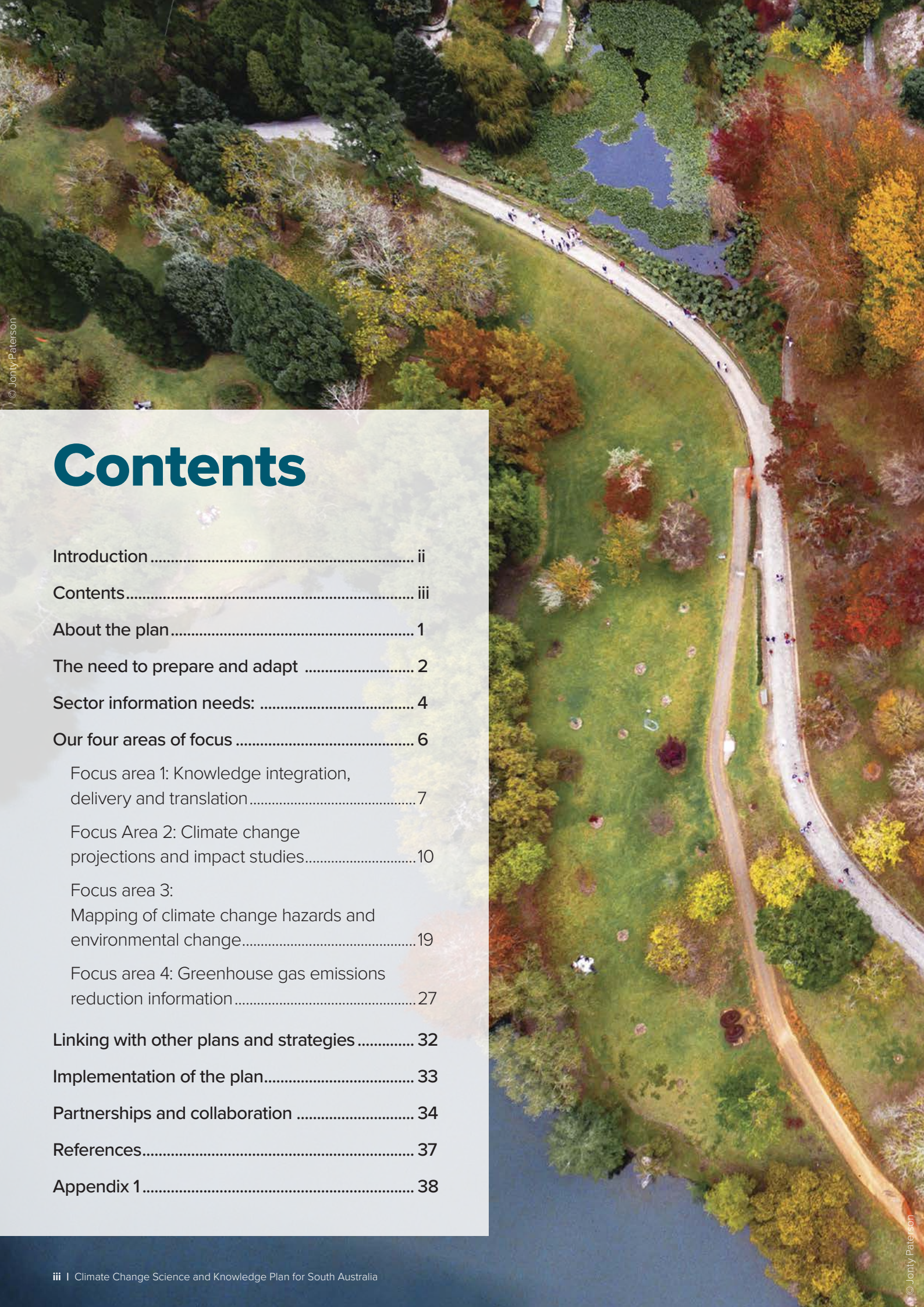
We know climate change will challenge the resilience of our natural resources, our infrastructure, our financial security and economic competitiveness, and the health and well-being of our people. Our recent experiences of high river flows and flooding in SA's Riverland region, and catastrophic bushfires in several areas of the state, highlight the need to act decisively with the best available science and information.

Making decisions for our state's future requires us to understand climate change, as well as its expected impacts. A changing climate presents challenges to and opportunities for our state to prosper through low emissions industries and effective adaptation. The South Australian government is committed to improving the evidence base to help the state make the best decisions, find innovative solutions, and take action to respond and adapt to our changing climate.

The Climate Change Science and Knowledge Plan for South Australia provides a framework for renewed effort and action. This plan underpins South Australia's responses to climate change and ensures we will continue to grow the best evidence base for South Australia to respond today and into the future.

This 2022 update of the plan reflects our current technical information resources and the future actions required to respond to knowledge gaps.

Providing high-quality, accessible information is a critical component of the South Australian Government Climate Change Action Plan 2021–2025, which sets the pathway for climate-smart planning and action.



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About the plan

The *Climate Change Science and Knowledge Plan for South Australia* seeks to improve the evidence base to support South Australia's responses to climate change.

Providing high-quality, accessible information is a critical component of the South Australian Government Climate Change Action Plan 2021-2025, which sets the pathway for climate-smart planning and action.

The plan identifies the accessible science and information that will be required to implement a whole-of-government climate change strategy and to ensure the needs of all sectors are addressed.

Through this plan, the South Australian government provides vital information on climate change risk assessment, mitigation, planning and adaptation responses in South Australia. It fosters a shared understanding of our critical datasets and gaps, and enables our community of practice to work together towards addressing these gaps.

Implementation of this plan will help decision-makers identify, apply, and use science and knowledge to make the best decisions, find innovative solutions, and take action. Implementation will include:

- identifying the science and information needed by government, business and industry to understand impacts and risk, and support climate change planning and response activities
- coordinating, curating and communicating climate change science and knowledge
- making existing data, science and information more accessible
- prioritising new science and information-generating activity according to demand
- facilitating new science required for decision-making.

This plan was developed following consultation with South Australia's emergency management, health, infrastructure, primary production and natural resources sectors.

The potential use of climate change technical information is broad. We cannot predict how information will be applied by different sectors. Similarly, sector needs can be quite specific. This plan forms a broad baseline of evidence for everyone to draw from and add to for their specific knowledge needs.

As the South Australian government authority on the state's environment and natural resources, the Department for Environment and Water (DEW) is the lead agency for the implementation of this plan.

While DEW provides leadership for this plan, its implementation will require the support of the community of practice with responsibility for climate change risk assessment, mitigation, planning and adaptation responses in South Australia. This community of practice includes lead state and federal agencies, local government, the research sector and other sector partners and stakeholders.

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The need to prepare and adapt

Responding to our changing climate requires South Australia to prepare and adapt. To do this well, we need to be equipped with the best science and knowledge.

South Australia is becoming hotter and drier, with rising sea levels and an increased risk of more frequent and intense heatwaves, bushfires, storms, and floods.

Average temperatures in South Australia are now more than 1˚C warmer than in 1960. The state's daily maximum temperature is projected to rise by as much as 2.1˚C by 2050.

Across Australia, 2019 records show that 2019 was both the warmest and driest year on record. For South Australia, the overall mean temperature was 1.45°C above average, making it the state's second-warmest year on record and warmest since 2013. Rainfall for South Australia was 65% below average, the State's driest year on record.

There has been a persistent decline in rainfall in the state's southern agricultural areas. In 2019, large areas of the South Australian pastoral districts received less than 30mm. Rainfall is predicted to continue to decline in most parts of the state, which will impact water security, agricultural yields and the environment, as well as increasing fire risk.

Sea levels rose 17cm from 1901 to 2000. Sea levels are projected to rise by a further 22 to 25cm by 2050, exacerbating shoreline erosion and putting at risk coastal communities and infrastructure.

The climate change projections of CSIRO and the Bureau of Meteorology indicate more heatwaves and storm events, greater rainfall intensity, more time spent in drought, and an acceleration in the rate of sea level rise over the coming decades.

Increased temperatures and more frequent extreme weather (including heatwaves, floods and storms) will impact on the built and natural environments and communities. Vulnerable members of the community are particularly susceptible, including the elderly, the very young, those who live in remote or vulnerable coastal communities, and low-income households.

These trends will impact sectors such as the agriculture, food, wine, and forestry industries, which are a vital part of the state's economy, generating about $22.5 billion in 2016-17. These sectors will increasingly be impacted by climate change, and they will need to continue to respond and adjust with innovative soluions to ensure their resilience.

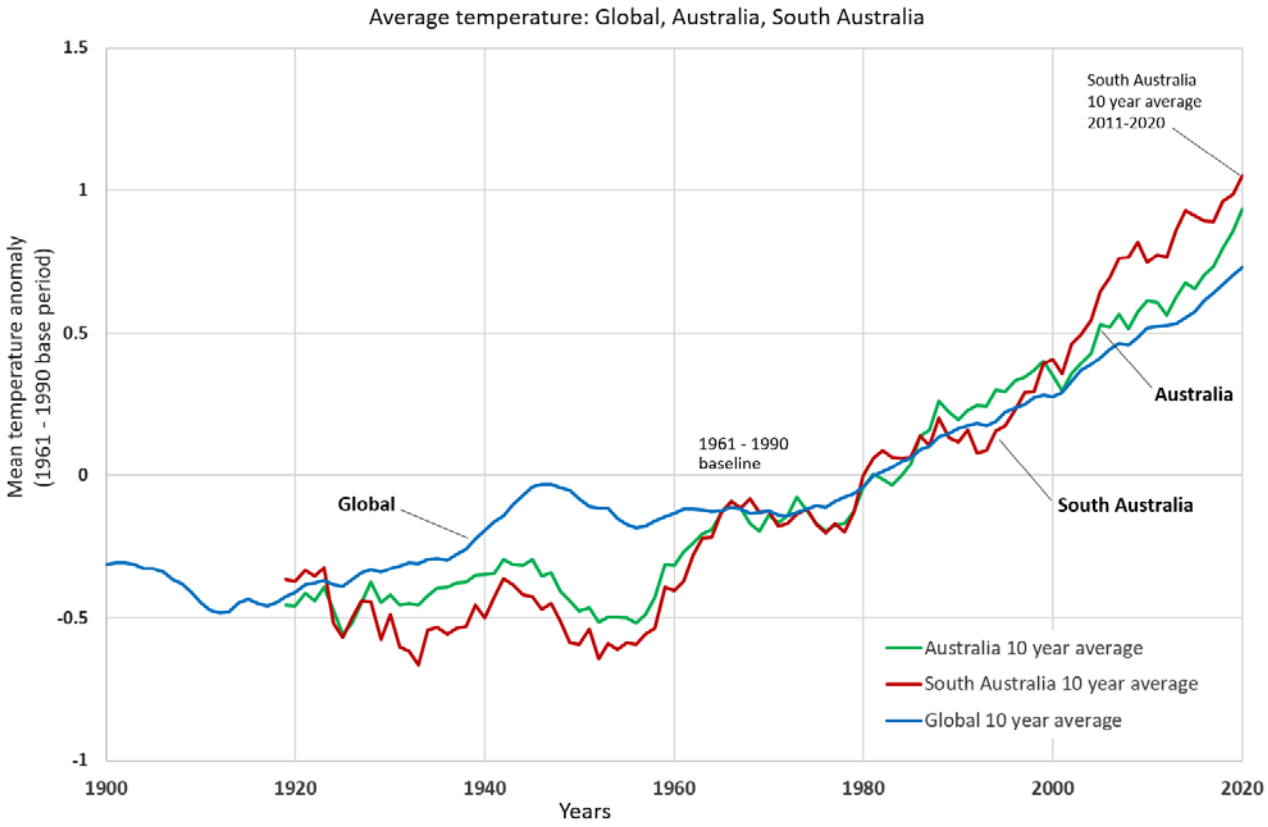
Many of our high-value export industries, particularly in agriculture and mining, require access to sufficient, secure water resources to maintain a competitive advantage. Current projections of the impact of climate change on water resources indicate that supply from existing state-based resources is likely to decline. This will increasingly challenge the state's ability to meet current and emerging demands for water resources for different industry sectors while maintaining critical environmental values.

Similarly, the state's $6.2 billion tourism industry is a significant component of South Australia's economy. Tourism in South Australia is vulnerable to climate change impacts. Our internationally recognised outdoor event program and nature-based attractions are at risk from extreme hot weather conditions, increasing extreme weather events, bushfires, and sea level rise.

The ability to access credit and insurance will increasingly become conditional on the ability to demonstrate an understanding of climate-related risks and a plan to manage them. South Australian businesses will have an advantage in understanding, reporting and acting on their climate-related risks when they have ready access to technical information and expert advice on climate change and its likely impacts within South Australia.

By understanding the impacts of climate change on our communities, industries and environment, we can better prepare and adapt for the future.

Figure 1: Changes in average temperature (global, Australia, and South Australia), 1910 to 2020



Key points from Figure 1

- The average temperature in South Australia is rising at a higher rate than global and Australian average temperatures.
- In the 10 years to 2020, the average temperature of South Australia was approximately 1.05°C higher than the average temperature of the 30 years to 1990.
- The ten hottest years on record in South Australia have all occurred since 2005.have occurred since 2005.

Average temperatures in South Australia are projected to continue to rise, by as much as 2.1°C by 2050, under a high emissions scenario (RCP8.5)*

*What are 'emissions scenarios' and 'RCPs'?

A range of scenarios are used to describe possible future trends in emissions of greenhouse gases into the atmosphere. These scenarios are based on assumptions about future socio-economic trends and their likely implications for emissions. Under a high scenario, emissions of greenhouse gases are not subject to widespread national or international regulations. A low emissions scenario is one in which all nations make early and substantial efforts to reduce emissions.

