dsquared

Department of Planning and Environment

Snowy Mountains Special Activation Precinct

Climate Change Adaptation Plan

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We confirm that all work has been undertaken in accordance with our ISO 9001 accredited quality management system.

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Executive summary

This document comprises the Climate Change Adaptation Plan for the Snowy Mountains Special Activation Precinct (SAP) and summarises the predicted local climate change scenarios and risks and proposes mitigation measures for incorporation into the Master Plan and associated Delivery Plans and Development Control Plans. Due to the scope of this document focussing on the Master Plan and associated planning policies and controls, it should be noted that this assessment is based on a point in time during the Master Plan development, is unable to fully mitigate climate change risks with built environment improvements and planning controls only, and that an ongoing governance structure and management systems are required to plan for and respond to climate change over time.

There are a number of identified triggers for the development of this Plan:

- The significant capital investment required to construct new buildings and infrastructure and the need to ensure that they remain in safe efficient operation throughout their operating life, and for the SAP Master Plan development timeline.
- The significant business and societal risk impacts as a result of climate change and the flow on impact on the health and productivity of business and the broader community.
- The need to ensure that future impacts on the environment are mitigated, and that the expected economic performance of the Snowy Mountains SAP is not overly compromised by climate change impacts.

This Plan has been prepared in accordance with the Australian Greenhouse Office (AGO) guidance document: *Climate Change Impacts & Risk Management – A Guide for Business and Government*, and follows the guidance included within AS 5334:2013 *Climate Change Adaptation for Settlements and Infrastructure.* Climate change projections are based on the suite of reports published by the NSW Department of Planning and Environment (DPE) titled *Climate change impacts in the NSW and ACT Alpine region 2019, and* the *CSIRO Climate Change In Australia (CCIA) Technical Report*, 2015, and other sources.

The SAP development timeframe extends to 2060, at which point the SAP program development program is expected to have reached a conclusion with the required outcomes having been achieved at a sustainable level. For the purposes of aligning the climate change risk assessment time frame with available climate change projection data, the following two milestones have been used:

- **Near future (2020-2039)**: being at a point reaching mid-way in the SAP development timeline, coinciding with the milestone for the completion of a number of key infrastructure projects.
- **Far future (2060-2079)**: being at the point in time of the conclusion of the SAP program.

A climate change risk assessment workshop was held via Zoom on 13rd April 2021 to review the future projected climate change risks and how they might impact on the Snowy Mountains SAP. Stakeholders attending the workshop and contributing to the risk assessment included representatives of NSW National Parks & Wildlife Service (NPWS), Department of Regional NSW, Department of Planning and Environment (DPE), Regional Growth NSW Development Corporation (RGDC), Snowy Monaro Regional Council, and technical consultants WSP and dsquared. A MURAL board was developed, and workshop participants asked to complete the risk rating and add other issues or considerations related to existing or proposed potential mitigation strategies.

The climate change risk assessment highlighted the complex and diverse nature of the Snowy Mountains SAP, that there are multiple parties involved in the ongoing management of climate change risks and that the Snowy Mountains SAP incorporates a number of precincts and sub-precincts that are impacted by climate change to varying degrees. Due to this assessment focussing on the Master Plan and associated Delivery Plan/s and Development Control Plan/s, there are a number of climate change risks which are unable to be mitigated by actions identified in this plan.

The risk assessment identified a number of high and extreme climate change risks which require adequate mitigation measures to be implemented. However, a number of the climate change impacts are significant enough to remain at a high or extreme level, even if all practicable mitigation measures are implemented as part of the Master Plan and associated Delivery Plan/s and Development Control Plan/s. These include climate change events such as:

- **Temperature rises are predicted to radically impact on the existing snow-based economies**. Although the Snowy Mountains SAP is supporting a transition to being a year-round destination with the aim to mitigate this impact as far as possible, the effectiveness of this mitigation measure will need to be monitored over time. In addition, increased weather variability is expected which can lead to more extreme weather conditions in the short term, such as the increased snow season length and snow cover currently being experienced, while the longer-term trend of declining snow conditions continues. The key risk is that current snow conditions will create a sense of complacency for operators in the Snowy Mountains SAP, and a number of poor snow seasons due to weather variability could be unsustainable for businesses and resorts.
- **Community growth and resilience, and flora, fauna, biodiversity, and human safety resulting from a loss of snow cover**. The impact of climate change on the community and environment is expected to be significant and a number of protected flora and fauna in the alpine region area are at risk of being lost due to being dependent on snow conditions. Many of these risks are outside the scope of this plan, require ongoing monitoring and governance systems to plan for and respond to climate change over time, and will require a multi-agency response.
- **An increase in bushfire frequency and intensity**. An increase in average and extreme fire weather days is expected to impact the alpine areas and Kosciuszko National Park in particular, with human safety and infrastructure at risk from increased bushfire frequency and intensity. In addition, many of the mitigation measures identified in the risk assessment require ongoing governance systems and resources to be implemented.

Throughout the development of the Structure Plan and Master Plan, and repeatedly voiced during the stakeholder engagement undertaken to develop this Climate Change Adaptation Plan, it has been made clear that climate change mitigation measures will only be followed through into action if there is a clear, strong, and fully funded governance structure and management systems in place. This will require existing management systems within NSW Government, NPWS and local council to be maintained, improved systems to monitor and plan for climate change be implemented to drive continual improvement, and a lead agency such as DPE or RGDC to coordinate the governance structure and systems for the Snowy Mountains SAP.

To achieve this, the over-arching recommendation is that a formalised governance structure is in place, with supporting policy, planning and operational legislative requirements, monitoring and reporting mechanisms facilitating the implementation of the Climate Change Adaptation Plan. The governance structure will require membership and investment from multiple agencies, organisations and businesses to be successful, including DPE, RGDC, Council, Snowy Hydro, the resorts, and businesses within the SAP.

It is recommended that an Environmental Management System certified in accordance with ISO 14001 is considered for the SAP, encompassing the Kosciusko National Park Plan of Management, Carrying Capacity Framework, the Kosciusko National Park /Resort Environmental Management System frameworks, and this Plan. This is an appropriate framework and mechanism for the ongoing management of climate change risks and the associated mitigation measures. However, the current approach is to have an EMS in place for the Alpine Precinct and it is recommended that a governance structure is implemented to manage climate change risks and impacts across the entire Snowy Mountains SAP to ensure learnings and mitigation measures are coordinated across the Snowy Mountains SAP.

In order to assist with providing some focus for the Delivery Plan and DCP development, the top climate change impacts resulting from this risk assessment are summarised below:

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
Temperature increase 	Increase of 2.0 to 2.5°C	1. Change in species distribution in and around township, weed/pest invasions including mosquitos, decline in biodiversity and natural amenity including fishing	1. Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit. 2. Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term 3. Faster snow melt reducing snow coverage, leading to an increase in snow making and salt/environmental impacts, or reducing length and financial viability of snow season
Increased hot days 	12 to 32 days above 35°C	1. Heat stress for the community population, including residents and visitors (relative heat wave impacts) 2. Increased demand and utilisation of public infrastructure for respite e.g. lake foreshore and public/community buildings	1. Heat stress for the community population and in particular visitors using active tourism offerings that could be susceptible to increased hot days (e.g. hiking and mountain biking events).

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
Reduced annual rainfall 	10% reduction in average rainfall	1. Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	1. Reduced water availability and increased water storage requirements for alpine areas not connected to a mains water supply.
Reduced snow conditions 	60% reduction of suitable snowmaking conditions, a reduction of 35 to 40 days	1. Reduced winter tourism due to shorter and more intermittent snow seasons 2. Reduced tourism expenditure during winter impacting business financial viability and economic growth 3. Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	1. Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park. 2. Change in and loss of biodiversity and ecology, including loss of alpine flora and fauna, snow gum die back, flora/fauna loss/migration, and other sudden unforeseen impacts. 3. Introduction of additional snow making facilities increases utility demand, greenhouse gas emissions, and salt and synthetic ingredient contamination/run off/ecology impacts.
Increased bushfire risk/intensity 	1 to 2 day increase in extreme fire weather days per annum, occurring in spring and summer.	1. Increased risk ratings and fire life safety standards for new and replaced infrastructure. 2. Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications). 3. Repeated bushfires and visual amenity impact reducing tourism, visitation and economic growth (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/RPZ)	1. Increased risk ratings and fire life safety standards for new and replaced infrastructure. 2. Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications). 3. Damage/loss of indigenous and non-indigenous heritage (buildings, natural landscape, features etc) due to repeated and uncontrolled bushfire impacts. 4. Reduced tourism due to increased bushfire risk, in particular in KNP during summer. For example, tourist evacuation orders

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
		4. Adverse mental health and economic recovery impacts of repeated bushfires	have been issued in the past significantly impacting the tourism industry. 5. Increased risk to tourists/campers/visitors in low communication areas (poor telecommunications).

Detailed risk assessment and mitigation measure schedules are provided in Sections 4 and 5 of this report.

The risk assessment and review process has identified a series of mitigation measures that will need to be implemented in order to reduce the risk impact resulting from climate change. These mitigation measures have been reviewed as part of the development of the final Master Plan however some impacts cannot be mitigated through the Master Plan and will require ongoing review and integration into supporting design and planning frameworks for the Snowy Mountains SAP. This includes integrating applicable parts of this Climate Change Adaptation Plan and zones into the following precinct Delivery Plans and DCPs.

- **Zone 1** (covers Jindabyne Catalyst and Jindabyne Growth Precincts) - Delivery Plan/s will be developed by RGDC/DPE for the Jindabyne Catalyst Precinct, and an amendment to the Snowy River DCP will be developed by Council/DPE for the Jindabyne Growth Precinct.
- **Zone 2** (covers the Alpine precinct) - an Alpine DCP will be prepared by DPE, with support from NPWS, for the Alpine Precinct.

The ongoing development of the SAP and the initiation of all new supporting infrastructure projects and investor led projects will be guided and driven by a number of key documents and plans and frameworks as follows:

- The Snowy Mountains SAP Master Plan, Delivery Plans and Development Control Plans
- Kosciuszko National Park Plan of Management
- Existing frameworks of governance agencies including NPWS, DPE and Council
- Planning Rules including the Precincts-Regional SEPP and Snowy River LEP
- Design and development standards and guidelines, and conditions of consent for development applications
- Performance targets to be achieved including energy, water, waste, and environmental protection
- The proposed SAP Environmental Management System (EMS) framework.

We reinforce the importance of ensuring that climate change risks and mitigation measures are fully recognised within the Delivery Plan/s and Development Control Plan/s (captured in Section 7 of this report) and that an effective governance structure is implemented to integrate climate change into all of the above documents and associated plans.

It is recommended that this plan and referenced data sources and information are reviewed regularly or in the event of a change in policy or process to ensure current projects and investments are planning for future climate condition based on the latest available information.

1 Introduction

1.1 Objectives

The Department of Planning and Environment (DPE, or the Department) has appointed dsquared to establish Climate Change Risk Assessment and Adaptation considerations to embed into the Snowy Mountains Special Activation Precinct (SAP) Master Plan, Delivery Plans and Development Control Plans.

The objectives of this appointment are to:

- Ensure there is an understanding and consideration of climate change risks and adaption considerations within the Special Activation Precinct Master Plan, Precincts-Regional SEPP, and Snowy River LEP.
- Identify and assess climate change risks to the SAP and local government area (LGA) including the impact of these risks on natural and built assets and future development scenarios, insofar as they impact on the SAP developable areas.
- Initiate consultation with key stakeholders to develop a greater understanding and consideration of climate change risk and adaptation opportunities for each of the Special Activation Precinct developable areas.
- Develop a robust Climate Change Risk Assessment for the SAP consistent with DPE's Guide to Climate Change Risk Assessment for NSW Local Government (2019)
- Develop adaptation considerations for integration into the SAP consistent with the OEH Checklist for best practice adaptation planning and implementation (2013).

This document comprises the Climate Change Adaptation Plan for the Snowy Mountains Special Activation Precinct (SAP) and summarises the established local climate change scenario projections and risks and proposes mitigation measures (if required) for incorporation into the Snowy Mountains Master Plan, Delivery Plan/s or Development Control Plan/s.

dsquared would like to acknowledge the invaluable input of multiple technical consultants and stakeholders, including, but not limited to:

- Anthony Evans, NSW National Parks & Wildlife Service, Principal Project Officer
- Wil Allen, NSW National Parks & Wildlife Service, Senior Planner
- Willem Clasie, Department of Regional NSW, Director Special Activation Precincts
- Melinda Hillery, NSW DPE, Senior Project Officer, Climate Resilience and Net Zero Emissions Branch
- Jess Henderson-Wilson, NSW DPE, Senior Planner
- Krishti Akhter, NSW DPE, Senior Planner
- Alysia Smith, Regional Growth NSW Development Corporation
- Mark Adams, Snowy Monaro Regional Council, Coordinator Economic Development
- Henry Swan, WSP Infrastructure, Technical Consultant.

1.2 Scope

The scope of this assessment is the Snowy Mountains SAP located within the Snowy Monaro Regional Council Local Government Area LGA (Figure 1) in New South Wales. Around 130 kilometres south of Canberra CBD, the SAP investigation area is approximately 722 square kilometres and encompasses diverse alpine and sub-alpine terrain.

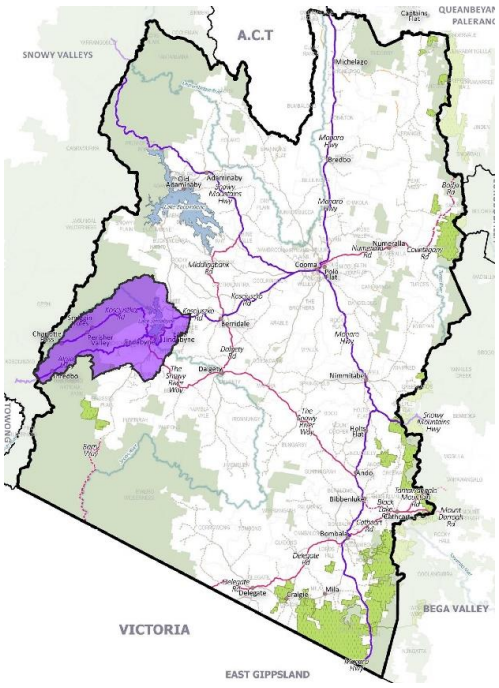


Figure 1: Snowy Monaro LGA and SAP. Source: Snowy Monaro Regional Council/dsquared

The Plan investigates the impacts of climate change on the precinct directly (Figure 2 – Boundary 1) and on crucial infrastructure (e.g. roads, utilities; Figure 2 – Boundary 2) that serves the SAP.

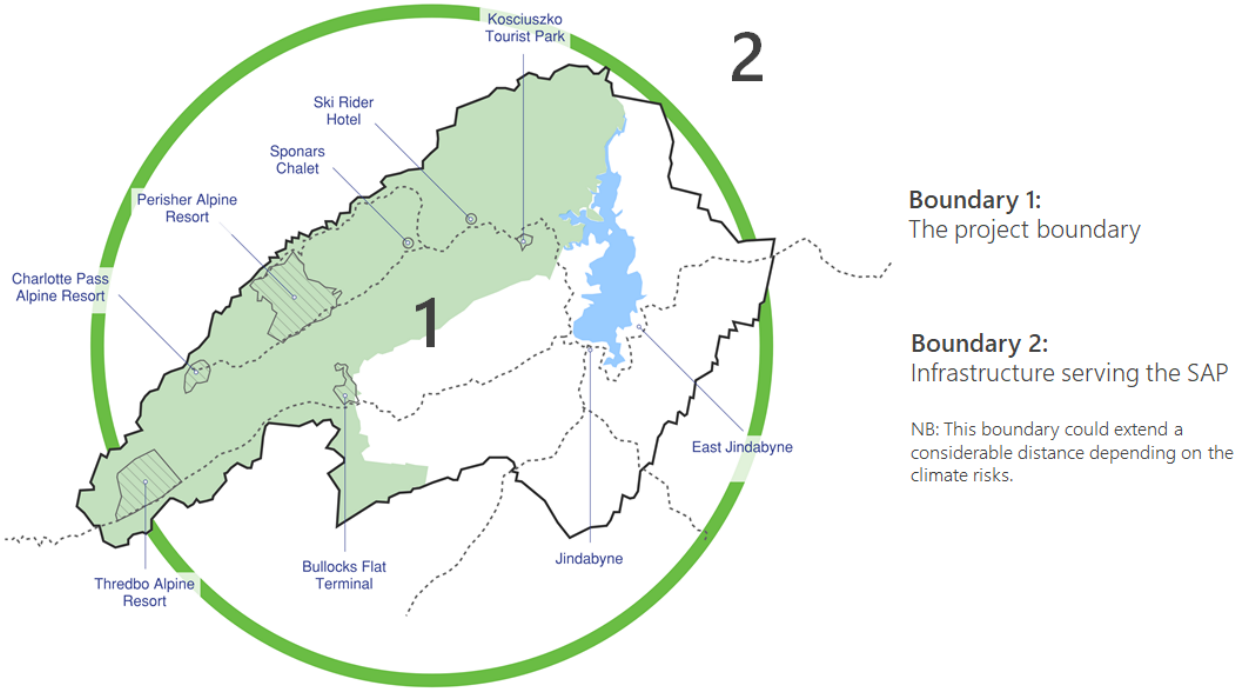


Figure 2: Scope boundaries. Source: dsquared

1.3 Methodology

This Plan has been prepared in accordance with the Australian Greenhouse Office (AGO) guidance document AS 5334:2013 *Climate Change Adaptation for Settlements and Infrastructure* following the workflow as shown in Figure 3.

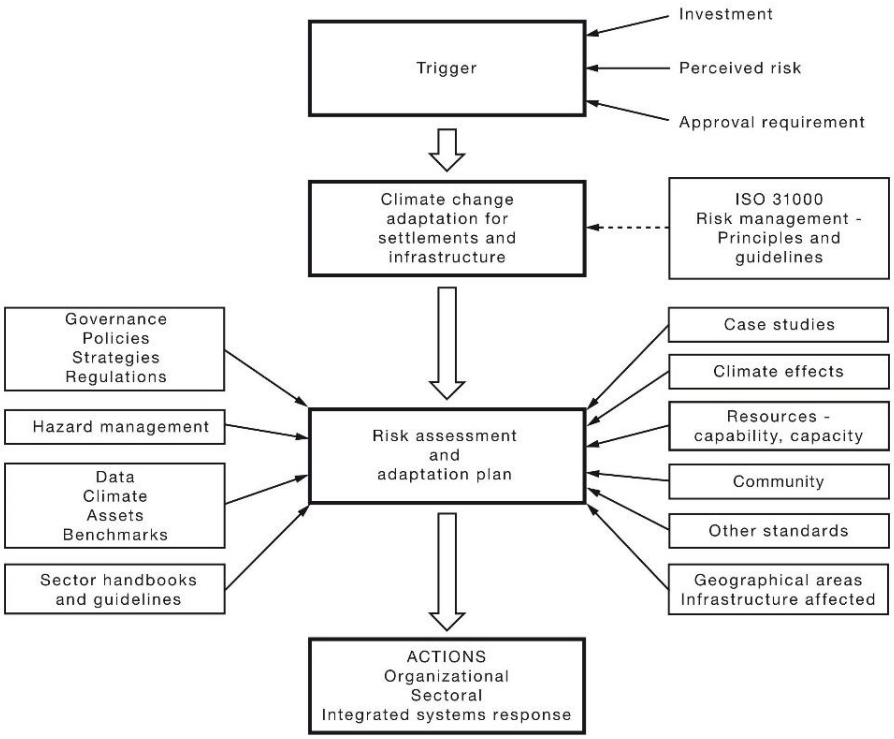


Figure 3: AS 5334:2013 Climate Change Adaption Approach

The climate change risk assessment of this Plan is aligned with the five-step process as outlined in the AGO Guide (refer Figure 4) and AS/NSZ 2018 Standard and adopted by the State of NSW and Office of Environment and Heritage (OEH) *Guide to Climate Change Risk Assessment for NSW Local Government 2011* to identify and evaluate the risks of climate change to council assets, its operations and provided services.

Figure 4: Steps in the risk management process. Source: AGO

It allows organisations to prioritise risks and develop mitigating strategies as basis for decision-making and planning, and to implement risk managing initiatives which enhance their resilience against the challenges of climate change.

The methodology used to translate this workflow into a CCAP is summarised as follows.

Table 1: Methodology

Inception
Hold an inception meeting facilitated using Zoom to: • confirm project objectives, methodology and milestones; • agree workshop structure and time; • agree risk categories suitable to the Special Activation Precinct and responsible stakeholders; and • discuss workshop attendees. Receive all current technical and structure plan teams reports and a briefing on the SAP, so that SAP-specific methodologies and programmes can be drafted for discussion.
Desktop Analysis
Undertake a desktop analysis comprising: • benchmarking of existing risk frameworks and plans for similar projects to enable successful facilitation of a risk workshop and context for the integration of adaptation considerations; • review and consideration of technical reports prepared for the SAP to estimate the impacts of climate change and integration into the climate change snapshot and risk assessment processes; • undertake a gap analysis to determine if additional work by the SAP project teams will be necessary to support the climate change risk assessment; • review and collation of climate change data and risks to provide Snapshots of key projections for the SAP. The Climate Risks considered will include: ▪ Climate (including large-scale climate patterns e.g., El Niño) ▪ Temperature (including hot days/ cold nights); ▪ Rainfall (including frequency/ intensity); ▪ Flooding; ▪ Snow; ▪ Bushfire; ▪ Solar Radiation; ▪ Soil; ▪ Wind Speed; ▪ Humidity; ▪ Evapotranspiration; ▪ Biodiversity; and

Undertake all risk assessments cognisant of:

- AS ISO 31000:2018.
- NARCLIM 1.0 Climate Projections.
- NSW Government Asset Management Policy TPP 19-07.
- Risk assessment reports generated using the XDI tool, provided with the support of DPE staff.

- mapping and/or visual representation of key climate change risks within the SAP.

Risk Assessment

Undertake a risk assessment comprising:

- preparing a Risk Matrix for review by the Department and use during the workshop;
- preparing a brief summary report containing relevant information to enable participants to contribute effectively to a Risk Assessment workshop;
- conducting an online climate change risk assessment with a multidisciplinary stakeholder group within an agreed risk management framework. The presentations will be provided via Zoom with the ability to directly capture stakeholder feedback via an online system called Mural.
- prepare the findings of the risk workshop in a brief report including a Risk Register, key themes and Top 5 risks for the Special Activation Precinct; and
- presenting these findings to the Special Activation Precinct team and other relevant stakeholders.

Risk assessments should be consistent with Australian and New Zealand Standard for Risk Management, AS/NZS 4360:2004 and Australian Greenhouse Office's (2006) Climate change impact and risk management - A guide for business and government.

Adaptation Action Integration

Adaptation actions are then considered and integrated into the SAP Technical Studies, Structure Plan, and Delivery Plan, as follows:

- prepare Adaptation considerations which identify options to embed the consideration of climate change within the Special Activation Precinct framework including the Master Plan and/or Delivery Plan;
- adaptation considerations prepared for input into a Master Plan should recommend Performance Criteria with associated targets. Consideration should be given to alignment with any existing performance criteria where a working document is available; and
- adaptation considerations prepared for input into a Delivery Plan should recommend Performance Measures. Consideration should be given to alignment with any existing performance measures where a working or final document is available.

Recommendations should be separated by discipline to ease their integration into technical consultant reports, and the delivery plans. Recommendations and targets should be aligned with any known SEPP, Delivery Plan, Sustainability Plan, EMS, or other frameworks either known or to be developed to ensure ongoing monitoring, reporting and compliance is incorporated.

1.4 Identified triggers

There are a number of identified triggers for the development of this Plan:

- The significant capital investment required to construct new buildings and infrastructure and the need to ensure that they remain in safe efficient operation throughout their operating life, and for the SAP Master Plan development timeline.
- The significant business and societal risk impacts as a result of climate change and the flow on impact on the health and productivity of business and the broader community.
- The need to ensure that future impacts on the environment are mitigated, and that the expected economic performance of the Snowy Mountains SAP is not overly compromised by climate change impacts.

1.5 Timeframe for risk assessment

Available climate change modelling consistently uses averages forecast over 20-year time periods, commonly 2030 (2020-2039), 2050 (2040-2059), 2070 (2060-2079), and 2090 (2080-2099), although a number of studies include other timeframes and milestones.

Climate change projections are generally modelled from a reference period of 1986 to 2005, with the CSIRO projections based on a slightly longer reference period spanning 1981 to 2010.

The SAP development timeframe extends to 2060, at which point the SAP program development program is expected to have reached a conclusion. For the purposes of aligning the climate change risk assessment time frame with available climate change projection data, the following two milestones will be used:

- **Near future (2020-2039)**: being at a point reaching mid-way in the SAP development timeline, coinciding with the milestone for the completion of a number of key infrastructure projects; and
- **Far future (2060-2079)**: being at the point in time of the conclusion of the SAP program.

1.6 Global emissions scenarios

The rate and extent of future climate change impacts will be directly proportional to the actual change in atmospheric greenhouse gases. Because of the variability in modelling accuracy, climate change projections are based on a range of greenhouse gas intensity scenarios called Representative Concentration Pathways, or RCPs. The four commonly referenced RCPs range from aspirational (RCP2.6) through intermediate (RCP4.5 and RCP6.0) to very high (RCP8.5), with a RCP8.5 the required pathway for risk assessments under NSW Government guidelines.

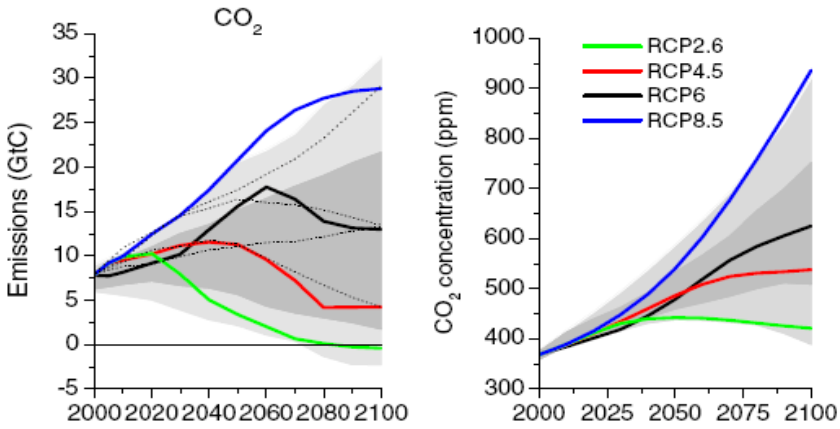


Figure 5: Summary of carbon dioxide level scenarios (RCPs)

The below provides a summary of the RCPs for further information:

- RCP2.6 is an emissions pathway which is required to meet the maximum 2.0°C temperature limit under the Paris Agreement. It is considered to be too conservative, with many of the projections already having been reached (meaning, emissions are already exceeding this pathway);
- RCP4.5 is an intermediate pathway with emissions peaking earlier than the RCP6.0 model (around 2040) and CO_2 concentration reaching 540 ppm by 2100. However, in this scenario, emission reduction measures are not sufficient to meet the Paris Agreement target of limiting mean surface temperature increases to 2°C or lower by 2100 (projected to reach over 2.4°C). This scenario is considered to be possible to occur in the event of current policy commitments are achieved and there is an increase in emission reduction measures however under current emission projections this pathway is not being achieved; and
- RCP8.5 is referred to as a business-as-usual (BAU) pathway under NSW Government guidelines and is to be included in a risk assessment as the projected scenario, with CO_2 concentrations continuing to rapidly rise, reaching 940 ppm by 2100. There is a large difference between RCP4.5 and RCP8.5 and so it is important to consider this in the context of the anticipated building and infrastructure life, which is particularly relevant for the Snowy Mountains SAP.

1.7 Sources of information

The following sources of information have been used in developing this Plan:

- *Climate change impacts in the NSW and ACT Alpine region: Projected climate,* November 2020, published by the NSW Department of Planning, Industry & Environment
- Suite of reports published by the NSW Department of Planning, Industry & Environment titled *Climate change impacts in the NSW and ACT Alpine region 2019, including:*
    - Impacts on biodiversity
    - Impacts on crop suitability
    - Impacts on fire weather
    - Projected changes in snowmaking conditions
    - Impacts of extreme rainfall on soil erosivity and hillslope erosion
    - Impacts on water availability;
- Climate Change in Australia Technical Report 2015, published by the NRM and CSIRO;
- CSIRO State of the Climate 2018;
- CSIRO State of the Climate 2020;
- NARCliM (NSW/ACT Regional Climate modelling in conjunction with University of NSW);
- Bureau of Meteorology (BOM) Database;
- CSIRO Climate Change In Australia (CCIA) Website, Climate Change Calculator and Data Set Viewers. http://www.climatechangeinaustralia.gov.au
- Technical Reports prepared by the Snowy SAP Structure Plan team, including:
    - Legislative Framework Options, prepared by Ramboll
    - Public Space Study, prepared by Jensen Plus
    - Social Infrastructure Study, prepared by Liesl Codrington
    - Sport Infrastructure Study, prepared by DHW
    - Heritage, Historic Heritage, and Aboriginal Cultural Heritage Reports, prepared by OzArk
    - Salt Management Report, prepared by WSP
    - Biodiversity Report, prepared by WSP
    - Strategic Bushfire Management Report, prepared by Black Ash
    - Carrying Capacity Framework Report, prepared by WSP
    - Housing Accommodation Study, prepared by Eths Urban
    - NSW Regional Snowy Mountains Economic Growth Report, prepared by CIE
    - Transport Infrastructure Report, prepared by WSP
    - Infrastructure Report, prepared by WSP
    - Renewable Energy Opportunities Report, prepared by WSP
    - Flooding Report, prepared by WSP
    - Hydrogeology Report, prepared by WSP

- Geotechnical Report, prepared by WSP
- Airport Infrastructure Options Report, prepared by ARUP
- Tourism Development Study, prepared by Stafford Strategy;

- Draft Snowy Mountains SAP Structure Plan 2021, prepared by Jensen Plus; and
- Draft Snowy Mountains SAP Master Plan 2021, prepared by DPE.

1.8 Stakeholders

The below outlines the main stakeholders and parties that will have a role in managing climate change risks:

Organisation	Role
Department of Planning and Environment (DPE)	Ensuring climate change impacts are integrated into the Master Plan and associated planning policies and development controls. This is the focus of this Climate Change Adaptation Plan.
NSW National Parks & Wildlife Service	Ensuring climate change impacts are integrated into the Kosciuszko National Park (KNP) Plan of Management (PoM) and associated management systems, leases and as part of operations.
Regional Growth NSW Development Corporation (RGDC)	Understanding climate change risks unable to be mitigated via the Master Plan and associated development controls and working with stakeholders to mitigate and adapt to these impacts over time.
Snowy Monaro Regional Council	Understanding climate change impacts and planning for improved climate resilience for the community. Community
Resorts	Understanding climate change risks for their operations and implementing appropriate systems to mitigate and adapt to climate change without negatively impacting the environment.
Businesses in the SAP	Understanding climate change risks for their operations and implementing appropriate systems to mitigate and adapt to climate change.
Residents and tourists	General awareness of climate change and supporting initiatives implemented to mitigate and adapt to climate change.

1.8.1 Stakeholder engagement

A climate change risk assessment workshop was held via Zoom on 13rd April 2021 to review the future projected climate change risks and how they might impact on the Snowy Mountains Special Activation Precinct. A MURAL board was developed, and workshop participants shared issues and considerations related to the risk assessment process, both to this MURAL board and also verbally.

Workshop participants and MURAL risk assessment contributors included:

- Anthony Evans, NSW National Parks & Wildlife Service, Principal Project Officer
- Wil Allen, NSW National Parks & Wildlife Service, Senior Planner
- Willem Clasie, Department of Regional NSW, Director Special Activation Precincts
- Melinda Hillery, NSW DPE, Senior Project Officer, Climate Resilience and Net Zero Emissions Branch

- Jess Henderson-Wilson, NSW DPE, Senior Planner
- Krishti Akhter, NSW DPE, Senior Planner
- Alysia Smith, Regional Growth NSW Development Corporation (RGDC)
- Mark Adams, Snowy Monaro Regional Council, Coordinator Economic Development
- Henry Swan, WSP Infrastructure, Technical Consultant
- Morgan Cardiff, WSP Carrying Capacity, Technical Consultant
- Jane Jackson, Meridian Urban, Senior Planner
- Kim Kirstein, Meridian Urban, Senior Planner
- Jacob Potter, dsquared (workshop Chair)

Following the Climate Change Risk Assessment Workshop, a review of the identified climate impacts was undertaken and consolidated into a climate risk assessment table. The tables were added to the MURAL workspace and each stakeholder was able to provide input on the risk assessment.

1.9 Plan Author

The report has been prepared by Paul Davy, a Director of consultancy firm dsquared.

Paul has over 30 years' experience in the UK, Europe, Asia and Australia as an engineering, ESD, and sustainability consultant.

Paul holds IEng and MCIBSE Accreditation, is a Green Star Accredited Professional (Design & As-Built, Performance, Communities), Green Star Certified Assessor, a Green Building Council of Australia Teaching Faculty Member, an Ambassador for the Living Futures Institute of Australia, a WELL Accredited Professional, and a member of the South Australian Government ODASA Design Review Panel.

Paul has over 13 years' experience in climate change risk assessment and adaptation planning in Australia, with many major projects for the Government of South Australia including the Tonsley Park site, Bowden Village, Lot Fourteen (the former Royal Adelaide Hospital), and the Adelaide Festival Square redevelopment site.

dsquared is a Certified Carbon Neutral company and appointed in 2019 as Carbon Neutral Adelaide Ambassadors.

2 Site Information

2.1 Location

The SAP is located within the South East and Tablelands planning region of New South Wales and the ACT and forms a part of the ACT and NSW Alpine region (Figure 6).

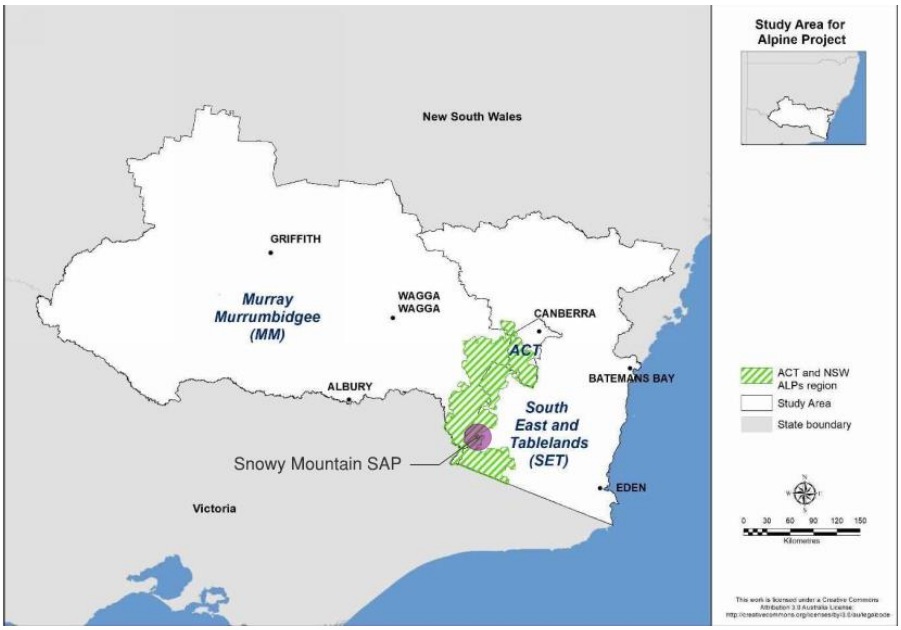


Figure 6: South East and Tablelands (SET) planning region Source: DPE

Centred on the Jindabyne township, the Snowy Mountains SAP investigation area covers approximately 722 square kilometres of diverse alpine and sub-alpine terrain, partially including the Kosciuszko National Park, and several developable areas, as shown in Figure 7. The final Master Plan will differ to the below investigation area.

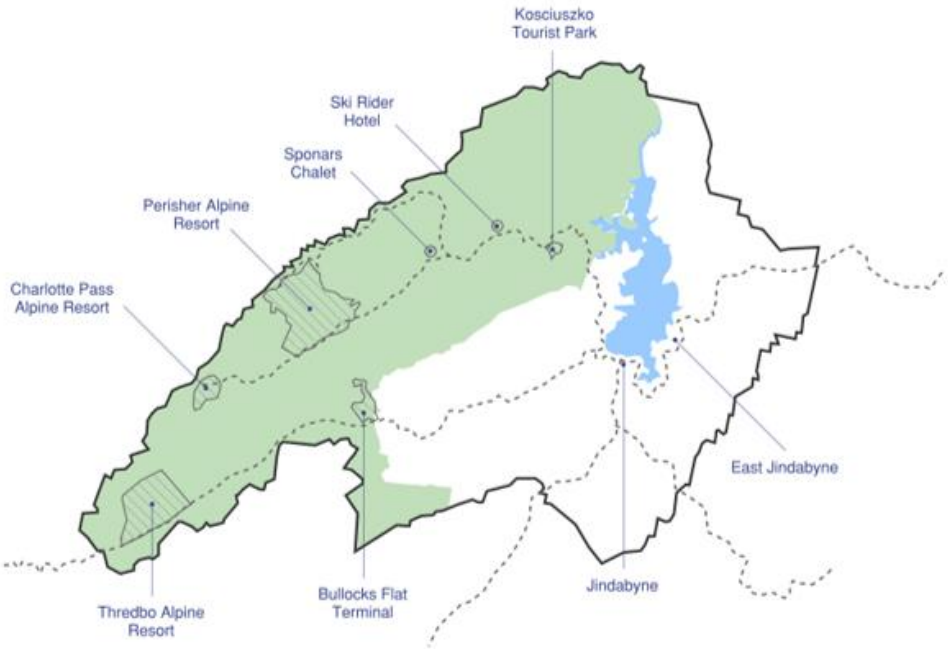


Figure 7: Snowy Mountains SAP Investigation Area. Source: dsquared

For the purposes of conducting the risk assessment, and to adequately recognise the diversity of risks and risk impacts, the SAP has been broken down into two zones:

- **Zone 1:** broadly defined as "Sub-Alpine" encompassing the Jindabyne township and surrounds (Figure 8); and
- **Zone 2:** broadly defined as "Alpine" encompassing the ski resorts and the Kosciuszko National Park (Figure 9).

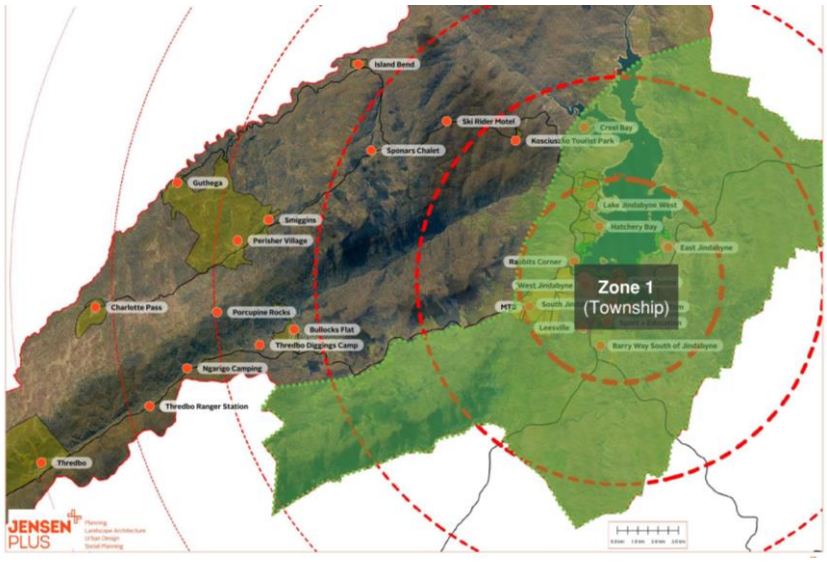


Figure 8: Zone 1 – Sub-Alpine, Jindabyne township and surrounds. Source: Jensen Plus

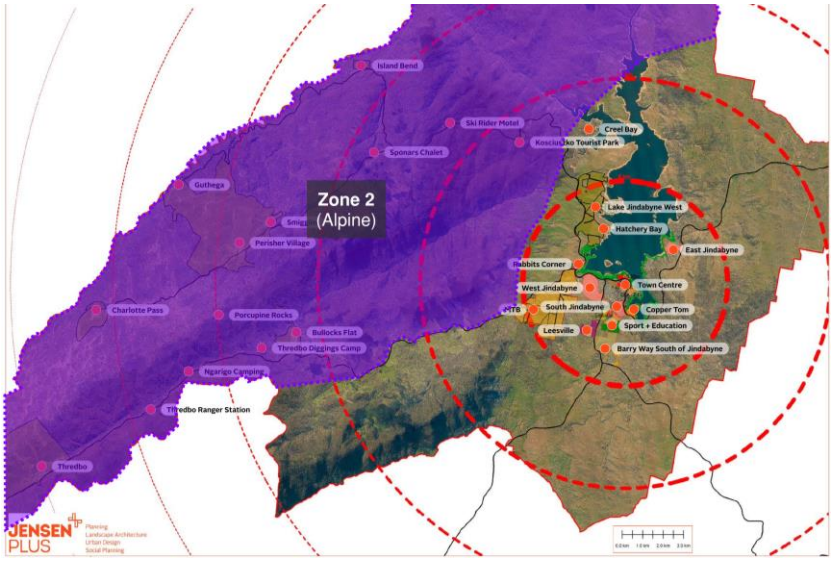


Figure 9: Zone 2 – Alpine, Ski resorts and Kosciuszko National Park. Source: Jensen Plus

It is recognised that the broad definitions are imperfect as the southern portion of Zone 2 is in fact sub-alpine, but the developable areas and predominant climate change impacts are more closely related to the Alpine region than the township.

To obtain the most relevant data for future climate change projections, the investigated area has been identified to form parts of the following climate regions/ clusters:

- NARCliM South East and Tablelands region
- CSIRO cluster Southern Slopes and sub-cluster Victoria East

As both, SET region and Southern Slopes (Vic East) cluster, cover a very large and diverse topographic area, the assessment is prioritising the sources of obtained climate change projection data as follows:

- Climate change projections for Alpine region – Data set *Climate change impacts in the NSW and ACT Alpine region* by DPE (high preference)
- Climate change projections for Jindabyne township – Data set *Climate change impacts in the NSW and ACT Alpine region* by DPE (high preference) and NARCliM data *South East and Tablelands* by AdaptNSW (medium preference)
- Climate change projections for the Alpine region and the Jindabyne township to support above-mentioned sources or to cover risks that are relevant but not covered – Data set Climate Change Projections – Southern Slopes (Vic East) by CSIRO (medium to low preference).

2.1.1 South East and Tablelands

The South East and Tablelands (SET) climate region extends from the Southern Highlands and Tablelands in the north along the coastline from Durras Lake near Batemans Bay to the Victorian border in the south (refer Figure 10). It encompasses Australia's highest summits and the headwaters of the Snowy, Murray, Murrumbidgee, and Lachlan rivers.

Figure 10: Snowy Mountain SAP location in context; SET Region. Source: OEH (edited)

The South East and Tablelands Region is one of twelve climate regions defined by the NSW and ACT Regional Climate Model (NARCliM) to provide high resolution climate change projections and assist with strategic planning initiatives across NSW.

The 12 models under the IPCC high emission scenario (RCP8.5) run by NARCliM have produced datasets for three time periods, whereby the modelled data for the period from 1990 to 2009 serves as baseline for climate change projections for the near future (2020 to 2039) and far future (2060 to 2079). The datasets for the most commonly used variables are available via the Adapt NSW website.

In addition, detailed Climate change impact reports for the NSW and ACT Alpine region have bene developed by DPE which have been used extensively to inform the climate risk assessment undertaken for the alpine areas.

2.1.2 Southern Slopes (Vic East)

The Snowy Mountain SAP is also located in the CSIRO Climate Change sub-cluster defined as "Southern Slopes (Vic East)". Within the 'midlatitudes' of the global climate system, falling between the subtropical ridge of high pressure (at about 30 °S) and the so called 'Roaring Forties' (at 40-50 °S).

Rainfall in the region is caused by various weather systems, predominately by cold fronts and troughs from the west as well as cut-off lows and other systems.

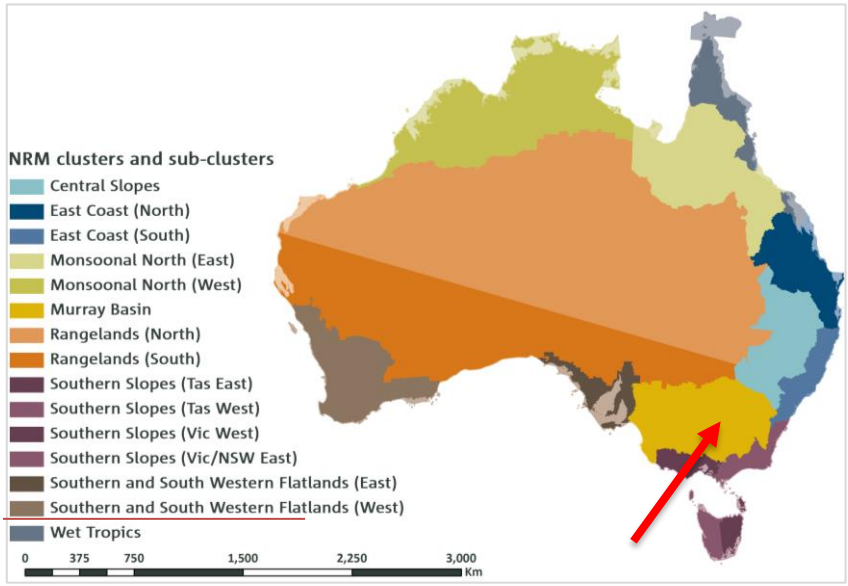


Figure 11: CSIRO Climate Change Regions Map. Source: CCIA Technical Report 2015

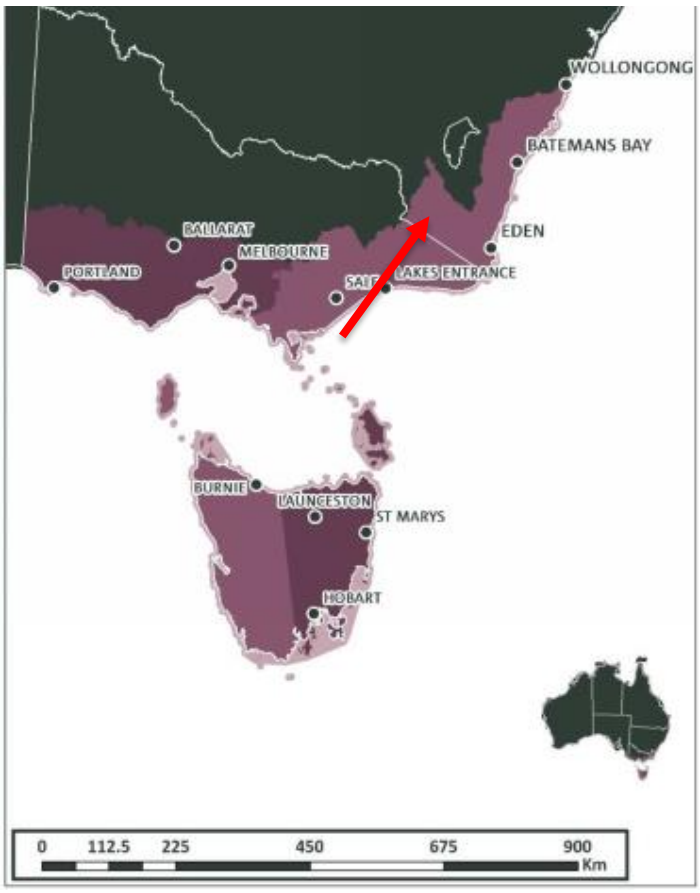


Figure 12: CSIRO Climate Change Regions Map – Southern Slopes. Source: CSIRO

2.2 Climate

There are a number of Bureau of Meteorology (BOM) weather stations within the SAP boundary, at the ski resorts and in the Jindabyne area. However, historical weather data for the investigated region is only available for the Thredbo and Perisher stations and thus, Thredbo (#071041) data was chosen to represent the local climate for the alpine region.

To represent the climate for Jindabyne township, weather data from the Cooma Airport station (#070217) was obtained. Although Cooma Airport is not part of the SAP, its close proximity to the Jindabyne township (27km away) and a similar altitude (Jindabyne 915 metres, Cooma 930 metres), climate conditions are assumed to be similar at both locations.

2.2.1 Thredbo – Alpine climate

The climate at Thredbo is typical of the Snowy Mountains alpine region, with cold snowy winters and mild summers. Monthly rainfall in summer averages between 88mm to 122mm and between 159mm and 192mm in Winter (Figure 13).

Mean temperatures in Thredbo range from a high of 21.6°C in January to a low of 5.5°C in July (1969-2021).

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years		Plot	Map
Temperature																	
Mean maximum temperature (°C)	21.6	21.0	18.2	14.0	10.0	6.6	5.5	6.6	9.9	13.5	16.6	19.4	13.6	47	1969 2021		
Mean minimum temperature (°C)	7.5	7.0	4.8	1.7	-0.5	-2.4	-3.6	-2.5	-0.4	1.8	3.9	5.5	1.9	46	1969 2021		
Rainfall																	
Mean rainfall (mm)	110.6	88.3	118.3	112.3	153.8	159.3	166.8	192.2	202.8	180.9	161.0	122.0	1774.7	31	1969 2021		
Decile 5 (median) rainfall (mm)	101.0	80.8	109.2	97.2	141.7	151.8	149.4	182.5	205.2	168.9	146.1	122.9	1775.0	47	1969 2021		
Mean number of days of rain ≥ 1 mm	8.9	8.4	8.8	9.0	10.8	12.3	13.2	14.0	13.7	11.9	11.2	9.2	131.4	47	1971 2021		
Other daily elements																	
Mean daily sunshine (hours)																	
Mean number of clear days	10.0	8.6	9.6	9.0	7.6	6.8	8.2	8.2	7.0	6.2	6.5	8.6	96.3	38	1969 2010		
Mean number of cloudy days	8.8	8.6	8.6	10.5	13.2	12.0	12.2	12.6	11.6	10.7	11.0	9.8	129.6	38	1969 2010		
9 am conditions																	
Mean 9am temperature (°C)	14.3	13.5	11.5	8.6	4.5	1.4	0.2	2.1	5.6	8.8	11.0	13.3	7.9	37	1969 2017		
Mean 9am relative humidity (%)	65	73	73	71	77	83	84	76	66	60	64	62	71	21	1973 2017		
Mean 9am wind speed (km/h)	6.2	4.5	5.5	6.1	6.2	6.5	7.0	7.7	8.4	9.2	7.6	7.5	6.9	35	1969 2017		
9am wind speed vs direction plot																	
3 pm conditions																	
Mean 3pm temperature (°C)	19.7	19.5	16.7	12.3	8.0	4.5	3.1	4.6	8.0	11.2	14.8	17.4	11.6	37	1969 2010		
Mean 3pm relative humidity (%)	50	54	57	61	67	73	75	69	62	55	56	52	61	21	1973 2010		
Mean 3pm wind speed (km/h)	9.7	8.6	8.6	8.1	8.3	7.5	8.0	8.2	8.8	9.0	9.2	9.9	8.7	34	1969 2010		
3pm wind speed vs direction plot																	

red = highest value blue = lowest value

Figure 13: Climate data summary, Thredbo Village. Source: BOM

2.2.2 Cooma Airport – Township climate

Cooma airport is at a lower evaluation than Thredbo and as a result, has a higher average temperature and lower annual rainfall. Summers are typically mild with average rainfall between 49mm to 52mm. Winters are cool and have a lower average rainfall averaging between 30mm and 39mm per month (Figure 14).

Mean temperatures in Cooma range from a high of 26.7°C in January to a low of 10.3°C in July (1991-2021).

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years		Plot	Map
Temperature																	
Mean maximum temperature (°C)	26.7	25.0	22.3	18.2	14.2	10.7	10.3	11.9	15.1	18.4	21.4	24.2	18.2	29	1991 2021		
Mean minimum temperature (°C)	10.9	10.3	7.7	3.8	0.6	-1.1	-2.0	-1.5	1.1	3.6	6.6	8.7	4.1	29	1991 2021		
Rainfall																	
Mean rainfall (mm)	52.2	49.8	49.5	38.5	28.9	39.9	30.1	31.3	36.0	44.9	66.3	52.9	529.5	31	1982 2021		
Decile 5 (median) rainfall (mm)	38.0	31.1	36.6	23.0	21.2	23.0	18.4	26.8	32.7	36.6	58.5	45.4	521.6	34	1982 2021		
Mean number of days of rain ≥ 1 mm	5.7	5.7	5.4	4.9	4.8	5.1	5.1	4.7	6.0	6.7	7.3	6.4	67.8	33	1982 2021		
Other daily elements																	
Mean daily sunshine (hours)																	
Mean number of clear days														3	2005 2010		
Mean number of cloudy days														3	2005 2010		
9 am conditions																	
Mean 9am temperature (°C)	17.1	15.6	13.1	10.5	7.0	4.3	3.5	5.3	8.9	11.8	13.6	15.8	10.5	19	1991 2010		
Mean 9am relative humidity (%)	69	78	80	78	83	85	82	75	68	64	68	66	75	19	1991 2010		
Mean 9am wind speed (km/h)	16.0	14.7	13.3	14.3	12.7	13.2	13.1	15.7	18.1	18.3	17.1	16.4	15.2	19	1991 2010		
9am wind speed vs direction plot																	
3 pm conditions																	
Mean 3pm temperature (°C)	24.7	23.7	21.1	16.9	13.0	9.7	9.0	10.7	13.5	16.5	19.5	22.4	16.7	19	1991 2010		
Mean 3pm relative humidity (%)	39	43	43	46	54	60	57	48	46	43	43	39	47	19	1991 2010		
Mean 3pm wind speed (km/h)	20.3	19.5	18.2	17.6	17.1	18.3	19.2	20.6	22.2	21.7	21.3	20.7	19.7	19	1991 2010		
3pm wind speed vs direction plot																	

red = highest value blue = lowest value

Figure 14: Climate data summary, Cooma Airport. Source: BOM

3 Climate Change Scenarios

3.1 Introduction

The following is a summary of Climate Change Scenarios and projections identified. These will be used as the basis for the identification of climate change impacts, and the associated risk assessment.

The SAP area covers a large area and encompasses alpine and sub-alpine regions, and as such the climate change projections vary dependent upon the region and the developable area being considered.

Where the climate projections vary significantly between both zones, they are explained separately to assist when considering climate risks, impacts and adaptation strategies.

3.2 Carbon dioxide

Source: adapted from CSIRO Climate Change In Australia (2015) Technical Report, CSIRO State of the Climate 2018, and DEW Guide to Climate Projections November 2020.

Atmospheric carbon dioxide concentrations will continue to rise from a 2020 baseline of 400ppm, reaching 540ppm by 2090 in the RCP4.5 scenario, 660ppm by 2070, and 940ppm by 2090 in the RCP8.5 scenario (Figure 15).

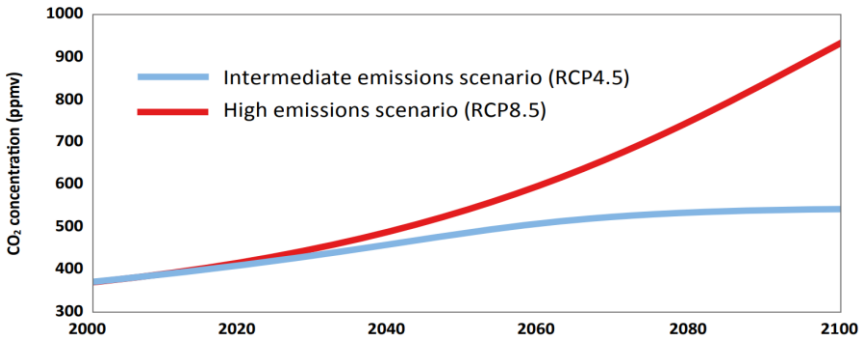


Figure 15: Atmospheric carbon dioxide levels for RCP4.5 and RCP8.5

The World Health Organisation (WHO), the International WELL Building Institute (IWBI), and the Green Building Council of Australia recommend that internal building carbon dioxide concentrations are limited to a maximum of 700ppm if a high cognitive function is to be expected from the occupants. The WHO advises that human health risk is expected where exposed to CO_2 levels of higher than 1,000 ppm for prolonged periods.

3.3 Temperature

Source: Climate change impacts in the NSW and ACT Alpine region, Adapt NSW, CSIRO Projections for Australia's NRM regions – Southern Slopes (Vic East), CSIRO Climate Change In Australia (2015) Technical Report, and CSIRO Projections Tools.

The following projections are mainly sourced from the Climate change impacts in the NSW and ACT Alpine region published by the NSW Department of Planning and Environment (DPE). The investigated area includes the NARCliM Murray Murrumbidgee region to the west, South East and Tablelands (SET) to the east and the ACT. However, this assessment focuses on results relevant for the SAP.

It should be noted that under the NARCliM projections are based on the SRES A2 scenario from the IPCC's third and fourth assessment reports. Under these projections, a 0.7 degree temperature increase has been projected for the near future scenario, however average temperature increases of 1.0 degrees have already been experienced. As a result, may of the below projections have already been met or exceeded.

3.3.1 Maximum temperature (Baseline, 1990 to 2009)

For the baseline period from 1990 to 2009, the mean maximum temperature in the SAP ranged from below 10°C in parts of the Alpine region and 15°C in the Jindabyne township (Figure 16) with seasonal variations as shown in Figure 17.

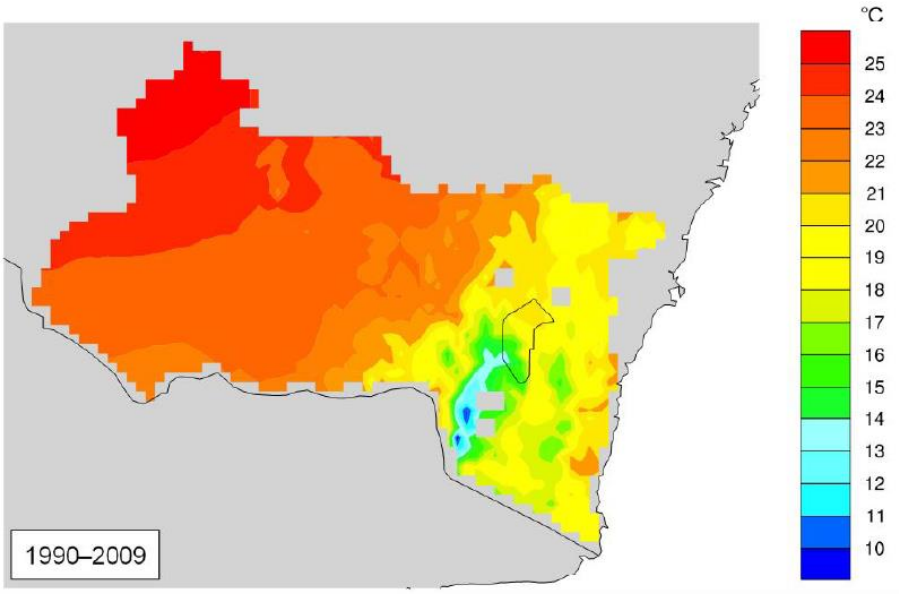


Figure 16: Mean annual maximum temperature for 1990 to 2009. Source: DPE

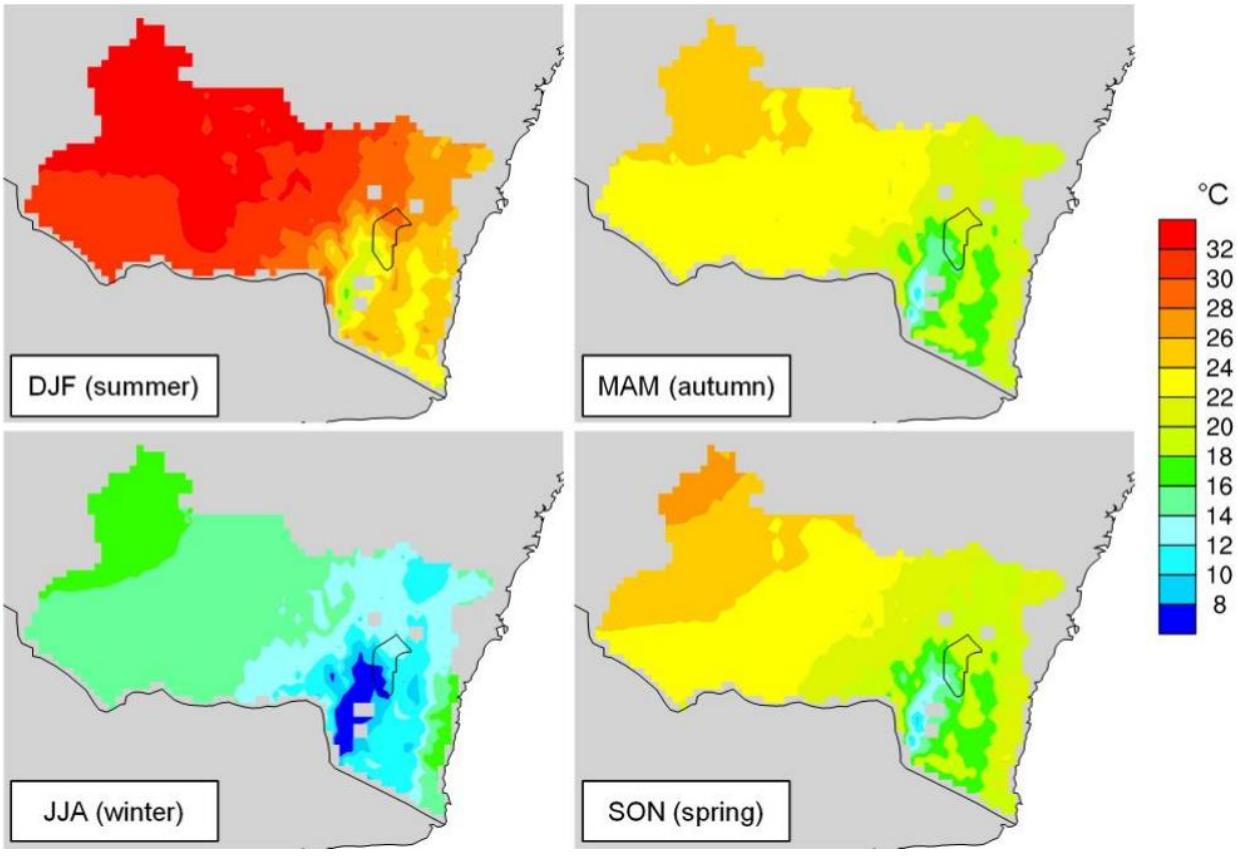


Figure 17: Mean seasonal maximum temperature for 1990 to 2009. Source: DPE

3.3.2 Maximum temperature (Near future, 2020 to 2039)

Changes in annual maximum temperature in the near future are expected to be small with an increase of 0.5-0.75°C for most of the area (including Jindabyne township) with some exceptions for the Alpine region where an increase between 0.75-1.0°C is projected due to the lower temperatures in the alpine region being impacted to a higher degree (Figure 18).

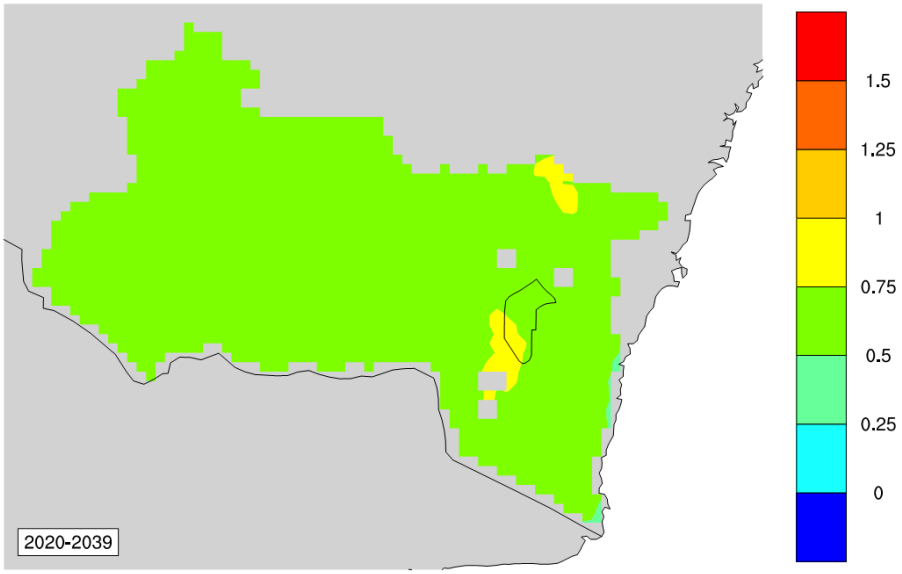


Figure 18: Projected changes in mean annual maximum temperature for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Seasonal increases in maximum temperature are more pronounced in spring and summer across the region with a 0.75-1.0°C increase. The Jindabyne region could experience an even higher increase of 1.25°C in summer. Increase in maximum temperatures in winter are expected to be less than 0.5°C except in the Alpine zone where winter maximum temperatures projected to increase by 0.5-0.75°C (Figure 19).

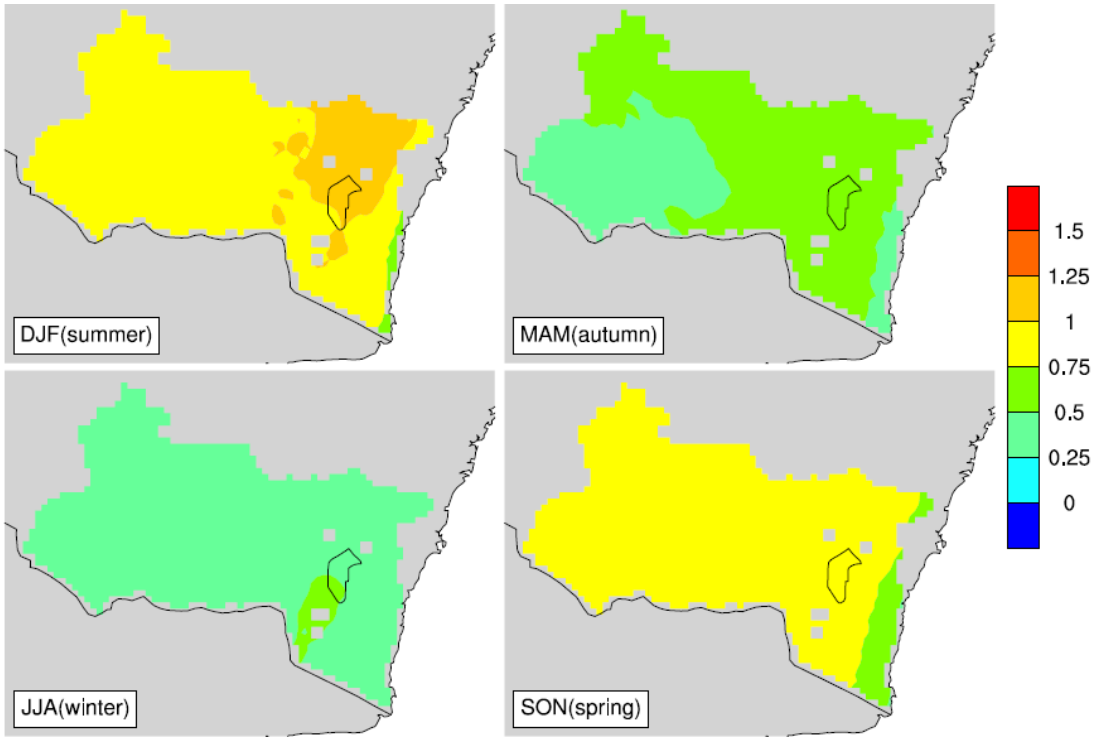


Figure 19: Change in mean seasonal maximum temperature for 2020 to 2039 relative to 1990 to 2009. Source: DPE

3.3.3 Maximum temperature (Far future, 2060 to 2079)

For the far future, changes in annual maximum temperature are more significant when compared to near future changes, with an increase of 2.25-2.5°C for the entire SAP (Figure 20). The differences in temperature change is due to varying altitudes and local climate conditions.

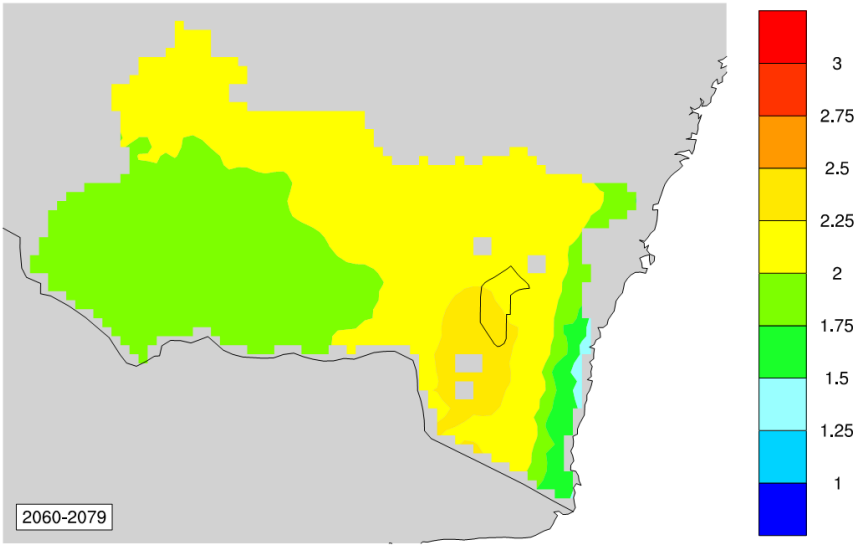


Figure 20: Projected changes in mean annual maximum temperature from 2060 to 2079 relative to 1990 to 2009. Source: DPE

Seasonal increases in mean maximum temperatures are more pronounced in spring and summer across the SAP. Projected changes for the Jindabyne region range from a 2.0-2.5°C in autumn and winter 3.0°C in summer and spring. Except from winter, seasonal changes in maximum temperature for some of the SAP's Alpine regions are expected to be around 0.5°C below the projections for the Jindabyne township. Changes in winter are expected to be the same across the SAP (Figure 21).

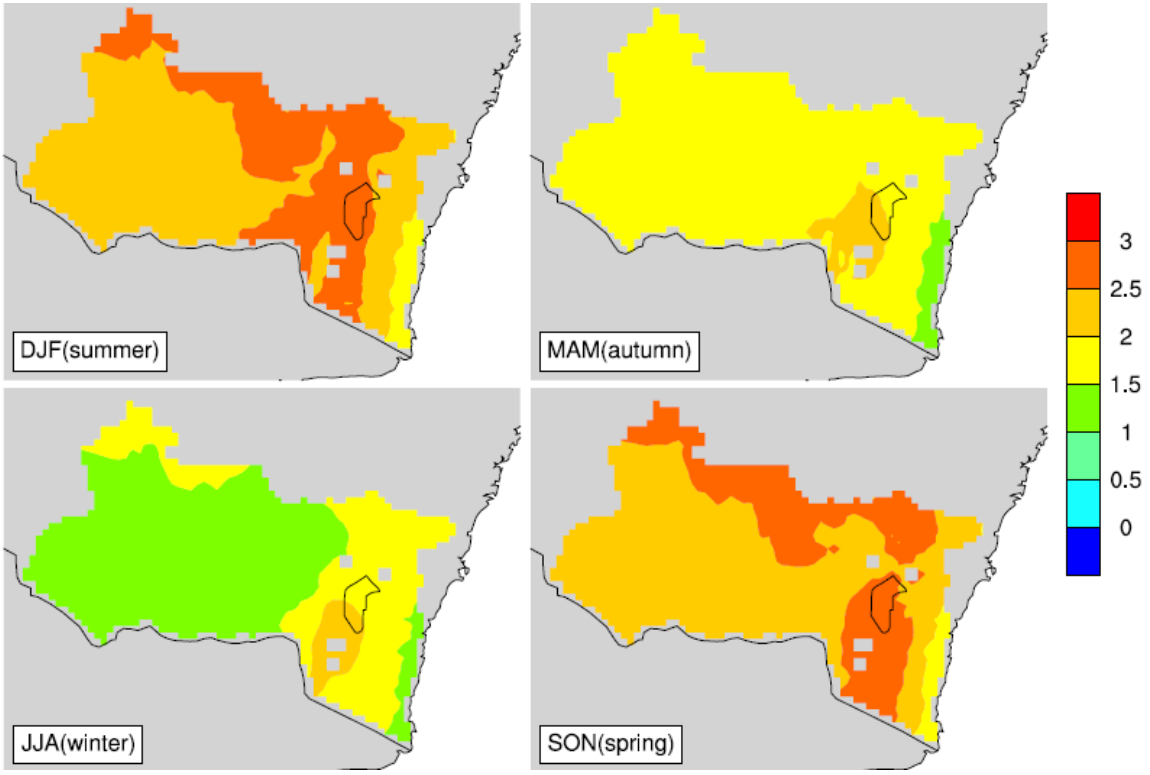


Figure 21: Projected changes in mean seasonal maximum temperature for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.3.4 Hot Days (maximum temperature above 35°C)

The annual number of hot days during the 1990 to 2009 period is below 5 across the SAP (Figure 22).

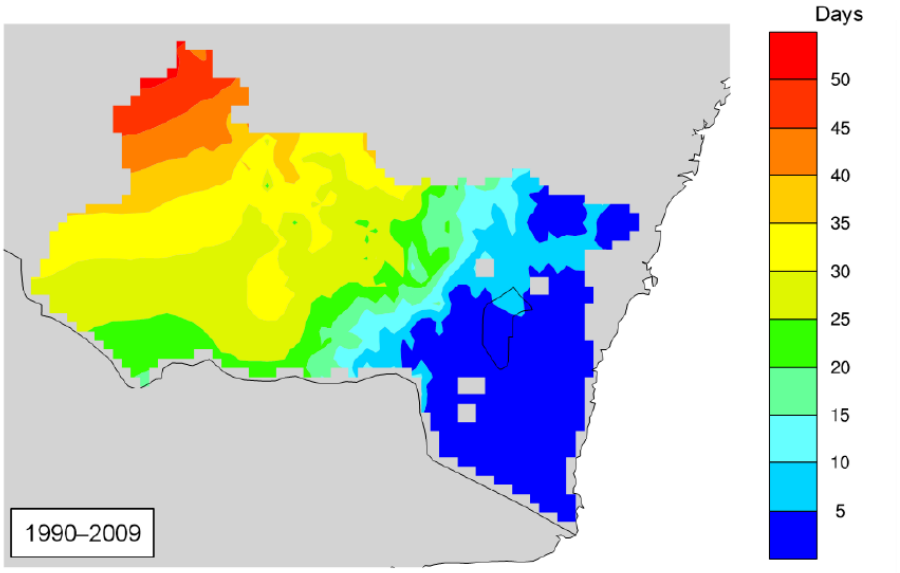


Figure 22: Mean annual number of hot days for 1990 to 2009. Source: DPE

As Figure 23 shows, there are no reported instances for the cold season (JJA) where the maximum temperature of 35°C was exceeded across the entire study area.

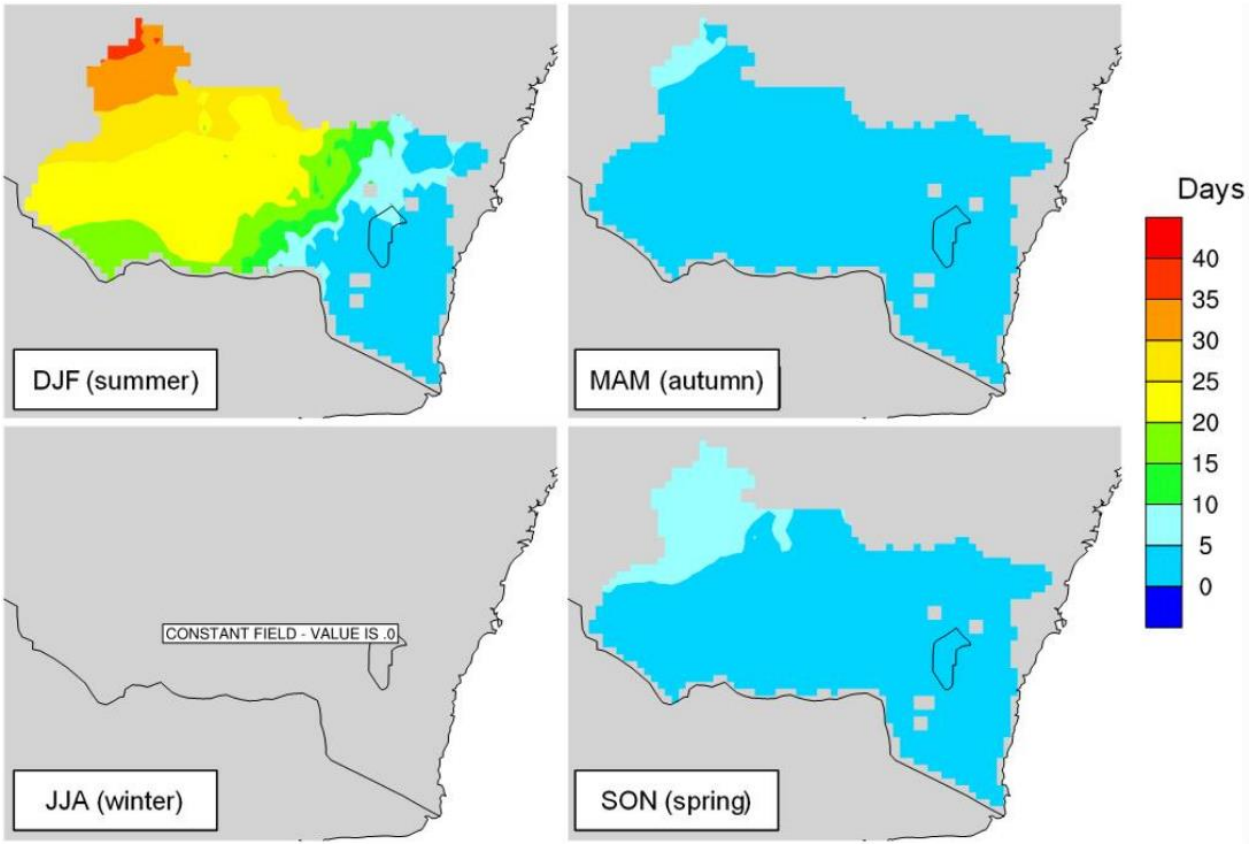


Figure 23: Mean seasonal number of hot days for 1990 to 2009. Source: DPE

The near future projections show an only slight increase in number of hot days relative to the baseline period with the change in number of annual hot days to be below 1 for most of the SAP and maximum 2 in some of the lower-lying areas (Figure 24).

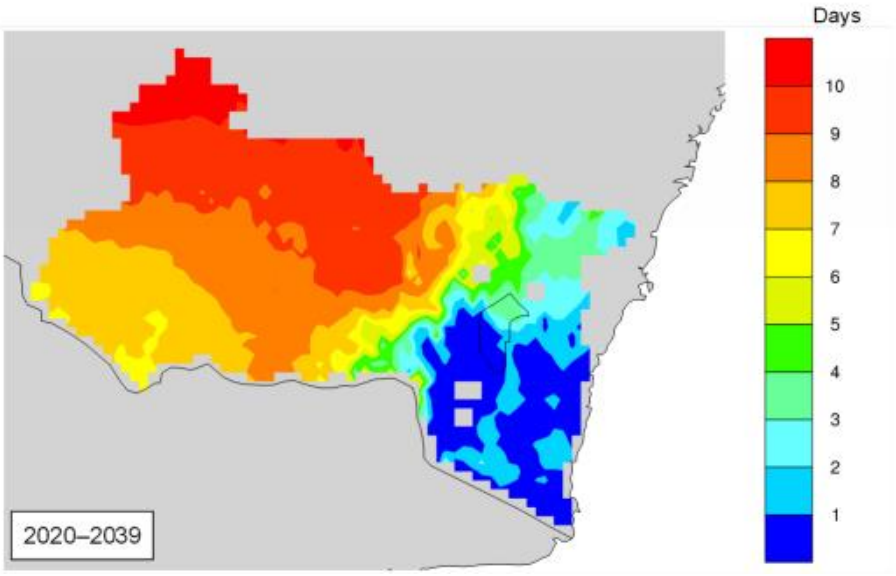


Figure 24: Projected changes in annual hot days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Seasonal increases in hot days are projected to be on average below 1 for the entire SAP in all seasons. During summer the number could increase of 2 days in the Jindabyne area and surrounds while during autumn the average number is projected to increase to zero for some of the Alpine region. No changes are expected in the near future for the winter.