RCP stands for 'Representative Concentration Pathway'. The RCPs range from high (RCP8.5) through to intermediate (RCP4.5) to low (RCP2.6) scenarios. We use the RCPs to model climate change and build scenarios about the impacts.The IPCC's Sixth Assessment Report introduces the use of a range of Shared Socioeconomic Pathways (SSPs) to derive greenhouse gas scenarios for climate modelling. The next generation of climate projections will be based on these scenarios.

Sector information needs:

Individual sector information needs

In preparing this plan, we listened to representatives from five key industry sectors from metropolitan and regional communities to understand their climate change information requirements. This section shares a summary of each sector's needs, based on their feedback.

Emergency management sector

Key points of feedback:

- improved understanding of the likelihood of 'compounding events' (that is, when two or more extreme weather-related events coincide), to inform risk reduction strategies
- information to better identify and communicate the changing risks and vulnerabilities of communities and risk reduction strategies
- analysis of emergency response system vulnerabilities, cross-dependencies, and cascading events during major incidents
- better understanding of the impact of climate and vegetation changes on future fire behaviour
- improved understanding of changing preparedness and response requirements for extreme weather events such as storms, heatwaves and floods
- projected changes in soil dryness, vegetation, and fire weather behaviour before and after prescribed burns
- information on changes in fire season length and implications for emergency services
- Information to assist climate-sensitive development in areas that are at high risk from natural hazards, floods and fires.

Infrastructure sector

Urban infrastructure

Key points of feedback:

- information on the benefits and optimal design of urban green infrastructure to cool Adelaide
- agreed climate change projection data for use in designing climate resilient critical infrastructure
- community vulnerability to infrastructure failure and community expectation of infrastructure to mitigate risks: sea walls, flood levees, bushfire refuges, heat wave refuges
- information for the design of carbon-efficient living environments
- how to adapt the design of new or existing infrastructure (including green infrastructure) to improve its resilience to climate change impacts
- information to support development of climate-smart buildings that reduce demand for water and energy and mitigate impacts of rising temperatures
- metropolitan scale stormwater run-off analysis in response to climate change and urban infill
- changes to performance of water sensitive and biodiversity sensitive urban design under projected future rainfall and temperature conditions
- city-scale urban water management analysis: quantifying benefits of urban irrigation, green infrastructure for city cooling spatial analysis to determine highest priority locations for urban green infrastructure.

Coastal infrastructure

Key points of feedback:

- comprehensive data on coastal elevation, erosion and inundation risks and the impact of sea level rise in the coastal zone
- risks to critical infrastructure, including green infrastructure, such as waste-water management schemes in low-lying areas in the coastal zone and coastal buffer zones - sand dunes, mangroves, salt marshes
- location of protection infrastructure: optimal locations for protection infrastructure, such as sea walls and flood levees
- modelling and mapping of areas at risk of coastal erosion
- data to inform the management and restoration of coastal environments, including beach sand management, seagrass and shellfish reefs.

Health sector

Key points of feedback:

- surge event impact assessment: tailored climate data on specific extreme weather events, such as heatwaves, to assess the preparedness of hospital infrastructure and other health services
- change in disease patterns and community health–specific issues of concern such as legionella, mosquito-borne diseases, food-borne diseases and weather-borne asthma events
- health infrastructure risk assessment: data to enable the sector to better understand priority areas of vulnerability, the timing of potential impacts, and to explore mitigation options
- how to identify climate vulnerable communities and individuals, how they can adapt and build resilience

- how the demands on health sector staff will change through time, and how to address through strategic and operational workforce planning
- preventative health benefits of urban green space at a local scale in South Australia to inform planning and build the business case for green infrastructure
- understanding of climate influences (particularly drought and extreme heat) on mental health, including in rural and farming communities
- co-benefits of active transport: public health and emissions.

Primary production sector

Key points of feedback:

- impacts of the changing climate on drought severity and length and implications for government policy and industry drought risk management
- projections and impacts of changing rainfall patterns and extreme heat on dryland and irrigated crop and livestock production
- water availability and quality: improved understanding of how water quality and quantity will change in the future, for industries and production regions
- water demand: how farm/industry water requirements and demands will change with increased temperatures, reduced rainfall, and more frequent and intense heatwaves
- water allocation: changes in the water available in prescribed water resources planning areas and how this will impact allocations to producers
- impacts on horticultural crops of changes to chill hour accumulation as temperatures increase
- impact of climate change on biosecurity risks for key land-based and aquatic primary industries
- impacts of wetter summers on pests and disease such as foliar diseases in viticulture and horticulture and blow flies in sheep production
- impacts of bushfires and controlled burning on agriculture, especially industry and managing risks of smoke taint in viticulture as a result of bushfire
- impacts of abundant fauna species on farm productivity, especially during droughts
- impacts on the health, wellbeing and resilience of rural communities in response to a transition to larger farms and smaller rural populations
- improved understanding of climate influences on farm business viability and farm business exits
- impacts of seawater temperature changes on commercial fishing yields.

Natural resources sector

Terrestrial and marine biodiversity

Key points of feedback:

- develop a climate change impact assessment and response framework for biodiversity conservation, which considers species, ecosystems and landscapes
- likely changes to ecological communities under different climate scenarios, and the implications for conservation and ecosystem services
- impacts of sea level rise on coastal ecosystems (particularly saltmarsh, mangrove and tidal flats), and feasible adaptation responses
- impacts of annual and seasonal rainfall and runoff changes on water dependent ecosystems, and feasible adaptation responses
- likely responses of pest plant and animal species, and the implications for biodiversity conservation, including when and where changes may occur
- priority knowledge gaps on the likely response of species, ecosystems and landscapes to climate change and viable adaptation responses
- how to integrate landscape and biodiversity planning with bushfire risk reduction to ensure complementary response strategies
- strategies to preserve the conservation function of land-based and marine protected areas, considering predicted changes in the distribution of plants and animals due to climate change
- information to support initiatives to sequester carbon in landscapes and coastal environments
- information on carbon credits and co-benefits that could result from soil and landscape carbon sequestration activities.

Water resources

Key points of feedback:

- water security options analysis, including supply and demand side impacts
- changes in water demand profile: how the demand for water for potable, industrial, agricultural and environmental uses changes as conditions become warmer and drier
- water resource modelling: integration of climate projections into water resource modelling for water allocation and security planning.

Our four areas of focus

This plan organises the state's climate change science and information needs into four areas of focus. The actions described in these focus areas guide current and future investment in climate change science and knowledge. Some are new actions requiring new effort, while others are existing or continuing activities.

The four focus areas are guided by common information needs brought up repeatedly across multiple sectors during cross-sectoral consultation.

The common information needs identified included:

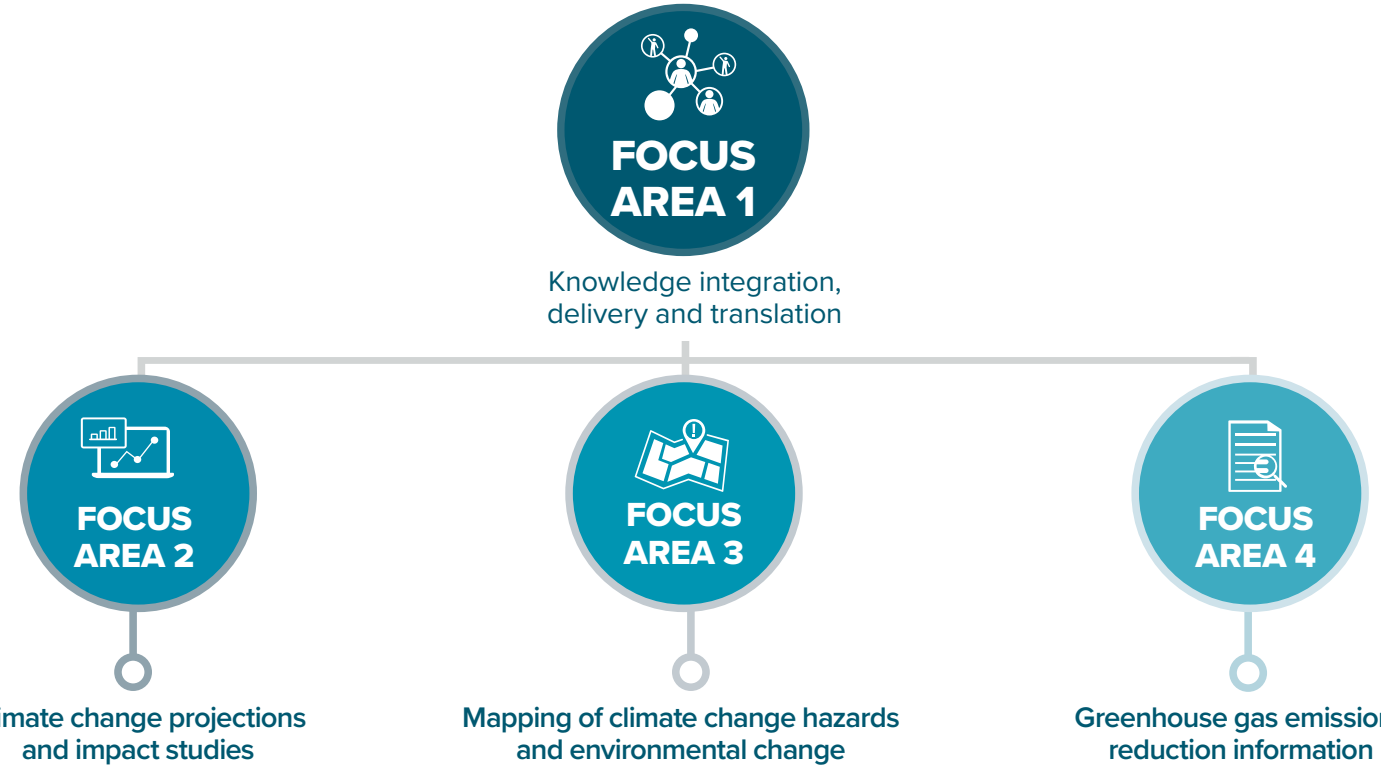
- improved discoverability, delivery and access to existing climate change information
- tailoring of information to more sector-specific variables, for example, the likely change in flood risk in specific locations
- standard datasets, projections, emission scenarios and model outputs to consider when planning adaptation measures, designing new infrastructure, or informing impact assessments
- likely change in occurrence of extreme weather events, including for concurrent events relevant to multiple sectors
- capacity building and ongoing engagement as necessary to assist sectors to develop appropriate response measures
- uptake and integration of social sciences and socio-economic data to inform climate response planning
- coordinated and integrated mapping of where hazard-prone areas occur for risks such as bushfire, flooding, storm surge and extreme heat to guide development.

This plan describes the broad evidence base South Australia requires to support climate change adaptation, mitigation and risk assessment. It does not target all individual sector-specific needs, which in many cases will need to be addressed by subject-matter experts working within the relevant sector.

Focus area one reflects the need to make information more discoverable and accessible, and includes knowledge integration, delivery and translation. Focus area one underpins the other three focus areas by ensuring climate change science and information is available, accessible and applicable for climate change risk assessment, mitigation, and adaptation planning.

The other three focus areas describe actions required to provide the science and information, categorised by information type.

Implementation of these actions will require the support of the community of practice with responsibility for climate change risk assessment, mitigation, planning and adaptation responses in South Australia.



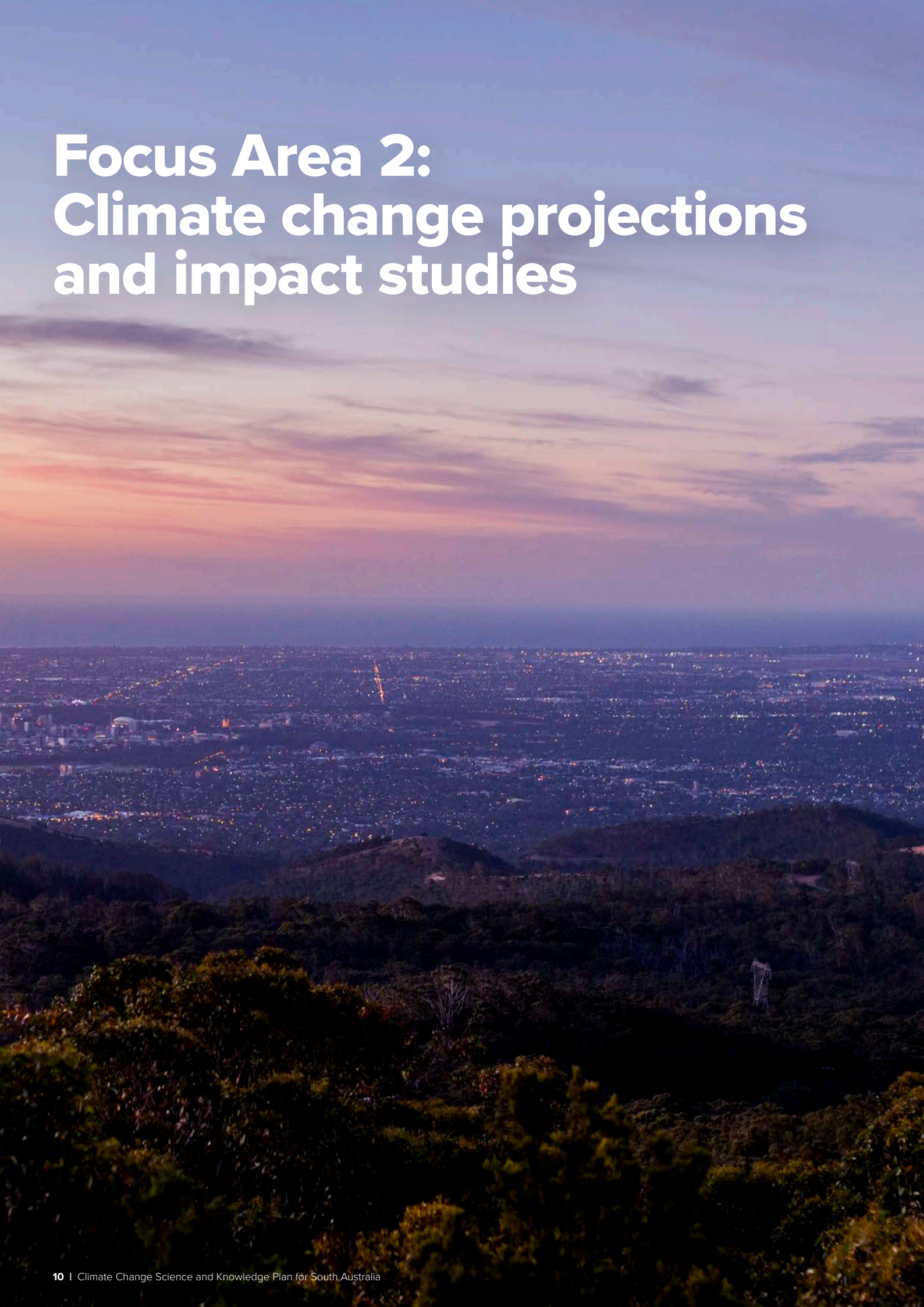
Focus area 1: Knowledge integration, delivery and translation

Focus area 1 underpins the other three focus areas by ensuring climate change science and information is available, accessible and applicable for climate change risk assessment, mitigation, and adaptation planning.

Themes:	Identified needs:	Action required:
1. Science and information delivery	Access to the most current and appropriate information is required for industry, public and the South Australian government. An effective online information delivery platform is needed to improve the ability of planners and decision-makers to discover, access and apply scientific and technical information for climate change response planning.	1. Develop an South Australian-focused online delivery platform for climate change science and information, making existing and new products more readily accessible.
2. Knowledge integration, translation and communication	There is a need for the South Australian government to advise on the most appropriate science and information for use in climate change risk assessment, and the planning of adaptation and mitigation responses. The South Australian government will assist in the integrating of information, ensuring users have a clear pathway to relevant information, fostering understanding and improving the capability of users to apply the information to planning and decision-making.	2. Consolidate and integrate climate change science and information so it can be more readily used and applied. 3. Translate climate change science and information to foster its uptake and use in planning, risk assessment and decision-making among a range of users. 4. Improve decision-maker awareness and uptake of climate change science and information to support climate change risk assessment, and the planning of adaptation and mitigation responses. 5. Ensure climate change status and condition is reported through SA's Trend and Condition Report Cards.
3. Integrating social sciences into climate response planning	The informing of climate change responses requires an evidence base that is drawn from not only the physical sciences, but also social sciences and socio-economic data Social sciences inform strategies for transitioning and managing change, providing an understanding of ways to effect change to practices, behaviour, attitudes, social systems and governance regimes. Strategies informed by social science products will help to foster the implementation of proposed adaptation and mitigation actions and the transition towards more resilient practices.	6. Identify social science and socio-economic data to inform strategies that drive community adaptation and social and behavioural change to improve the resilience of communities, industries and the environment. Scope and specify new social science requirements.

Themes:	Identified needs:	Action required:
4. Analysis methods and case studies	Robust methods to use and apply information for the analysis and evaluation of climate risks and impacts are essential to understand the implications of climate change. Analysis frameworks, methods and decision support tools are required for climate change response planning that takes into account climate projections and impacts as well as the potential for management, operational changes or investments to mitigate future risks. An agreed set of methods in common practice among climate change assessors and adaptation planners is required. By compiling a catalogue with clear explanations and case study examples to show how these methods have been applied, the South Australian government will help to promote their uptake and use among a larger user base.	7. Curate a collection of established methods of analysis, risk assessment, and climate change adaptation planning. Develop guidance documentation describing how to apply these.
5. Information and frameworks for government risk management	The South Australian Government climate risk management program will adopt new risk management arrangements to reduce climate related risks across assets, infrastructure, and services. A range of climate science and information products will be delivered and methods and frameworks developed to enable informed risk assessment. These will include: • Climate projections data • Maps and spatial data relating to climate hazards such as coastal and riverine flooding, coastal erosion, bushfire and extreme heat • Frameworks for analysing and assessing risks and testing mitigation options.	8. Investigate and develop methods and frameworks that enable government agencies to apply climate and natural hazard data to analyse climate related risks to assets, infrastructure and services.
6. Engagement with business and industry	Businesses are increasingly required to understand their exposure to physical, transitional and liability risks related to climate change by regulatory authorities and financing bodies. Robust technical information is required with relevance to the locations of their business operations. South Australian businesses will have an advantage in understanding, reporting and acting on their climate-related risks if they have ready access to climate change science, technical information and expert advice on climate change and its likely impacts within South Australia.	9. Engage with relevant industry and business organisations to ensure they can readily access information.

Focus Area 2: Climate change projections and impact studies



Actions under this focus area will coordinate and collate science and information on projected climate change and its impacts in South Australia, and provide guidance on the most appropriate data to assist decision-making.

Themes:	Identified needs:	Action required:
1. Climate change projections for South Australia	Climate projections produced from a sophisticated and standardised method are essential to provide a foundation of reliable scientific evidence that increases levels of confidence in policy decisions on climate change responses. Climate modelling information must be available and easily accessible and enable users to identify and locate the climate change projection data that is most suited to their needs. As climate modelling continues to improve, climate change projections for South Australia require periodic updating. The South Australian government is engaged with national and interstate programs developing projections for Australia, based on the latest generation of climate models.	1. Make climate change projections data and information accessible. Provide guidance on use of datasets for climate change planning and risk assessment. 2. Develop climate change projection data products tailored for use in climate change risk and impact analysis and adaptation planning. 3. Extend, update and improve scale of climate change projection data products in collaboration with interstate and national agencies, for example, through the NSW and ACT Regional Climate Modelling project (NARCliM 2.0) and Climate Change in Australia (CCIA).
2. Climate change impacts in South Australia	To inform risk assessments and adaptation planning, decision-makers require targeted assessments on the likely impacts that will result from the projected changes in climate. This includes impacts affecting health, emergency management, infrastructure, agriculture and natural resources. Climate change impact studies are often specific to the concerns of individual sectors, and are typically undertaken within, or commissioned by, the organisations concerned in each case. It is the role of state government to ensure the underpinning climate information is available, and provide guidance in its application to sector-specific impact studies.	4. Identify and collate available science and information on climate change impacts in South Australia and create a catalogue of these information resources to support policy, planning and decision-making. 5. Provide guidance to potential users of climate change impacts studies, highlighting and translating existing science. 6. Provide guidance on the risks of compounding/ cascading impacts, with particular emphasis on emergency management planning and property damage risks.
3. Standard climate change scenario information for planning	There is a cross-sectoral requirement for consistent, reliable and accessible advice on future climate scenarios. Guidelines are required to enable agencies to assess risks and plan adaptation measures according to a common range of future climate scenarios. A benchmark suite of climate change projections for South Australia and supporting information is needed to provide a common basis for government, businesses and communities to develop adaptation plans and undertake more detailed modelling and planning.	7. Develop guidelines on recommended standard climate change scenario information for use in climate risk assessments and adaptation planning. 8. Provide guidance on the use of climate change projection information for planning and modelling.
4. Changes in extreme weather events	Several sectors, particularly the emergency management, health and infrastructure sectors, need to understand the changes in the frequency and severity of extreme weather events in South Australia for climate change risk assessment and adaptation planning. Users require a tool to search and filter climate datasets according to their case-specific needs, to extract the historic and projected frequency statistics relating to weather events of a specified type and magnitude.	9. Develop a climate data filter and search tool to enable frequency statistics for extreme weather events to be determined from historic and projected future climate datasets.

Climate change projections for South Australia

The South Australian government is committed to delivering information on climate projections and possible climate change impacts so we can understand the risks to our communities, industries and environment, and to build resilience to and minimise the impacts of climate change.

There are currently three sources of information providing downscaled projections of future climate change in South Australia: the NSW Australian Regional Climate Modelling (NARCliM) project, SA Climate Ready (CSIRO/Goyder Institute), and Climate Change in Australia (CSIRO/BoM).

NARCliM project

The NSW Government's NARCliM project provides gridded climate projection datasets, useful for modelling likely changes to landscapes, agriculture and ecosystems over large areas, to inform climate impacts and risk assessments, landscape management, native vegetation planning and biodiversity conservation.

The South Australian government has established a partnership with the NSW government for NARCliM version 2.0, which will provide updated climate projections, including:

- higher-resolution downscaling, with a 4km spacing for the whole model domain
- continuous climate projections that simulate past and future climate from 1950 to 2100
- use of the most current global climate models
- the latest global greenhouse gas emissions scenarios.

The NARCliM 2.0 project will be complete in 2024.

The climate projection datasets of the NARCliM project will enable the following products to be developed in 2022/23:

Guide to Climate Projections for Risk Assessment and Planning (NARCliM 1.5 projections update)

An update to the projections in the Guide to Climate Projections for Risk Assessment and Planning, a quick reference guide to the basic projected changes in average and extreme temperature, rainfall for SA's landscape regions plus tables of projected changes to extremes in Adelaide and regional centres.

Interactive online mapping tool for projected changes in primary climate variables

Provides locally-specific data on the amounts of change projected in 10km grid cells of average minimum and maximum temperatures, frequency of extreme temperatures, average rainfall, frequency of rainfall extremes. Users can view projected changes for locations such as council areas, regional towns, agricultural regions.

SA Climate Ready

The South Australian government's current suite of climate change projection data for South Australia is known as SA Climate Ready.

Data is available for six climate variables (rainfall, maximum and minimum temperature, evapotranspiration, solar radiation and vapor pressure deficit) for 200 locations across the state.

These are based on two emission scenarios (high emissions -referred to as RCP8.5, and intermediate emissions - RCP4.5) and they project South Australia's climate to the year 2100.

SA Climate Ready provides two distinct types of information with differences in their potential applications:

- projected climate trend information at a regional scale, useful for conveying the probable direction and approximate magnitude of change in mean annual and seasonal daily temperature minima and maxima, and changes to mean annual and seasonal rainfall
- detailed, daily time-step future climate scenario datasets at the scale of individual weather station locations, enabling more detailed investigation of the likely impacts of changes in local climate on systems, communities and assets.

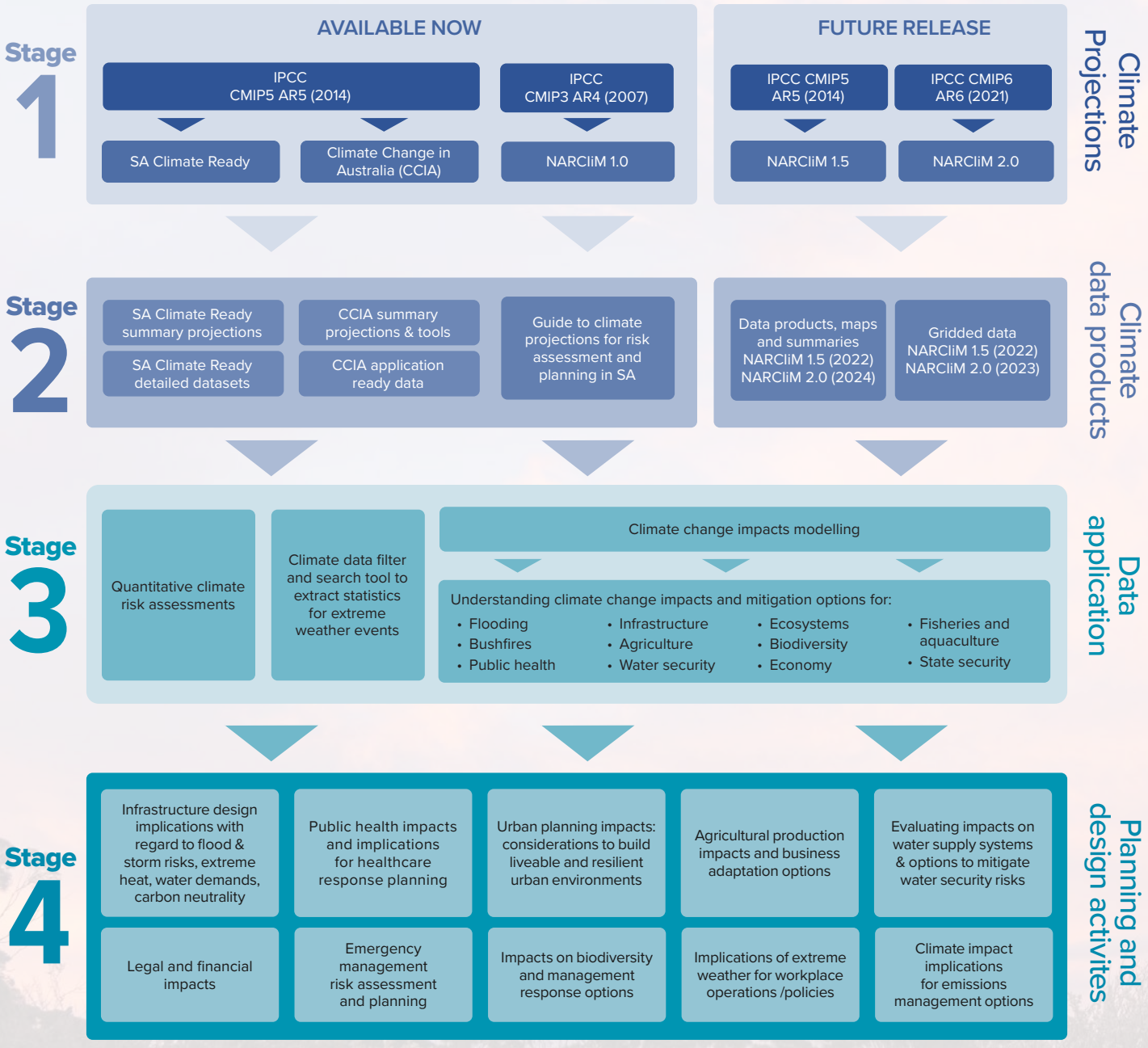
The SA Climate Ready datasets have been used for a variety of purposes, including assessment of climate change impacts on water resources and infrastructure.