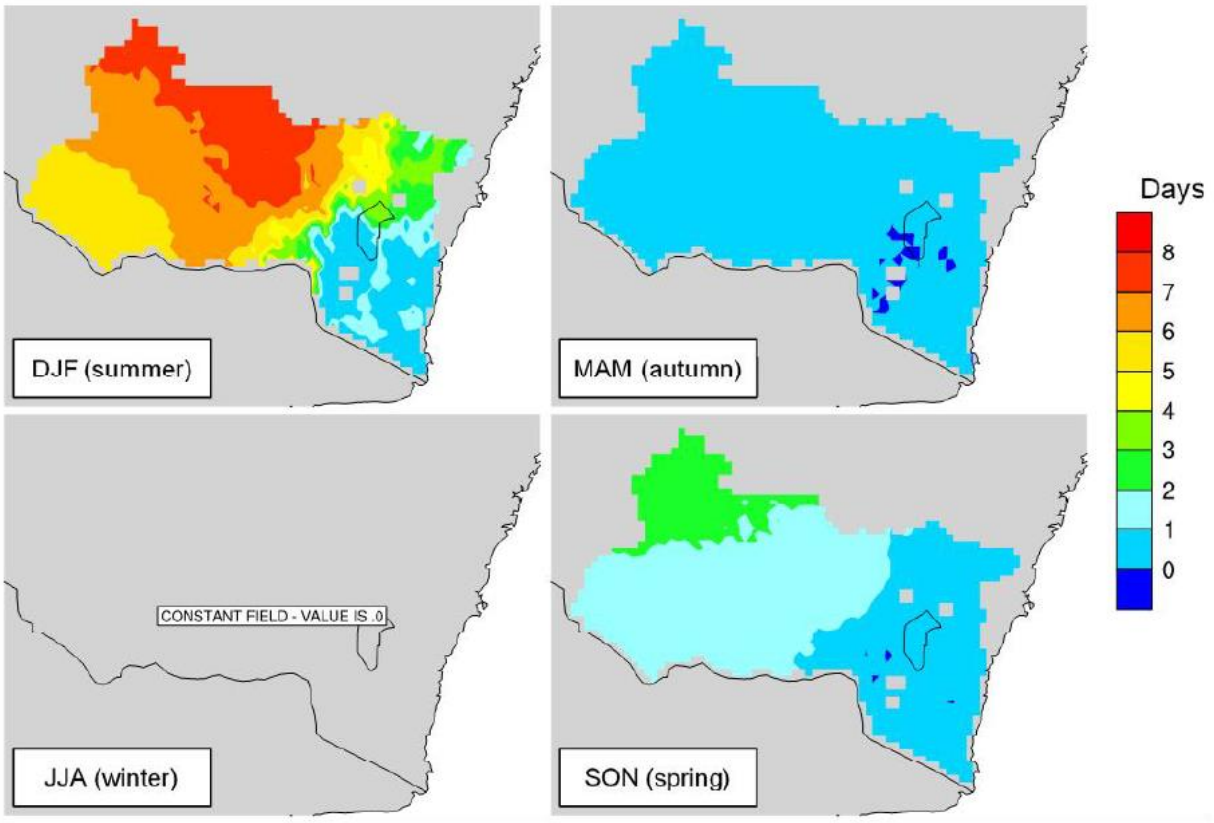


Figure 25: Projected changes in seasonal hot days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

For the far future (2060-2079), the number of hot days is expected to further increase in all seasons and to be annually between 0 and 4 days across the entire SAP (Figure 26).

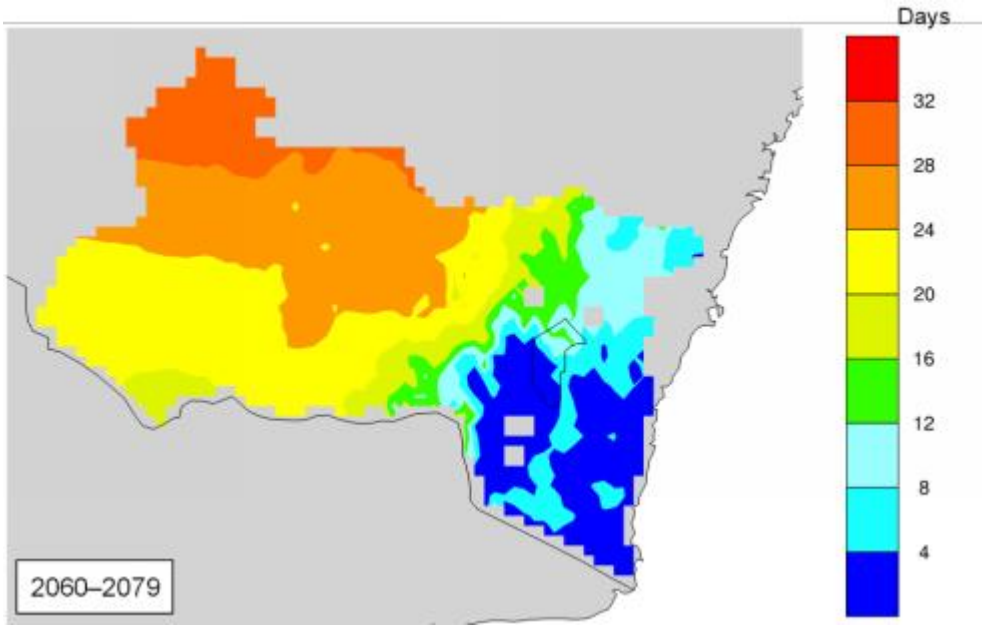


Figure 26: Projected changes in annual hot days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

As the seasonal projections (Figure 27) show, the number of hot days is expected to increase 2 days in all seasons for SAP with an additional increase of 2 days for summers in the Jindabyne township and surrounds.

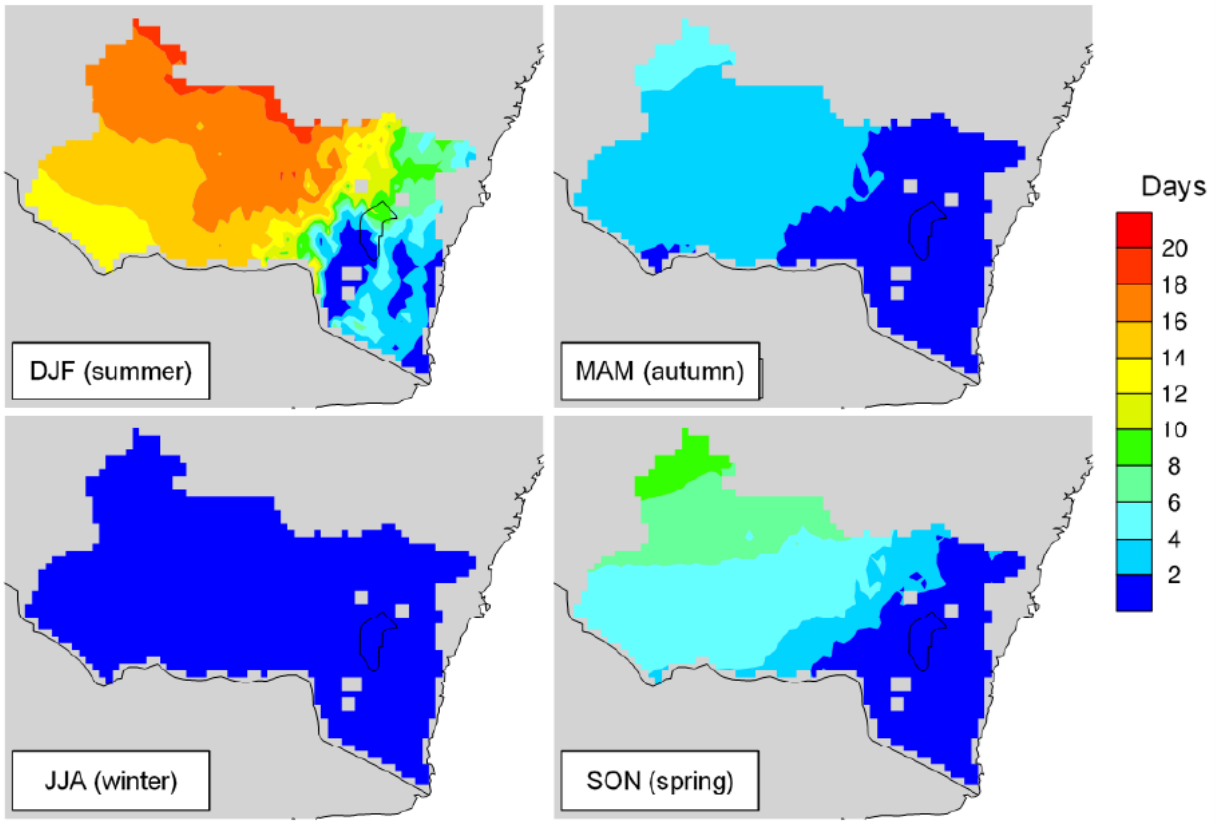


Figure 27: Projected changes in seasonal hot days for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.3.5 Minimum temperature (Baseline, 1990 to 2009)

Mean annual minimum temperature in both the Alpine Zone and Jindabyne township and surrounds is less than 4°C (Figure 28).

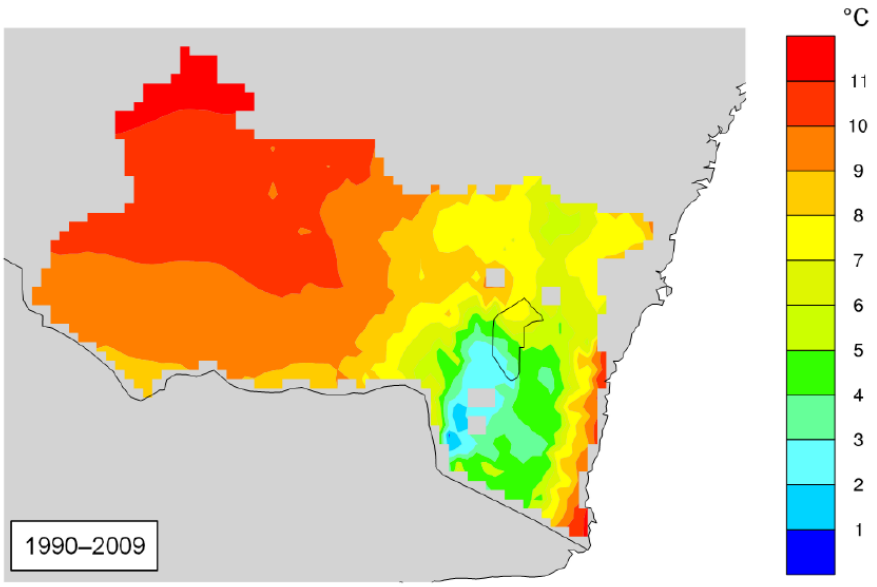


Figure 28: Mean annual minimum temperature for 1990 to 2009

There is a clear seasonal variation in minimum temperature with minimum temperatures ranging from below minus 2°C for the Alpine region in winter and 8°C for the Jindabyne township and surrounds in summer.

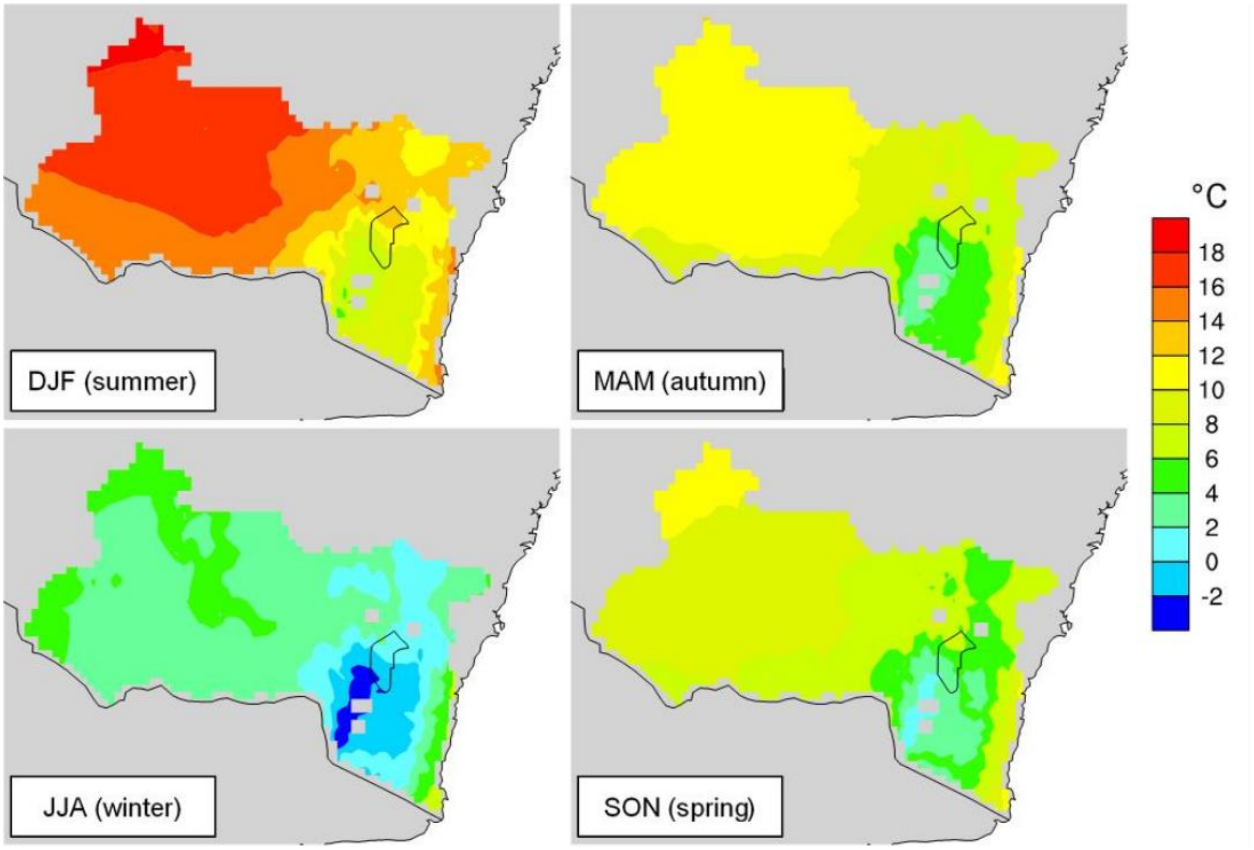


Figure 29: Mean seasonal minimum temperature for 1990 to 2009. Source: DPE

3.3.6 Minimum temperature (Near future, 2020 to 2039)

The change in minimum temperature for the near future for both the Alpine Zone and Jindabyne township and surrounds is projected to increase by 0.5-0.75°C (Figure 30).

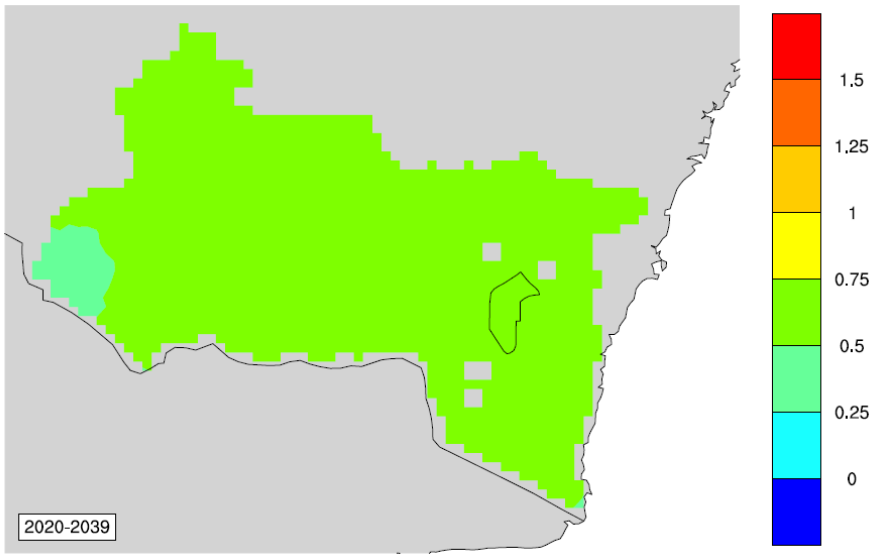


Figure 30: Projected changes in mean annual minimum temperature for 2020 to 2039 relative to 1990 to 2009. Source: DPE

The minimum temperature is expected to increase for all seasons in the SAP with 1°C in summer and 0.5°C in winter. Changes in autumn and spring are projected to be between 0.5 and 0.75°C (Figure 31).

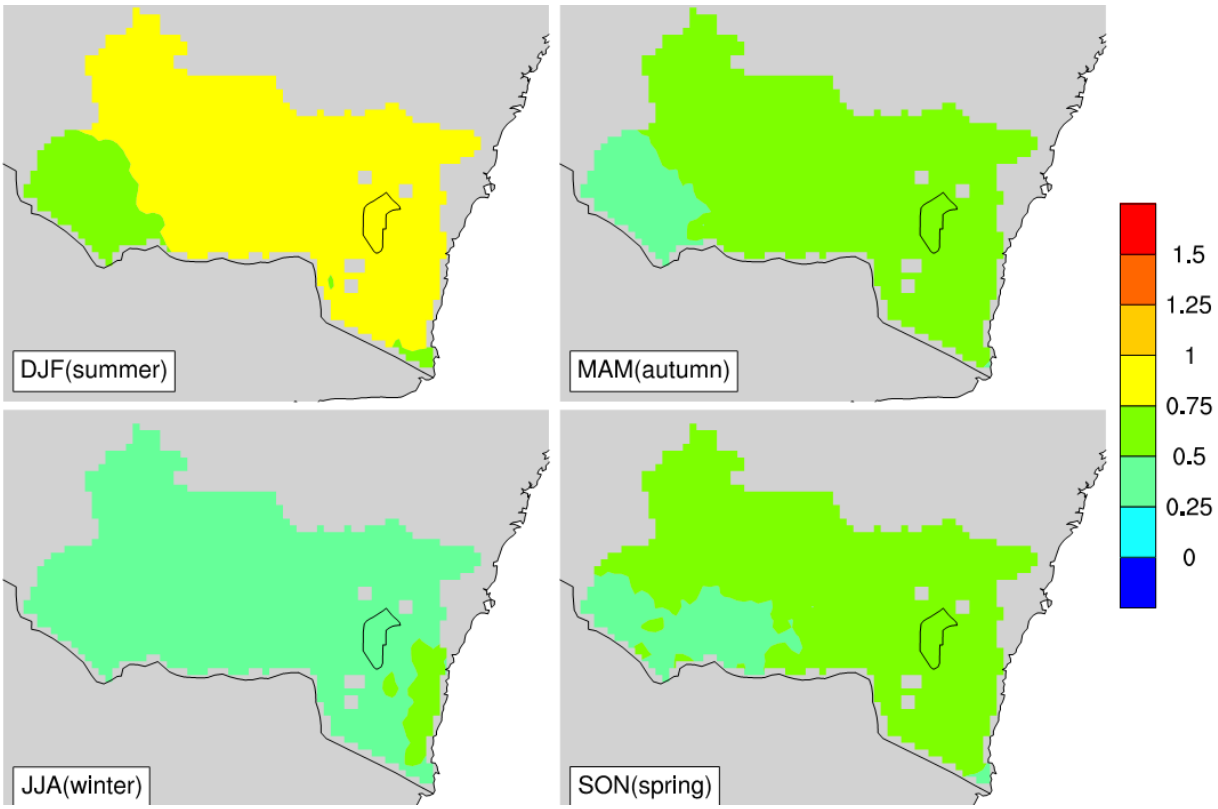


Figure 31: Projected changes in mean seasonal minimum temperature for 2020 to 2039 relative to 1990 to 2009. Source: DPE

3.3.7 Minimum temperature (Far future, 2060 to 2079)

In the far future, the minimum temperature is projected to increase by 1.5-2.0°C in the SAP's Alpine region and 2.5°C in the lower-lying areas, Jindabyne township and surrounds (Figure 32).

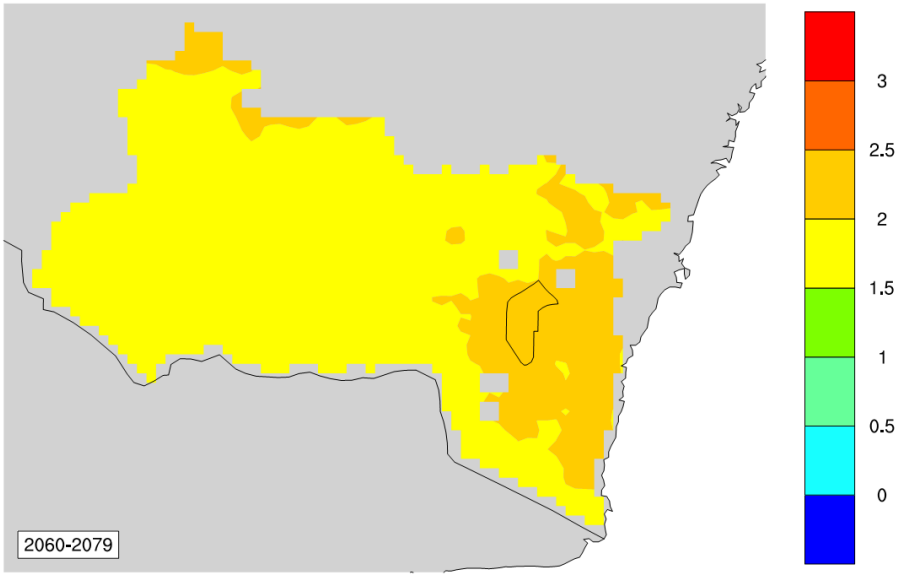


Figure 32: Projected changes in mean annual minimum temperature for 2060 to 2079 relative to 1990 to 2009. Source: DPE

For the SAP, increase in seasonal minimum temperature is projected to be the highest in summer in the order of 2.0-2.5°C and lowest in winter being between 1.5 to 2.0°C. Changes in autumn and spring are expected to be between 1.5 to 2.0°C in the Alpine region and 2.0-2.5°C in the Jindabyne area (Figure 33).

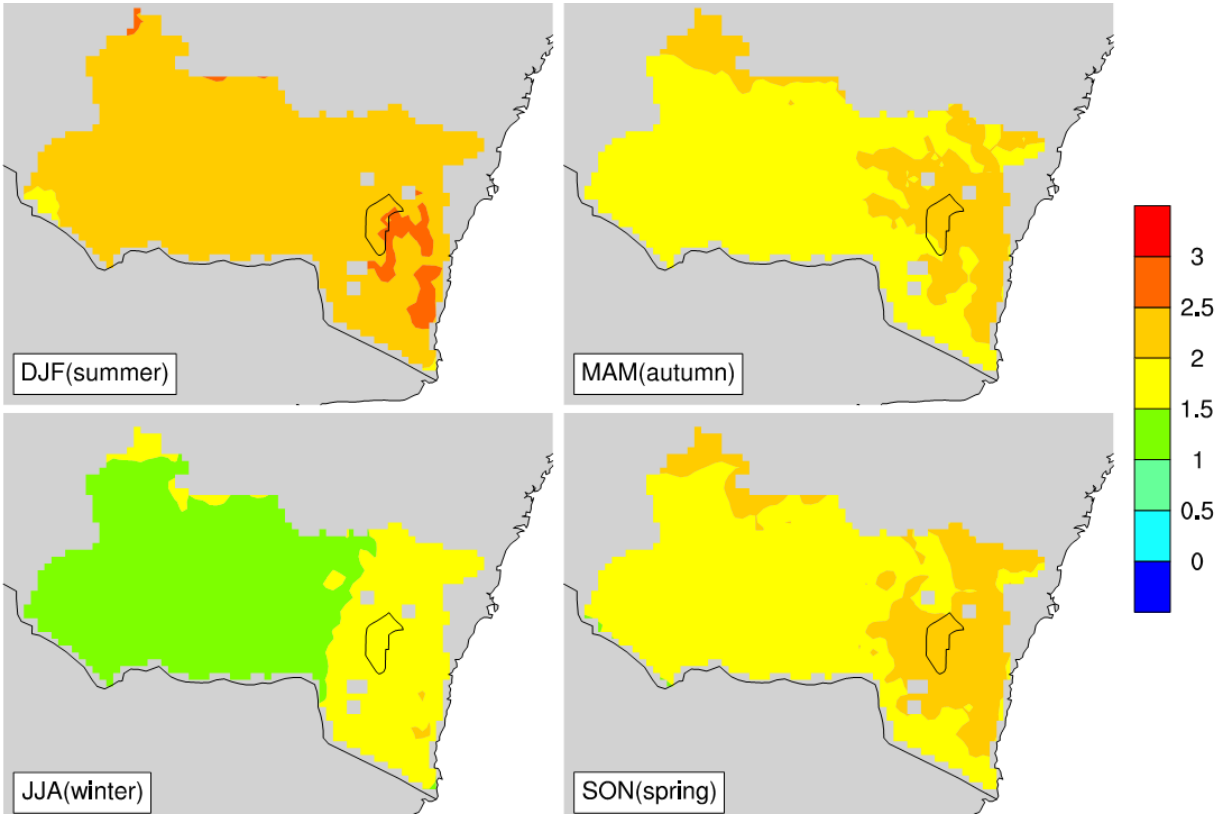


Figure 33: Projected changes in mean seasonal minimum temperature for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.3.8 Cold nights (minimum temperature below -2°C)

The annual number of cold nights is greater than 110 for some of the Alpine region and between 60 and 80 in the Jindabyne township and surrounds for the baseline period from 1990 to 2009 (Figure 34).

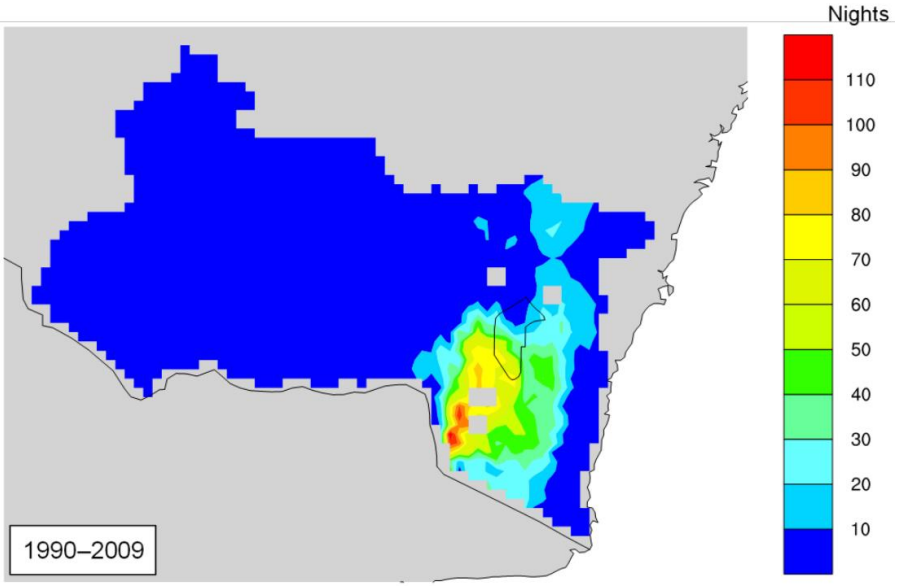


Figure 34: Mean annual cold nights for 1990 to 2009. Source: DPE

There are 70 cold nights in the Alpine region and 30 to 50 cold nights in the Jindabyne township area with 5 cold nights throughout the seasons. During summer there are 5 cold nights across the Alpine region and Jindabyne township, with more cold nights occurring for the Alpine region than for the township in autumn and spring. In autumn 20 cold nights can be experienced in the Alpine and 10 nights in the Jindabyne region, and 30 nights in the Alpine region and 20 nights in Jindabyne during spring (Figure 35).

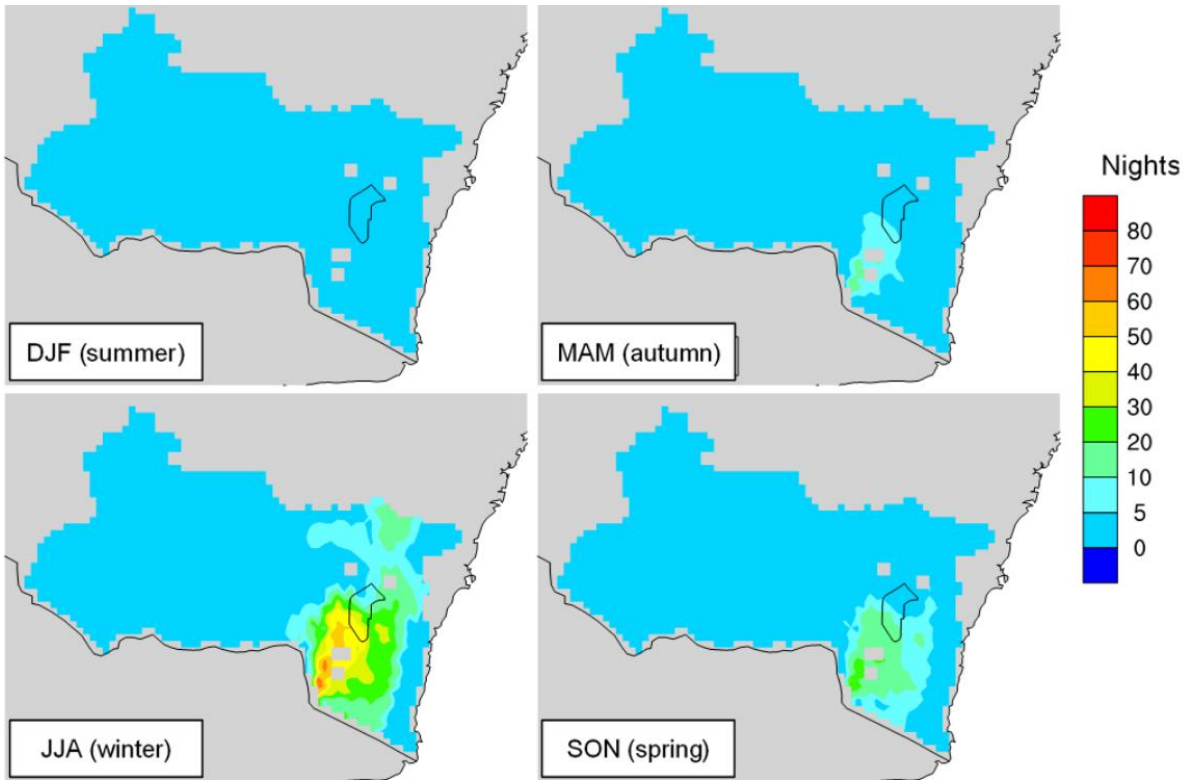


Figure 35: Mean seasonal cold nights for 1990 to 2009. Source: DPE

In the near future (2020-2039) fewer cold nights are expected in the area with the largest decrease projected for the Alpine region with a decrease of 13 nights a year in some parts of the region. An annual decrease of 10-12 nights is projected for the Jindabyne township and surrounds (Figure 36).

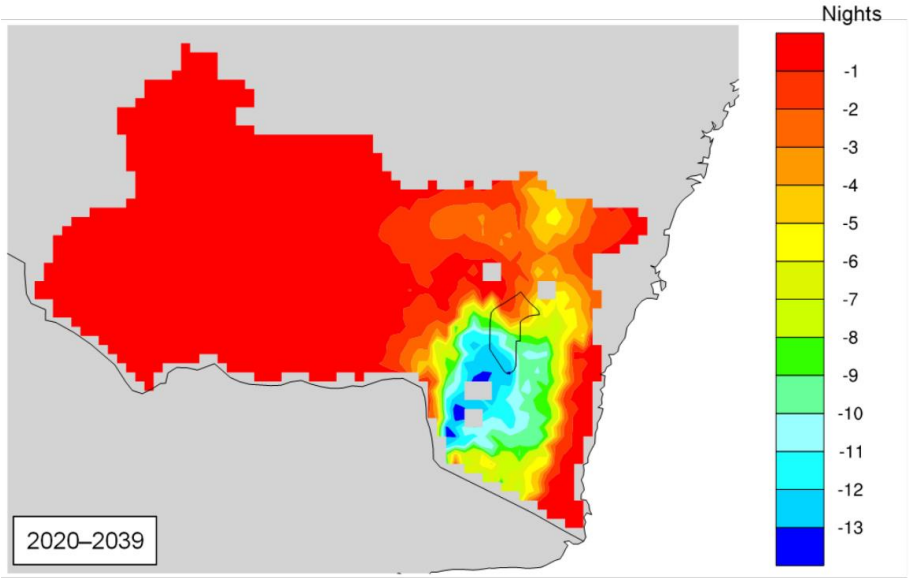


Figure 36: Projected changes in annual cold nights for 2020 to 2039 relative to 1990 to 2009. Source: DPE

The reduction in cold nights will mostly occur in winter and is reasonably consistent across the Alpine zone and Jindabyne township and surrounds. Compared with the 1990-2009 baseline, winter is projected to have 7 fewer cold nights and summer a reduction of 1 cold night. The Alpine region is expected to experience 4 fewer cold nights in autumn and between 3 to 4 in spring. Cold nights in Jindabyne and surround are projected to reduce by 2 to 3 in autumn and 3 to 4 in spring (Figure 36).

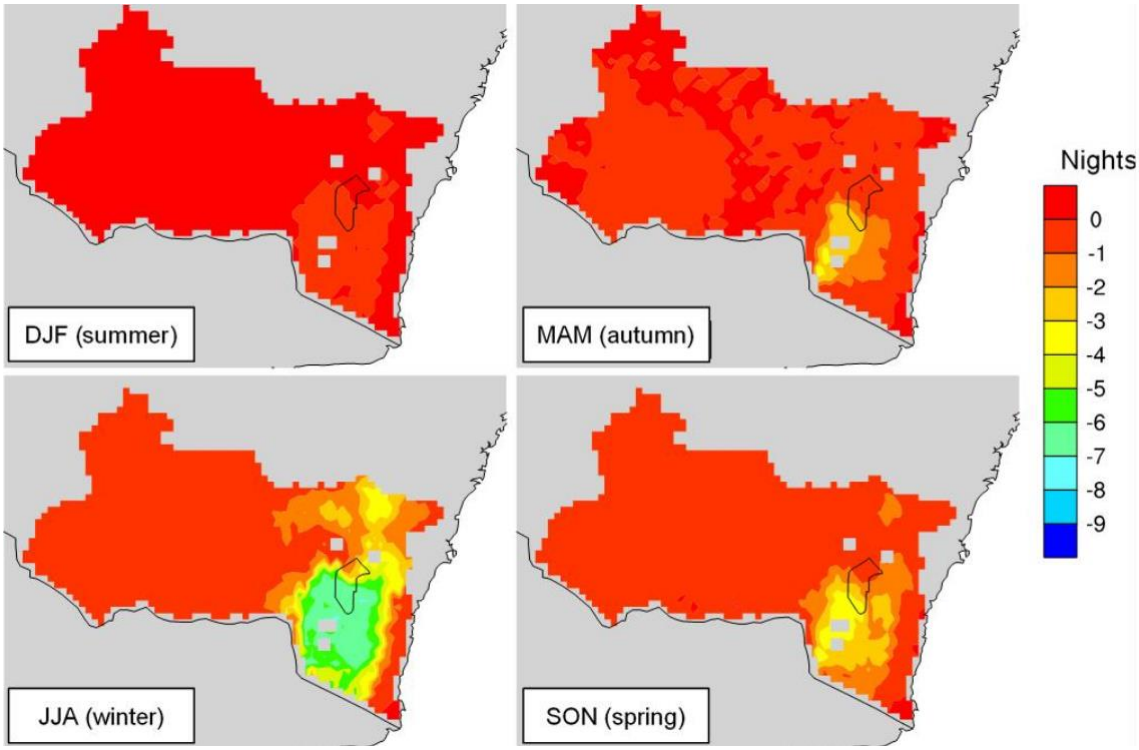


Figure 37: Changes in seasonal cold nights for 2020 to 2039 relative to 1990 to 2009

For the far future (2060-2079) changes in number of cold nights are more significant with more than 28 fewer cold nights in the Jindabyne and more than 44 in the Alpine region (on mountain peaks) a year.

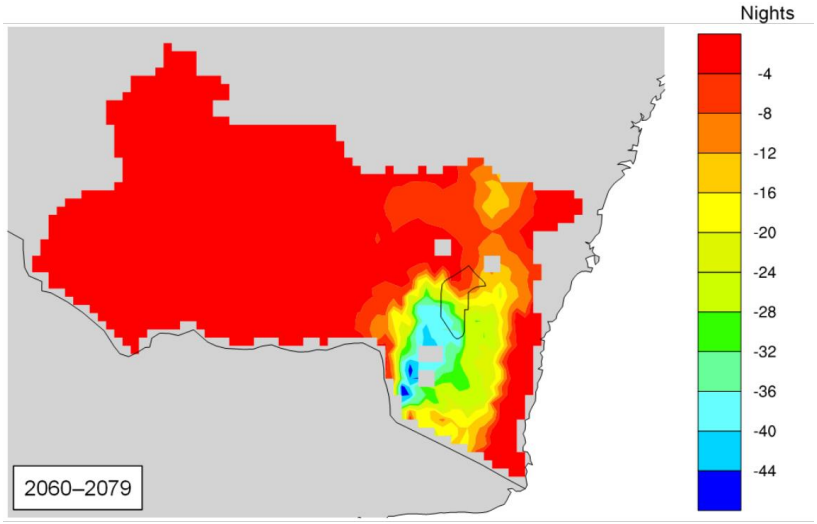


Figure 38: Projected changes in annual cold nights for 2060 to 2079 relative to 1990 to 2009. Source: DPE

The largest reduction across the SAP is expected to occur in winter and to a lesser extent in spring. In winter, the number of cold nights is expected to reduce by more than 20 for the Alpine region and 18 to 20 for the Jindabyne area and surrounds. In spring, 14 fewer cold nights are projected for the Alpine region and 6 to 10 for Jindabyne (Figure 39).

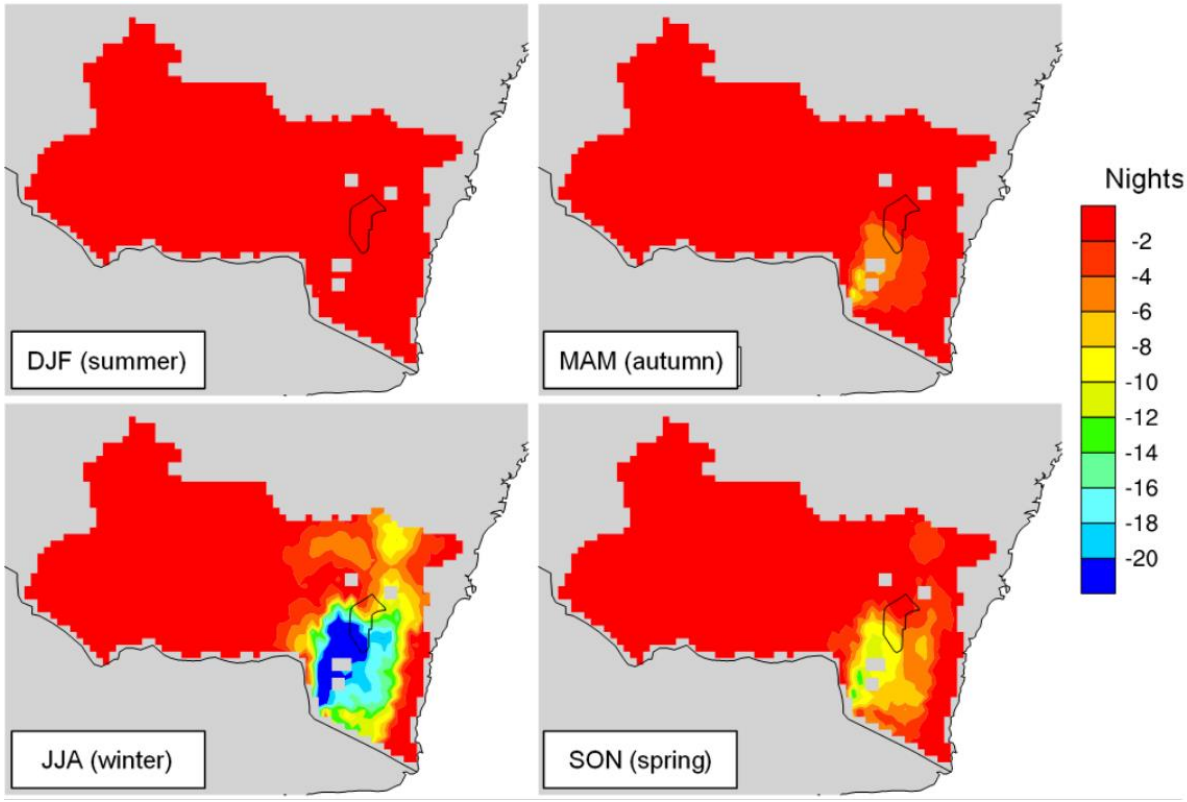


Figure 39: Projected changes in seasonal cold nights for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.4 Precipitation

Due to the complexities of precipitation causing weather systems, reliable predictions of rainfall trends are challenging. Seasonal rainfall projections for the near and far future span both drying and wetting scenarios and should be used with care.

3.4.1 Baseline period 1990 to 2009

Mean annual precipitation in the Alpine zone is 1,800 Millimetres / year over the 1990 to 2009 baseline period. Annual precipitation varies between 400 and 1,000 Millimetres /year for the lower-lying areas within the SAP, Jindabyne township and surrounds (Figure 40).

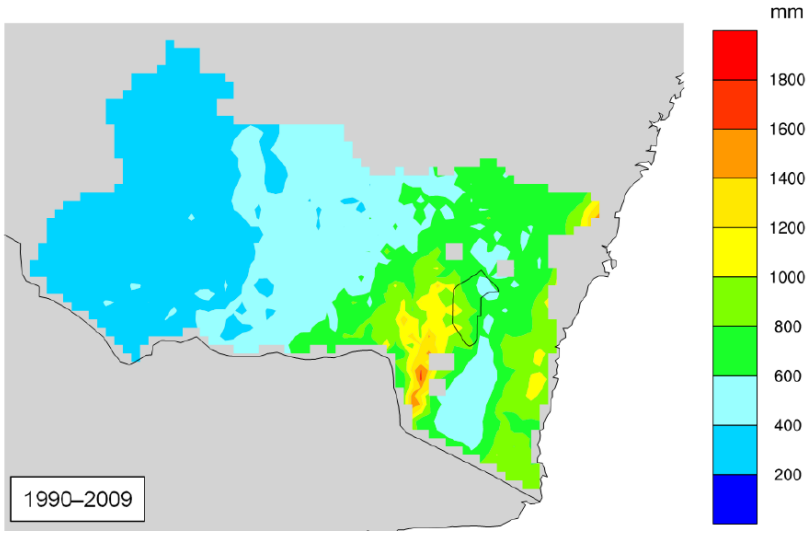


Figure 40: Mean annual precipitation for the 1990 to 2009 baseline period. Source: DPE

There is a clear seasonal variation in the SAP with a wet winter and dry summer precipitation. Winter and autumn are the wettest in the SAP's Alpine Zone with more than 450mm of rainfall on the tops. Precipitation in Jindabyne and surrounds is more consistent throughout the seasons ranging from 50-200mm in autumn and winter to 150-250mm in spring and summer (Figure 41).

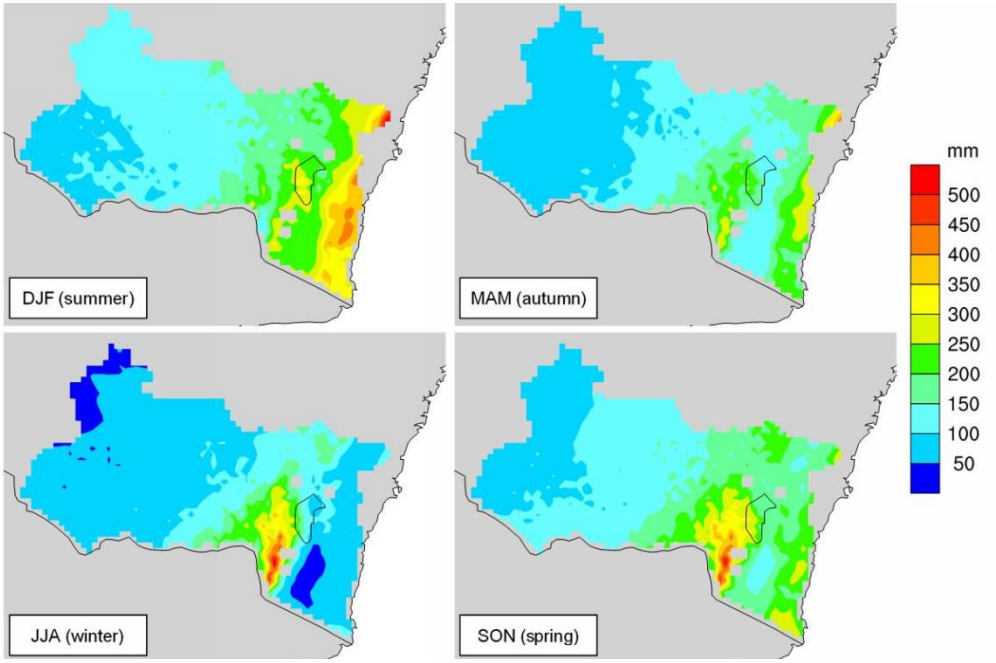


Figure 41: Mean seasonal precipitation for the 1990 to 2009 baseline period. Source: DPE

3.4.2 Near future projections (2020 to 2039)

For the near future, a small decrease (5%) in annual precipitation is projected for the SAP (Figure 42).

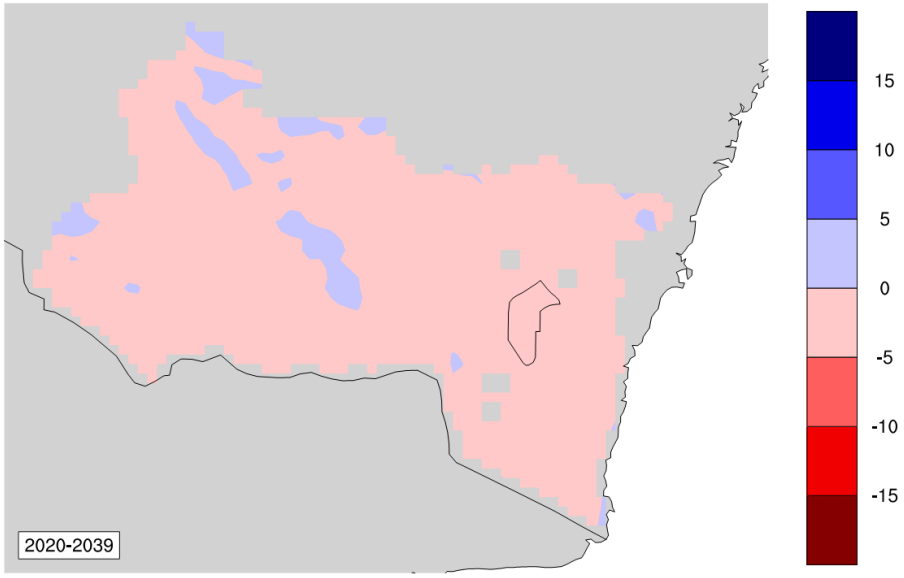


Figure 42: Projected changes in annual precipitation (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Projected precipitation changes vary across the seasons and ranging from wetter projections for autumn to dryer projections for the other seasons. The largest seasonal change in both the Alpine Zone and Jindabyne township and surrounds is in spring with a 10% reduction for the entire SAP. Reductions for winter are expected to be in the order of 5% for the Alpine region and 10% in the Jindabyne township and surrounds. Projected precipitation reduction in summer is 5% with a possibly higher reduction of 10% around Mt. Kosciuszko.

Autumn precipitations are expected to slightly increase in the near future by 5% (Figure 43).

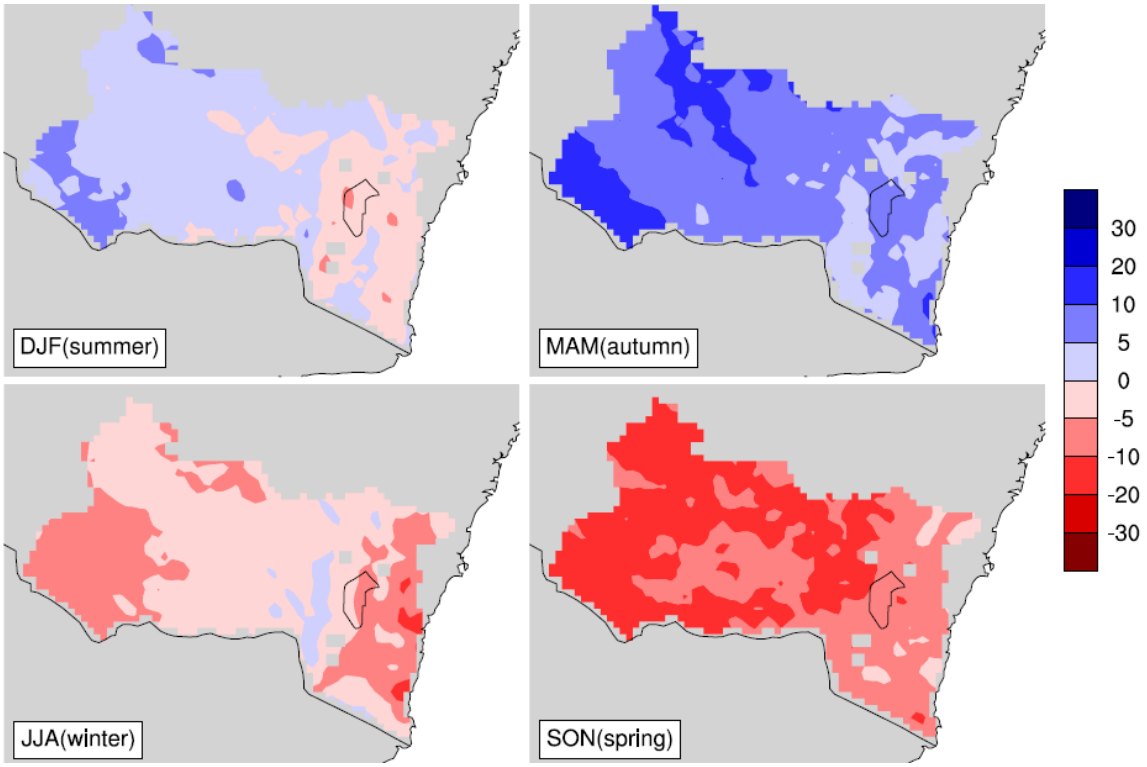


Figure 43: Projected changes in seasonal precipitation (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

3.4.3 Far future projections (2060 to 2079)

For the far future changes in annual precipitations are much clearer compared with the near future projections with a reduction of 5% for Jindabyne and surrounds and 10% for the Alpine region within the SAP (Figure 44).

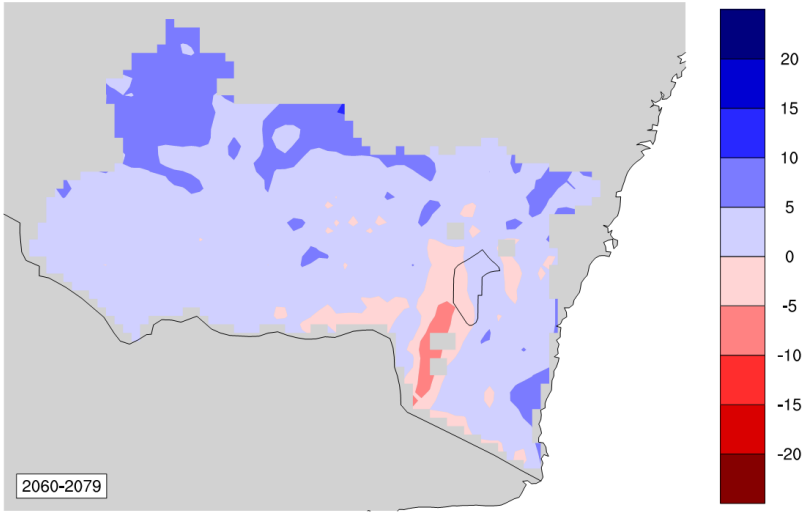


Figure 44: Projected changes in annual precipitation (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

Seasonal precipitation projections show a larger change in the far future compared with near future projections. Summers and autumns are projected to be wetter and springs dryer. For the winter projections show a wetter scenario to the west of the mountain ridge and a dryer scenario to the east.

Precipitation for the Jindabyne township and surrounds is expected to increase by 10% in summer and 20% in autumn. The area is expected to experience dryer winters and springs with a precipitation reduction of 10% in winter and 20% in spring. In winter the Alpine zone is split into wetter projections for the west with a 10% increase in precipitations and dryer conditions to the east with a projected decrease in precipitation of 20%. Summer and autumns are expected to be wetter in the Alpine zone. The projections range from an increase of 5% in the lower Alpine zone areas to a slight decrease on the mountain tops in summer and general increase for the zone of 10% in autumn. Spring is expected to be dryer in the future in the Alpine zone with a decrease of 20% in the region and more than 20% at higher altitudes (Figure 45).

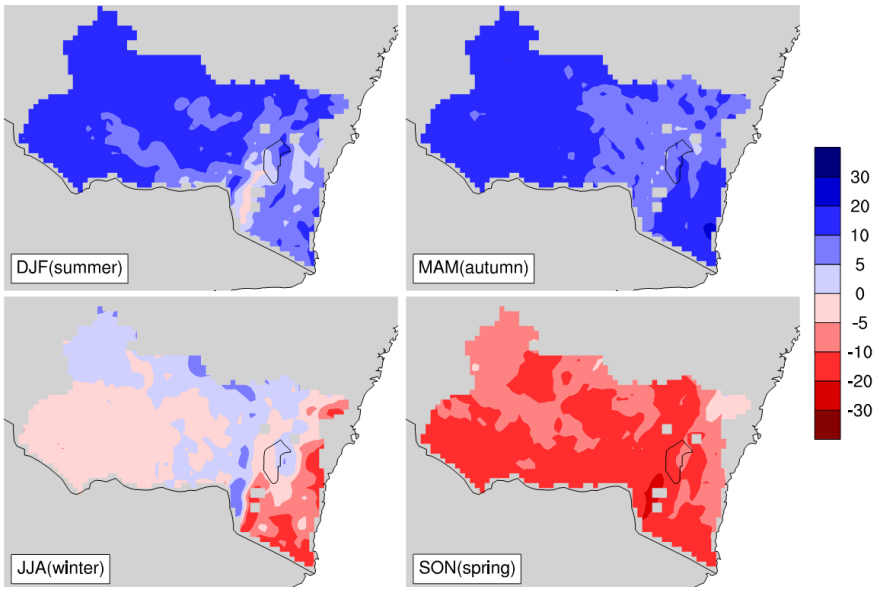


Figure 45: Projected changes in seasonal precipitation (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.4.4 Dry days (Precipitation below 0.2 mm/day)

For the baseline period, the number of dry days in the SAP ranging from 240 days (2/3 of the year) in the Jindabyne township and surrounds to less than 180 days on the mountain tops (Figure 46).

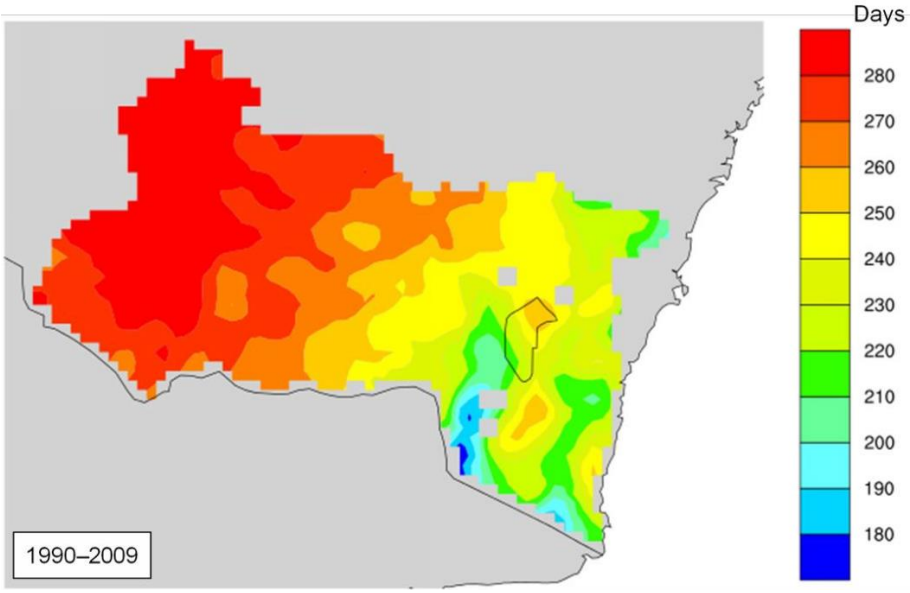


Figure 46: Simulated number of annual dry days for 1990 to 2009. Source: DPE

The lower-lying areas of the SAP, Jindabyne and surrounds, experience 50-60 dry days in summer and spring and 60-70 days in autumn and winter. For the SAP's Alpine region, the number of dry days is in the order of 40-50 in summer and spring, decreasing in winter to less than 40 days and increasing in autumn ranging from 50-60 days. Overall, number of dry days decreases across the SAP for all seasons with increasing altitude (Figure 47).

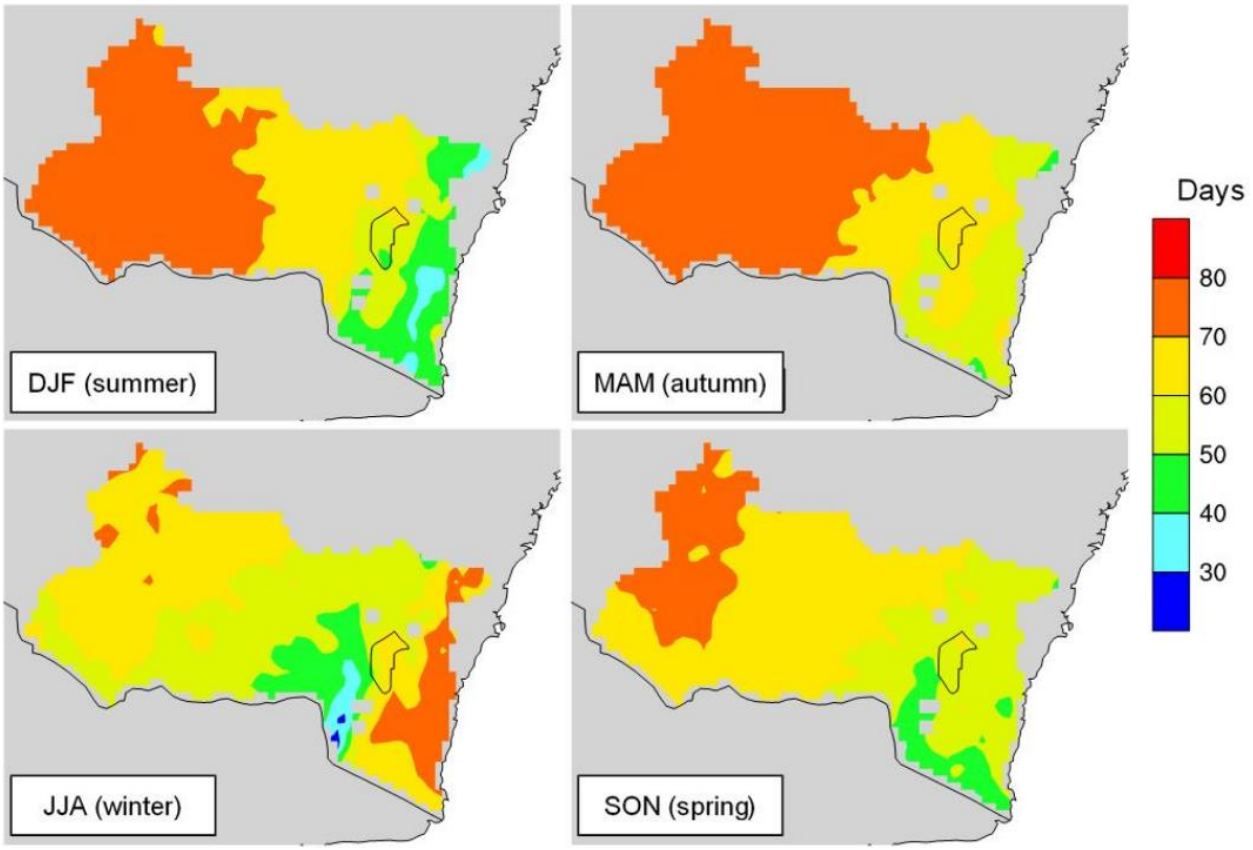


Figure 47: Simulated number of seasonal dry days for 1990 to 2009. Source: DPE

The annual number of dry days in the SAP is expected to increase in the near future by 2% in the Jindabyne township and surrounds and 4% in the Alpine zone (Figure 48).

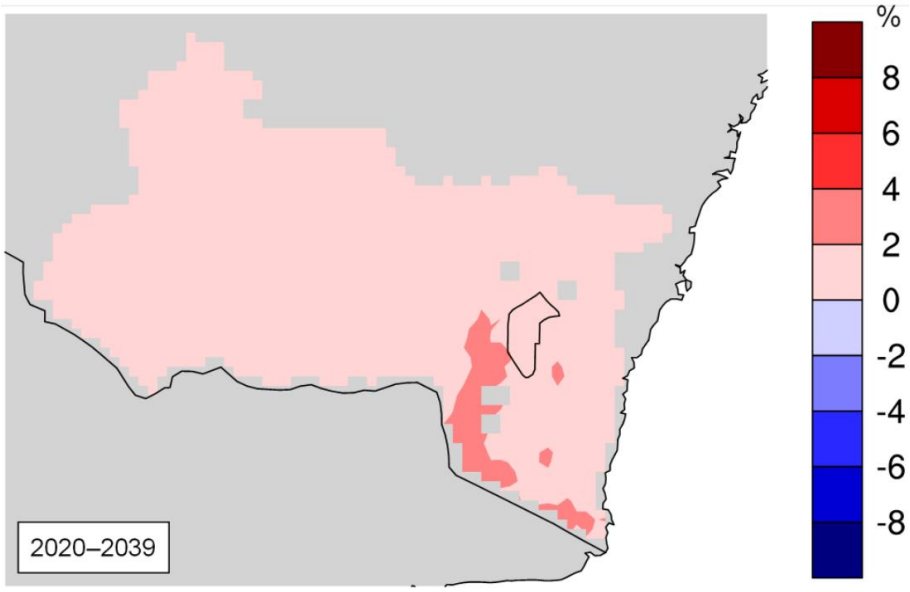


Figure 48: Projected changes in annual dry days (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Projected seasonal changes in number of dry days ranging from a slight decrease in winter to increase in all other seasons. The largest change is expected to occur in spring with an increase in number of dry days for the lower-lying areas, Jindabyne and surrounds, of 4-8% and more than 8% in the Alpine zone. While for the SAP a decrease of dry days is projected for the winter season in the order of 2%, dry days in summer and autumn are projected to increase by 2% (Figure 49).

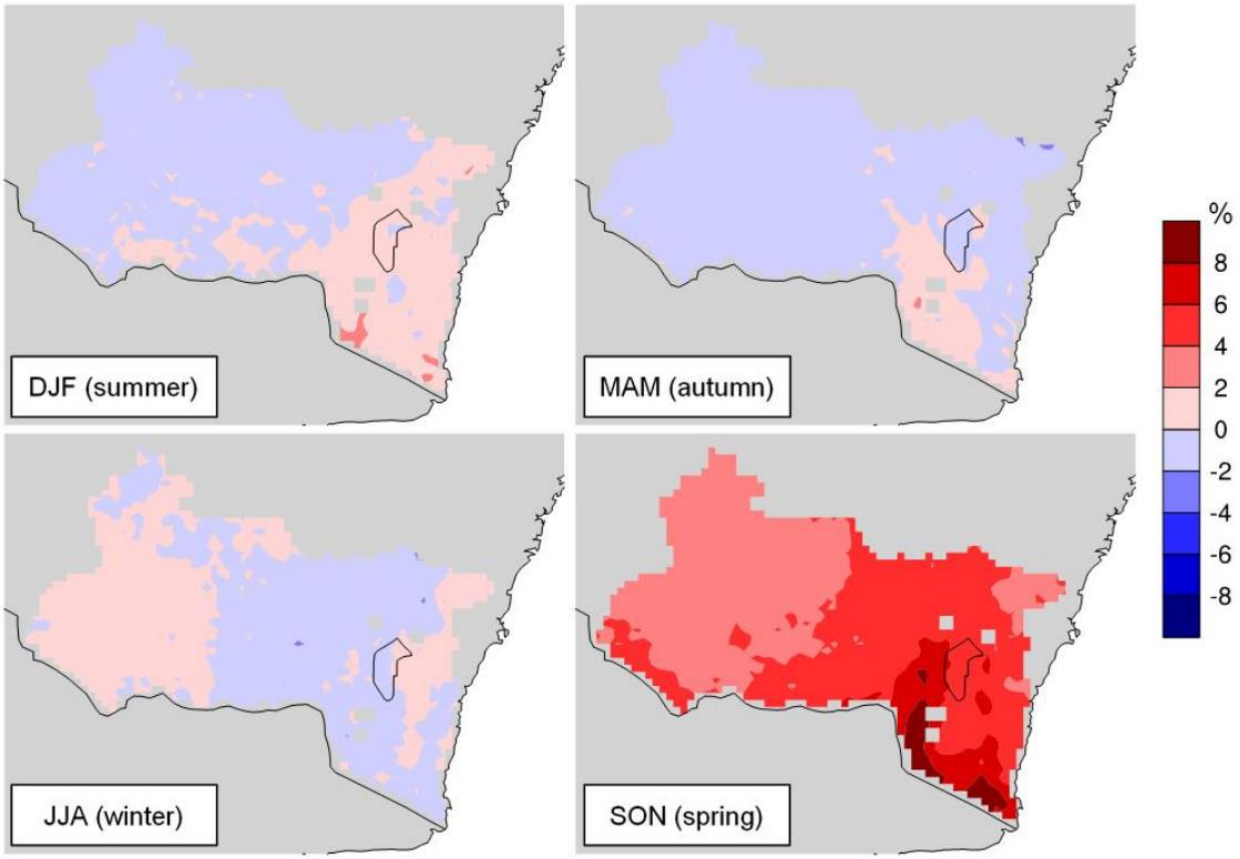


Figure 49: Projected changes in seasonal dry days (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

For the far future a more significant increase in dry days is projected per year with 4-6% in Jindabyne township and surrounds and more than 8% in the Alpine zone (Figure 50).

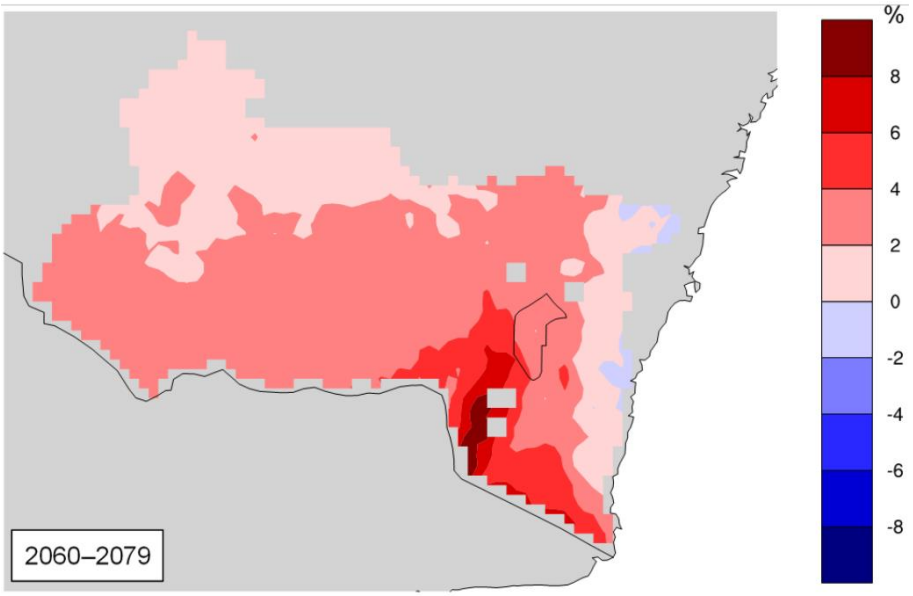


Figure 50: Projected changes in annual dry days (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

Overall, seasonal changes are expected to more extensive in the far future. Winters and springs are expected to be much dryer. Jindabyne and surrounds are expected to experience 4-8% more dry days in winter and 12-16% in spring and the SAP's Alpine zone 8-12% and more than 16%, respectively. Number of dry days projected to increase by 4% for Jindabyne and 4-8% in the southern parts of the Alpine region. Number of dry days trend in autumns are projected to be different on the east and west side of SAP with a separation along the mountain ridge. Number of dry days are expected to increase in the east and decrease in the west, both in a similar scale of 4% (Figure 51).

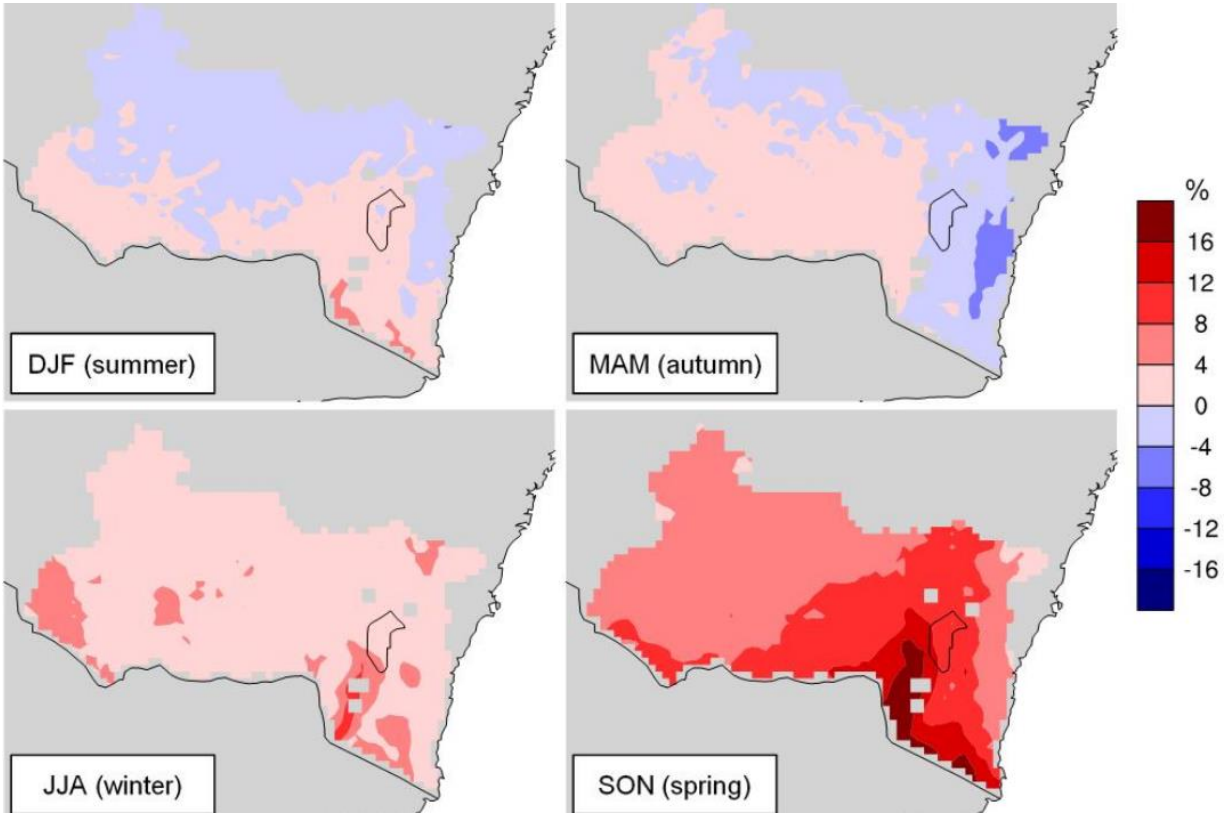


Figure 51: Projected changes in seasonal dry days (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.4.5 Heavy precipitation days (rainfall above 25 mm/day)

Most of the heavy precipitation days occur in the Alpine zone of the SAP with more than 12 days per year, thus twice as many days than the Jindabyne and surrounds (Figure 52).

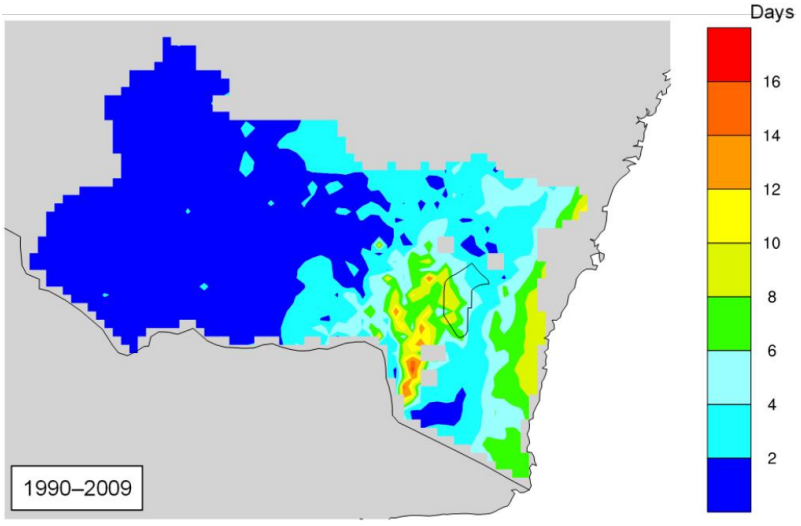


Figure 52: Annual heavy precipitation days for 1990 to 2009. Source: DPE

Heavy precipitation days occur all year round and are in the order of 1-2 days in summer for Jindabyne and surrounds. The Alpine zone experiences 2-3 days most of the seasons with more than 6 for the mountain tops in winter (Figure 53).

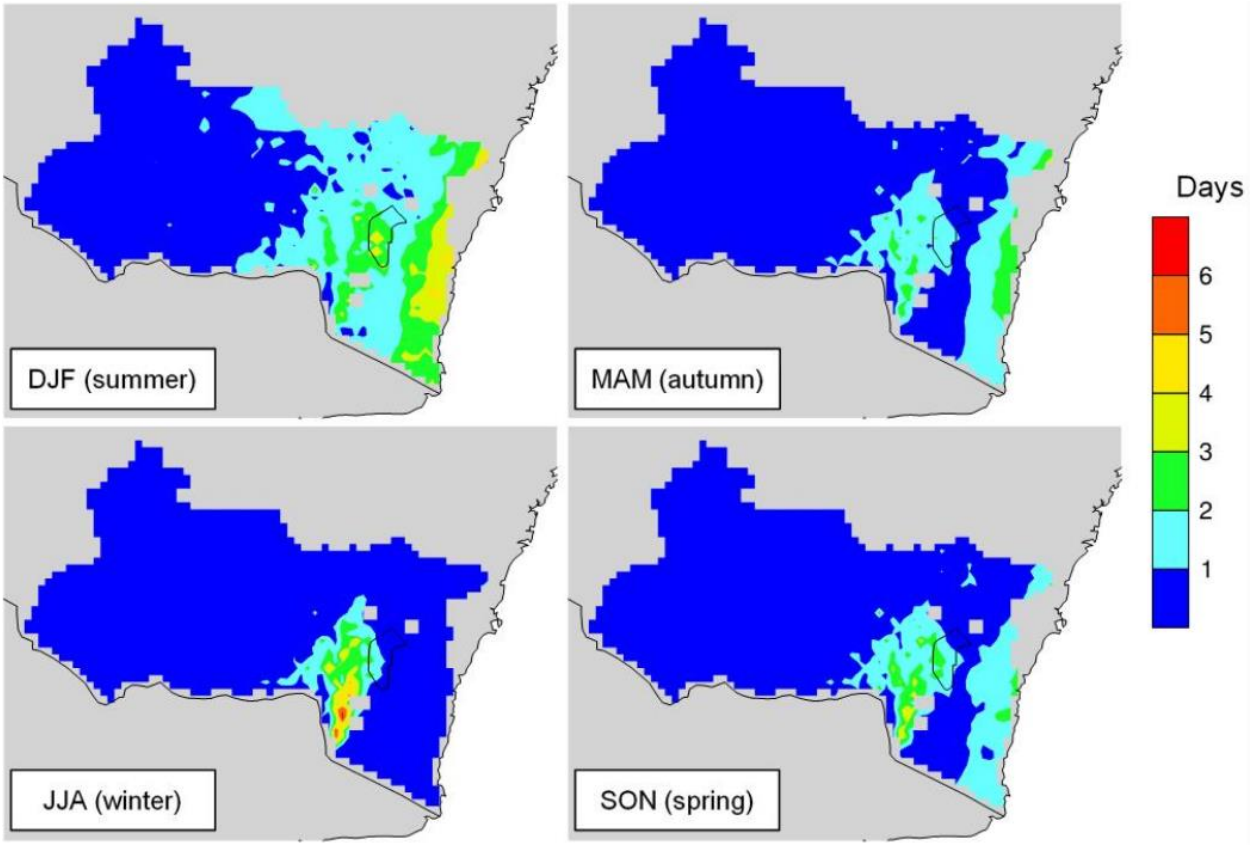


Figure 53: Seasonal heavy precipitation days for 1990 to 2009. Source: DPE

For the near future, overall a decrease in annual heavy precipitation days of 10% is projected for the SAP (Figure 54).

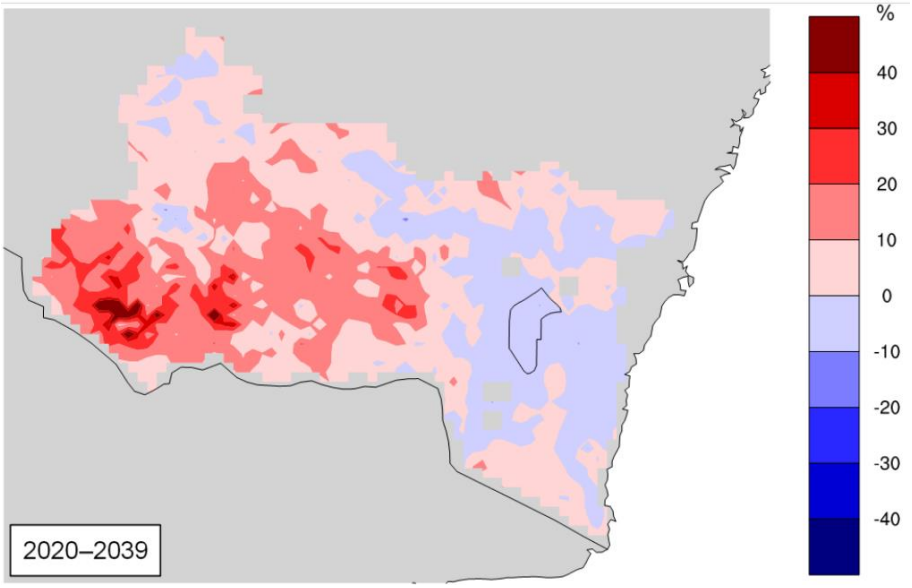


Figure 54: Projected changes in annual heavy precipitation days (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

For the lower-lying areas within the SAP, Jindabyne and surrounds, the seasonal number of heavy precipitation days is projected to decrease except for spring where an increase of 20-40% is projected. The largest decrease in this area is expected to occur in winter with an 80% decrease for some areas. Summer and autumn numbers are projected to decrease by 20%. In spring the number of heavy precipitation days is expected to increase by 20% in most of the lower-lying areas and 40% in Jindabyne township. For the Alpine zone, numbers are projected to decrease by 20% in summer, winter and spring and to increase by 20% in autumn (Figure 55).

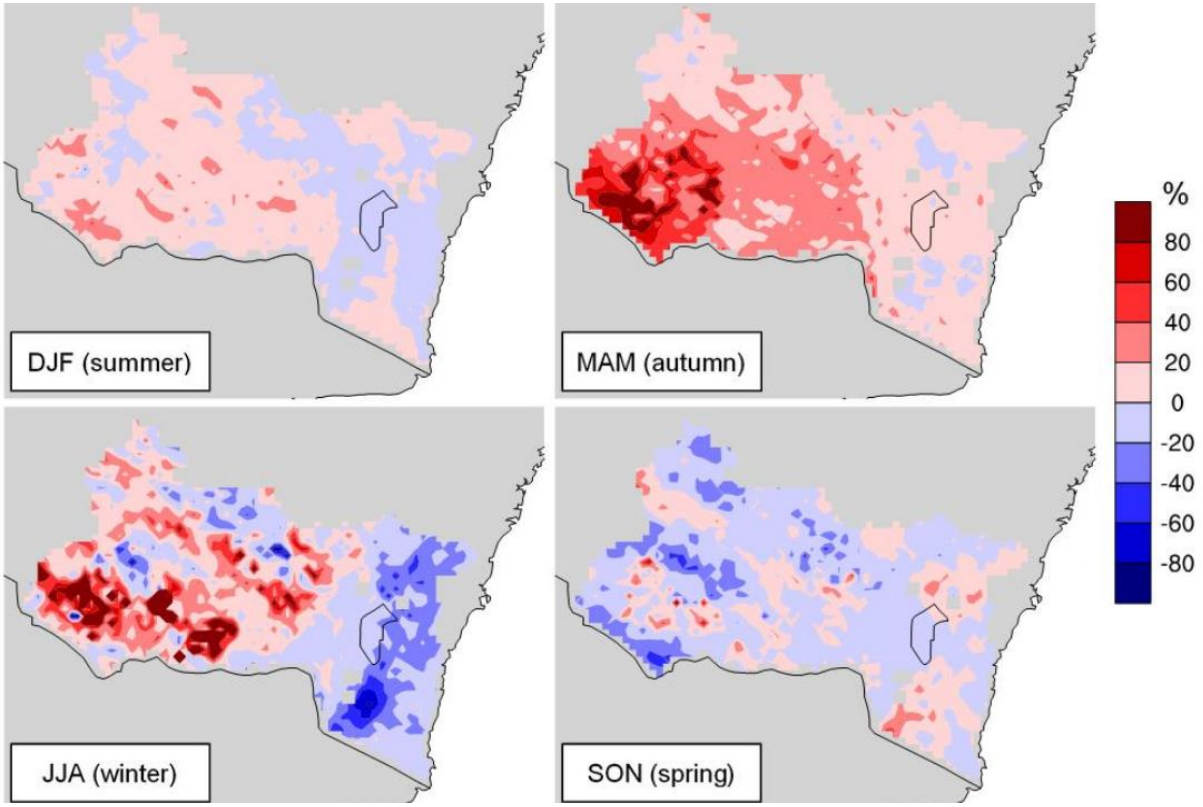


Figure 55: Projected changes in seasonal heavy precipitation days (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

The far future projections show an increase of heavy precipitation days for most of the SAP with a small declining trend along the mountain ridge (Figure 56).