Climate Change in Australia (CCIA)

CSIRO and the Bureau of Meteorology (BoM) provide projected climate change information via the Climate Change in Australia project. This project is a principal source of climate change data and its information products are used widely in climate change planning and risk assessment across Australia.

The CCIA technical reports and website provide a wealth of information on the likely future changes in climate for each of 15 regions across Australia, defined by climatic characteristics and natural resource planning region boundaries. Climate change projection data from CCIA is also available in a downscaled form, as a 5km grid covering the whole of Australia. This is less locally specific than the SA Climate Ready datasets, but is more extensive.

Figure 2: Stages of analysis for applying climate projections to planning and design activities in South Australia



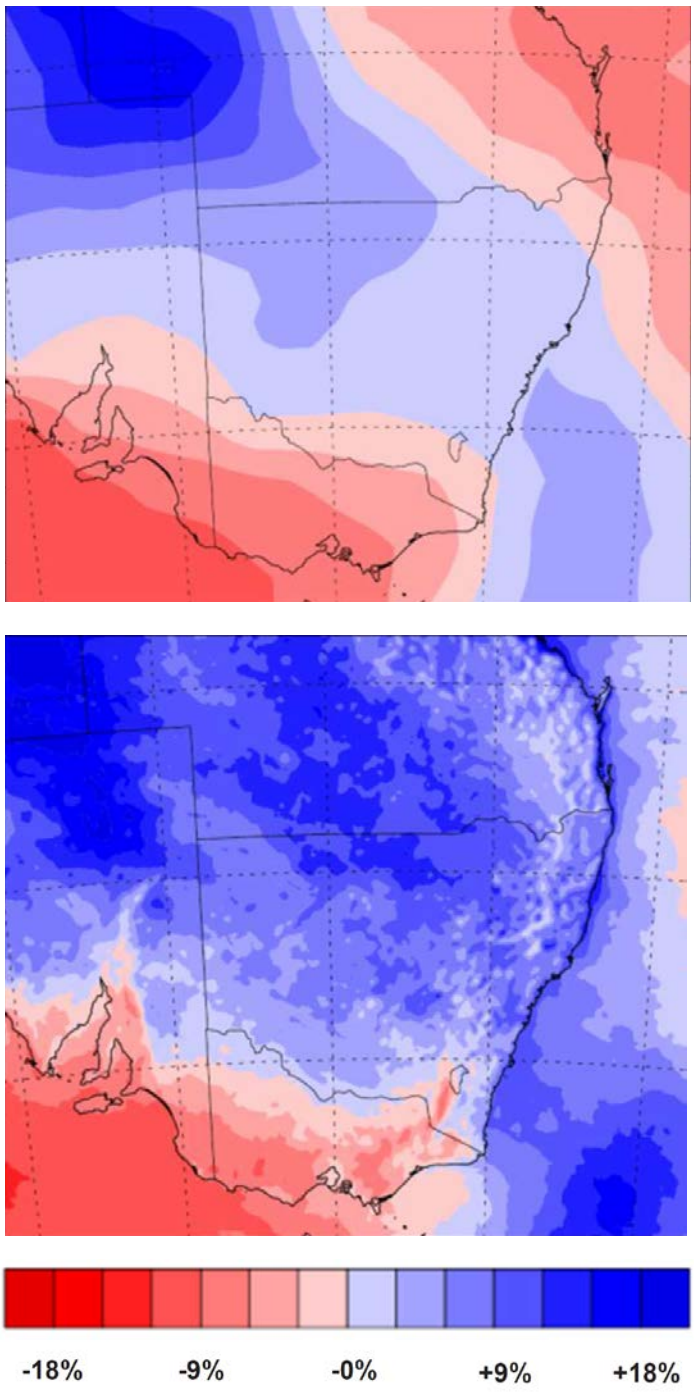
Key points Figure 2:

Climate projection datasets typically require a number of stages of analysis and/or application to case-specific climate impact modelling to derive information for use in planning and design activities.

The importance of 'downscaling' climate projections

Clear differences can be seen (Figure 3, adjacent) between the results of a global scale climate model (above) and a downscaled result from a regional model (below) in these two projections of change in annual rainfall for south eastern Australia in 2060-79 compared with 1990-2009. In this example, some areas, such as the SA Riverland and parts of the Mid North of SA, show an opposite direction of projected future rainfall change in the output of the regional model compared with the output of the global climate model illustrated here. Note, this illustration shows the result of only one global climate model; the majority of climate models project a decline in rainfall for most of the agricultural regions of southern Australia.

Figure 3: Projected changes in average rainfall in global versus regional models.



Mean annual rainfall 2060 to 2079 compared with 1990 to 2009. Source: NARCliM projections at: climatechange.environment.nsw.gov.au/Climate-projections-for-NSW

Climate change impact studies in South Australia

Climate science provides us with vital information on the characteristics of current and future climates. However, targeted impact studies are required to understand the implications of projected climate conditions on the economy, communities and the environment.

The climate projections of the SA Climate Ready project and the NARCliM project have been used for a variety of purposes, including assessment of climate change impacts on water resources, infrastructure and the environment.

Impacts on water supply

SA Climate Ready climate projection datasets have been used to investigate the likely impacts of future rainfall changes on the annual flow of water into the Mount Bold Reservoir – Adelaide's largest public water supply reservoir. Their findings project significant declines in average inflows to the reservoir.

A large range of future rainfall scenarios under climate change were considered, which resulted in declines of up to 55 per cent (median 24 per cent) in the period 2036–65, and up to 75 per cent (median 33 per cent) in the period 2056–85, compared to inflows during 1986–2005 (Westra et al. 2014).

Impacts on wetlands

Rainfall projections from SA Climate Ready data were applied to hydrological models to predict future changes in groundwater levels and consequent changes to surface water levels at Middlepoint Swamp, a wetland of ecological significance in the South East of South Australia.

The results predicted surface water level in the swamp to fall by up to 1 metre by 2030, almost completely drying the wetland. The assessment helped to identify a number of management options to address climate change risks through water allocation planning.

Impacts on heatwaves

The NSW government's Office of Environment and Heritage applied downscaled climate projections from the NARCliM regional climate modelling project to understand the likely impacts of climate change on the frequency, intensity and duration of heatwaves in NSW.

The study showed statistically significant increases in the number of heatwave events are projected for most of NSW and the ACT in the near future (2030), with even bigger increases projected for the far future (2070). In the far future, the number of heatwaves is projected to increase by 2.5 to 4.5 events per year, with somewhat larger increases in the central and northern parts of NSW.

The duration of heatwaves and the number of days of extreme heat was also found to increase. In the near future, the longest heatwave of the year will last 1.5 to 3.5 more days on average over most regions. Increases are even greater in the far future, with the longest heatwave of the year projected to be 2 to 11 days longer on average, with the largest increases in the north-east and the smallest changes in the southern part of NSW.

Other studies have shown the existence of temperature thresholds; that is, a particular daily temperature (usually maximum temperature) above which there are marked increases in mortality and morbidity (Loughnan et al. 2010; Williams et al. 2011, 2018). These temperature thresholds vary significantly across regions and climatic zones due to the population's ability to acclimatise.

Impacts on infrastructure design

Better planning and design now will save costly retrofitting of major infrastructure in the future. SA Climate Ready rainfall projections were applied to hydrological models to estimate future changes to the depth of groundwater beneath the Torrens Road to River Torrens roadway project.

This major infrastructure project includes a lowered motorway section, below the existing surface of South Road, intercepting the level of water table.

Investigations were required to determine the risk of local groundwater rising above historically observed levels, under projected future rainfall patterns. The modelling found that groundwater levels at the site of the lowered roadway are very likely to fall in future due to rainfall changes, resulting in a low level of risk to the lowered roadway.

Current and emerging issues for investigation

Through consultation across a range of sectors and levels of government, a number of issues related to climate change impacts have emerged that are of immediate interest among state and local governments within South Australia.

Impacts of changing climate on the natural environment

Managing, conserving, and sustaining our natural environment is vital for the wellbeing of all South Australians and our economy.

Climate change is already having a direct impact on native wildlife, ecosystems and habitats, and these effects will increase in the future, driving changes in the distribution of species and the ecosystems and habitats they live in. The impacts of climate change will also exacerbate existing threats such as habitat loss, pest plants and animals, drought, and bushfire. This will have implications for the natural environment and its ability to continue to provide the social and economic benefits that we currently enjoy.

The national parks estate conserves 32 per cent of the South Australia's native vegetation and is key to protecting our native biodiversity. While our parks continue to be the cornerstone of nature conservation, 68 per cent of the state's native habitat exists outside the national parks estate.

Land managers – both public and private – need to know how to manage biodiversity in the context of a changing climate. Courses of action could include improving resilience through managing existing threats, or through novel management such as species translocation (both plants and animals) where appropriate.

Additional information needs

Climate change will alter both habitat availability and suitability, exacerbating existing impacts on native plants and animals and potentially accelerating the rates of decline and extinction. It will also cause increasing wildlife welfare issues linked to intense heat waves, droughts, and fire events. It is estimated that the 2019-20 summer bushfires killed or displaced nearly three billion native animals across Australia, and had a significant impact on populations of nationally threatened species, including the Kangaroo Island Dunnart and Glossy Black Cockatoo in South Australia.

Responding to this challenge and identifying opportunities to support our wildlife, ecosystems and habitats to adapt will require us to forecast these potential changes and understand how this may differ across different parts of the state.

To manage the impacts of climate change on native wildlife, ecosystems and habitats and to reduce the likelihood of future wildlife welfare crises, we need improved forecasting and delivery of pre-emptive responses. In some instances it may be sufficient to improve the quality of existing habitat, whereas other responses may require the protection of specific refuges from drought or fire or even the active movement of wildlife to more suitable habitats. For example, the northern extent of the range of the nationally threatened Pygmy Bluetongue Lizard is expected to become unsuitable within the next 50 years. Opportunities and mechanisms to increase the number of populations in the southern part of their range are actively being pursued.

This forecasting and pre-emptive response capacity also needs to consider how current threats such as invasive plants and animal species, habitat degradation, land use change, and fire regimes may change under future climates and how this will further impact biodiversity and wildlife. Improving the resilience of our wildlife, ecosystems and habitats will ensure that our unique environment continues to contribute to our economy and our wellbeing.

There is a community expectation that animal welfare will be managed in extreme events such as fire, heatwaves and flood. This means understanding how extreme events will impact wildlife, with a view to better predicting what support will need to be mobilised to minimise welfare issues and to understand population loss. This was highlighted by the number of rescued koalas and the associated care and welfare issues in Queensland, New South Wales, Victoria and South Australia after the 2019-20 summer fires.

Changes to bushfire frequency and severity

Climate change is projected to lead to drier and hotter conditions for much of South Australia, and a greater likelihood of extreme weather. There is a need for improved understanding of how these changes will affect the risk presented by bushfires, and the appropriate responses for bushfire fuel load management, wildlife conservation, and development planning.

The implications of climate change and altered fire frequency and severity will vary across landscapes with different vegetation structures. An understanding of the implications of climate change impacts on bushfire characteristics will be essential to our ability to plan and adapt to protect life and property, achieve positive outcomes for biodiversity, and maintain ecosystem services.

See Focus Area 3 'Mapping of climate change hazards and environmental change', Theme 4: Bushfire hazard mapping for more information.

Impacts of heatwaves on human health

Heatwaves and days of extreme high temperature have impacts on public health. Extreme heat events are responsible for more fatalities in Australia than all other natural hazards combined (Coates et al. 2014). Among the five major cities in Australia, Adelaide experiences the most days with temperatures above a threshold that makes heat-related deaths more likely (Longden, 2018).

During the 2009 extreme heatwave, admissions to hospitals in South Australia increased by 8 per cent, ambulance call-outs by 16 per cent and emergency presentations by 2 per cent. While no increase in mortality had been observed in earlier heatwaves, in 2009, total mortality increased by 10 per cent (excess death of 32 people), and in 15-to 64-year-olds mortality increased by 37 per cent during the heatwave (Nitschke et al, 2017).

To enable operational and resource planning to respond to these events, health sector and emergency management planners need to know the likely future changes in the frequency and intensity of heatwaves or of days with a maximum temperature above a critical threshold. Further, the variables which indicate vulnerability to ill health during heatwaves are mainly of a socio-economic nature, such as living alone, age, income/education, access to air-conditioning, no social interaction and pre-existing medical conditions. The addressing of the additional risks to communities from increases in heatwaves therefore requires social science and socio-economic data, in addition to the products of physical sciences.

Impacts of the changing climate on the built environment

Our built environment plays an important role in supporting communities and underpinning economic growth. Much of the infrastructure, buildings and urban design that we establish now will still be in place in 2050 and beyond.

An increase in climate-related hazards including bushfire, flood, extreme heat and coastal inundation poses a risk to our built environment with potential for greater damage, disruption and costs for businesses and communities.

Asset owners and land use planners require climate, hazard and infrastructure data and information and tools to assess current and future risk from natural hazards as the climate changes. Development of high quality information and tools for risk assessment and planning is a key future priority.

Impacts of hot days on business operations

In 2019, South Australia's mean daily maximum temperature was 2.30°C above average, the highest on record, exceeding the previous highest of +2.02°C in 2013.