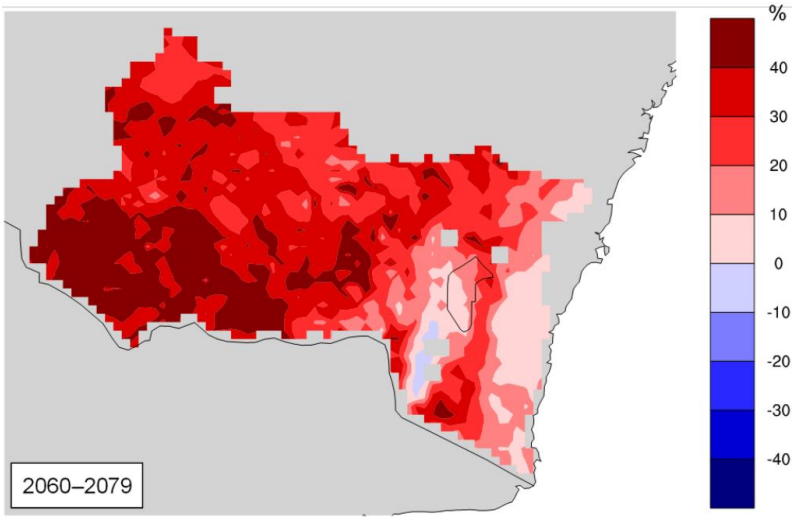


Figure 56: Projected changes in annual heavy precipitation days (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

For the far future, heavy precipitation days in the SAP are projected to increase in summer and autumn and decrease in winter and spring. A 40% decrease is projected in summer and autumn for Jindabyne and surrounds and 20% in summer and 40% in autumn for the Alpine zone. A decline in the number of heavy precipitation days for winter and autumn is projected to be 20% for most of the SAP. However, some areas to the east and south of the lake could possibly experience a slight increase in days with heavy precipitation in the far future (Figure 57).

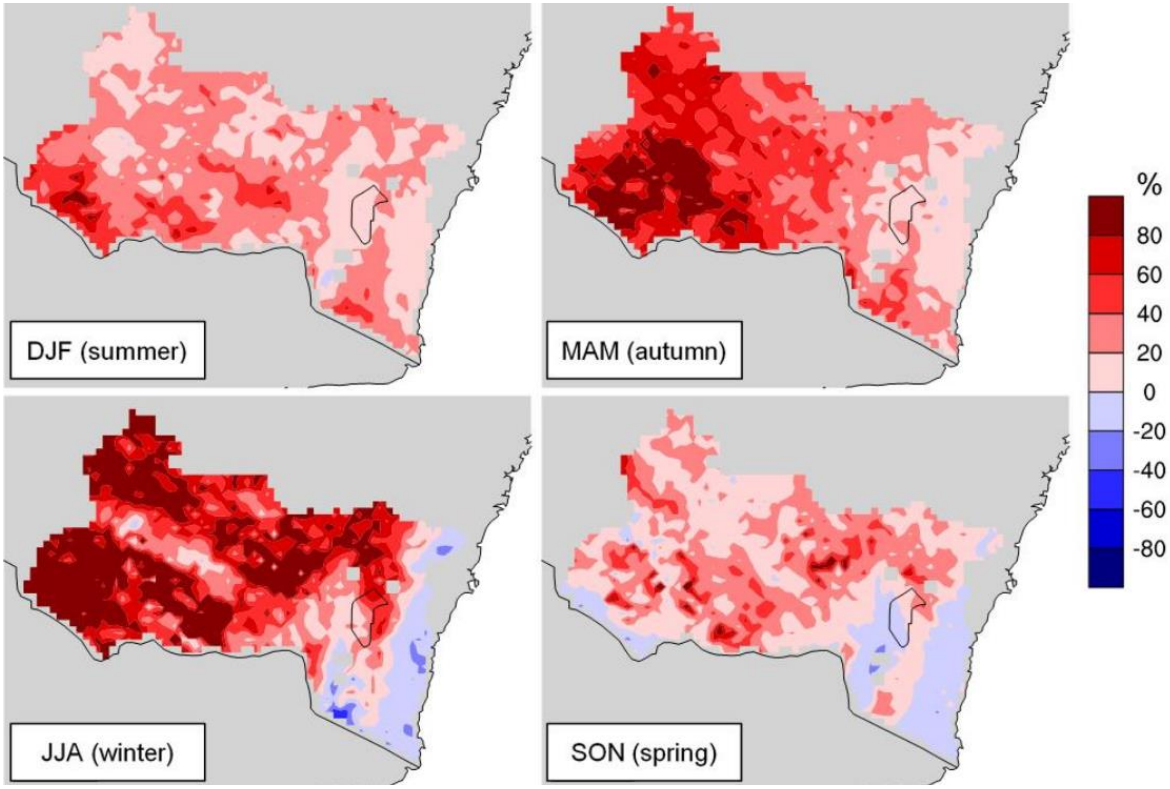


Figure 57: Projected changes in seasonal heavy precipitation days (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.4.6 Rainfall Intensity

All CSIRO models agree that frequency and magnitude of extreme rainfall events will increase over the course of the century in the Southern Slope cluster, wherein the SAP is located (Figure 58).

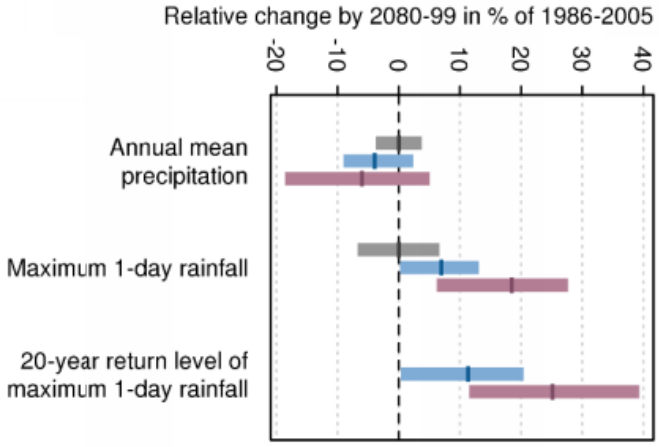


Figure 58: Modelled differences (per cent) in annual average rainfall, rainfall on the wettest day of the year, and rainfall on the wettest day in 20 years for 2080-2099 compared to 1986 to 2005 under RCP4.5 (blue) and RCP8.5 (purple). Natural climate variability is represented by the grey bar. Source: CSIRO

Consistent with the findings of prior chapters of this assessment, rainfall intensity is projected to increase in the near and far future in the SAP. In accordance to the Australian Rainfall and Runoff Guideline (ARR 2019), rainfall intensity in area is expected to increase by 16.3% by 2090 increasing the risk of flash floods.

3.5 Flooding

Based on the ARR 2019 data sets, the Technical Study Report Flooding by WSP has modelled the impact of climate change on flood levels in the SAP. The report has investigated flood inundation levels in 2090 for the following areas:

- Jindabyne and surrounds
- Thredbo Village
- Bullocks Flat
- Perisher Valley.

Under climate change conditions, flood levels in the Jindabyne area show almost no change to present conditions (Figure 59, Figure 60) same as for the Thredbo Village (Figure 61, Figure 62). While peak flood depths are expected to rise in Bullocks Flat (Figure 63, Figure 64) due to the influence of climate change, they are projected to decrease in the Perisher Valley (Figure 65, Figure 66).

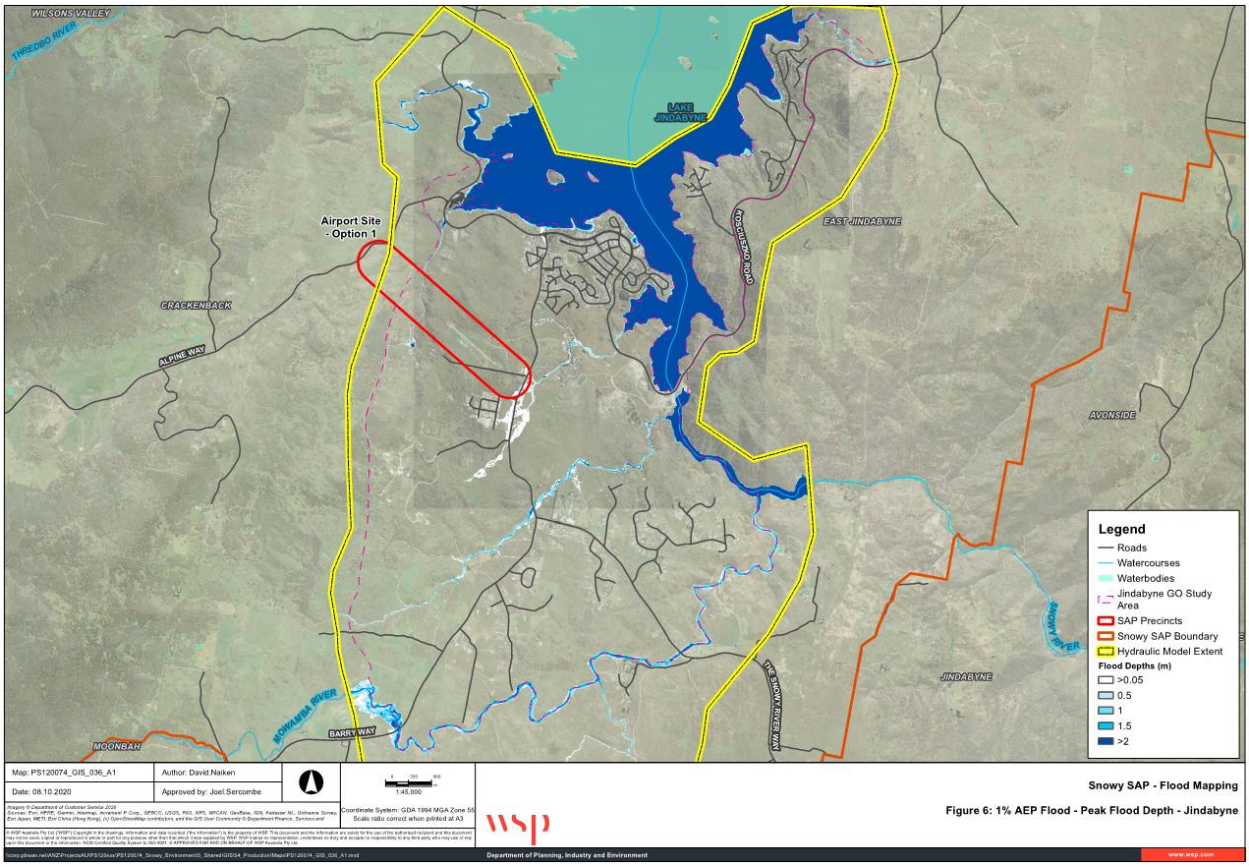


Figure 59: 1% AEP Flood – Peak Flood Depth – Jindabyne, under current conditions. Source: WSP

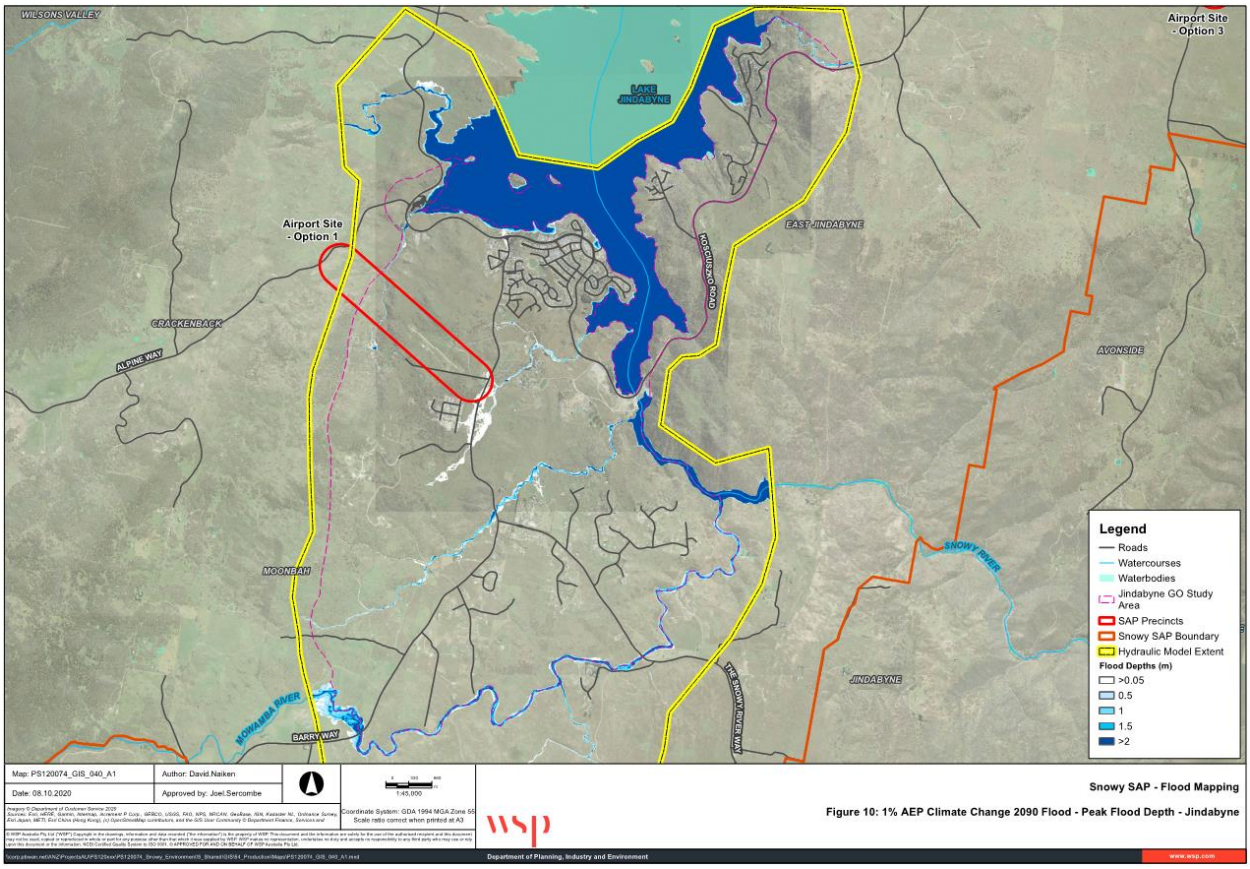


Figure 60: 1% AEP Flood – Peak Flood Depth – Jindabyne, under 2090 climate change conditions. Source: WSP

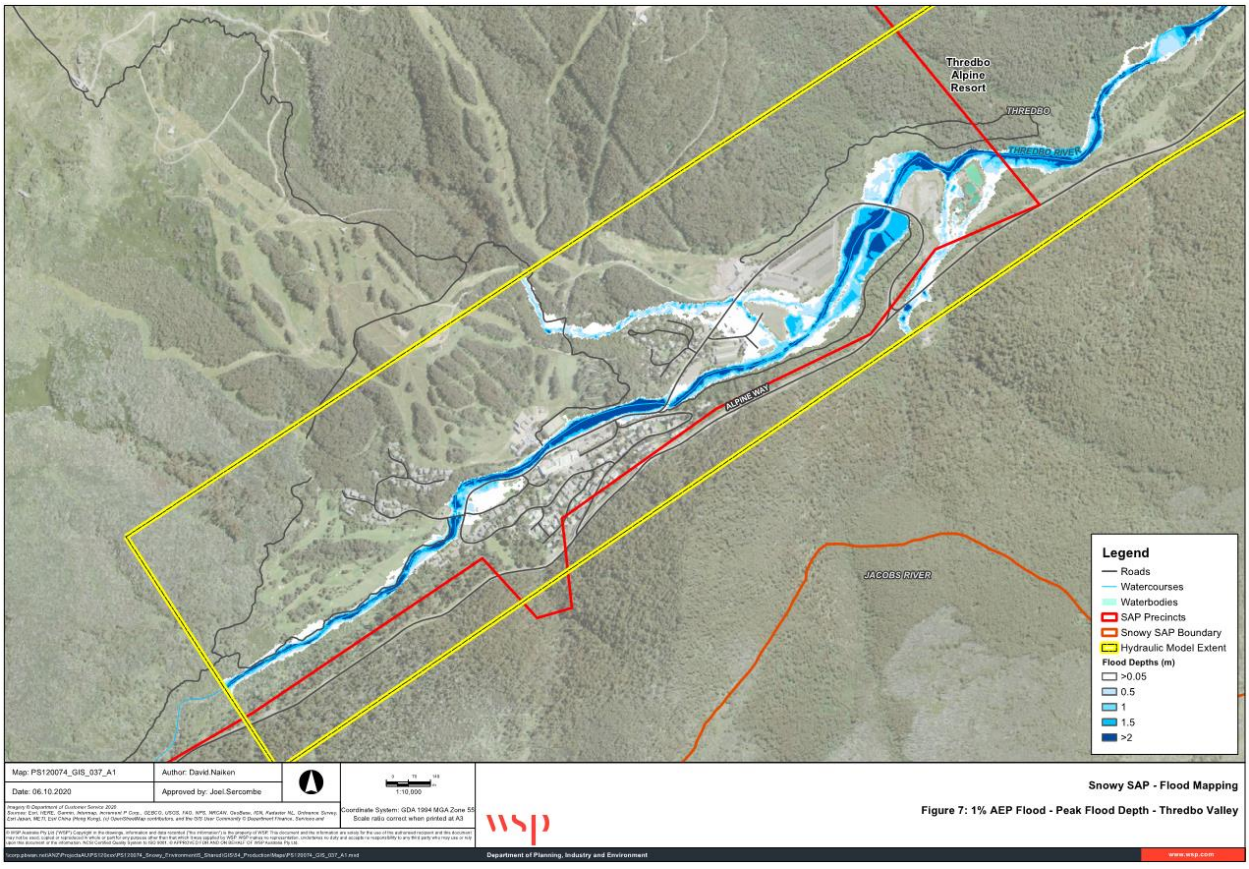


Figure 61: 1% AEP Flood – Peak Flood Depth – Thredbo Valley, under current conditions. Source: WSP

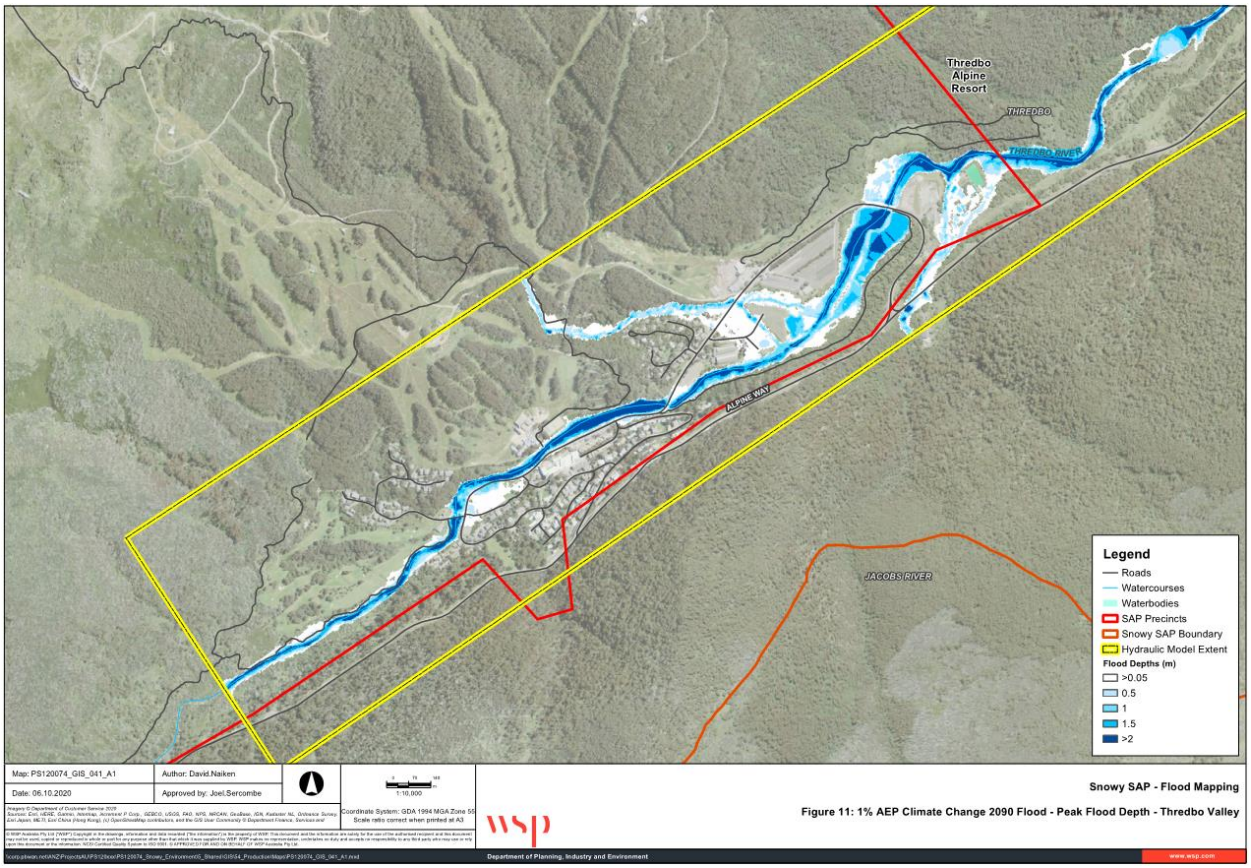


Figure 62: 1% AEP Flood – Peak Flood Depth – Thredbo Valley, under 2090 climate change conditions. Source: WSP

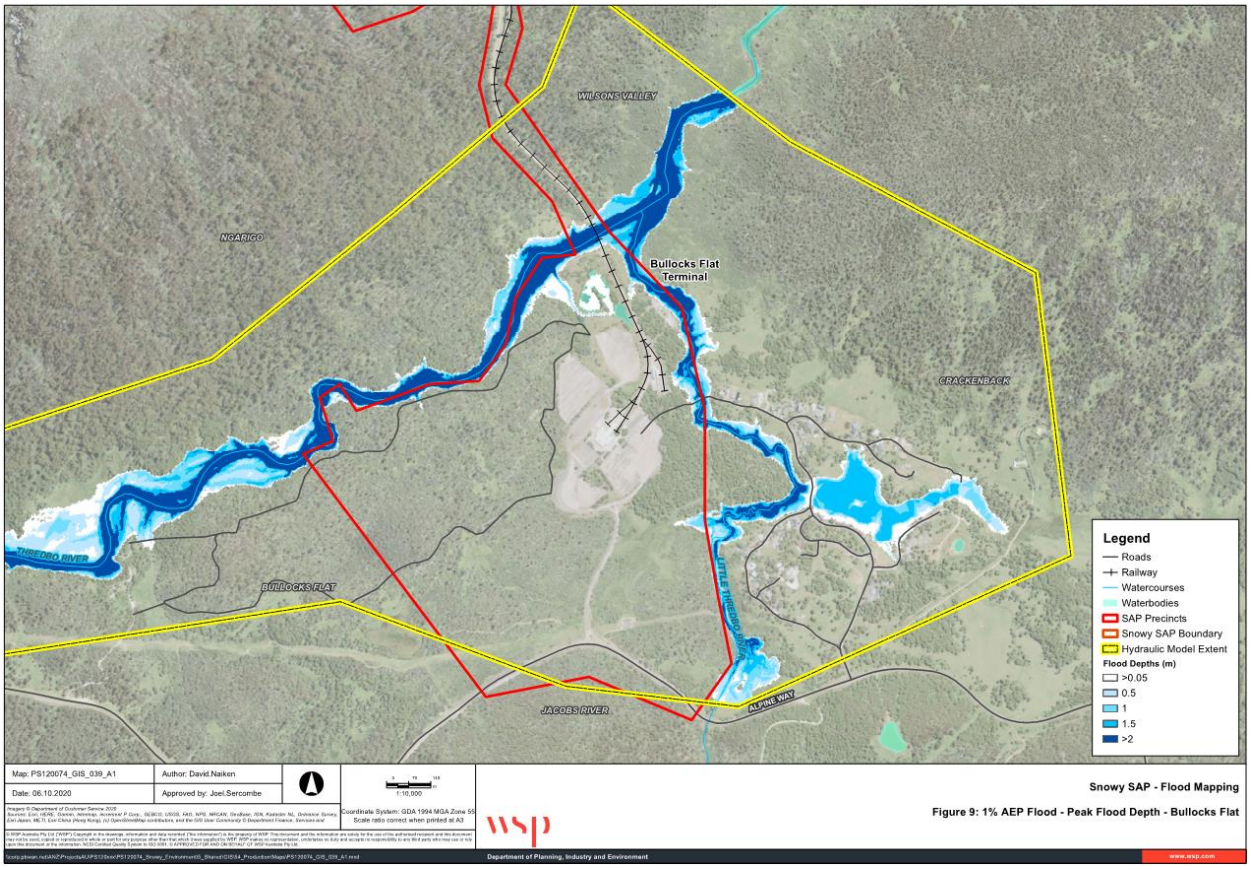


Figure 63: 1% AEP Flood – Peak Flood Depth – Bullocks Flat, under current conditions. Source: WSP

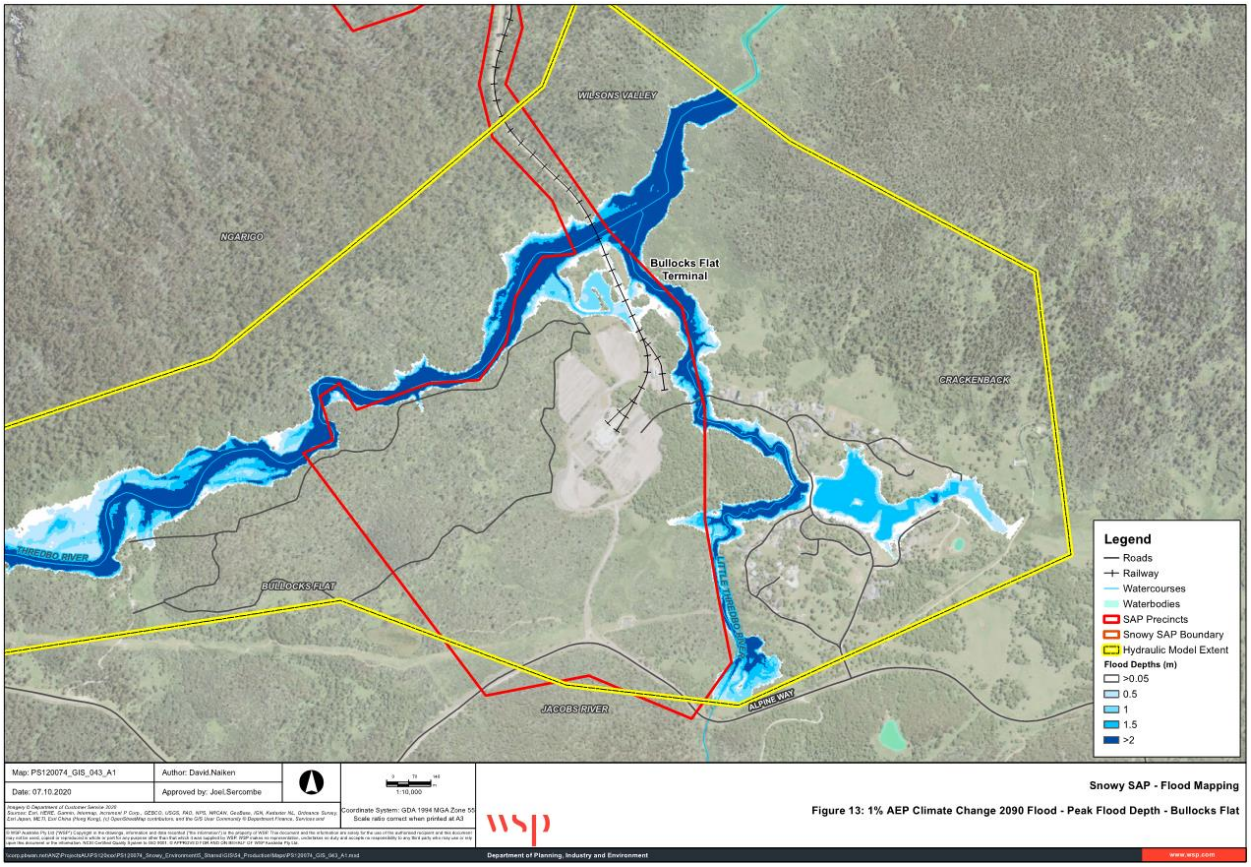


Figure 64: 1% AEP Flood – Peak Flood Depth – Bullocks Flat, under 2090 climate change conditions. Source: WSP

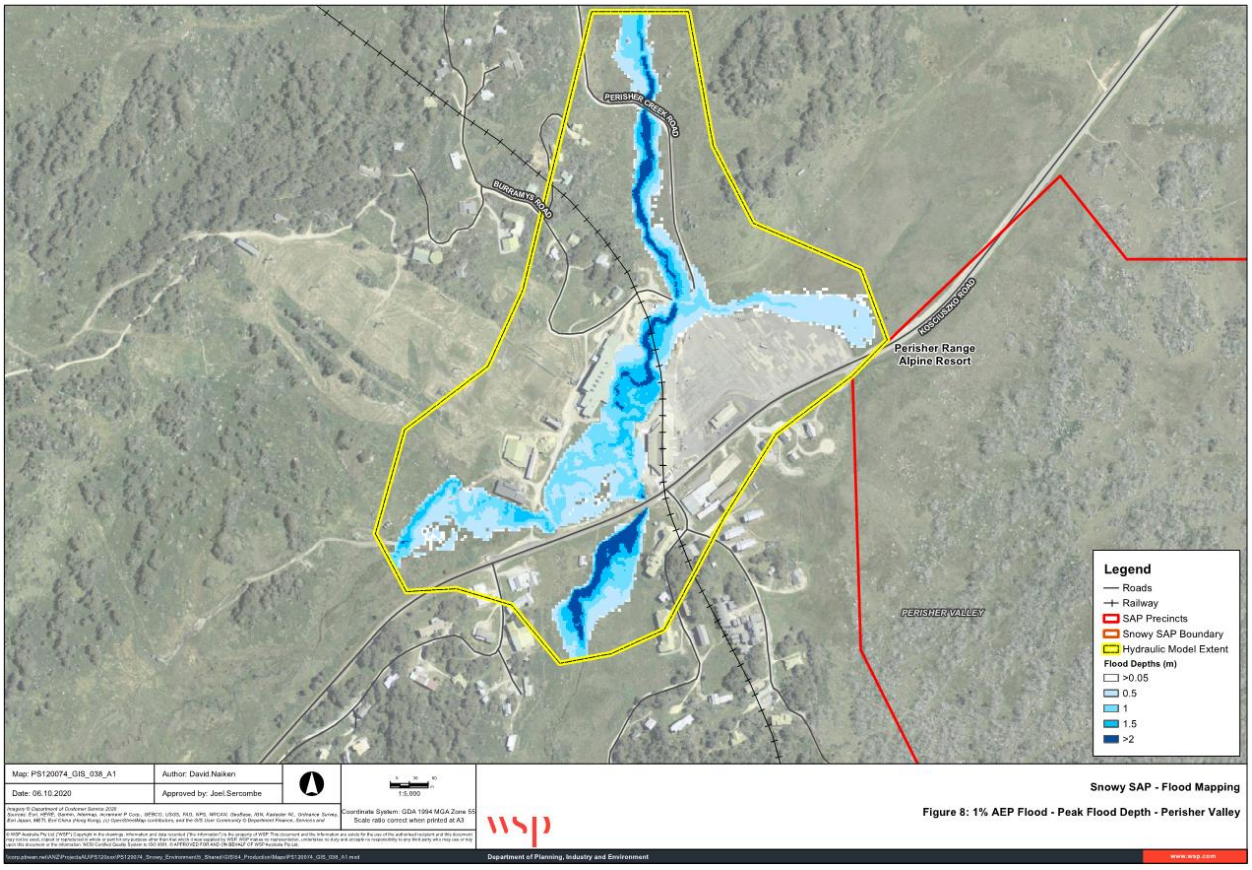


Figure 65: 1% AEP Flood – Peak Flood Depth – Perisher Valley, under current conditions. Source: WSP

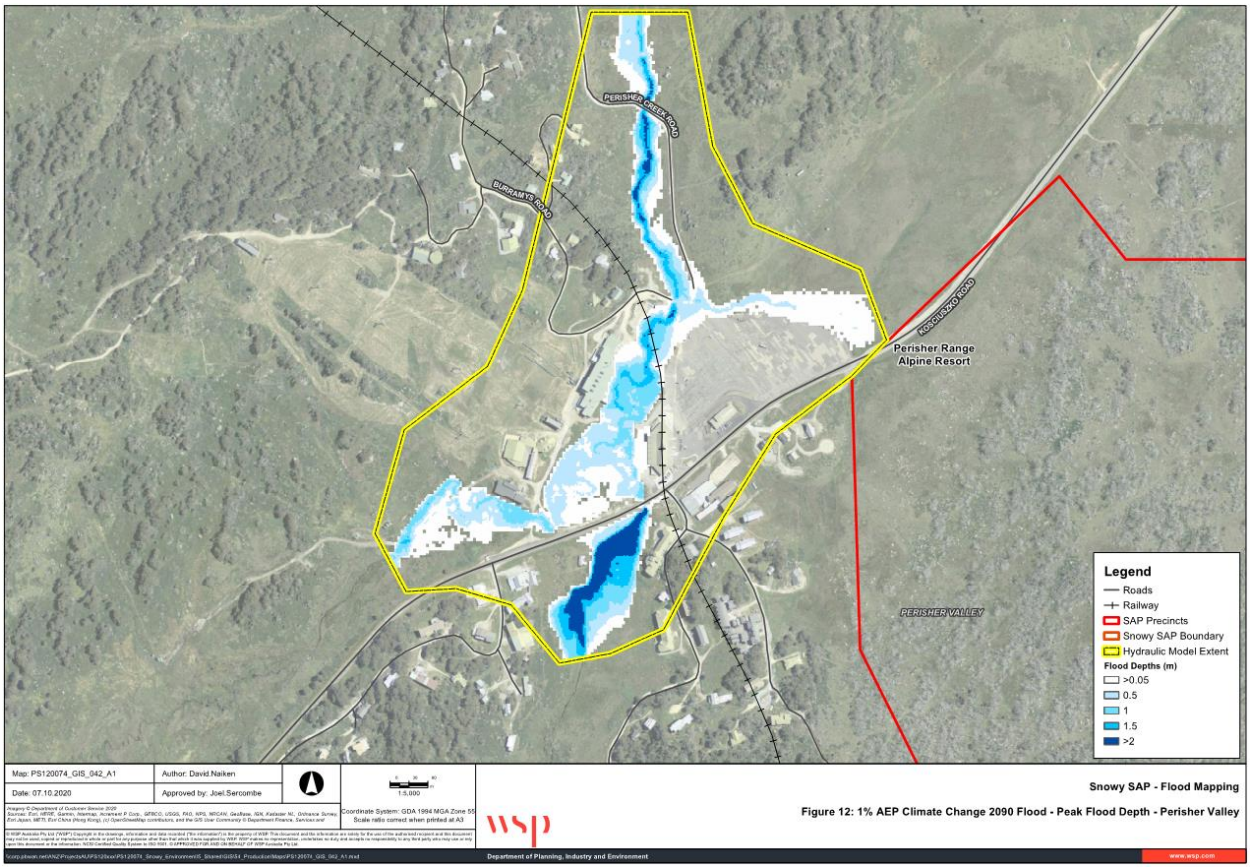


Figure 66: 1% AEP Flood – Peak Flood Depth – Perisher Valley, under 2090 climate change conditions. Source: WSP

3.6 Snow

Natural snow depth has declined over time and is projected to decrease across all Australian alpine areas, in particular at lower elevations. Changes in snow depth and conditions are interconnected with temperature increases and precipitation in line with sections 3.3 and 3.4.

Table 2 shows the elevation for selected ski resorts in the SAP.

Table 2: Ski resorts elevations

Resort	Elevation (m)
Thredbo	1,780
Sponars Chalet	1,500
Perisher	1,881
Charlotte Pass	1,832

As natural snow production reduces over time, more artificial snow will need to be produced to maintain effective snow cover. Traditionally, snow making required temperatures below -2 degrees however newer technologies are enabling snow making to be undertaken at higher temperatures. Regardless, projections indicate that the number of hours suitable for snowmaking will decrease significantly in future.

For the baseline period (1990-2009), there are more than 600 suitable snowmaking hours in the higher elevation areas of the Alpine zone (above 1700 metres), fewer than 100 suitable hours in the lower elevations (below 1500 metres) and zero hours below 500 metres (Figure 67).

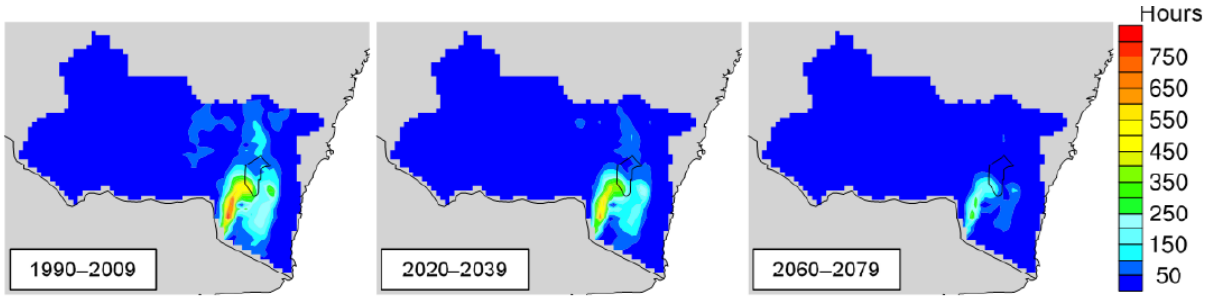


Figure 67: Suitable snowmaking conditions (in hours) for 1990 to 2009, 202 to 2039 and 2060 to 2079 for the -2°C threshold. Source DPE

As Figure 67 shows, there are large declines in snowmaking hours projected for the near and far future with higher elevation sites having 300 fewer suitable snowmaking hours and lower elevations projected to be generally unsuitable for snowmaking in the far future.

The monthly variation in time suitable for snowmaking remains relatively unchanged, with its peak occurring in winter. However, there is a substantially contraction of the entire season, with much fewer suitable snowmaking hours at the start and end of the season. The mean suitable snowmaking hours is projected to decrease by around 30% in the near and 70% in the far future (Figure 68).

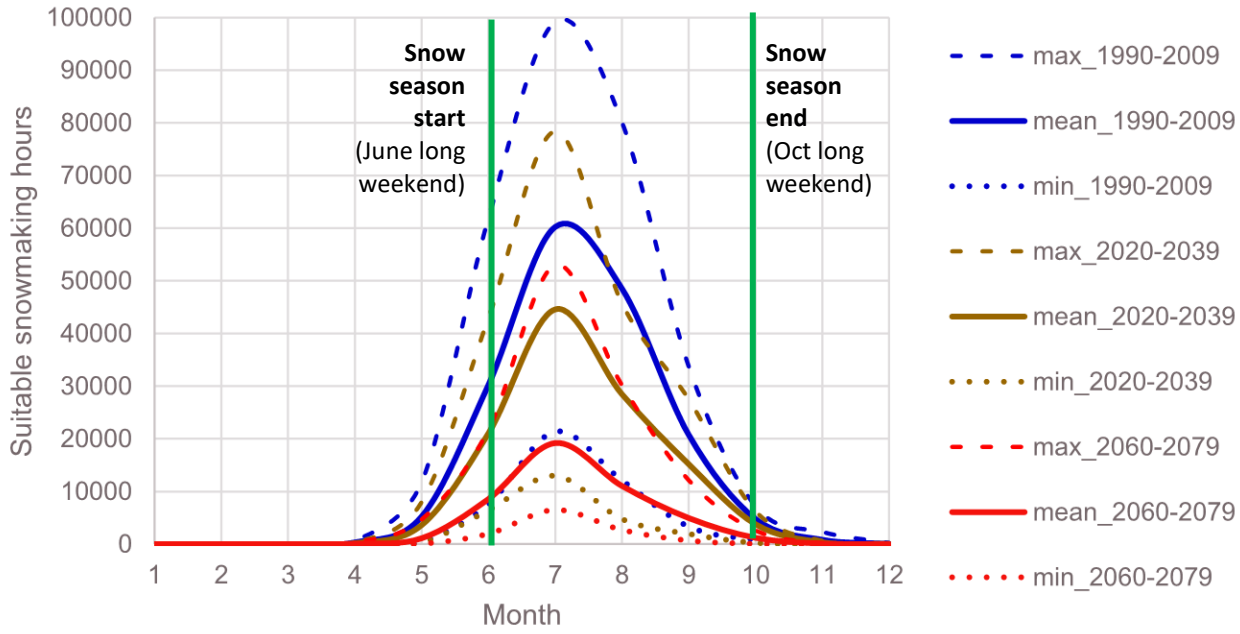


Figure 68: Simulated monthly distribution of suitable snowmaking conditions for the Alpine region for best (dashed lines), mean (solid lines) and worst-case (dotted lines) scenarios in the 12-member NARCliM ensemble for the –2°C threshold. Source: DPE

3.7 Fire weather

The Mean Forest Fire Danger Index (FFDI) for the baseline period 1990 to 2009 is rated at 1 to 2 for the Alpine zone and Jindabyne township and surrounds due to generally low average temperatures and high annual precipitations (Figure 69).

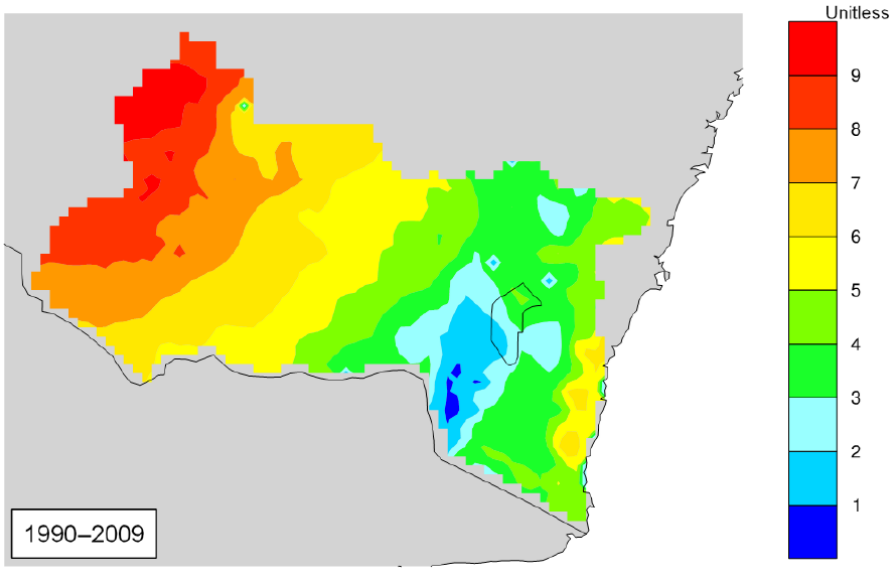


Figure 69: Mean annual FFDI from the 1990 to 2009 baseline period. Source: DPE

As Figure 70 shows, in all seasons, fire rating is low across the SAP.

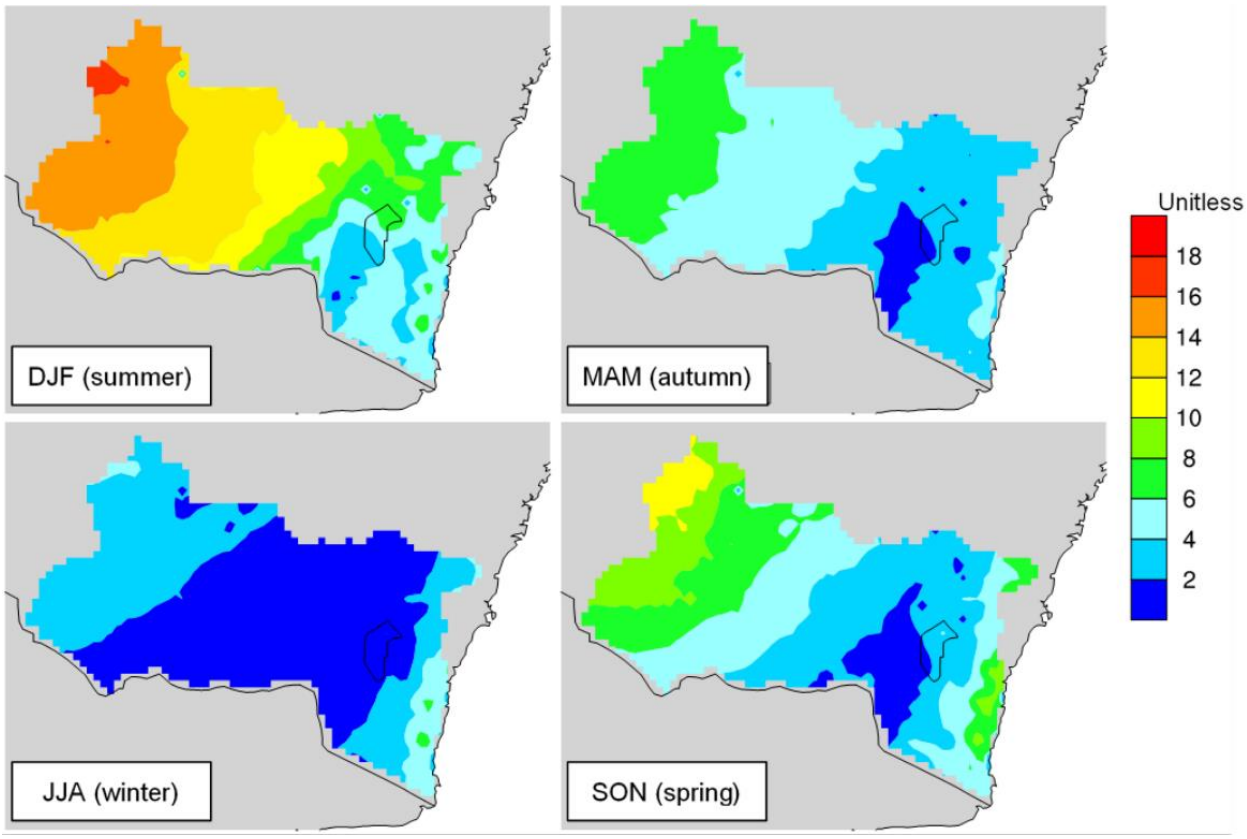


Figure 70: Mean seasonal FFDI for the 1990 to 2009 baseline period. Source: DPE

In the near future, an increase in daily FFDI is expected in the southern parts of the SAP's Alpine zone (mostly due to a decrease in precipitation and increasing temperatures) with a decrease in the Jindabyne township and surrounds (Figure 71).

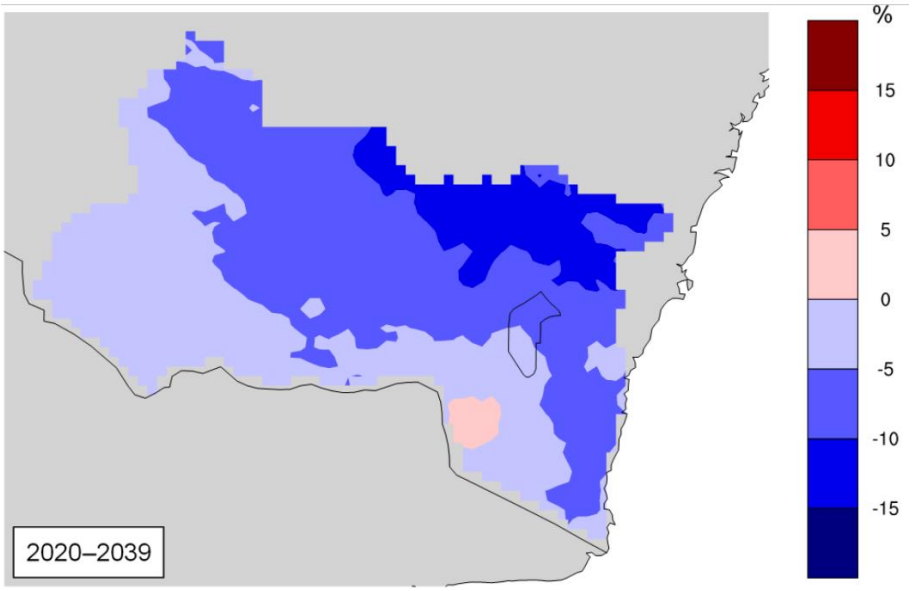


Figure 71: Projected changes in annual FFDI (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Seasonal increases in winter and spring are 30% in the Alpine zone and 10% for the Jindabyne township and surrounds due to the decrease in rainfall. FFDI in summer and autumn are expected to reduce by 10% across the SAP (Figure 72).

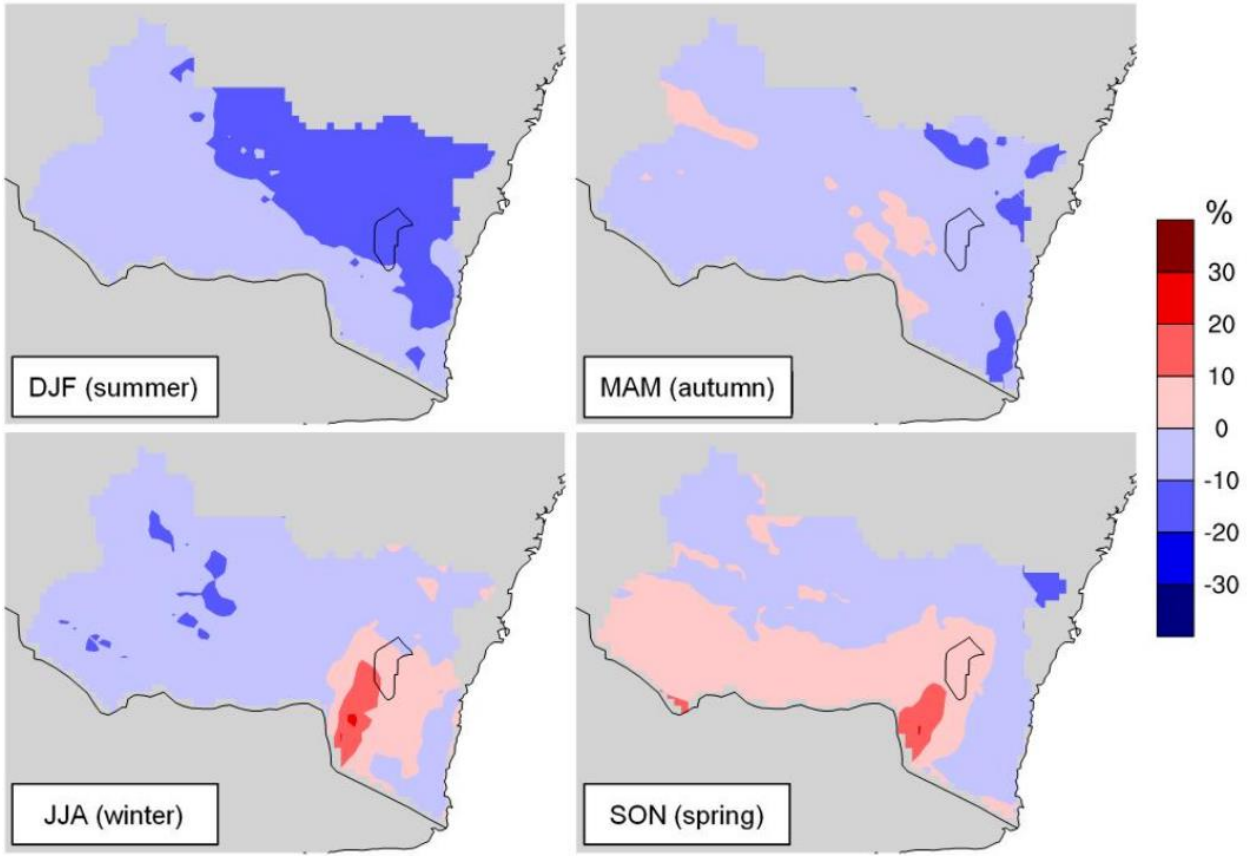


Figure 72: Projected changes in seasonal FFDI (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

In the far future, a 5-10% increase in the FFDI is projected for the entire SAP correlating a projected 10% decrease in precipitation, increasing number of dry days and maximum temperatures.

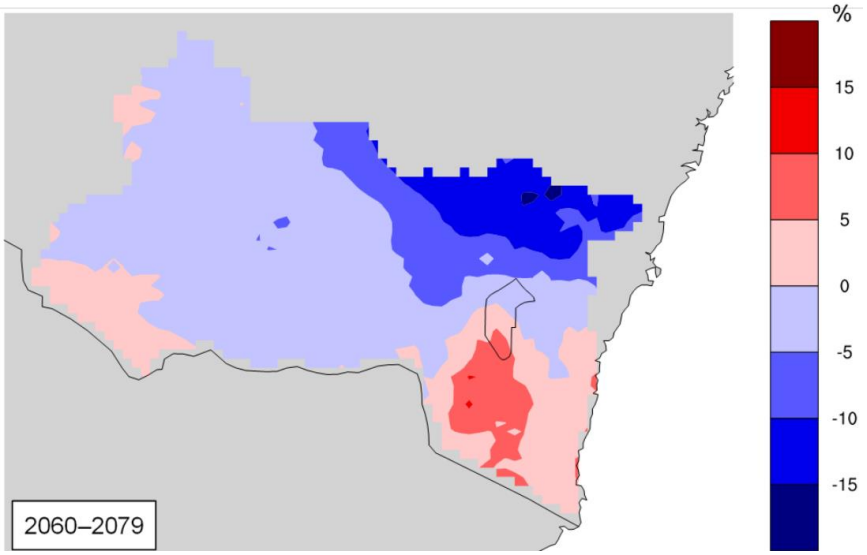


Figure 73: Projected changes in annual FFDI (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

The seasonal effects are elevated in spring and winter with greater than 30% increase in FFDI for almost the entire SAP as result of an expected decrease in precipitation and increases in temperature. A decrease in FFDI of 10-20% in the Alpine zone and 10% in Jindabyne and surrounds is projected for summer, while to decline by 10% in autumn (Figure 74).

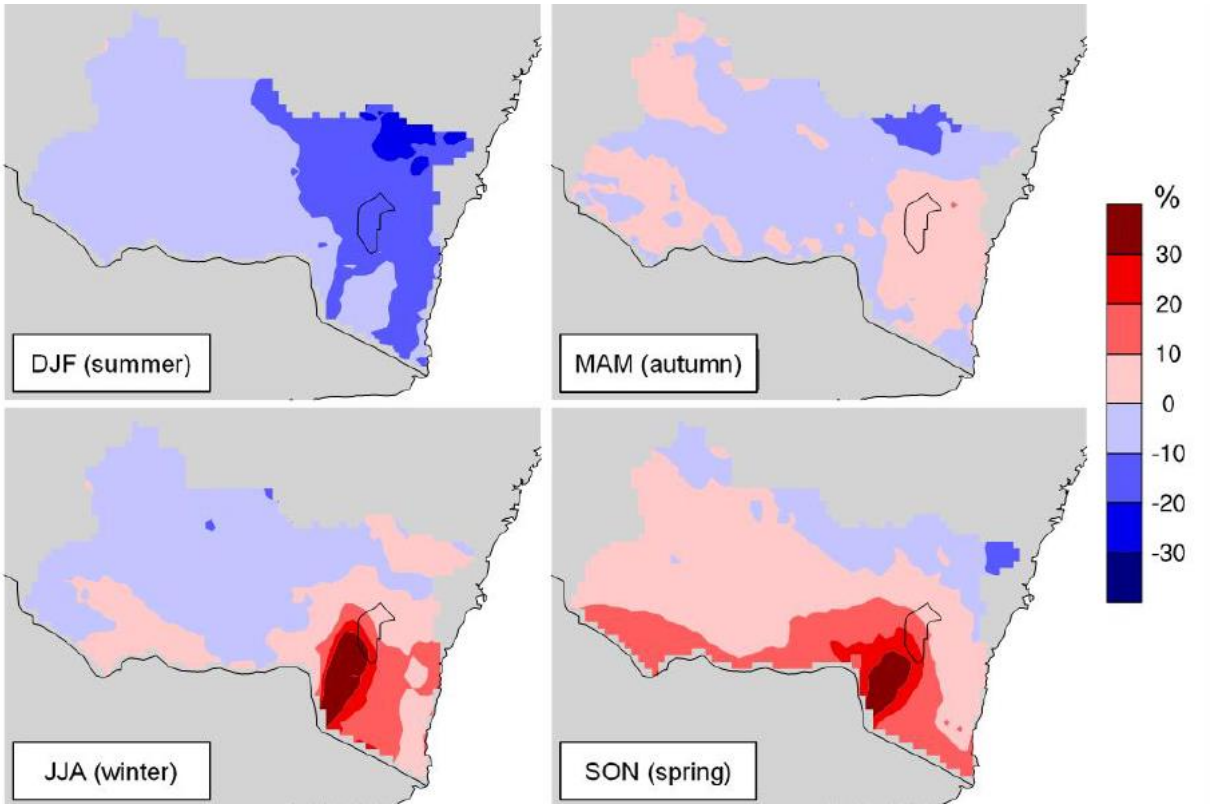


Figure 74: Projected changes in seasonal FFDI (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

As part of the development of the Snowy Master Plan, Blackash Bushfire Consulting have investigated the SAP and assessed nine proposed sites around the Jindabyne township and their ability to provide complying asset protection zones. Ski resorts or other zones within the SAP were not assessed.

3.8 Solar radiation

Increased solar radiation has been projected for the region with a high confidence. Due to reduced rainfall and therefore cloud cover, solar radiation in winter and spring is expected to increase (Figure 75). Increased solar radiation is expected to increase snow temperatures in alpine areas and increasing surface temperatures in the Jindabyne township and surrounds.

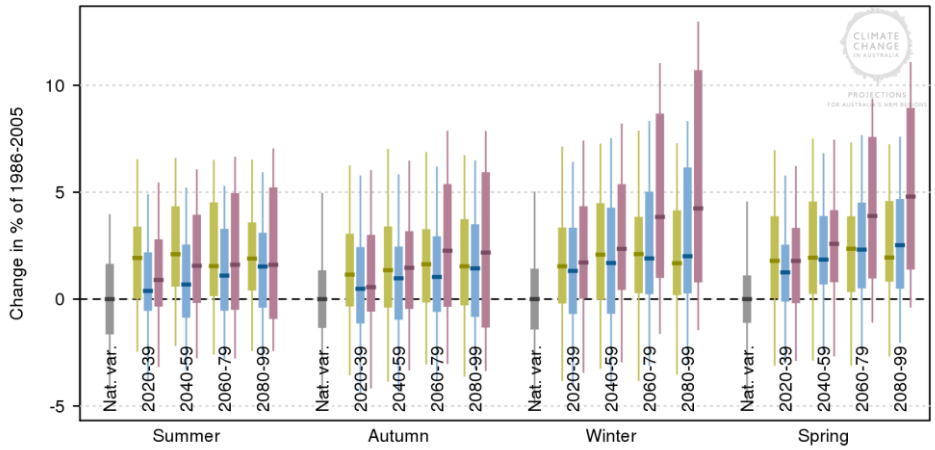


Figure 75: Projected seasonal solar radiation changes for the Southern Slope cluster with RCP2.6 (green), RCP4.5 (blue), RCP8.5 (purple). Source: CSIRO

3.9 Evapotranspiration

The CCIA projections incorporated a potential increase in evapotranspiration across all seasons by 2090, with associated decreases in rainfall reducing soil moisture. Evapotranspiration is the combined process of evaporation over land (from soil, wetlands, and standing water) and transpiration is when plants release water vapor. This can lead to increased water demand for plants, including crops and drier soil conditions.

3.10 Wind speed

For the baseline period 1990 to 2009, the region has experienced strong winds with speeds of more than 8 m/s in the Alpine zone and 6-7 m/s in Jindabyne township and surrounds (Figure 76).

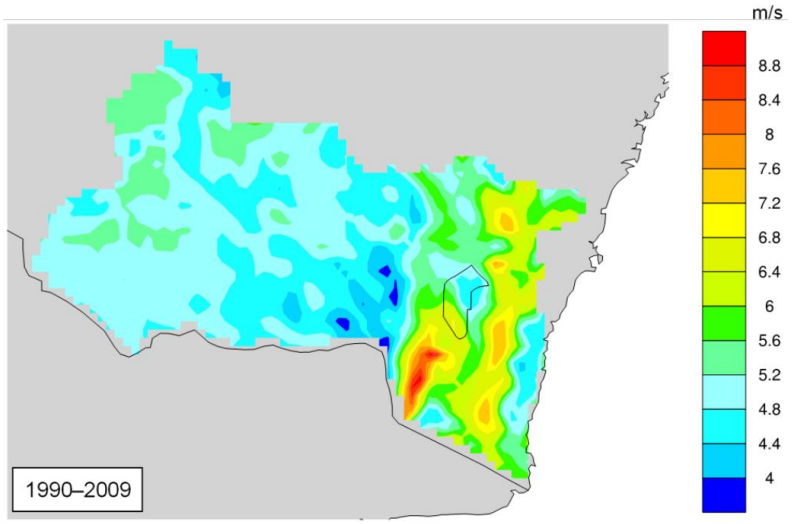


Figure 76: Simulated annual mean wind speed for 1990 to 2009. Source: DPE

Seasonal wind speeds are much higher in winter and spring with more than 9 m/s in the Alpine region and 7 m/s in the township. Wind speeds in summer are above 5 m/s in Jindabyne and 7.5 m/s in the Alpine zone. For autumn wind speeds in the SAP ranging from above 5.5 m/s in the lower-lying regions to more than 7.5 m/s in the Alpine zone (Figure 77).

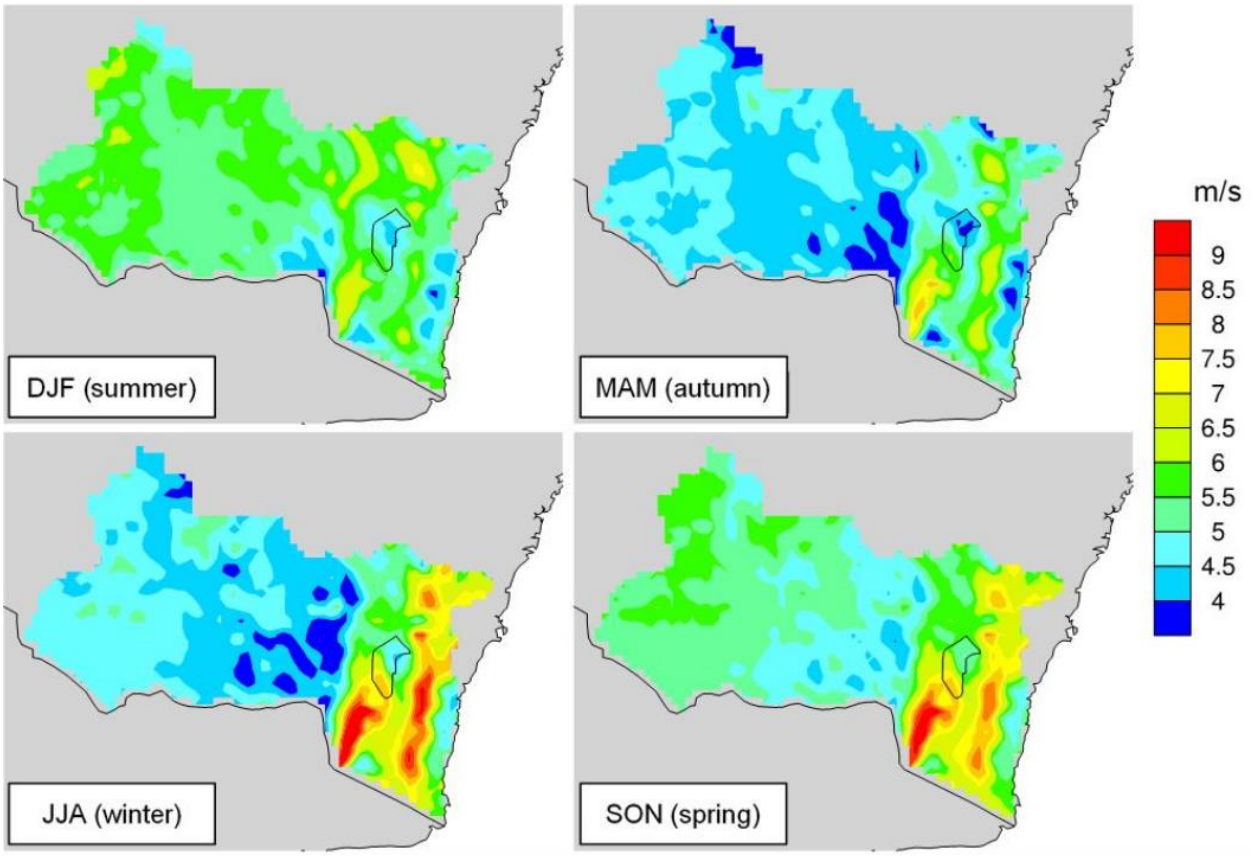


Figure 77: Simulated seasonal mean wind speed for 1990 to 2009. Source: DPE

Changes in wind speed are projected to be small in the near and far future and vary across the seasons.

In the near future, annual mean wind speed is expected to decrease by 4% across the entire SAP (Figure 78).

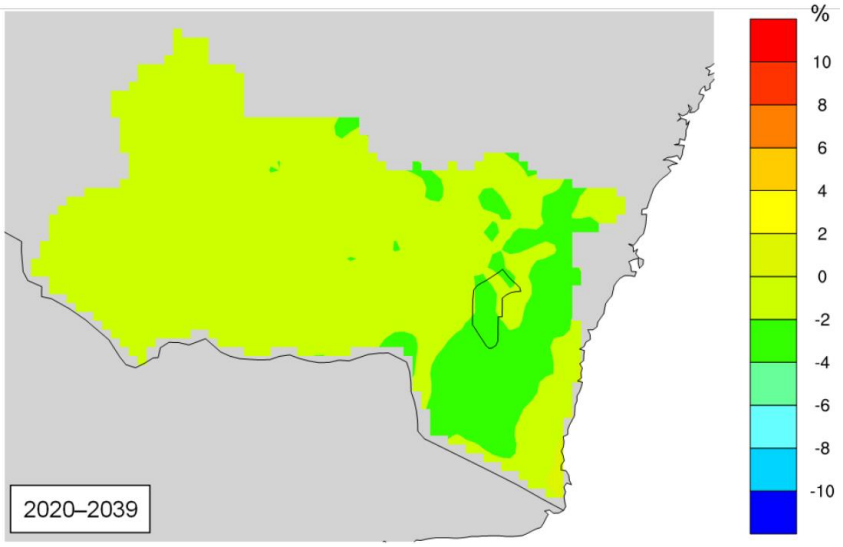


Figure 78: Projected changes in annual mean wind speed (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Seasonal mean wind speeds are expected to little increase in summer and winter for the SAP. During autumn and spring, wind speed projected to decrease across the SAP by more than 4-6% in both seasons with a possible decrease of 8% in spring in the Jindabyne area (Figure 79).

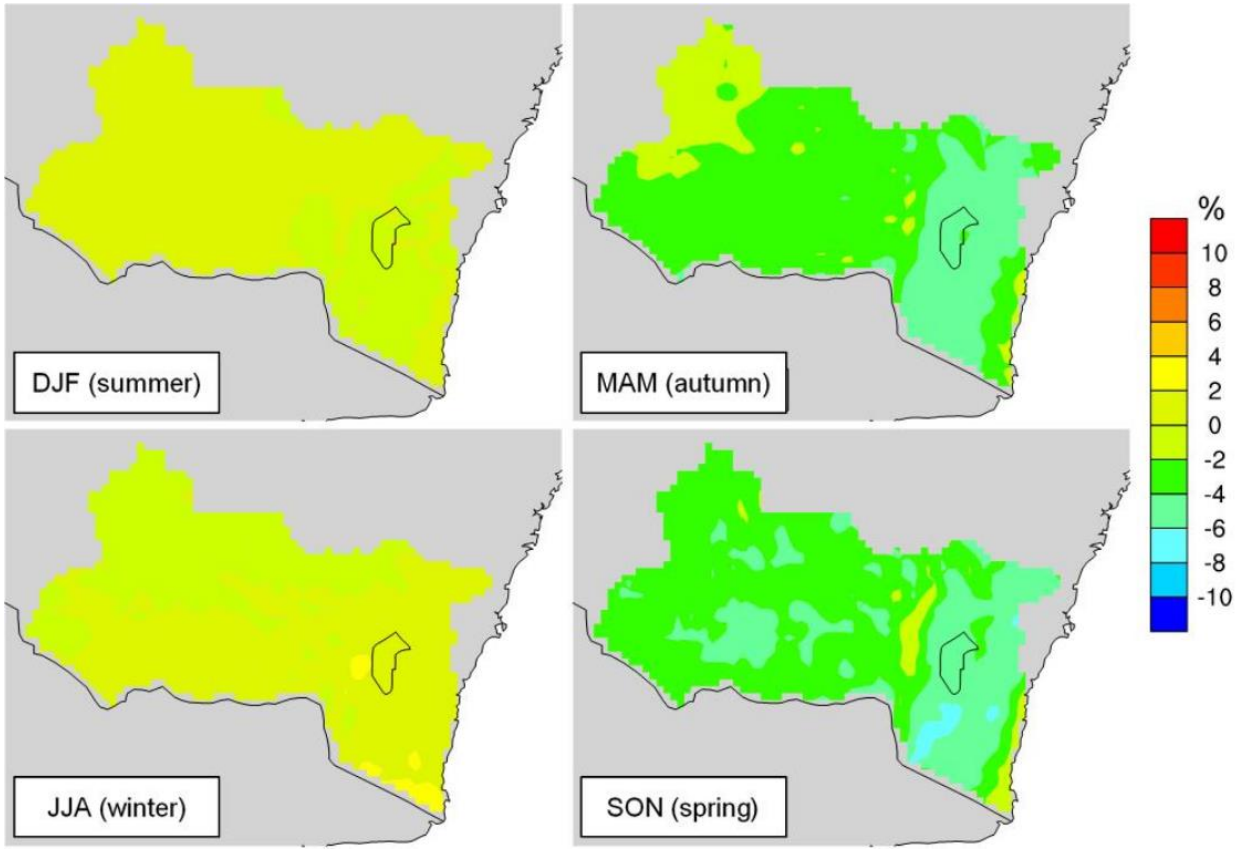


Figure 79: Projected changes in seasonal mean wind speed (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

By the 2060 to 2079 period, annual mean wind speed is projected to further decrease by 4-6% (Figure 80).

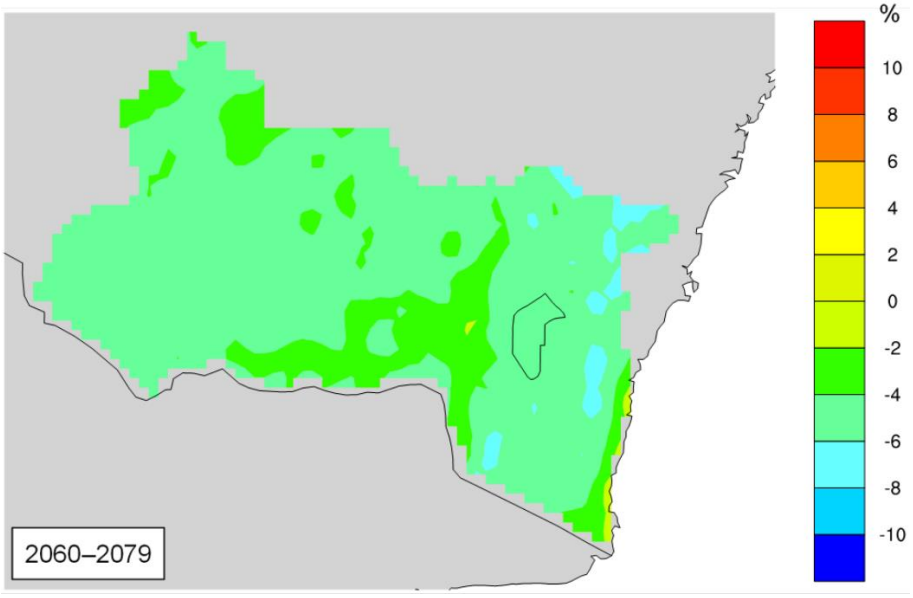


Figure 80: Projected changes in in annual mean wind speed (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

The most significantly change in wind speed is expected to occur in spring with a decrease of more than 10% in some parts of the Alpine region and the Jindabyne area. Wind speed in autumn is expected to decrease by 6-8% in the SAP while changes for summer and winter projected to decrease by 4% (Figure 81).

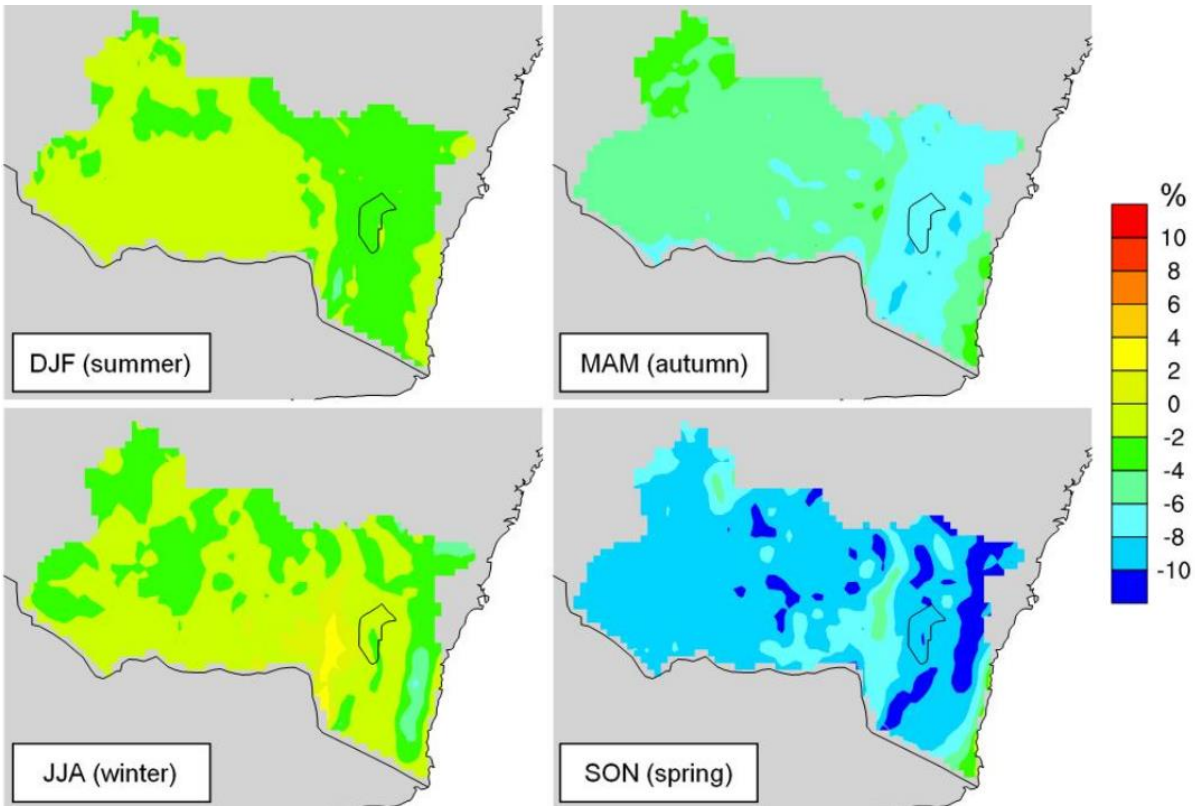


Figure 81: Projected changes in seasonal mean wind speed (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.10.1 Maximum daily wind speed

Maximum wind speed is high across the SAP ranging from more than 16 m/s in the lower lying areas to more than 22 m/s on mountain peaks (Figure 82).

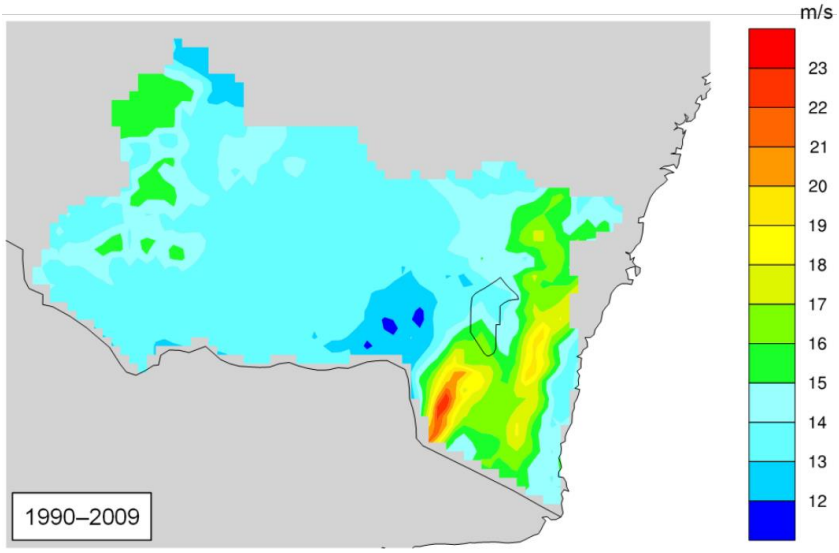


Figure 82: Annual mean maximum wind speed for 1990 to 2009. Source: DPE

The highest wind speeds in the SAP occurring during winter and spring with more than 24 m/s on the Alpine region's peaks and 18-20 m/s in the Jindabyne township and surrounds. Wind speeds in the SAP during summer in the order of 14-18 m/s for the lower-lying areas and 20 m/s in the higher regions of the Alpine zone. Wind speeds in autumn are similar to summer with higher wind speeds of 22 m/s on the mountain tops (Figure 83).

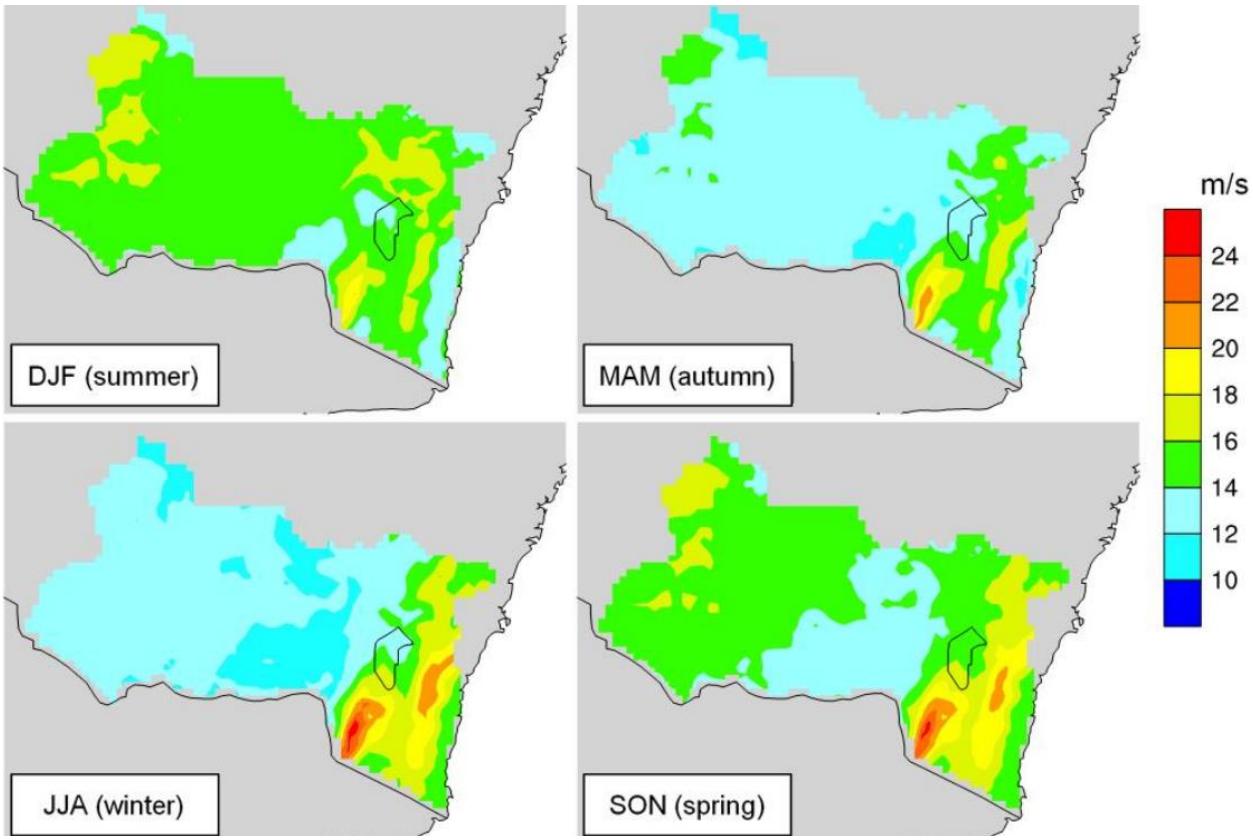


Figure 83: Seasonal maximum wind speed for 1990 to 2009. Source: DPE

Overall, little change in annual maximum wind speed is projected for 2020 to 2039 with a decrease of 2% for the Jindabyne township and 4% for some areas of the Alpine region (Figure 84).