Hot weather and the resulting heat stress on workers are known to result in productivity losses and economic impacts in Australia (Zander et al. 2015; Dunne et al. 2013), affecting businesses and government operations at a local, state and national level. Many organisations and businesses have workplace extreme heat policies, which limit working practices above a certain temperature threshold. For those organisations with employees who commonly work outside, the increase in hot weather is already resulting in considerable losses in productivity and business profitability.

In local government operations, on days of very high temperature, the capacity of the workforce of councils is compromised and the ability to deliver essential community services is reduced. This impacts on a range of services, such as road repairs, street maintenance and community support services.

Among South Australian local government organisations, the historic and current extent of work interrupted by extreme heat has not been quantified, however several Adelaide metropolitan councils are evaluating the costs of these impacts.

Total grazing pressure

In the pastoral regions of South Australia, grazing by domestic, native and introduced herbivores influences, and is influenced by, the availability of native fodder. Overwhelmingly, however, these dynamics are driven by the distribution of rainfall in space and time. Climate change will have a strong influence on these spatial and temporal patterns of rainfall. The response of herbivores (both domestic and wild) will also have an impact on productivity, economic viability and sustainability of soil, water and native ecosystems. There is a need to understand how total grazing pressure and climate change will interact, and the implications this will have for ecosystems and pastoral stocking rates.

The ability to predict the response of vegetation to a plausible range of climate, land management and wildlife management scenarios will assist in the development of pastoral, land and wildlife management strategies, including business planning for pastoral enterprises.

Climate sensitive cities and urban water management

Many of the science and information needs affecting the creation of climate sensitive towns and cities are related to the supply, use and demand for water.

There is a growing requirement to minimise the effects of increasing summer peak temperatures in urban areas with urban cooling measures, such as increased green space and shading, as well as 'blue space' (i.e. open water bodies) in the urban landscape.

Information is needed to inform the most reliable water supply mix to meet the urban demands into the future. Issues to be addressed by new and existing science include:

- impacts of climate change on urban water demand
  - changes to domestic and municipal water use
  - future water demand to mitigate urban heating effects of climate change
- effects of climate change on urban water supply from all water sources. For example, River Murray, Mt Lofty Ranges reservoirs, stormwater, groundwater, wastewater, roof runoff
- future optimum water mix for Adelaide
- cooling our cities and urban environments effectively, including:
  - the most effective urban cooling measures
  - optimising urban green and blue space for its cooling effect
- cooling effects of different surfaces, including irrigated vegetation, grass and waterbodies
- optimising water application for greening and cooling
  - appropriate tree selection according to projected climate conditions and optimum cooling effect.
- available water for the urban environment to support living 'green infrastructure'.

What is 'green infrastructure'?

- Green infrastructure refers to standalone and strategically networked environmental features. It includes planted and indigenous street trees, wetlands, parks, green open spaces, grasslands, and woodlands.
- Green infrastructure provides services and functions in the same way as conventional infrastructure. Benefits include reduced urban heat, lower building energy demand and improved storm-water management.

Focus area 3: Mapping of climate change hazards and environmental change

Actions under this focus area will provide spatial information regarding climate-related hazards (such as bushfire, flooding, storm surge and extreme heat) and environmental change, including guidance on the use of this information for climate risk assessment.

Themes:	Identified needs:	Action required:
1. Coastal inundation and erosion risk mapping	Coastal inundation and flooding risk maps are essential for identifying coastal areas at high risk of flooding under future sea level rise scenarios; informing the planning of flood mitigation measures; and planning and development regulations for these high-risk areas. Assessment of the increased risk of coastal erosion due to sea level rise is a priority for coastal management planning, particularly for highly vulnerable locations. High quality LiDAR (Light Detection and Ranging) elevation data has been captured for majority of SA coastline from west of Ceduna to the SA and Victoria border, including all of Kangaroo Island. New LiDAR data capture is required for these areas to enable a complete assessment of inundation and erosion risks due to sea level rise to the whole state's coastline. Regional authorities require assistance from the South Australian government to apply these data sets to generate coastal inundation and flooding risk maps.	1. Develop mapping products to determine implications of sea level rise for coastal flooding and erosion in all high-risk locations in South Australia. 2. Investigate coastal erosion modelling and mapping for highly vulnerable locations. 3. Procure high resolution, high accuracy elevation data capture for remaining priority sections of the South Australian coast, from west of Ceduna to the WA border to create a contiguous LiDAR dataset for all South Australian coasts.

Changes in coastal inundation risks

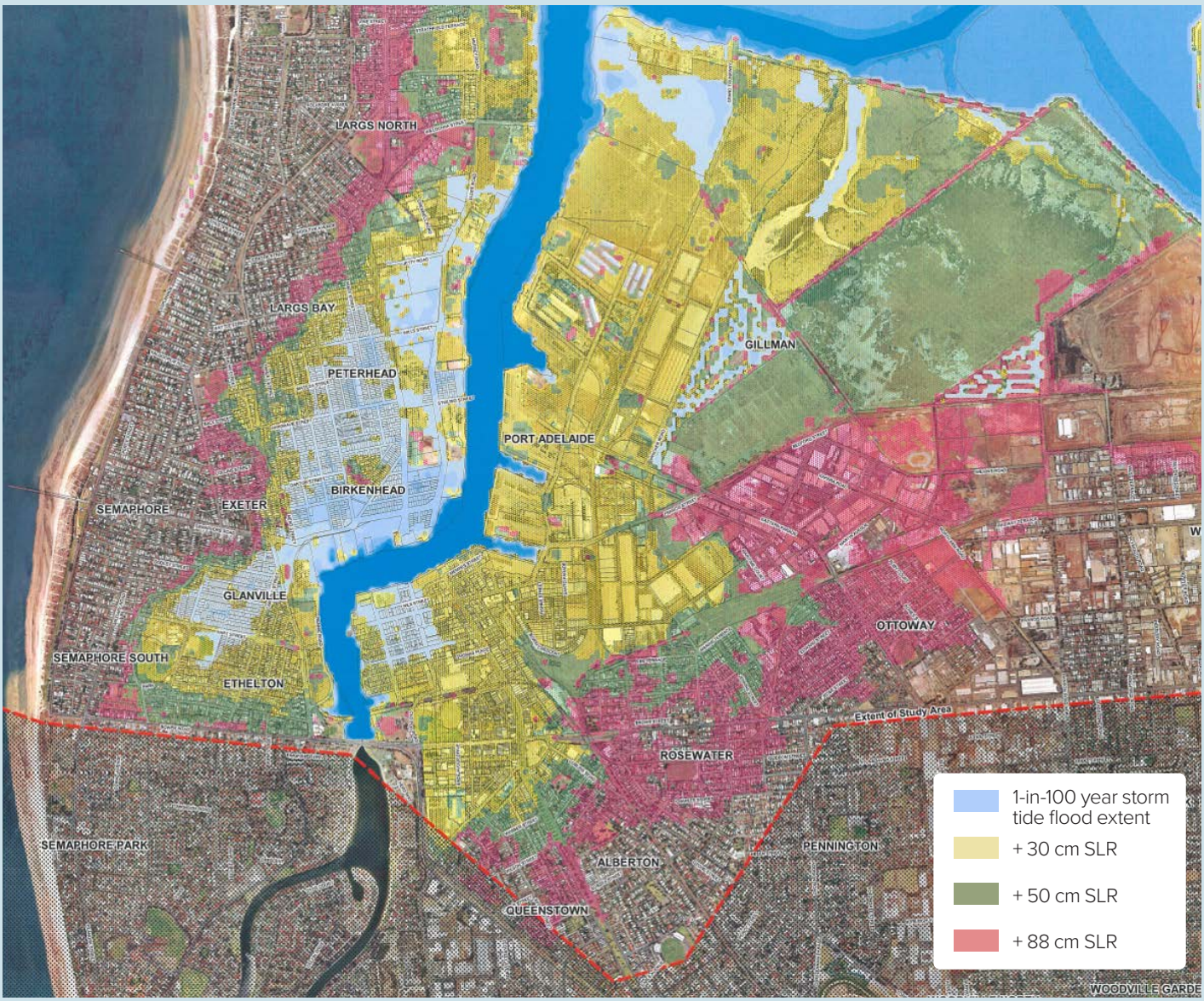
South Australia has 5,067km of coastline. It is a crucial drawcard for our tourism industry, is home to hundreds of species of birds and animals, and provides thousands of jobs. Sea level rise is a key consideration for future planning for our coasts.

The amount of sea level rise depends on the amount of climate change. Sea levels rose by 17cm from 1901 to 2000, and are projected to rise by a further 22 to 25cm by 2050.

The 1-in-100-year storm tide level is the localised sea level caused by a combination of a high spring tide and a storm surge. It has a statistical probability of occurring once in a hundred years, based on historic local sea level variations. With only a moderate rise in mean sea level, a 1-in-100 year coastal inundation event on the Adelaide coastline becomes much more extensive, resulting in much larger areas of Port Adelaide and West Lakes at risk of flooding during extreme storm tide events (Figure 4, below).

This kind of information informs the future development of protection infrastructure, which will help to reduce the amount of area flooded in these events

Figure 4: 1-in-100-year storm tide level mapping



Source: Port Adelaide Seawater Stormwater Flooding Study, Tonkin Consulting and WBM Ocanics Australia for City of Port Adelaide Enfield, October 2005.

Themes:	Identified needs:	Action required:
2. Urban heat mapping	The Metropolitan Adelaide Urban Heat Mapping project makes heat maps for the whole of the Adelaide metropolitan accessible through the South Australian government's Urban Heat Mapping Viewer. The maps require collaborative commitment to periodic updating so the effectiveness of urban heat mitigation measures can be assessed from the changes observed in urban heat islands over time. The future capture of new heat mapping data requires continued coordination to ensure decision-makers' requirements are addressed, data capture frequency is adequate to detect spatial trends, and that there is consistency of technical specifications across datasets.	4. 4. Building on the methods used across metropolitan Adelaide, document and promote a standard, coordinated method for heat mapping across South Australia's other urban areas. 5. 5. Coordinate future repeat captures of urban heat data for Adelaide at a frequency that meets the requirements of decision makers. 6. Coordinate data capture and urban heat map preparation for regional urban centres.
3. Flood risk mapping	Most South Australian flood risk studies are based on historical rainfall records. Only a handful include scenarios incorporating future climate risks, such as higher sea levels or altered rainfall. AGD Planning and Land Use Services are finalising flood risk studies for high-risk catchments and have invested in generalised flood mapping products. The data will be shared on the National Flood Risk Information Portal and will be added to DEW's Flood Awareness information portal. To manage flooding in high-risk river catchments, stormwater infrastructure is designed to cope with runoff events up to a designated size (specified by average return interval). Information is required on how the magnitude of catchment flows will change under a likely future climate with changes in the size or intensity of rain events. Agreed guidelines are required for incorporating climate change impacts into hydrological modelling for stormwater design and flood risk management. There is a need to identify catchment areas most at risk of increases in flooding. These will guide the priorities for new modelling studies that include projected future climate rainfall scenarios to understand how flood risks may change under future rainfall patterns.	7. Make data from flood risk studies accessible through national and state online services. 8. Develop guidelines for incorporating climate change impacts into hydrological modelling for stormwater design and flood risk management. 9. Establish a flood risk study to demonstrate application of the agreed climate change impacts guidelines. 10. Identify river catchments and urban areas most likely to suffer from increased flood risks due to projected changes in climate and sea level.

Urban heat mapping

The frequency of exceptionally hot days in Adelaide has increased markedly in the past 10 years. As cities warm and the need for climate adaptation strategies increases, a more detailed understanding of the cooling effects of building material and land cover will be necessary to guide management decisions.

Extreme heat has profound impacts on human and animal health, energy consumption and costs, sport, leisure and tourism events, and infrastructure functioning.

The severity of heat experienced in cities during hot weather varies across the urban landscape. Areas with a larger thermal mass of non-climate-sensitive structures, (such as concrete or bitumen) exhibit higher surface temperatures compared to parklands or vegetated areas.

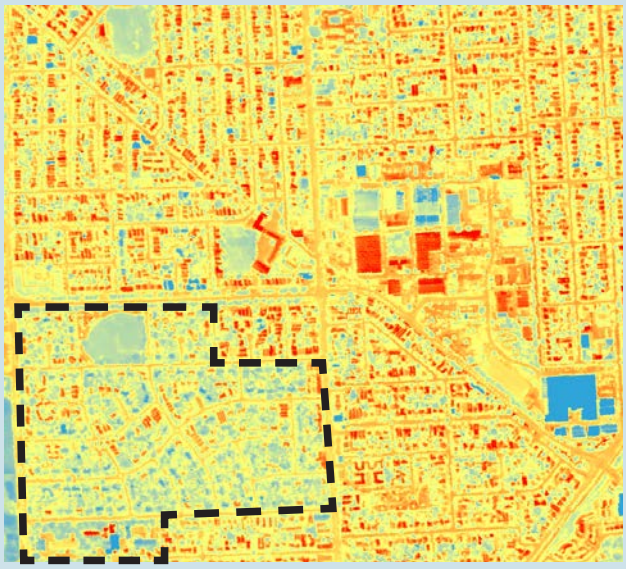
Options to mitigate heat in urban areas include climate-sensitive design of infrastructure, urban greening, and targeted use of water for irrigation of urban green areas. Investments in these initiatives require suitable information to identify where in the urban landscape the greatest heat stress risks exist.

Heat mapping provides critical data for making better decisions related to urban planning, infrastructure and municipal water use, including water requirements for living green infrastructure, like street trees and green spaces.

The following suburban Adelaide heat mapping examples (Seaton, right, and Adelaide Oval and Riverside precinct, below) illustrate how surface materials affect temperatures.