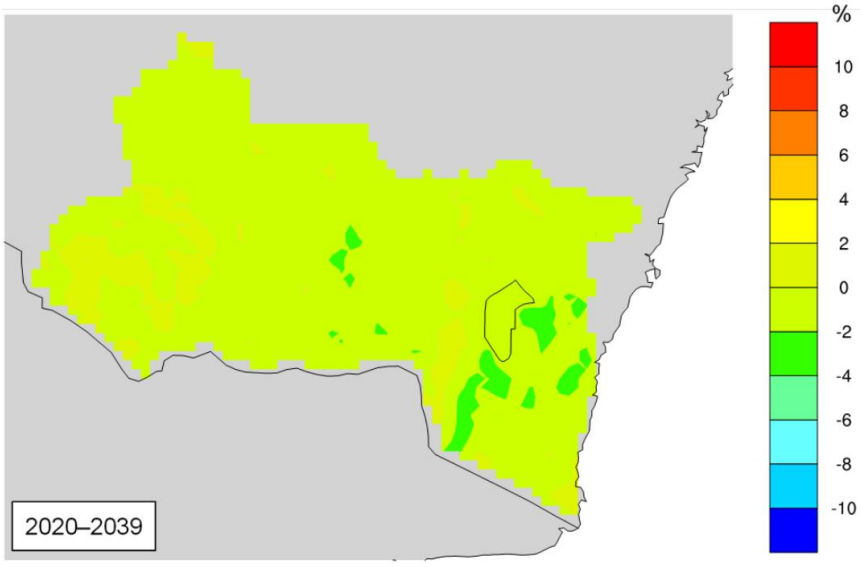


Figure 84: Projected changes in annual mean maximum wind speed (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Throughout the year, seasonal variations in changes in maximum wind speed are projected to be small. The largest variation is expected to occur in spring and autumn with a decrease by 4-8% for the Alpine region and 2-6% for the Jindabyne area in spring and 4% across the SAP in autumn. In summer, a slight increase of 2% for some of the Alpine region is projected while no change in wind speed is expected for the rest of the SAP (Figure 85).

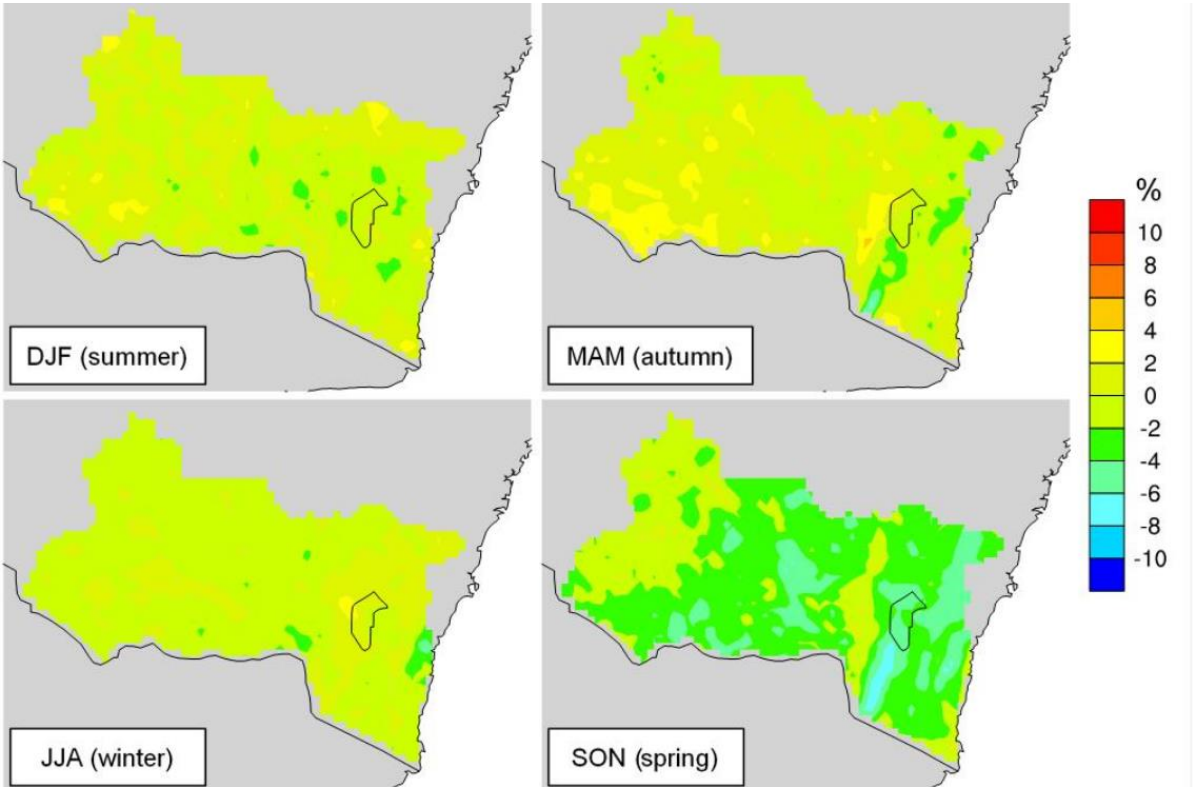


Figure 85: Projected changes in seasonal mean maximum wind speed (%) for 2020 to 2039 relative to 1990 to 2009. Source: DPE

For the far future, changes in maximum wind speed are projected to be similar to the near future projections and the same across the entire SAP (Figure 86).

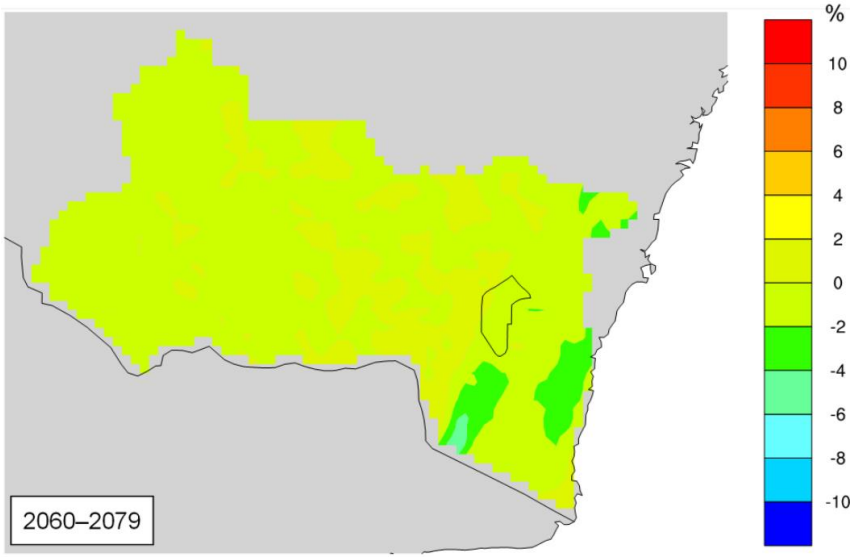


Figure 86: Projected changes in annual mean maximum wind speed (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

However, seasonal variations in maximum wind speed changes are slightly larger for the far future compared with near future projections and show an overall decreasing trend for all seasons. The largest variation is expected to occur in spring and autumn with a decrease by 6-8% for the Alpine region and 4-6% for the Jindabyne area in spring and 2-4% for the Jindabyne township and 6% in the Alpine region in autumn. In summer, a decrease of 2-4% in maximum wind speed is projected across the SAP with the larger decrease to occur in the Jindabyne township and surrounds (Figure 87).

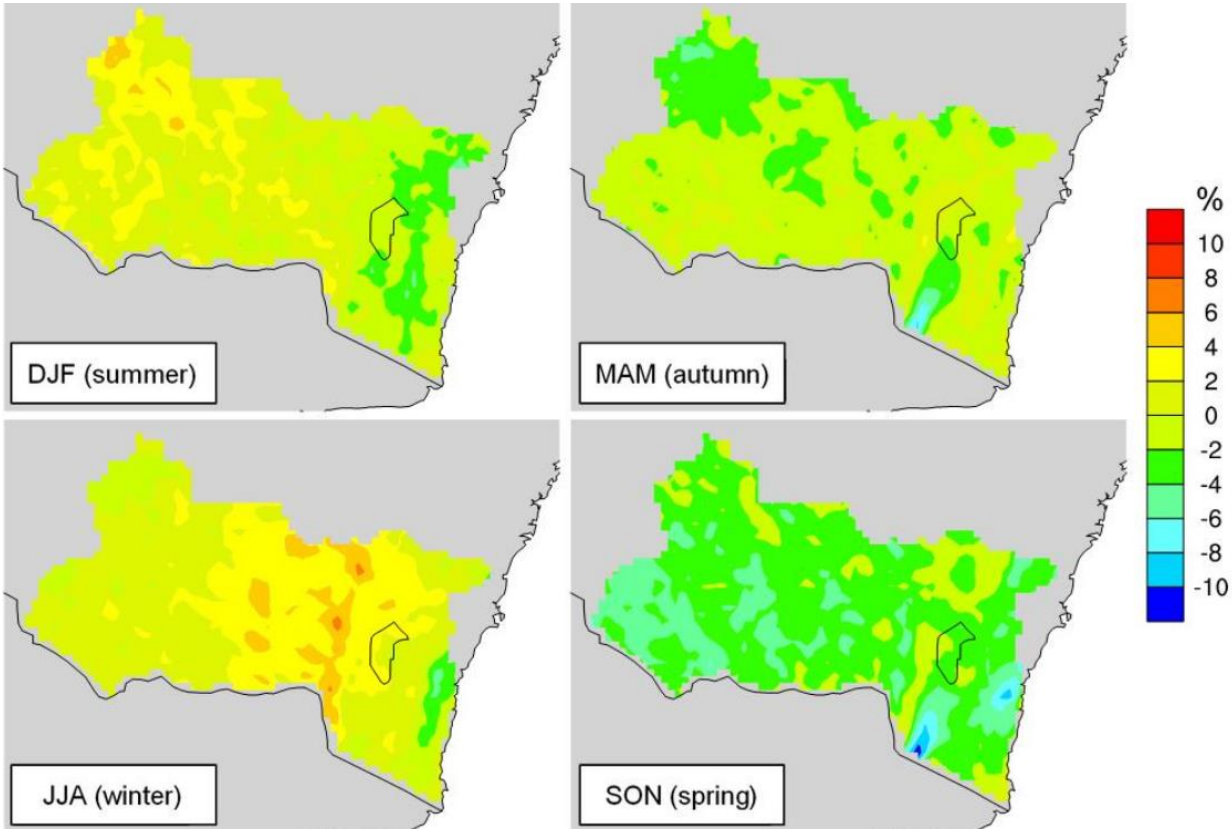


Figure 87: Projected changes in seasonal mean maximum wind speed (%) for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.10.2 Strong wind days (max. wind speed above 13 m/s)

Correlating with the topography of the region, strong wind occurs on more than 120 days in the Alpine region and 60-80 days in the lower-lying Jindabyne township and surrounds (Figure 88).

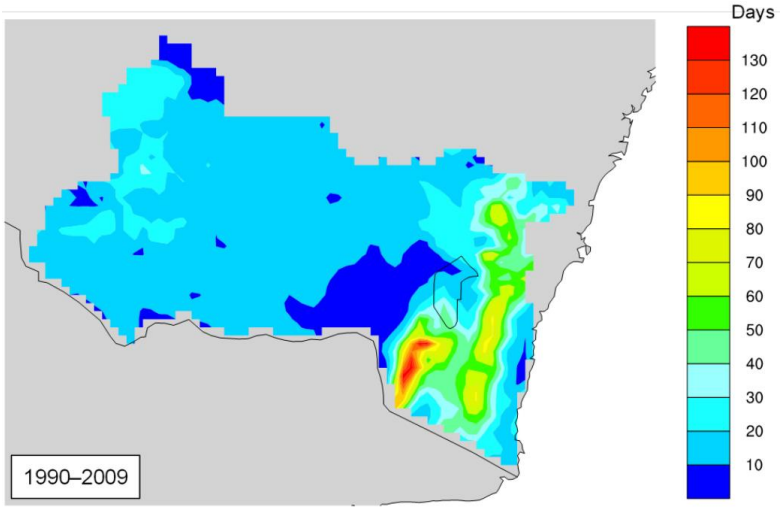


Figure 88: Number of annual strong wind days for 1990 to 2009. Source: DPE

For the SAP, most of the strong wind days are in winter and spring. During winter, the Alpine region experiences more than 50 days and the Jindabyne township more than 20 days of strong wind. For autumn, the number of strong wind days is about the same for Jindabyne, while the Alpine region experiences fewer strong wind days (30 days) than in winter (Figure 89).

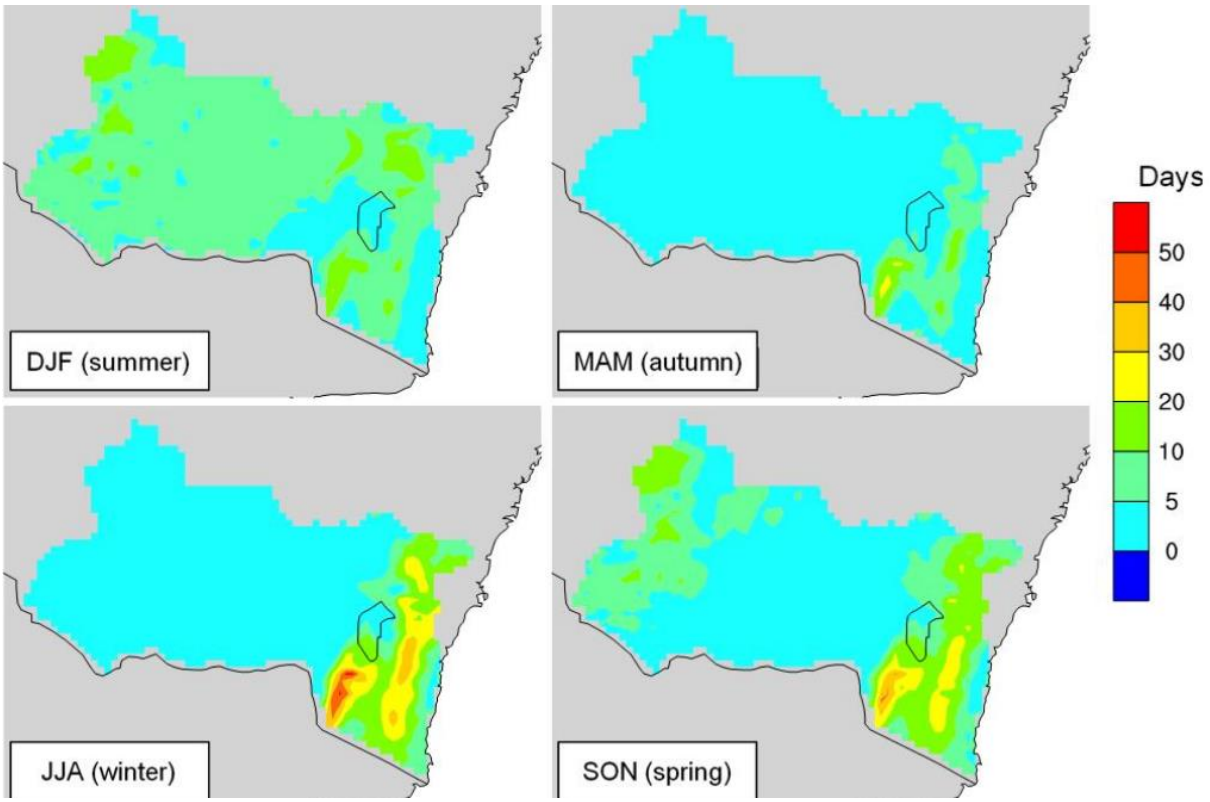


Figure 89: Number of seasonal strong wind days for 1990 to 2009. Source: DPE

For the near future, changes are expected to be small with 1-2 more days of strong wind in the Jindabyne area and 1 more day for the Alpine region.

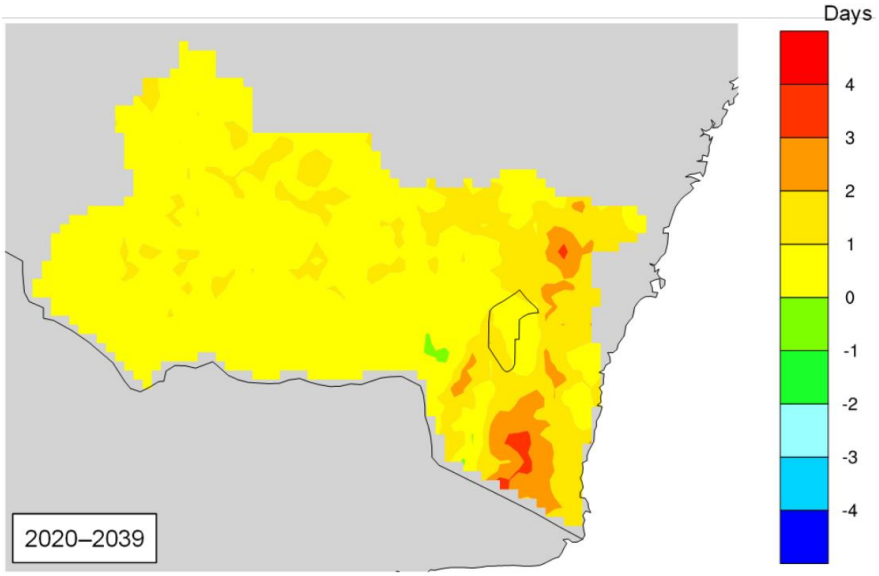


Figure 90: Projected changes in annual strong wind days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Although a small increase in annual strong wind days is projected, the number of strong wind days is only expected to increase in winter in the SAP and to decrease for the rest of the year. In the Jindabyne

township, strong wind days are expected to increase 1.5-2 more days in winter while a slight decrease of 1 day is projected for the Alpine region. In spring the number of strong wind days is projected to decrease by more than 2.5 days across the SAP. Changes in summer and autumn are in the order of 0.5-1.5 fewer strong wind days in the Jindabyne township and 1-2 fewer days in the Alpine region with a possibly higher decrease of more than 2 days in summer (Figure 91).

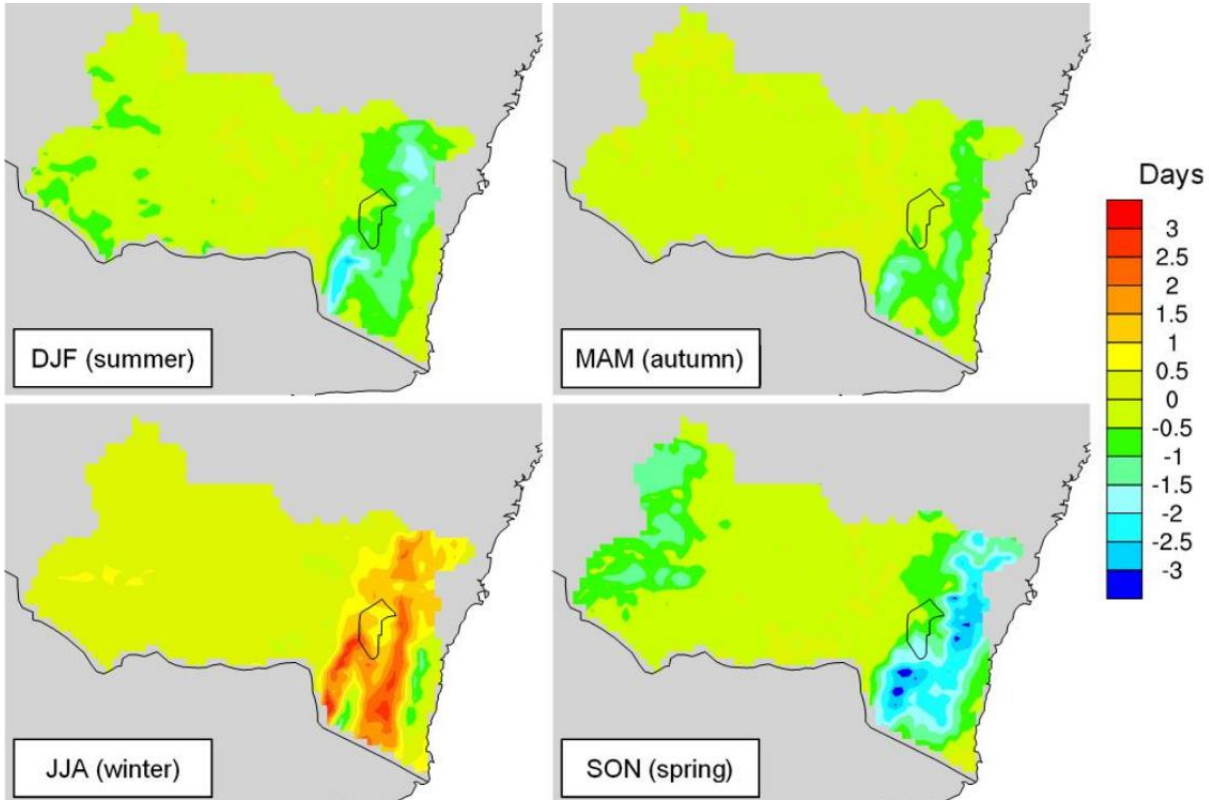


Figure 91: Projected changes in seasonal strong wind days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Overall, annual number of strong wind days is expected to decrease in the SAP in the far future by 2 days in Jindabyne and surrounds and 4-6 days in the Alpine zone (Figure 92).

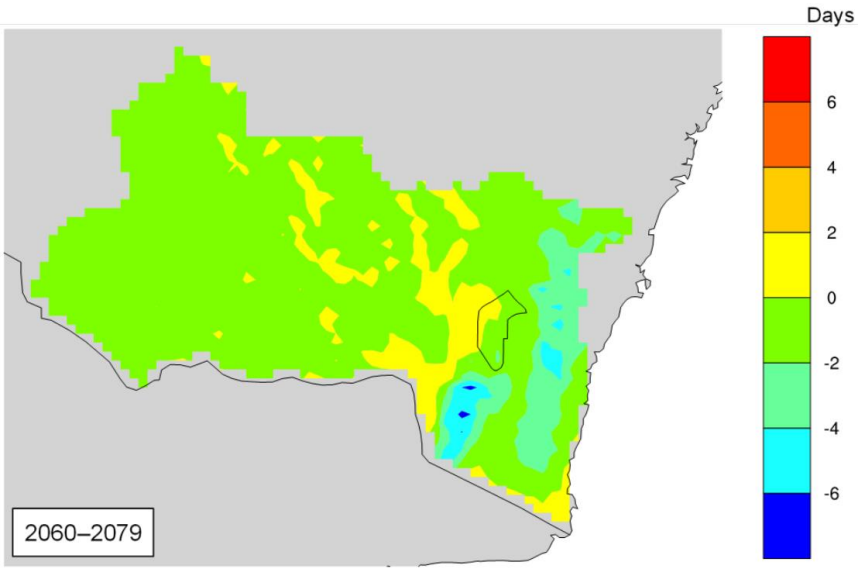


Figure 92: Projected changes in annual strong wind days for 2060 to 2079 relative to 1990 to 2009. Source: DPE

Seasonal changes in strong wind days for the 2060 to 2079 (Figure 93) period are similar in scale compared with the near future projections (Figure 91).

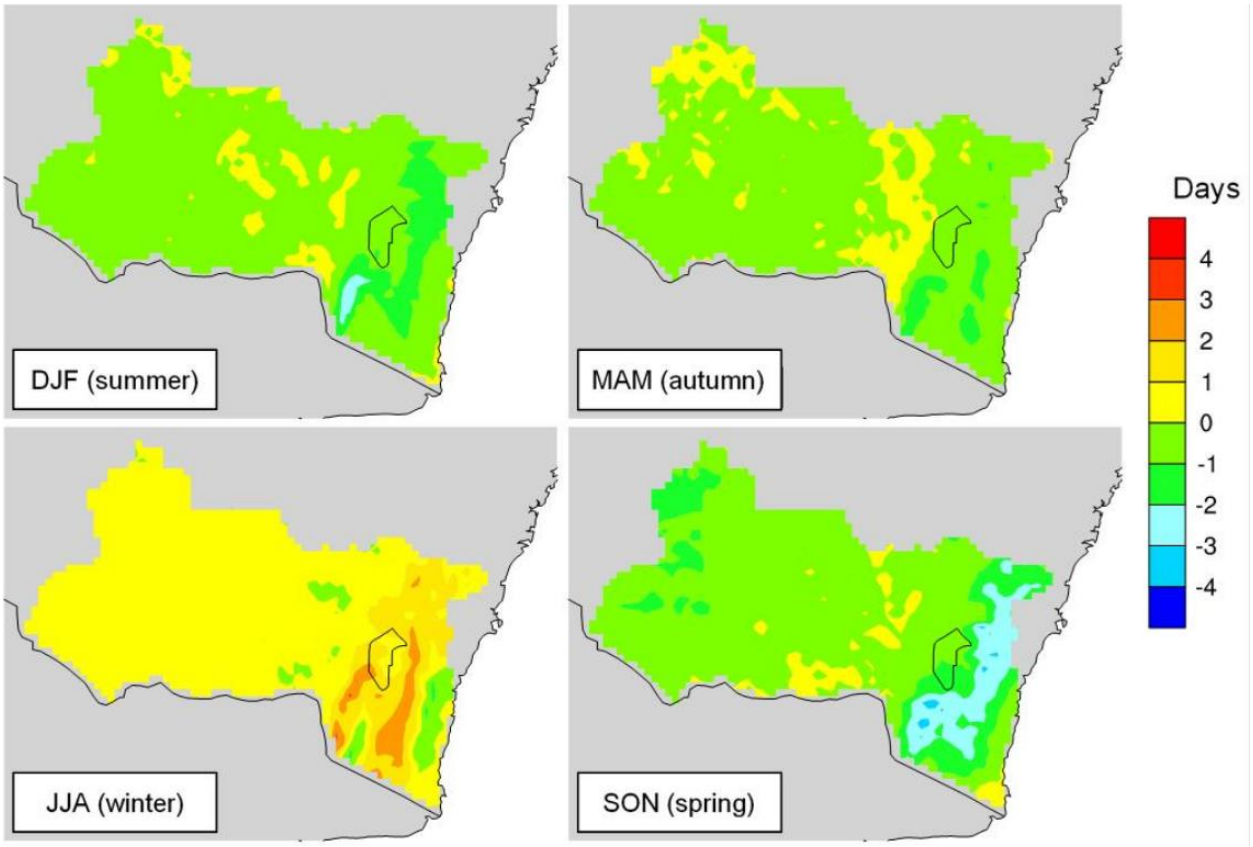


Figure 93: Projected changes in seasonal strong wind days for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.10.3 Gale days (maximum wind speed above 17 m/s)

Mean number of gale days in the SAP for the 1990 to 2009 baseline period is 8-20 for the lower-lying areas (including Jindabyne township) and more than 20 for the Alpine region.

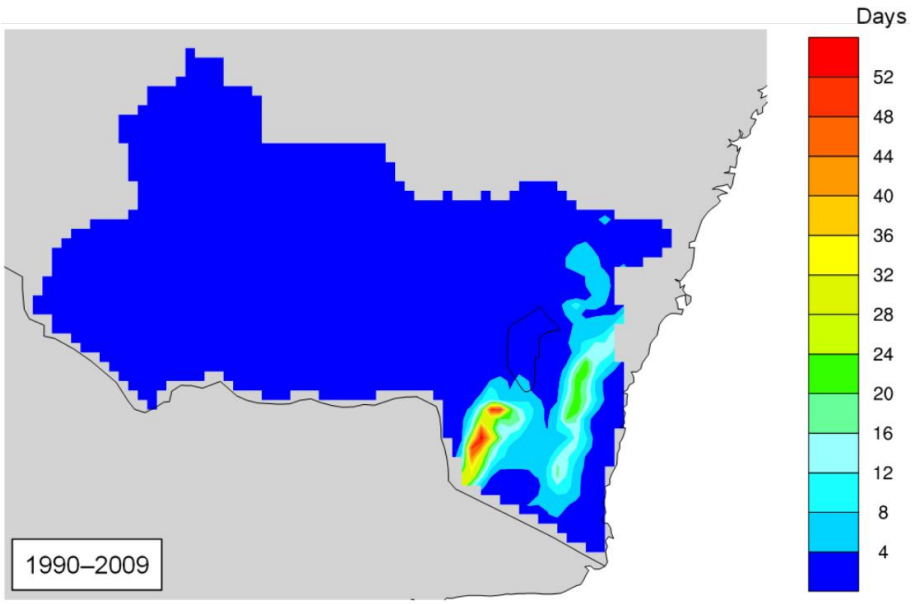


Figure 94: Annual gale days for 1990 to 2009. Source: DPE

Though gale days can occur at any time, most occur during winter and spring with 2-6 days in Jindabyne and surrounds and 10-16 days in the Alpine region and more than 18 on the mountain peaks. In summer and autumn, 2 gale days are projected in the Jindabyne area and 6 in the Alpine zone (Figure 95).

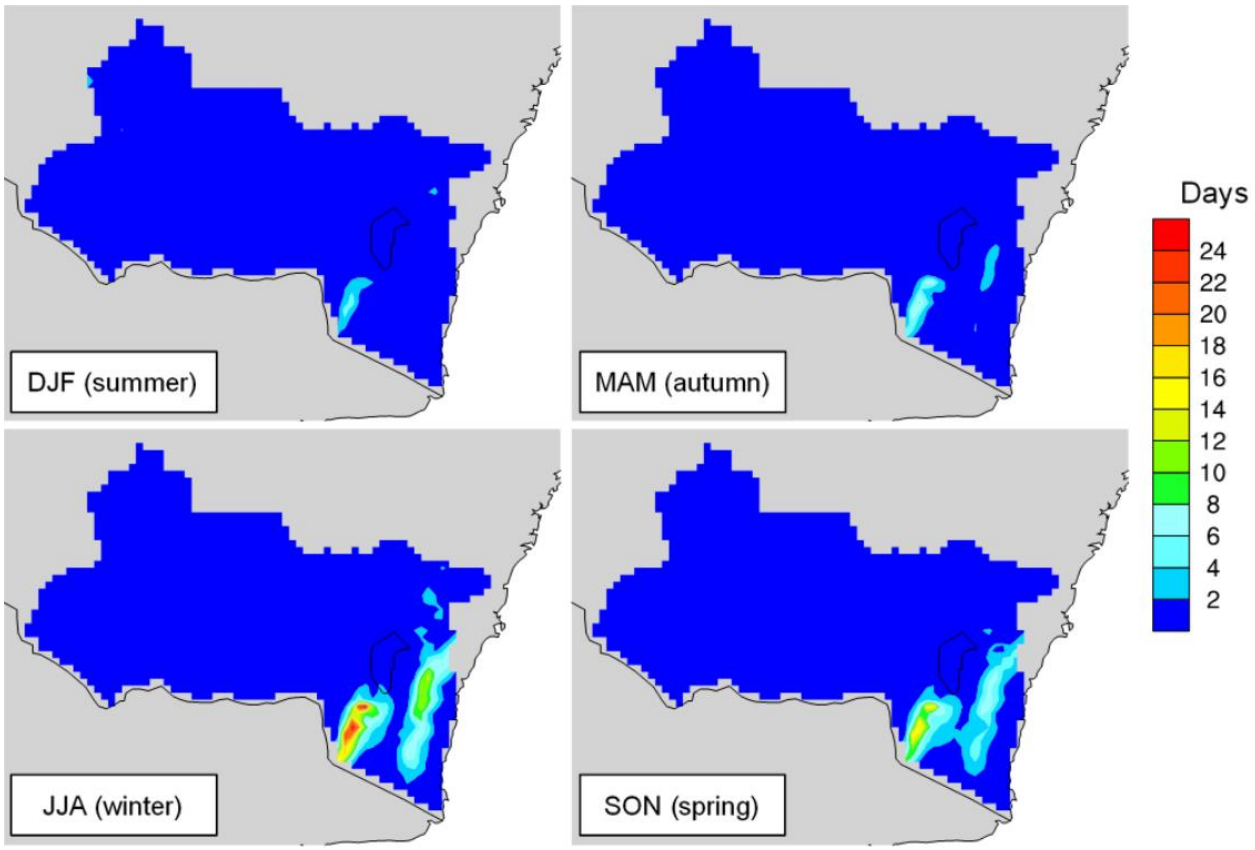


Figure 95: Seasonal gale days for 1990 to 2009. Source: DPE

A few more gale days are projected for the Alpine area in the near future.

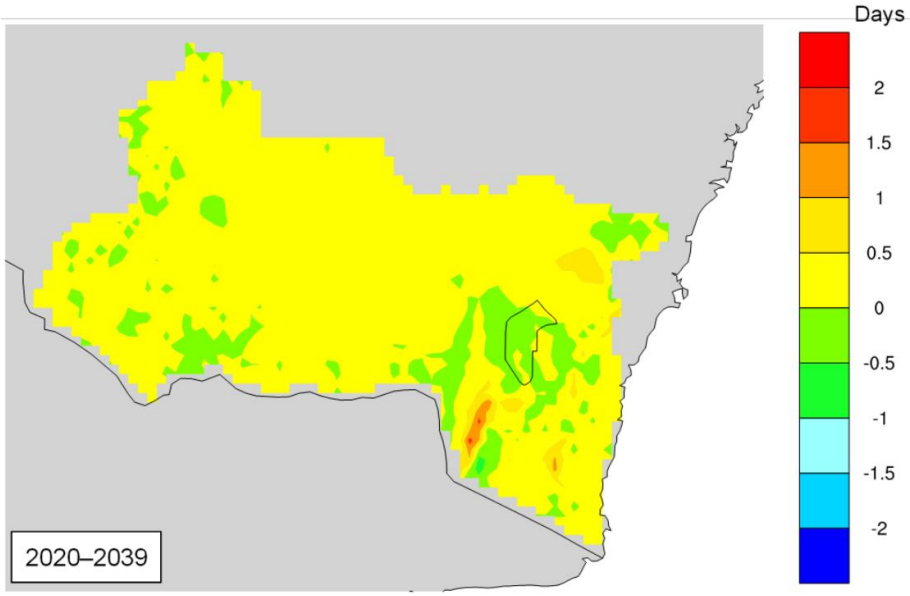


Figure 96: Projected changes in annual gale days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

For the near future, the number of gale days is likely to increase in winter with 2 more days in the Alpine region and 1.5 more days in Jindabyne and surrounds. There is a declining trend in number of gale days in the order of 0.5 day for Jindabyne for all other three seasons and 0.5-1 day for the Alpine region in summer and autumn and 2 fewer days in spring (Figure 97).

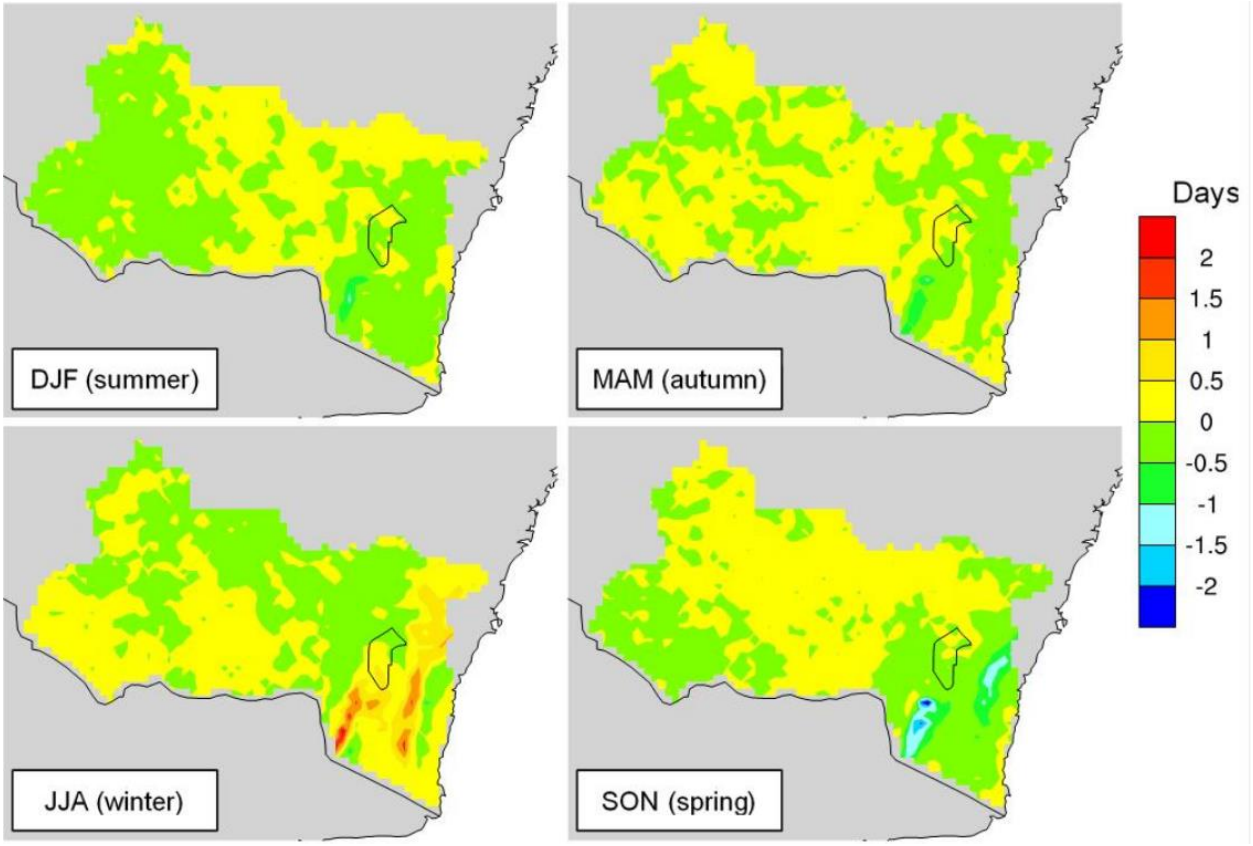


Figure 97: Projected changes in seasonal gale days for 2020 to 2039 relative to 1990 to 2009. Source: DPE

Similar to 2020 to 2039, there is little change in the number of gale days for 2060 to 2079, with 2–4 fewer gale days a year projected at the top of the Alpine region (Figure 98).

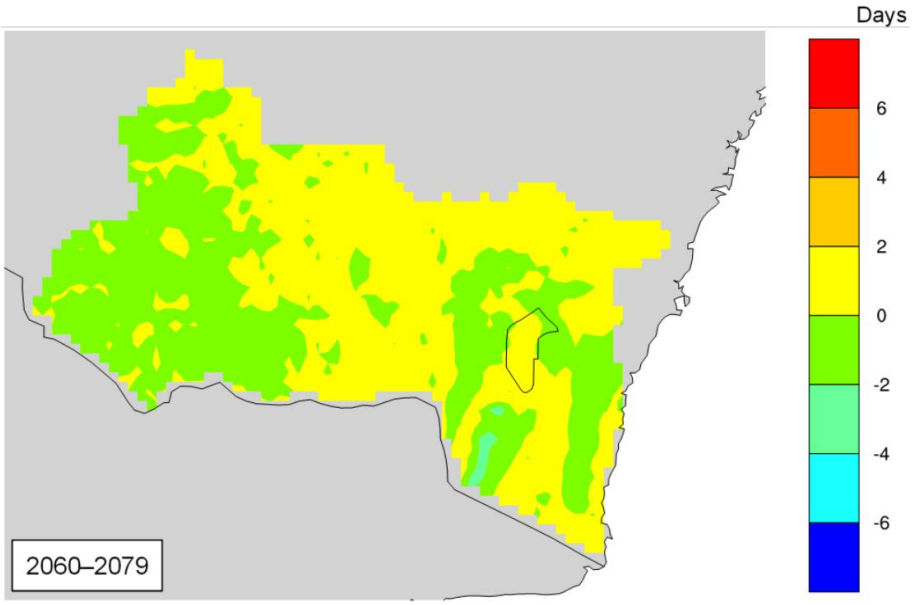


Figure 98: Projected changes in annual gale days for 2060 to 2079 relative to 1990 to 2009. Source: DPE

Seasonal changes in number of gale days are similar to near future projections. The number of gale days is likely to increase in winter with 1-2 more days in the Alpine region and 1 more day in Jindabyne and surrounds. There is a declining trend in number of gale days in the order of 1 day for Jindabyne the Alpine region for all other three seasons with 2 fewer gale days for the Alpine region in spring (Figure 99).