Source: DEW Urban Heat Mapping Viewer

Figure 5: Seaton, South Australia, a cooler suburban environment

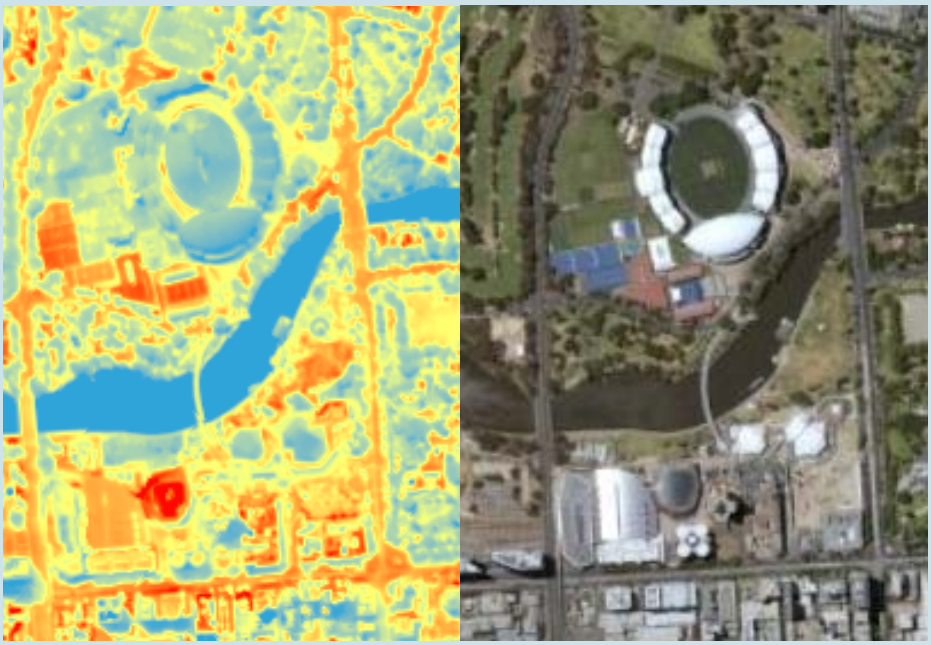


Tree-lined streets and lighter coloured roofs are cooler, and show as pale blue. Dark coloured roofs and streets with minimal or no vegetation are hotter, and show as orange or red.

Figure 6: Heat characteristics of built materials in Adelaide Oval and Riverside precinct

The Torrens River and the white rooves of the oval stands and the festival centre buildings show as cool blue. The dark coloured roofs of the Convention Centre and the synthetic court surfaces at Memorial Drive, are hotter and show as red.

= cooler = hotter



Themes:	Identified needs:	Action required:
4. Bushfire hazard mapping	A statewide analysis of the current and future impacts of climate change on bushfire hazard in South Australia is required to better prepare for and mitigate the exposure of communities to natural hazards such as bushfire, flooding, coastal inundation and extreme heat. This analysis is needed to inform fire management, including emergency services resources planning, fuel management strategies and development planning regulations for bushfire prone areas. Specific knowledge gaps to be addressed include: • how projected changes in climate will affect high fire danger conditions in South Australia • how native vegetation structure will change with a changing climate.	11. Investigate the impacts of climate change on fire risk factors including: o changes in vegetation structure and bushfire fuel characteristics o effects of drier conditions and increasing extreme weather on fire hazards and fire behaviour. 12. Investigate the implications of climate change impacts on bushfire characteristics and how they will affect biodiversity values and ecological processes.
5. Regional water security	Water supplies in much of regional South Australia are sourced from local groundwater and surface water resources, which are vulnerable to changes in rainfall patterns and higher temperatures. Investigations already undertaken into the likely impacts of climate change on some of South Australia's regional water resources indicate a high degree of vulnerability in many cases. An updated statewide water resource risk assessment is required, together with new studies to quantify likely impacts of climate change. Just as important is an analysis of how changes to water infrastructure or water resource management can be used to overcome the impacts of climate change.	13. Initiate statewide mapping of climate change risks to water supply, considering regional water demands and the vulnerability of regional water resources to climate change. 14. Analyse climate change vulnerability of water supplies in South Australia. Identify opportunities for improved water security outcomes through infrastructure and resource management changes or alternative water sources.

Bushfire history and hazard mapping

South Australia has experienced a number of major bushfire events in recent years. Fire history maps display statewide fire scar mapping for major bushfires that have occurred within South Australia and for prescribed burning activities that have occurred on land managed by state government agencies. The maps are publicly available through the Fire Management Maps interactive online mapping site and through the South Australian government Data Directory (data.sa.gov.au). Future improvements to fire history maps will be the inclusion of data on fire severity and intensity. These will enhance the utility of the maps for fire risk assessment by enabling comparisons of changes in the severity and intensity of fires over time.

The South Australian government maintains a map of the state's Bushfire Protection Areas for land-use and development planning. This shows the level of bushfire risk rated as high, medium, general or excluded, and determines the planning approvals and requirements under the Australian Building Code and Australian Standard for the construction of dwellings in bushfire risk areas. These were updated in 2019, and now include grassfire hazard areas, urban interface areas, and 24 new council areas, including cropping areas north of Goyder's Line.

A bushfire risk assessment model is to be developed by the South Australian government. This will draw information from bushfire histories and incorporate data relating to vegetation, communities, buildings and land use, together with modelled average return intervals of fire of a particular size within each region.

The model will provide ratings of fire exposure, likelihood and vulnerability. This project will produce spatial products indicating fire likelihood and consequence ratings and a risk layer combining those ratings. The model and bushfire risk layers will contribute to the information sources for statewide maps of Bushfire Protection Areas.

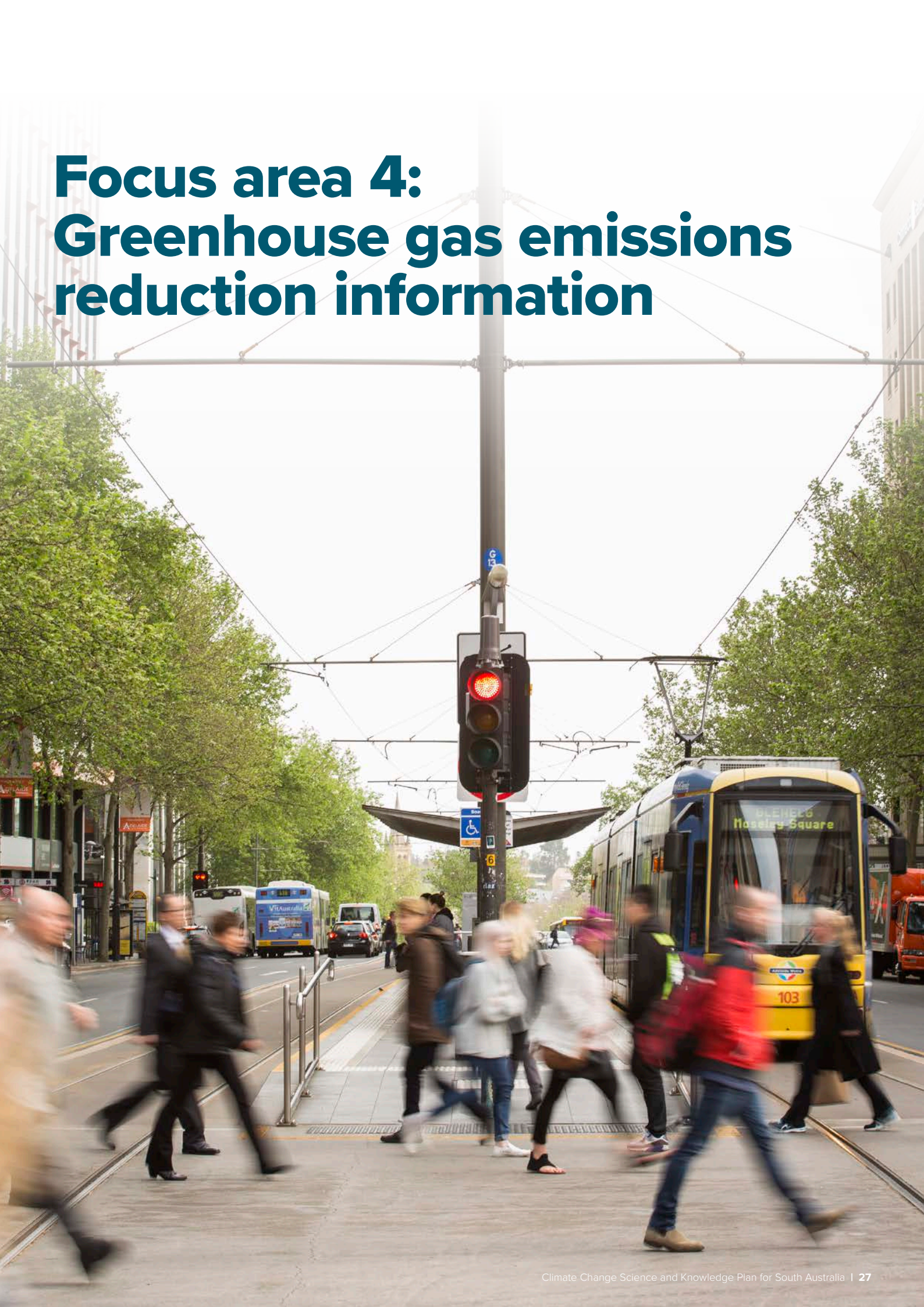
Rising risk of bushfire under climate change

Australia experienced widespread severe fire weather throughout 2019; national annual accumulated Forest Fire Danger Index was the highest since national records began.

South Australia has a large percentage of its population in areas of bushfire risk, particularly within the Adelaide Hills. Fire seasons in the Mount Lofty Ranges Fire Ban District are starting earlier and lasting longer. An overall increase in the length of the fire danger period is expected. The frequency of days with a fire danger index rating of severe and above is increasing and is predicted to have risen by approximately 60 per cent by 2030 (NRAMLR, 2018).

Themes:	Identified needs:	Action required:
6. Mapping the implications of climate change on species, ecosystems, landscapes and seascapes	There is a need to identify and document the implications of climate change on species, ecosystems, landscapes and seascapes, in the context of other threats and environmental change. Regular updating of land cover and ecosystem mapping will improve our understanding of how South Australia's biodiversity responds to climate change in the context of other pressures and our capacity to manage these. This is critical to developing measures of the resilience of the state's native biodiversity. Information is required to identify which species, ecosystems, landscapes and seascapes in South Australia should be prioritised for further research with respect to climate adaptation. Examples are species most threatened with extinction or most vulnerable to climate change. Key knowledge gaps remain at the landscape level, particularly for the northern parts of the state, where there are inherent differences in climate responses and land use compared with southern South Australia. This information is important to understand impacts on ecosystem services and production, as well as on biodiversity. Monitoring of a range of environmental indicators is required to evaluate whether the responses observed are consistent with those predicted by environmental response modelling. Where predictions align with observations, we can have increased confidence in our understanding and responses. Where predictions and observations are contrary, it indicates that our understanding requires improvement.	15. Map the coverage of information and identify priority knowledge gaps relating to the risks of impacts to species and ecosystems, and implications for management across South Australia. 16. Further develop approaches to the mapping of environmental change to better understand the vulnerability of species, ecosystems, landscapes and seascapes in response to climate change in the context of other pressures. 17. Identify, monitor and evaluate indicators of the response of biodiversity to climate change and the effectiveness of our interventions for priority species or ecosystems.
7. Environmental change mapping	To track the success of or constraints to adaptation responses, regular and consistent monitoring of human-induced changes in the landscape such as new infrastructure and changes in agricultural and peri-urban land use are needed.	18. Develop a statewide land-use data map that builds on current databases for planning and impact assessments relating to climate change.

Focus area 4: Greenhouse gas emissions reduction information



Actions under this focus area will provide information to support efforts to mitigate climate change through greenhouse gas reduction activities, including state emissions inventories, carbon farming initiatives, and coastal conservation and restoration to improve carbon sequestration in coastal environments.

Themes:	Identified needs:	Action required:
1. State Greenhouse Gas Inventory	The Commonwealth Government prepares an annual update to the State and Territories Greenhouse Gas Inventory (STGGI), which provides an analysis of the emissions from a range of sources and sectors within each of Australia's states and territories. The State Government prepares state reports on greenhouse gas emissions every two years. An on-line summary of the South Australian emissions information in the STGGI report is required to improve accessibility of this information to potential users, assist organisations to understand how South Australia is tracking in relation to its emissions reduction targets, and enable a comparison with other jurisdictions. This information will help identify where opportunities exist to reduce or offset emissions in South Australia.	1. Develop an annually updated summary of South Australia's emissions information reported in the STGGI, to improve accessibility and provide further analysis of the data.
2. Emissions reductions	There are opportunities to reduce emissions across the economy through innovative design and planning and adoption of new technology. Improved understanding of where these opportunities exist, and the likely scale of emissions reductions that can be achieved, will support decision-making in planning and design of government and business operations and infrastructure.	2. Identify technical knowledge gaps that are barriers to major emissions reduction opportunities in South Australia. Agencies collaborate to address knowledge gaps.
3. Carbon farming	Carbon farming projects can have positive environmental and economic co-benefits and, conversely, negative environmental impacts. Carbon farming opportunities are evaluated with consideration to existing environmental constraints, potential impacts, and the collective costs and benefits. The South Australian government facilitates carbon farming projects across the state through policy development and the provision of specialist advice to other government agencies and regional staff. As a holder and manager of landscape information, the South Australian government is able to provide information for potential project proponents to understand the opportunities for carbon farming. Improved methods are required to quantify environmental, economic or social co-benefits (such as biodiversity improvements) associated with carbon farming activities.	3. Provide information and advice to support identification and development of carbon farming projects. 4. Assist the establishment and uptake of research that identifies and measures carbon farming co-benefits.

Themes:	Identified needs:	Action required:
4. Blue carbon	'Blue carbon' is the carbon captured and stored in coastal ecosystems including seagrass meadows, saltmarshes and mangroves. Carbon can be captured and stored through restoration and protection of coastal and marine ecosystems, such as mangroves, saltmarsh and seagrass. Blue carbon offsets emissions and provides co-benefits such as a potential revenue source through carbon credits, protection of important fish habitats, enhanced biodiversity, improved water quality, and protection for coastal infrastructure against sea level rise. How to measure the greenhouse gas reduction and carbon sequestration potential of blue carbon projects is an emerging science. *The Blue Carbon Strategy for South Australia 2020–2025* sets a path for the South Australian government to establish a statewide, evidence-based program of projects and research geared towards blue carbon ecosystem protection and restoration.	5. Initiate further research and data gathering to inform the development of blue carbon projects, and quantify the potential carbon gains and other environmental benefits. 6. Coordinate and collate knowledge from current and historic seagrass restoration initiatives and research to develop a new ERF method for seagrass restoration.

Greenhouse gas emissions

Building our blue carbon knowledge base

Marine and coastal ecosystems are particularly significant in the global carbon cycle, reducing carbon dioxide (CO_2) concentrations in the atmosphere and providing long-term sinks for carbon. 'Blue carbon' refers to carbon stored and sequestered in coastal ecosystems including seagrass meadows, saltmarshes and mangroves.

Protecting and restoring blue carbon ecosystems is important due to their carbon sequestration and storage potential, and because these ecosystems can become sources of greenhouse gas emissions if degraded or cleared.

Vegetated tidal wetlands and coastal ecosystems have a high productivity and a much higher rate of storing carbon per unit area than any terrestrial vegetation, through their biomass and soil carbon stocks and long-term accumulation of carbon in sediments. The high carbon sequestration potential occurs in addition to other acknowledged ecosystem services provided by coastal ecosystems, such as shoreline protection, food, nursery habitat for fish, biodiversity and water quality.

Blue carbon initiatives consider not only the carbon sequestration and climate change mitigation potential, but the overall protection, restoration and sustainable use of coastal and marine ecosystems. The role of coastal Blue Carbon ecosystems in climate adaptation and mitigation is increasingly recognised.

The Blue Carbon Strategy for South Australia 2020-2025 sets a path for the South Australian government to establish a state-wide, evidence-based program of projects and research geared towards blue carbon ecosystem protection and restoration.

Research undertaken by the University of Adelaide and Flinders University, facilitated by the Goyder Institute and in collaboration with DEW, provided an understanding of carbon stocks and sequestration rates in three types of coastal environments. This knowledge enabled DEW to work with the Clean Energy Regulator in the development of the first accredited Emissions Reduction Fund (ERF) blue carbon method in 2022, for carbon resulting from tidal reconnection of mangrove and salt marsh environments.

DEW is now working with key stakeholders to bring together current and historic seagrass restoration initiatives and research to develop a new ERF method for seagrass restoration.

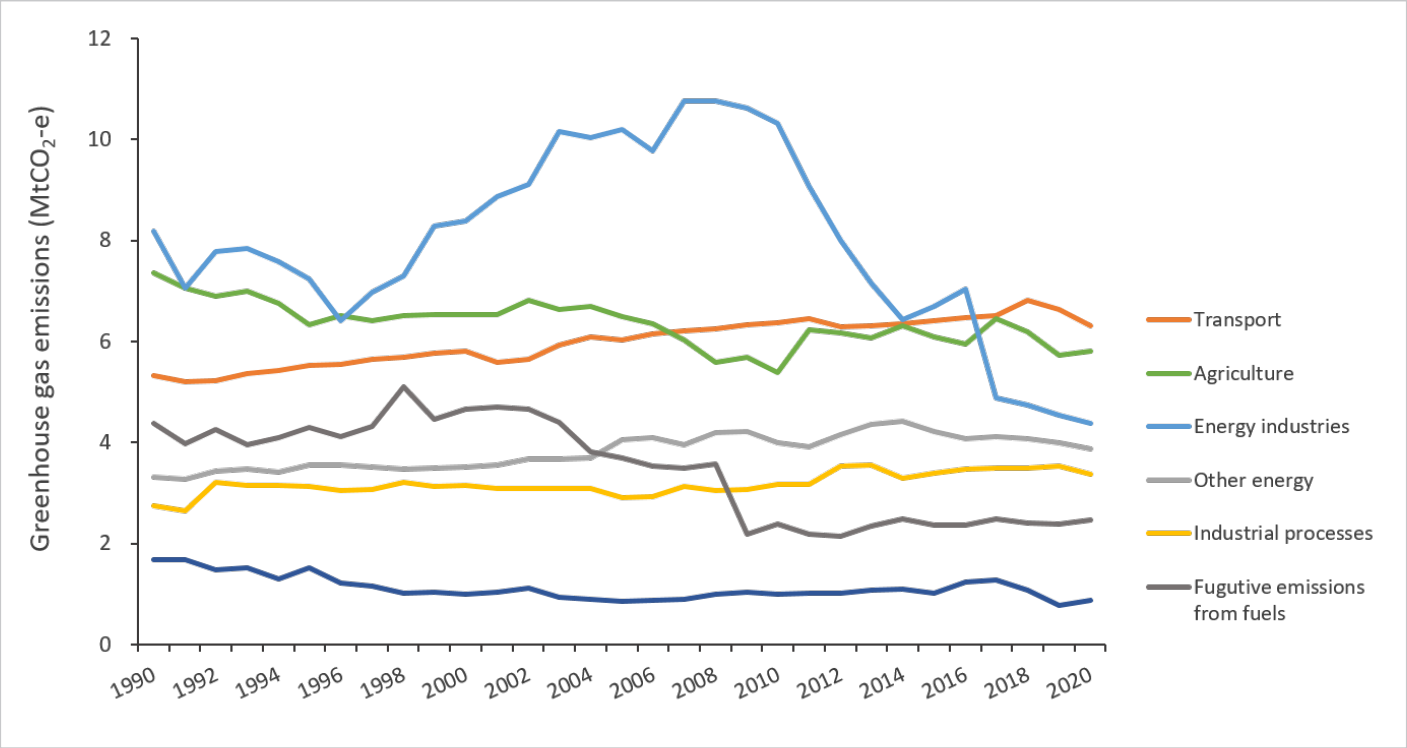
Information and advice for carbon farming

Carbon farming enables land managers to earn carbon credits by undertaking carbon offset projects that reduce greenhouse gas emissions, or store (sequester) carbon in plants and soils. Carbon farming can reduce emissions through production processes, while increasing productivity and sequestering carbon in the landscape. As well as helping to offset emissions and secure revenue through carbon credits, carbon farming activities can enhance biodiversity, provide soil protection, reduce salinity and improve farm productivity.

As a holder and manager of landscape information, the Department for Environment and Water provides advice and spatial data relating to carbon farming activities and opportunities. An example of this is the development by the department of the Guide to Carbon Planting in SA (DEWNR, 2018), which provides a range of information including spatial data and summary maps that may help guide decisions by landholders, industry groups, non-government organisations, and others involved with carbon farming. The guide also provides information on the potential environmental risks and opportunities of carbon planting in South Australia. This includes land use policy considerations and how to interpret the provided spatial data layers.

Carbon farming opportunities exist on private and public land through a range of mechanisms including planting and restoring vegetation, increasing soil carbon and livestock management techniques.

Figure 7: South Australia's Greenhouse Gas Emissions 1990 to 2020



Source: States and Territories Greenhouse Gas Inventory dataset, maintained by the Commonwealth Government. All data sets are published on http://ageis.climatechange.gov.au

Key points, Figure 7:

- South Australia's emissions (see above) are from a range of sources: energy industries, transport, agriculture, industrial processes, waste and other energy generation.
- To achieve net zero emissions by 2050, the total of our emissions need to equal the total of the carbon taken up by the state's carbon sinks – environments that capture carbon dioxide and store carbon in vegetation and soils.
- This can be achieved by both decreasing emissions and increasing land use sinks.
- Emissions from electricity generation have declined markedly since 2008 as the contribution of renewable energy sources in South Australia has increased.
- Emissions from transport have risen since 1990. In 2020, transport emissions were greater than those from any other category.
- Emissions from agriculture are moderately lower than in 1990, however emissions in this category have not declined significantly in the past ten years and in 2020 this was the second highest category of emissions in South Australia.
- 'Fugitive emissions' in South Australia primarily comprise the greenhouse gas emissions from the extraction and distribution of natural gas. This category has declined since 1990 but remains a significant source of emissions.
- Emissions from the treatment and disposal of waste have remained fairly constant over the past 20 years.

Linking with other plans and strategies

There are other plans and strategies in place that will intersect with the work undertaken to implement this plan. Information needs across sectors will be addressed through a cross-sectoral and collaborative approach.

South Australia's climate change strategy

The *Climate Change Science and Knowledge Plan for South Australia* is a key action of the South Australian Government Climate Change Action Plan 2021-2025, which sets the pathway for climate change mitigation and adaptation planning and action across the South Australian Government.

This plan supports the Premier's Climate Change Council's climate change strategy for South Australia. As the strategy is implemented, further plans and strategies will be developed across the South Australian government, seeking to address climate change risk assessment, adaptation planning and mitigation. These plans and strategies are likely to create further requirements for technical information, which will be addressed as the need arises. Actions described by the plan will be adapted to reflect these developments as required.

The state planning policies for South Australia

The State Planning Commission's State Planning Policies set a clear vision and priorities for our state's future.

State Planning Policies 5 and 15 identify the need to understand the risks and natural hazards associated with climate change and to plan and design accordingly.

The implementation of these policies will have a critical dependence on spatial information related to natural hazards and an understanding of the likely impacts of climate change and sea level rise.

State emergency management planning

State and national emergency management planning has adopted an emphasis on shared responsibility, community resilience, risk reduction and recovery. Ensuring that planning and development decisions are based on sound evidence and data will reduce risk and therefore minimise the need for emergency service responses. These principles are communicated in the National Strategy for Disaster Resilience, the *National Disaster Risk Reduction Framework*, and South Australia's Disaster Resilience Strategy. The State Emergency Management Committee (SEMC) has communicated a need for climate change data and information to inform the identification of risks, risk reduction and disaster recovery plans.

The SEMC *Strategic Plan 2017–22* sets out the priority themes and tasks for the emergency management sector in South Australia. This includes a number of strategic tasks that will drive the prioritisation of climate information needs, including the integrating of climate change consideration into the State Emergency Management Plan and incorporating climate change projections into the State Strategic Risk Assessment.

The *South Australian State Emergency Management Plan* (SEMP) sets out the state's emergency management arrangements and aims to ensure effective plans are in place to protect our communities and people. It acknowledges that climate change will continue to increase the frequency and severity of extreme weather events, leading to greater impacts upon the South Australian people and government.

In view of the range of strategies in the emergency management sector that express the importance of understanding and managing the risks of climate-related events, there will be a continuing strong demand from South Australia's emergency management agencies for technical information on climate change and climate-related hazards.

Implementation of the plan

The Climate Change Science and Knowledge Plan for South Australia is a plan for whole of government, and the broader climate change community of practice.

The *Climate Change Science and Knowledge Plan for South Australia* provides clear focus areas for the provision and coordination of climate change science and information over the next five years.

Implementing this plan will grow our evidence base to help climate change risk assessment, planning and adaptation responses for South Australia. It forms underpinning information to support the climate change strategy of the South Australian government.

While DEW provides leadership for this plan, it will be implemented through the community of practice with responsibility for climate change risk assessment, planning and adaptation responses in South Australia. This community of practice includes lead government agencies, industry, and other sector partners and stakeholders.

Partnerships and collaboration

The South Australian government recognises that a collaborative approach is needed to address information needs across sectors.

The South Australian government is building on our partnerships with all levels of government and centres of expertise in the environmental and natural resource sciences, including SARDI, the Bureau of Meteorology, CSIRO, the National Environmental Science Program (NESP), Geoscience Australia, and Cooperative Research Centres (CRCs).

South Australia's three universities and associated research institutions have significant expertise and capacity to address knowledge gaps and grow the South Australian climate change science and knowledge base. The research sector will continue to play a crucial role in addressing new information needs through research partnerships with government and industry.

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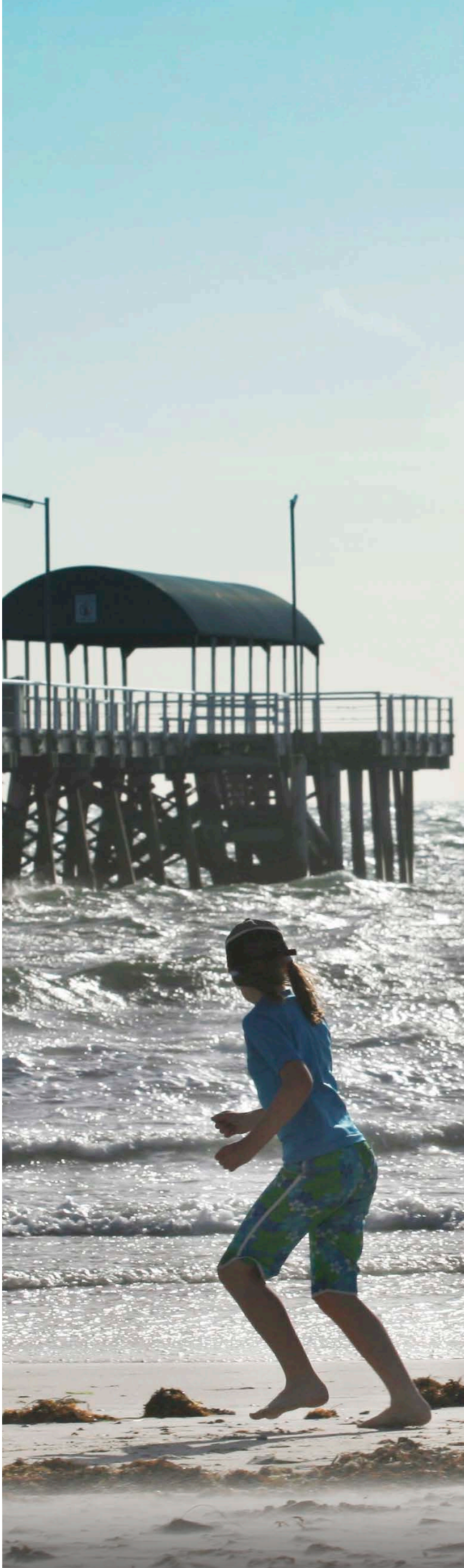

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Appendix 1

South Australia's climate change data: current status and additional requirements November 2022

The South Australian government maintains the state's evidence base of critical datasets for use in climate change modelling, and decision-making. Some available datasets need extending or updating and a number of derived products are required for use in the South Australian context.

Category	Why good information matters	Data product	Current status	Additional requirements
Climate change information delivery	An effective information delivery platform is needed to improve the ability of planners and decision-makers to discover, access, and apply scientific and technical information for climate change response planning.	South Australia-focused online delivery platform	Climate change technical information for South Australia is currently delivered via a variety of web-based platforms. In many cases, data is difficult for potential users to locate or access.	Develop an South Australia-focused online delivery platform for climate change science and information, making existing and new products more readily accessible.
Climate change projections for South Australia	Information on the likely direction and extent of climate change at the local scale allows us to understand the change in risks and impacts and the amount of change we need to plan to adapt to.	SA Climate Ready NARCliM projections Climate Change in Australia Project (CCIA) Application Ready Datasets	Downscaled future climate scenarios at daily or sub-daily time steps for primary climate variables to the year 2100.	Extend, update and improve scale of climate change projection data products for example through NARCliM 2.0 and CCIA.
Observed climate change evidence base for South Australia	Detailed data of past and current weather and climate conditions is essential to our understanding of how climate variability and the emerging changes in climate in South Australia are affecting us.	BoM rainfall and temperature time series data and trend maps.	Annual time series covering the whole of Australia is available for download from BoM website.	
		BoM Atmospheric high-resolution Regional Reanalysis for Australia dataset (BARRA)	Gridded data from 1990 to 2019 for South Australia (at 1.5km) and Australia (at 12km).	Derived analyses to identify correlations between historic weather conditions and weather-driven impacts, such as bushfires, floods, or crop yields.
Sea level	Accurate monitoring of sea levels on South Australian coastlines enables the assessment of emerging coastal inundation and erosion risks and verifies whether sea level rise is in line with projections.	BoM Australian Baseline Sea Level Monitoring Project.	Monthly sea level datasets for South Australian monitoring stations.	Continued maintenance and monitoring of South Australian sea level monitoring stations.
Sea surface temperature	Sea surface temperature variations affect marine ecosystems in a range of ways, including changes in species range, spread of invasive species and changes to disease risks.	Integrated Marine Observing System (IMOS) sea surface temperature mapping for Australian coastal waters.	All coastal waters updated at daily intervals.	Projections of sea surface temperature.

Category	Why good information matters	Data product	Current status	Additional requirements
Coastal inundation and erosion	Our coastal areas will be impacted by rising sea levels and extreme weather events. To manage risks to settlements and costs of repair we need better information on inundation and impact scenarios.	High-resolution (1m grid) ground elevation data from airborne LiDAR (Light Detection and Ranging) sensors	Majority of SA coastline captured from west of Ceduna to Vic and SA border including all of Kangaroo Island.	Complete LiDAR coverage from west of Ceduna to WA border to create a contiguous LiDAR dataset for all South Australian coasts. Erosion modelling for high-risk and high-vulnerability locations.
		Inundation layers for sea level scenarios	Available for coastline between West of Ceduna to SA and Vic border including Kangaroo Island. All inundation layers have been processed to the same specifications for consistency	Inundation layers for remaining South Australian coasts (from west of Ceduna to WA border), when LiDAR data is available. Dynamic hydrologic modelling of seawater flooding scenarios for high risk Adelaide coastal areas.
		Coastal erosion risk mapping	Statewide shoreline classification mapping: coastal erosion vulnerability assessment (including wave energy, geology, and coastal exposure).	Update erosion vulnerability maps.
		Coastal sand dune mapping	Statewide coastal hazards mapping: actual drift hazard (unvegetated sand dunes), and potential drift hazard (vegetated sand dunes).	Update dune drift hazard maps for high priority coasts.
Flood	Flooding impacts from extreme weather events will affect communities and catchments. To be informed about scenarios and manage risks, the best available water flow data and flood studies must be sought out and made transparent.	Flood risk studies and mapping	Data held by councils for some catchments and hazard sources (riverine and stormwater). Inconsistent coverage and many areas where flood risk is unknown.	Establish climate scenario standards for flood risk studies. Identify and fill gaps in flood risk mapping using high-resolution ground elevation data.
		Dam Risk Register	Covers prescribed water resource areas.	Update and expand to cover all flood relevant areas. Ensure compatibility with other South Australian government datasets (such as environmental and licencing).
		Levee Bank Register	Levee bank information database is in preparation.	Validate, complete and expand to cover all flood relevant areas.

Category	Why good information matters	Data product	Current status	Additional requirements
Bushfire	An increase in the number of hotter and drier days will lead to more days of extreme fire danger. Increased landscape dryness will cause those bushfires that do occur to be more intense and difficult to control. Planning and responding to protect life, property and environment will require up-to-date analysis and maps.	Fire history, derived fire frequency and last fire occurrence spatial data.	Statewide, with regional variation in data completeness. Maintained by DEW and updated approximately 4 times per year.	Integration of data from national fire mapping and hotspot detection services, such as Sentinel and North Australia Fire Information (NAFI), to improve fire history data coverage.
		Fire response models for priority wildlife species	Fire response models for priority wildlife species	A high-resolution digital elevation model is required to enable modelling of fuel and fire dynamics of ecosystems under future climate scenarios.
		Ecological Fire Management Thresholds of Potential Concern (TPC)	Various datasets statewide, with regional variation in data completeness. Currently in review within DEW.	Update TPC data with latest vegetation cover, fire history, and ecological datasets. Assessment of species most at risk of changes in fire regime, and research to better understand fire resilience of these species.
		Fire severity	Not statewide. Fire severity currently assessed on a project-by-project basis.	Statewide approach needed e.g. use remotely sensed imagery (satellite, aerial, drone) to map fire severity regularly. Routine capture of prescribed burns severity.
		BoM Atmospheric high-resolution Regional Reanalysis for Australia dataset (BARRA)	Gridded data from 1990 to 2019 for South Australia (at 1.5km) and Australia (at 12km).	Analyse data to derive indicative weather conditions for various hazards and historic weather events.
		Bushfire protection areas (BPA) mapping	State-wide BPA maps and bushfire hazard overlay in the online planning portal (2020 update). A Bushfire Risk Assessment Model (BRAM) was produced in 2020 and has been developed into the FLARE tool that is now being used for DEW Fire Management Plans.	Statewide BPA maps and bushfire hazard overlay in the online planning portal (2020 update).
		Fire response models for priority wildlife species	Limited information for a few priority species (e.g. Mallee Emu-wren)	Assessment of species most at risk of changes in fire regime, and research to better understand fire resilience of these species.

Category	Why good information matters	Data product	Current status	Additional requirements
Urban heat	Our cities will be hotter. We need a consistent way to monitor where urban heat is worse, where impacts will be felt most and where we are reducing heat with tree cover or strategic use of water.	Urban Heat mapping	Thermal data for 80% of the Adelaide metropolitan area was captured between March and April 2022. Remaining 20% to be captured later in 2022 when required weather conditions occur.	Data capture using agreed coordinated method across South Australia's urban areas, including regional centres. Repeat capture at appropriate intervals to determine impact of planning decisions and management decision and develop future strategies.
Urban tree coverage		Urban tree mapping	High resolution LiDAR data captured for entire Adelaide metropolitan project area in January 2022.	Rectify LIDAR point cloud classification. Process and classify LiDAR data into low, medium and tall vegetation classes and generate tree canopy layers. Once completed, urban tree coverage and statistics will be available early 2023. Analyse tree canopy mapping to improve understanding of heat mitigation, rainfall interception, health outcomes and urban greening impacts. Coordinate repeat data capture and processing at an appropriate frequency for metropolitan areas.
Environ-mental change	Consistent ways of recording changes in the landscape are needed as they a) may constrain potential opportunities for agriculture or natural systems in the face of climate change or b) reflect successful adaptation of industries and communities.	Land Use mapping shows economic or other uses of land resources (e.g. horticulture, residential, conservation).	2019 Generalised Land Use mapping released in late 2019. Statewide coverage from various years, variation in currency.	Current land use required with annual update.
		SA Land Cover mapping describes biophysical surfaces (e.g. trees, water, built urban).	Five yearly, statewide coverage 1987–2015.	Annual statewide coverage.
Biodiversity	Climate change will drive changes in the distribution of species, as well as which species occur together to form ecosystems.	Spatial data assessment of the nature of change posed by climate change on different ecosystems across the state.	There is currently no consistent assessment of the implications of climate change on the ecosystems of South Australia.	Spatial data assessment of the nature of change posed by climate change on different ecosystems across the state. Information to determine effective future on-ground actions for biodiversity conservation through landscape planning and operational programs.Collect and analyse data on species most sensitive to change, to validate predicted responses to the changing climate.
Total grazing pressure	Future changes in temperature and rainfall will affect pasture growth and biomass. There is a need to understand how total grazing pressure and climate change will interact, and the implications this will have for South Australian ecosystems and socio-economic values.	Vegetation cover maps of pasture growth rates and biomass.	National vegetation cover maps derived from satellite imagery are processed and made available every month.	Evaluate and extend existing products/interfaces to national vegetation cover mapping for use by South Australian audiences.
		Density maps and population estimates for domestic, native and introduced herbivores.	Monitoring programs and systems vary across regions and species.	Analyse what social, economic and environmental values are impacted by grazing and how they may change under climate change.

Category	Why good information matters	Data product	Current status	Additional requirements
Soil moisture	Soil moisture mapping provides an indication of the likely effects of drier and warmer conditions on the health of native vegetation and food crops, allowing land managers to make informed management choices.	National soil moisture mapping Includes information on soil water-holding capacity and wilting point, which vary with soil texture.	BoM Australian Landscape Water Balance soil moisture model (5km grid). Finer-resolution soil data and short-term dynamic forecasting products are being improved.	Further improvement of regional soil moisture sensor networks and soil characterisation data to inform landholder decision-making at local scales.
Soil erosion	Protecting the fertility and productive potential of soils depends on adequate vegetation cover. However future biomass production under climate change may be insufficient to protect soils in some annual cropping and grazing systems.	Maps of wind erosion risk and water erosion risk.	Soil erosion risk from wind and water under warming and drying scenarios have been modelled and mapped for the agricultural zone of South Australia. Erosion risk indicator (average number of days at risk) is published annually.	Other agricultural land uses and areas of South Australia are yet to be considered with regard to assessing risks to sustainable land management under climate change.
Landscape health	Landscape response to seasonal conditions and land management practices provides an indication of the impact of climate change on landscape health, condition and resilience.	Maps and statistics on plant growth and cover relative to long-term averages.	Based on analysis of MODIS satellite data. Charts and maps of plant growth and soil cover are generated regularly for both agricultural and rangelands areas.	Further improvement of outputs required. Provide accessibility to information via an interactive dashboard.
Agricultural pests and disease	Changes to climate are an additional risk for biosecurity. The timing and spectrum of current pests and diseases are also likely to change.	Surveillance data sets for priority pests and diseases affecting primary industries and/or natural ecosystems.	Separate data sets for animal health, plant health and invasive species, varying in scale, scope and information management system. Some data is commercially sensitive. Data collection and analysis is resourcing dependent, mostly focused on national and state priority lists.	More coordinated approach to data collection and analysis that includes routine early detection of new pest and diseases, rather than just target list of known threats.
Tracking primary industry production	Reporting yield and quality of production from key primary industries provides a measure of physical impacts of the changing climate including shocks such as droughts and extreme events	Reports and maps of production in yield/ hectare or fish catch.	PIRSA crop and pasture reports. https://pir.sa.gov.au/primary_industry/crops_and_pastures/crop_and_pasture_reports ABARES Agricultural production reports. Simulation studies that model the impact of climate on crops and pasture.	Improved linking of climate data to production data. Links to soil erosion and water availability. Opportunities to update and improve simulation modelling of crops and pastures to place recent production in historical context and simulate impacts of future climates.
Tracking primary industry value chains	Tracking the value chains of land-based and aquatic primary industries provides information on relative importance and trends. The data allows a measure of the impact of past droughts and extreme events on the economic output.	Reports and maps showing trends in economic value from key primary industries.	PIRSA scorecards (www.aginsight.sa.gov.au) currently provide detail on location of dairy, field crops, forestry, horticulture, seafood and wine.	Higher spatial resolution where feasible. Linking climate and total factor productivity to climate data.
Information for new and emerging primary industries	As climate changes there will be opportunities for new and emerging aquatic and land land-based primary industries.	Maps that match climate and soil to new opportunities for land land-based industries and ocean conditions for aquatic industries.	AgriFutures Australia has an emerging industries program and www.agrifutures.com.au/publications-resources/farm-diversity-search/ Some agro-climatic indices are mapped and available	Interaction with South Australian stakeholders. Links to South Australian climate change projections.

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