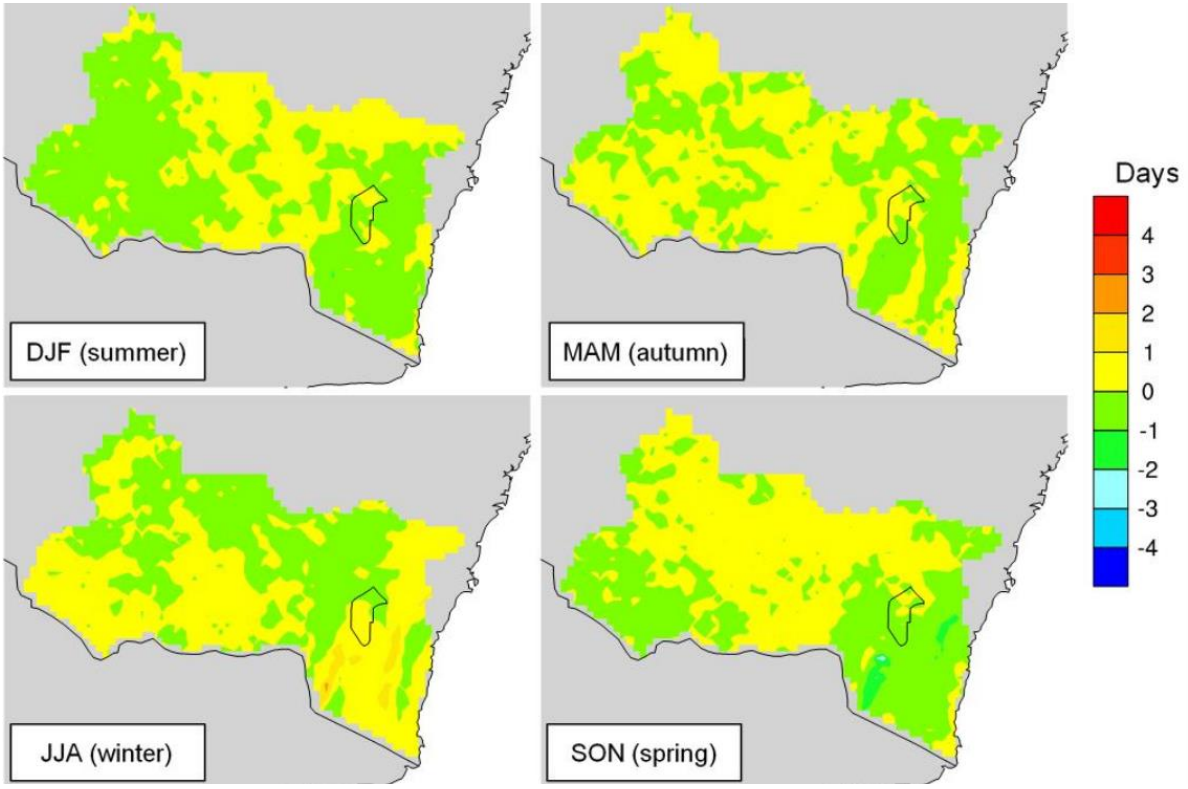


Figure 99: Projected changes in seasonal gale days for 2060 to 2079 relative to 1990 to 2009. Source: DPE

3.11 Humidity

Source: CSIRO Climate Change In Australia (2015) Technical Report, and CSIRO Climate Futures Projections Tool.

A tendency for a decline in relative humidity is projected for all seasons, with the largest decrease in spring (Figure 100).

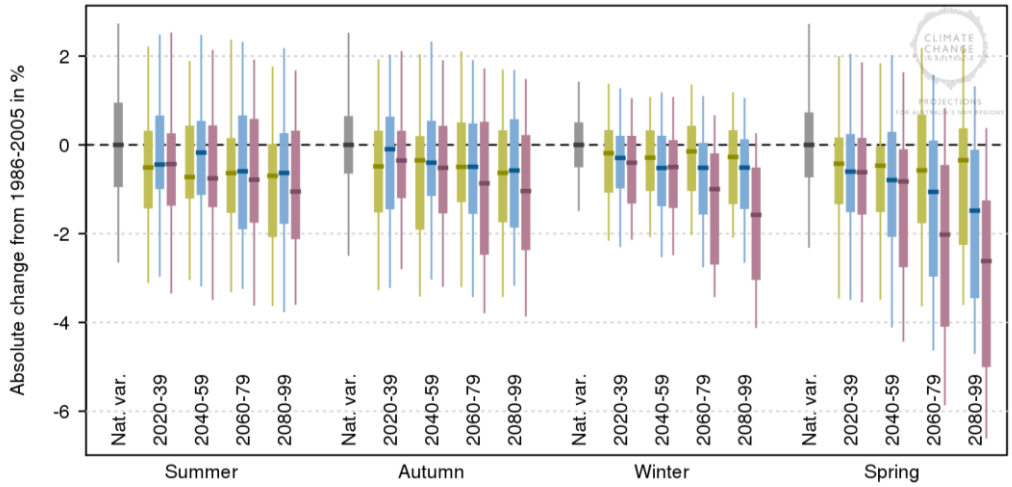


Figure 100: Projected seasonal humidity changes for Southern Slope cluster with RCP2.6 (green), RCP4.5 (blue), RCP8.5 (purple) and median (dark horizontal lines). Natural climate variability is represented by the grey bar. Source: CSIRO Climate Change Projections

3.12 Evapotranspiration

Source: CSIRO Regional Climate Change Explorer – Cluster Southern Slopes

Potential water evapotranspiration (the combined effect of evaporation from water bodies, and the transfer of water from vegetation to the atmosphere) is projected to increase in all seasons as warming progresses.

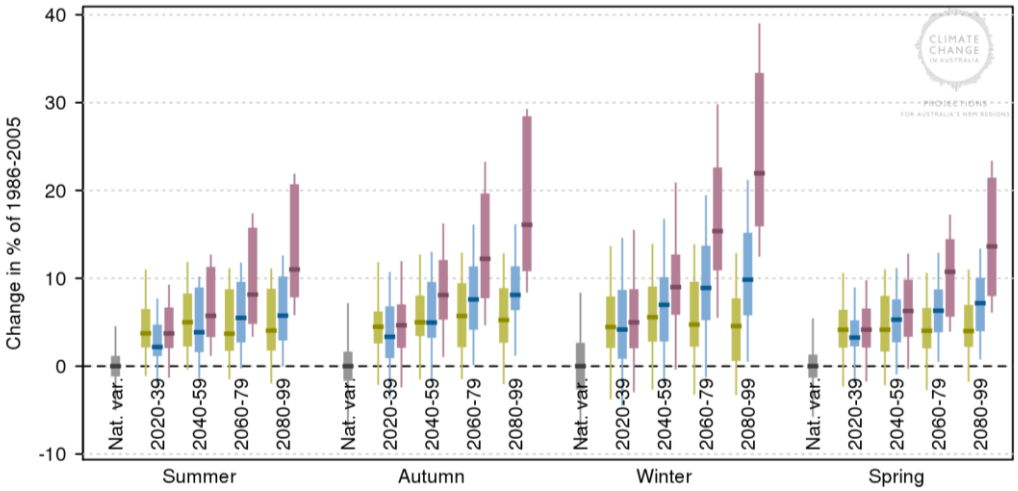


Figure 101: Projected seasonal evapotranspiration changes for Southern Slope cluster with RCP2.6 (green), RCP4.5 (blue), RCP8.5 (purple). Source: CSIRO

3.13 Biodiversity

As flora and fauna have found their survival niche by adapting to harsher alpine climate conditions over time, alpine biodiversity is highly vulnerable to the impacts of an accelerated climate change. Consequences for threatened flora and fauna in the Alpine region are greater than for those at lower elevations, as habitats for species and ecosystems are contracting and no suitable alternatives exist beyond mountain tops.

Biodiversity is expected to be impacted by a range of climate change projections including temperature increases, increased frequency of hot days, reductions in cold nights, rainfall variability, drier conditions and wind speed changes. The combined climate change impacts and associated bushfire risks, biodiversity is expected to be significantly impacted in the Snowy Mountains SAP, with the largest impacts occurring in the sub-alpine and alpine areas.

As a result of the climate change, the alpine vegetation is expected to experience 21-70% change in species composition with established ecosystems, such as Alpine Herbfields, Montane Lakes, Montane Bogs and Fens, Grassy Woodlands and Wet Sclerophyll Forest to decrease in area and species of lower-lying areas, such as Subalpine Woodland and Dry Sclerophyll Forest, expanding in these areas.

A more detailed assessment of biodiversity impacts is outside of the scope of this plan however further information for species composition and the impacts of climate change can be found in the *Climate change impacts in the NSW and ACT Alpine region: Impacts on biodiversity* report.

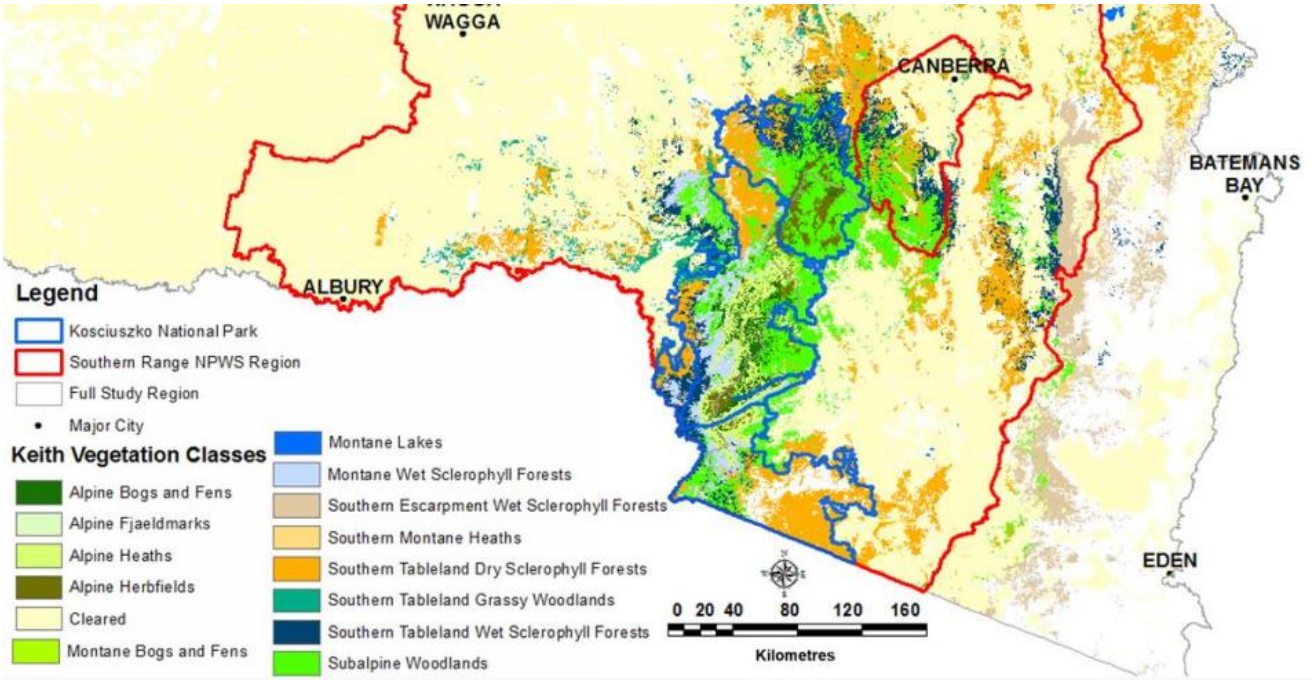


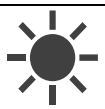
Figure 102: The mapped extent of the 13 alpine related vegetation classes. Source: DPE

3.14 Summary

A summary of the climate change projections for the Near Future and Far Future development milestones used as basis for the risk assessment is as follows:

Table 3: Climate change projections summary

Climate change risk		2030 Climate Change Projection	2070 Climate Change Projection
	Temperature increase	0.5 to 0.75°C	2.25 to 2.5°C
	Increased hot days	0 to 1 day above 35°C	2 to 4 days above 35°C
	Reduced cold nights	10-20 fewer cold nights	40 fewer cold nights
	Reduced snow conditions	20% reduction of suitable snowmaking conditions, a reduction of 100 hours	60% reduction of suitable snowmaking conditions, a reduction of 300 hours for the Alpine zone (above 1700m), lower lying areas become generally unsuitable

Climate change risk		2030 Climate Change Projection	2070 Climate Change Projection
	Reduced annual rainfall	5% reduction in annual rainfall harvest across the SAP 5 to 10% decrease in rainfall during spring. 5 to 10% increase in rainfall during autumn. 5% decrease in rainfall during summer 5% (Alpine) and 5-10% (Jindabyne) decrease in rainfall during winter	10% reduction in annual rainfall harvest for the SAP. 10-20% (Jindabyne) decrease and >20% (Alpine) decrease in rainfall during spring. 5-10% (Jindabyne) and 10-20% (Alpine) increase in rainfall during autumn. 5-10% increase (Jindabyne) and 5% decrease (Alpine) in rainfall during summer. 10-20% decrease in rainfall during winter
	Increased rainfall intensity	Increased variability with higher rainfall intensity, however difficult to quantify.	Increased variability with higher rainfall intensity, however difficult to quantify.
	Increased bushfire risk/intensity	Minimal annual change compared to current conditions. FFDI to reduce in summer and autumn by 10% and to increase in winter and spring by 10-20%.	5-10% increase in FFDI per annum, starting earlier in autumn and mainly occurring in spring and winter with > 30% increase in FFDI.
	Increased solar radiation	Minor increase in solar radiation projected <5%.	Minor increase in solar radiation projected <5%.
	Wind speed	2 to 4% decrease in mean wind speed. 1 to 2 days increase in strong wind days per annum across the SAP.	2 to 4% decrease in mean wind speed. 2 days (Jindabyne) and 4-6 days (Alpine) decrease in strong wind days.

4 Risk assessment

4.1 Introduction

The purpose of this section of the report is to summarise the risk assessment undertaken to determine the perceived impact of the climate change projections on the developable areas and supporting infrastructure within the SAP study area.

Separate risk assessments were undertaken for the two identified SAP zones being Zone 1 – Jindabyne and sub-alpine, and Zone 2 – Alpine, given that the perceived climate change impacts and therefore risk profile were considered to be potentially very different.

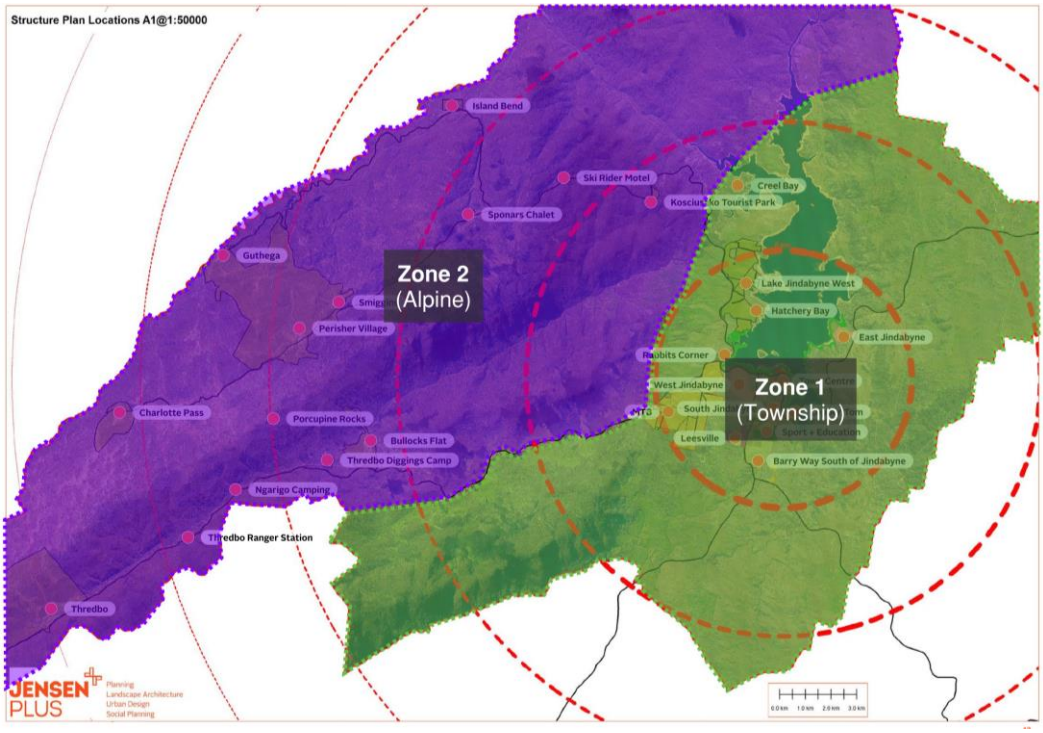


Figure 103: Risk assessment zones

The risk assessment was undertaken in three stages:

Table 4: Risk assessment stages and consultation

Risk assessment stage	Summary
Stage 1	Stakeholders were provided the opportunity to provide risk assessment inputs during a risk assessment workshop held on 13th April 2021.
Stage 2	Stakeholders were provided access to the Snowy SAP CCAP MURAL board and invited to provide input to the risk assessment matrices.
Stage 3	dsquared have undertaken a review of the stakeholder input, and all supporting technical reports for the Snowy SAP, and have consolidated the risk assessment, supplementing it with technical input as required.

4.2 Scope of risk assessment

The scope of the risk assessment is limited to the developable areas identified in the SAP Structure Plan and the associated connecting services and transport infrastructure.

The scope of this risk assessment does not include:

- The risk to flora and fauna.
- The risk to Kosciuszko National Park itself outside of the resort leased zones and the identified developable areas.
- Any places or infrastructure outside of the SAP boundary including interconnecting services and transport infrastructure.

4.3 Risk assessment criteria

The risk assessment criteria used has been undertaken adapted from *AS 5334:2013 Climate Change Adaptation for Settlements and Infrastructure* and utilises the Climate Risk Ready NSW Guide and referenced resources.

A multi-criteria analysis framework has been used to assign a risk level to each identified risk impact.

The first step is to identify the likelihood of the event occurring using the following categories and guidance:

Table 5: Risk likelihood

Rating	Recurrent risks	Single events
Almost certain	Could occur several times per year	More likely than not – probability greater than 50%
Likely	May arise about once per year	As likely as not – 50/50 chance
Possible	May arise once in 10 years	Less likely than not but still appreciable – probability less than 50% but still quite high
Unlikely	May arise once in 10 to 25 years	Unlikely but not negligible – probability low but noticeably greater than zero
Rare	Unlikely during the next 25 years	Negligible – probability very small, close to zero

The second step is to quantify the consequence of the impact using the following categories and guidance:

Table 6: Risk consequence

Consequence and success criteria	Public safety	Local growth and economy	Community and lifestyle	Environment and sustainability	Public administration	Infrastructure
Catastrophic	Large numbers of serious injuries or loss of lives	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support its community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service.
Major	Isolated instances of serious injuries or loss of lives	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen to be in danger of failing completely	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service.
Moderate	Small numbers of injuries	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts	Limited infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair.
Minor	Serious near misses or minor injuries	Individually significant but isolated areas of reduction in economic performance relative to current forecasts	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required.
Insignificant	Appearance of a threat but no actual harm	Minor shortfall relative to current forecasts	There would be minor areas in which the region was unable to maintain its current services	No environmental damage	There would be minor instances of public administration being under more than usual stress but it could be managed	No infrastructure damage, little change to service.

The *likelihood* rating and the *consequence* rating are then considered together using the following matrix to establish the *risk rating*:

Table 7: Risk matrix

		Consequence				
		Insignificant	***Minor***	***Moderate***	***Major***	***Catastrophic***
Likelihood	***Almost certain***	Medium	Medium	High	Extreme	Extreme
	Likely	Low	Medium	High	High	Extreme
	Possible	Low	Medium	Medium	High	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare	Low	Low	Low	Low	Medium

The risk ratings are contextualised as follows:

Low: The risk is of low importance and may be considered negligible. Unless the climate impact significantly increases over time no risk mitigation measures are considered necessary, with mitigation undertaken as a result of general routine maintenance.

Medium: The risk is significant as the impact will be measurable, and action will be required in order to mitigate the risk, such as a change in design standards and how assets are maintained and managed.

High: The risk is significant and will have a catastrophic impact and action must be undertaken as a high priority in order to mitigate the risk, at a senior management and governance level.

Extreme: The risk to the project is extreme and requires immediate action to mitigate the risk.

4.4 Risk assessment – Zone 1, Jindabyne township and sub-alpine

A consolidated risk assessment for Zone 1 – Jindabyne township and sub-alpine region is as follows:

Table 8: Zone 1 Jindabyne township and sub-alpine region - Consolidated risk assessment

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
Temperature increase 	Increased utility infrastructure demand (electricity and water) during summer months, including energy use for cooling	Low	Medium
	Increased variability impacting ability to accurately calculate network demand and design infrastructure	Low	Medium
	Potential disruption to sewerage treatment processes, particularly if settlement ponds are used	Low	Medium
	Change in species distribution in and around township, weed/pest invasions including mosquitos, decline in biodiversity and natural amenity including fishing	High	Extreme
Increased hot days 	Heat stress for the community population, including residents and visitors (relative heat wave impacts)	Medium	Extreme
	Reduced reliability and functionality of infrastructure services including sewage treatment, roads, public buildings, and electricity supply	Low	Medium
	Increased demand and utilisation of public infrastructure for respite e.g. lake foreshore and public/community buildings	Medium	High
	Reduction in visitor numbers during summer season, impacting adaptive capacity, finance, and economic growth	Medium	High
	Reduction in cultural, social, and sporting capacity and connectivity during summer season	Low	Medium
	Increased algae and other reductions in Lake Jindabyne water quality and amenity.	Low	Medium
Reduced snow conditions 	Reduced winter tourism due to shorter and more intermittent snow seasons	Medium	Extreme
	Reduced tourism expenditure during winter impacting business financial viability and economic growth	Medium	Extreme

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
	Reduced snow melt and runoff of water catchments (Lake Jindabyne levels may be impacted) and impacts on water quality	Medium	High
	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	High	Extreme
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	Medium	High
	Reduced lake water levels impacting water quality, lake access, recreational uses and visual amenity	Medium	High
	Increased dust and potential for dust storms, and tree and grass stress in recreational areas	Low	Low
	Low rainfall/drought periods impacting on soil conditions, and contributing to an increased bushfire risk	Low	Medium
Increased rainfall intensity 	Increased waterway and catchment area flooding impacting the built and natural environment (buildings, infrastructure, landscaping), and stormwater management systems	Low	Low
	Risk to human life as a result of increased intensity of flooding/flash flooding	Low	Low
	Increased erosion impacting built infrastructure (roads, pathways, trails)	Medium	Medium
	Increased sediment and runoff impacting Lake Jindabyne water quality	Medium	Medium
	Increased likelihood of access/egress/evacuation being blocked by waterway flooding (risk to life and property)	Low	Low

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
Increased bushfire risk/intensity 	Increased risk ratings and fire life safety standards for new and replaced infrastructure	Medium	High
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	Low	High
	Loss of biodiversity and threatened species	Low	Low
	Repeated bushfires and visual amenity impact reducing tourism, visitation and economic growth (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/APZ)	Medium	Medium
	Increased bushfire waste and resource material recovery/disposal requirements	Low	Low
	Ash and debris entering waterways impacting on water quality and visual amenity	Low	Medium
	Adverse mental health and economic recovery impacts of repeated bushfires	Medium	High
	Smoke inundation for township and resorts, disruption and poor air quality	Low	Medium
Increased solar radiation 	Increased solar radiation identified as posing no adverse risks	None	None
Wind speed 	Impacts on amenity at Lake Jindabyne foreshore during strong wind days	Low	Low

4.5 Risk assessment – Zone 2, Alpine

A consolidated risk assessment for Zone 2 – Alpine region is as follows:

Table 9: Zone 2 Alpine region - Consolidated risk assessment

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
Temperature increase 	Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit	Medium	High
	Increased discrepancy between natural snow fields and artificial snow fields impacting on amenity and visitor experience	Medium	Extreme
	Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term	Medium	Extreme
	Abandonment of snow infrastructure at lower altitudes as visitors migrate to higher altitudes, with resort operators unable to fund reparations/restoration	Low	High
	Faster snow melt reducing snow coverage, leading to an increase in snow making and salt/environmental impacts, or reducing length and financial viability of snow season	Medium	Extreme
	Over-investment in supporting infrastructure in the short term, to accommodate higher intensity use but then reducing ski areas	Medium	High
Increased hot days 	Heat stress for the community population and in particular visitors using active tourism offerings that could be susceptible to increased hot days (hiking and mountain biking events)	Medium	Extreme
	Increased water storage requirements and/or alternative water supplies where mains water is not connected, to cater for periods of high temperatures with increased water consumption	Low	Medium
	Heat stress and increased electricity demand and cost for buildings	Low	Medium

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
Reduced snow conditions 	Reduced winter tourism due to shorter and more intermittent snow seasons	Medium	Extreme
	Reduced tourism expenditure during winter impacting business financial viability and economic growth	Low	Extreme
	Increased impact of non-snow-based activities on sensitive alpine areas (previously not accessed e.g. hiking, mountain biking and camping.	Low	Medium
	Reduced snow melt and runoff of water catchments (impact on biodiversity resulting in ecological and amenity impacts)	High	Extreme
	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	High	Extreme
	Change in and loss of biodiversity and ecology, including loss of alpine flora and fauna, snow gum die back, flora/fauna loss/migration, and other sudden unforeseen impacts	High	Extreme
	Change in alpine scenic amenity (no snow), increase in weeds and shrubs, visitation is no longer to an alpine snow destination	Low	High
	Replacement of infrastructure at end of life neglected as the declining winter revenue means the resort operators see them as a stranded asset	Low	High
	Potential increase in landslide frequency in good snow seasons due to variability	Low	Low
	Increase in visitor costs/pricing driven by a shorter snow season, with a reduced capacity for premium users only, deterring tourism and driving a decline in amenity and visitation	Medium	Extreme
	Introduction of additional snow making facilities increases utility demand, greenhouse gas emissions, and salt and	Low	Medium

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
	synthetic ingredient contamination/run off/ecology impacts		
	Reduced financial viability of smaller businesses that have reduced capacity to respond to poor snow seasons	Medium	Extreme
	Unreliable snow making conditions, in particular during peak visitation, reducing visitor numbers	Medium	Extreme
	Introduction of new infrastructure and at higher altitudes and associated impacts on the natural environment	Low	High
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	Medium	High
	Reduced annual rainfall and catchments resulting in poor water quality	Medium	High
	Reduced water supply to resorts and increased water storage requirements	Low	Medium
	Low rainfall/drought periods impacting on soil conditions, and contributing to an increased bushfire risk	Low	Medium
Increased rainfall intensity 	Increased impact on local water treatment plant sizing and operating efficiency	Low	Medium
	Increased risk ratings and flood mitigation standards for new and replaced infrastructure (increased floor levels, stormwater discharge)	Medium	High
	Increased erosion impacting built infrastructure (roads, pathways, trails)	Medium	Medium
Increased bushfire risk/intensity	Increased risk ratings and fire life safety standards for new and replaced infrastructure	High	Extreme

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	High	Extreme
	Damage/loss of indigenous and non-indigenous heritage (buildings, natural landscape, features etc) due to repeated and uncontrolled bushfire impacts	High	High
	Loss of biodiversity and threatened species	Medium	High
	Visual amenity impact reducing tourism and visitation (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/RPZ)	High	High
	Increased bushfire waste and resource material recovery/disposal requirements	Low	Low
	Access to the resorts is lost and/or reduced if bushfire cuts off access into and out of the alpine areas, and/or roads cannot cope with peak evacuation demand	Medium	High
	Increased demand emergency services and community service response resourcing, and supporting buildings and infrastructure	Medium	High
	Reduced tourism due to increased bushfire risk, in particular in KNP during summer	Medium	High
	Changing conditions in insurance and affordability, particularly impacting on smaller businesses/lodges	Low	High
	Increased risk to tourists/campers/visitors in low communication areas (poor telecommunications)	Low	Medium
	Reduced water availability and reliability for firefighting due to increase in utilisation and other climate change impacts	Low	Medium
Increased solar radiation 	Increased risk of sun burn, particularly during ski season	Low	Low
	Increased snow temperatures and snow melt	Captured in snow conditions	

Climate change risk	Risk description	Near future Climate Change Risk Rating	Far future Climate Change Risk Rating
Wind speed 	Impacts on amenity and alpine experience during strong wind days	Low	Low

5 Risk Mitigation

5.1 Introduction

The purpose of this section of the report is to consider the risks identified and propose mitigation strategies to be adopted by the Master Plan, Delivery Plan/s (DP) and Development Control Plan/s (DCP) in order to reduce these risks to an appropriate level. Due to the proposed mitigation measures relating to the Master Plan, DP and DCP, it is acknowledged that some of the climate change risks cannot be fully mitigated with the Master Plan and planning controls. As a result, some of the residual risk ratings remain high to extreme, which will require ongoing monitoring and a governance structure to be implemented. Where mitigation measures are outside of the direct control of the Snowy Mountains SAP, they have been listed as "other" to highlight that additional work outside of the scope of this plan is required.

The risk mitigation measures have been adopted from those proposed during the stakeholder engagement process, captured on the MURAL board, and supplemented through consultation with the Technical Consultant team and input from dsquared.

As the SAP development program extends to at least 2060, the mitigation measures are those which deal with the climate risk rating at the 2070 milestone. The mitigation measures have been developed with the aim of reducing all current risk ratings to a residual risk rating of no higher than Medium.

5.2 Risk mitigation – Zone 1, Jindabyne Township and sub-alpine

A consolidated risk mitigation strategy for Zone 1 – Jindabyne township and sub-alpine region is as follows:

Table 10: Zone 1 - Jindabyne township and sub-alpine region - Risk mitigation strategies

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Temperature increase 	Increased utility infrastructure demand (electricity and water) during summer months, including energy use for cooling	Medium	1. Major infrastructure designs are to consider future expansions as demand increases. i.e. leaving space available at the substation site for future transformers or replacement, installing blank offtake valves on reservoir outlet pipes, so that additional reservoirs or pipe extensions can be connected easily to supplement supply as demand increases. 2. The capacity of utility infrastructure (i.e. water and electricity networks) will need to be considered together with the anticipated growth as a result of the SAP as part of infrastructure planning.	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
			3. New buildings and systems are to be designed with energy efficiency and energy use intensity standards established to reduce demand through efficient/sustainable design. 4. Smart energy and water monitoring and controls (e.g. demand response) integrated into new developments and landscaping. 5. Back-up energy and water provisions (rainwater storage and batteries) considered for new developments and incorporated into critical infrastructure and community facilities. Other: Asset operators are to regularly review the asset inspection and maintenance programs to respond to the changing environment, and system demands as the SAP development progresses.	
	Increased variability impacting ability to accurately calculate network demand and design infrastructure	Medium	1. The capacity of utility infrastructure (i.e. water and electricity networks) will need to be considered together with the anticipated growth as a result of the SAP as part of infrastructure planning. Includes water and energy storage and improving utility infrastructure resilience. Other: Consultation required with industry bodies to understand how they are responding to this. Increase variability may challenge some of the assumptions in the AUS/NZ standards when it comes to calculating demand, and an agreed model for undertaking this will need to be developed. This will need to be captured as part of the ongoing governance structure and is larger in scope than the Snowy Mountains SAP.	Low
	Potential disruption to sewerage treatment processes, particularly if settlement ponds are used	Medium	1. New water treatment systems are to be designed and sized to cater for future climate change projections, with settlement ponds not preferred and best practice infrastructure provisions incorporated. 2. Incorporate a strategic review and program for existing system upgrades ahead of the climate change projections timeline. This should be captured as part of asset management plans developed by sewerage treatment plant operators.	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Change in species distribution in and around township, weed/pest invasions including mosquitos, decline in biodiversity and natural amenity including fishing	Extreme	1. Develop a biodiversity and natural habitat management plan, including a governance and finance structure, and implement it. 2. Incorporate appropriate species selection, land and landscape specification requirements for the un-developed land uses surrounding the township.	Medium
Increased hot days 	Heat stress for the community population, including residents and visitors (relative heat wave impacts)	Extreme	1. Urban development planning to include green landscaping, tree canopies, and other natural ways to reduce heat island effect, while not increasing bushfire risk. 2. Provide adequate capacity for community heat stress respite e.g. free access to air conditioned/shaded spaces such as libraries, shopping, and community centres. 3. Design new buildings which are thermally resilient and therefore act as a first line of defence against heat stress. 4. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. Other: Implement a community resilience plan including networked communications, health and heat stress support programmes, particularly for those particularly vulnerable to heat stress. This would typically be undertaken by the local council with support provided by relevant areas in NSW Government (Climate Change Branch) and is outside the scope of this Snowy Mountains SAP.	Medium
	Reduced reliability and functionality of infrastructure services including sewage treatment, roads, public buildings, and electricity supply	Medium	1. Implement an effective program of infrastructure monitoring, maintenance and upgrades. 2. Design and construct new and upgraded infrastructure to be capable of withstanding future climate change projected impacts and improve resilience. 3. Consider the provision of new supporting infrastructure to improve reliability, for example water storage and energy storage systems such as batteries.	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
			4. Ensure capital (CAPEX) and operational (OPEX) budgets are based on integrating climate change impacts into the design, maintenance, and replacement of infrastructure.	
	Increased demand and utilisation of public infrastructure for respite e.g. lake foreshore and public/community buildings	High	1. Provide high quality public realm and foreshore infrastructure with improved amenity and capacity to support an increase in utilisation and contribute to visitor experience.	Low
	Reduction in visitor numbers during summer season, impacting adaptive capacity, finance, and economic growth	High	1. Mitigation measures listed elsewhere including the provision of community infrastructure, public realm design, shading, and green infrastructure will combine to assist with the mitigation of this risk. 2. Support high quality developments which provide a range of functions and diversify retail options and services e.g. retail developments that offer arrange of outdoor, indoor, and open-air premises that allow visitors options for their experiences.	Low
	Reduction in cultural, social, and sporting capacity and connectivity during summer season	Medium	1. Mitigation measures listed elsewhere including the provision of community infrastructure, public realm design, shading, and green infrastructure will combine to assist with the mitigation of this risk.	Low
	Increased algae and other reductions in Lake Jindabyne water quality and amenity.	Medium	Other: Implement a Lake governance, management and water treatment plan on consultation with Council and Snowy Hydro to manage water quality risks, including smart technology for monitoring, reporting and compliance.	Low
Reduced snow conditions 	Reduced winter tourism due to shorter and more intermittent snow seasons	Extreme	1. Diversification of the economy into year-round activities including eco-tourism, wellness and nature-based industries, with investment in supporting infrastructure and services to improve financial viability and increase business growth opportunities. 2. There are no mitigation measures as such to stop the reduction in the duration of the snow season, however technological advancements for snow making has been identified as a potential mitigation measure. As the effectiveness and impact on the environment is not known, this mitigation measure has not been quantified in the risk assessment.	High

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Reduced tourism expenditure during winter impacting business financial viability and economic growth	Extreme	1. Diversification of the economy into year-round activities including eco-tourism, wellness and nature-based industries, with investment in supporting infrastructure and services to improve financial viability and increase business growth opportunities. 2. Implement an investment development plan that promotes an increase in facilities for summer visitation to offset the loss in winter visitation.	Extreme
	Reduced snow melt and runoff of water catchments (Lake Jindabyne levels may be impacted)	High	Other: Implement a Lake governance, management and water treatment plan in consultation with Council and Snowy Hydro to manage water quality risks, including smart technology for monitoring, reporting and compliance. Forecasts must be shared with Snowy Hydro, and their own information shared with the SMRC to understand the impact of reduced snow melt. Initiatives can then be planned to deal with this and understand how it impacts access to the lake, use of lake water, impact on flora and fauna etc	Medium
	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	Extreme	1. NPWS to develop and implement a management and mitigation plan and integrate with the KNP POM and EMS. 2. Management and implementation plan to be shared with DPE and NPWS to inform the Delivery Plan.	Extreme
Reduced annual rainfall	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	High	1. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas. 2. Integrated water management plan, incorporated into the Carrying Capacity Framework to be developed to place clear targets and supporting infrastructure plans in place for future demand and capacity changes.	High

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
			3. Water hierarchy to be developed and governance structure implemented to ensure highest priority uses are catered for.	
	Reduced lake water levels impacting water quality, lake access, recreational uses and visual amenity	High	1. Implement a Lake governance, management and water treatment plan to manage water quality risks, including smart technologies for monitoring, reporting and compliance should be utilised.	Medium
	Increased dust and potential for dust storms, and tree and grass stress in recreational areas	Low	Low risk rating and mitigation measures incorporated into Master Plan, DP and DCP expected to assist in mitigating any risks (e.g. increased landscaping)	Low
	Low rainfall/drought periods impacting on soil conditions, and contributing to an increased bushfire risk	Medium	1. No specific mitigation strategy has been identified, as this is considered to be a contributary factor to the risks associated with Bushfire *(see Increased bushfire risk/intensity).*	Medium
Increased rainfall intensity	Increased waterway and catchment area flooding impacting the built environment (buildings, infrastructure, landscaping), and stormwater management systems	Low	1. New developments (buildings) and infrastructure are designed for future flood levels. 2. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas.	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Risk to human life as a result of increased intensity of flooding/flash flooding	Low	None applicable	Low
	Increased erosion impacting built infrastructure (roads, pathways, trails)	Medium	1. Need to understand the flood behaviour through FPCC mapping as well as the nature of the risk i.e. velocity, depth, evacuation etc. and then prepare development controls accordingly. In addition, the location of suitable areas for development which avoids high risk areas (i.e. FPCC1) should be considered as part of the master planning processes. 2. Flooding analysis will indicate the need for water storage and slow release at properties, so that drainage lines and pits are not inundated with flows from property and roof catchments. 3. The DP and DCP the catalyst sites should provide guidelines for landscaping as well as stormwater management. Appropriate precinct-wide landscaping and stormwater management/infrastructure should also be considered (i.e. growth areas through LEP controls) as well.	Low
	Increased sediment and runoff impacting Lake Jindabyne water quality	Medium	1. Streets that do not have kerb and gutter, or drainage systems, to be upgraded at the least to include a vegetated swale that catches water and sediments and directs it into water ways. Best scenario, is the construction of drainage networks to capture all hard surface run off and eliminate over land flows into water ways. 2. Delivery Plan to include requirements for construction management plans will help manage sediment and runoff at the site level during construction. 3. Implement smart technologies for monitoring, reporting and compliance.	Low
	Increased likelihood of access (roadways) being blocked by waterway flooding	Low	Other: Evacuation and emergency service plans to be developed and implemented, particularly for new locations (such the western Lake Jindabyne sub-precinct and an increase in dwelling numbers in East Jindabyne).	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Increased bushfire risk/intensity 	Increased risk ratings and fire life safety standards for new and replaced buildings and infrastructure	High	1. Consider bushfire risk rating and resilience when designing and building all new infrastructure. 2. Include “build back better” requirements in the development assessment rules (Delivery Plan and DCP) when restoring infrastructure after a bushfire event.	Medium
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	High	1. Establish reasonable clear zones and ensure proper maintenance of vegetation build up beneath power lines or around significant assets. 2. Installation of recycled water network and the Jindabyne sewer treatment plant to provide additional water supply if require for firefighting use. 3. Need to consider the resilience of planned infrastructure to natural hazard events, including the cost benefits of buildings and infrastructure to withstand bushfire inundation. Other: Asset owners to undertake a network review of redundancy in power and water systems. Asset owners to model and understand how they would run their networks if certain connections were taken offline due to fire. Scenario analysis to be run and understood in case of emergencies.	High
	Loss of biodiversity and threatened species	Low	None applicable	Low
	Visual amenity impact reducing tourism and visitation (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/RPZ)	Medium	1. No mitigation strategy has been identified for this. This is considered to be a secondary impact of bushfire.	Medium

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Increased bushfire waste and resource material recovery/disposal requirements	Low	None applicable	Low
	Ash and debris entering waterways impacting on water quality and visual amenity	Medium	1. Strategic review of stormwater capture and gross pollutant filtration to be undertaken to understand the implications of attempting to filter inflows of additional ash and debris. 2. Implement stormwater filtration infrastructure, noting it may not be practicable to fully filter under all circumstances, in which case this should be considered as per of the Lake management plan recommended. This includes smart technologies for monitoring, reporting and compliance for water quality.	Medium
	Adverse mental health and economic recovery impacts of repeated bushfires	High	1. Develop a community resilience and social infrastructure support plan, governance structure, and finance model to provide the necessary support.	Medium
	Smoke inundation for township and resorts, disruption and poor air quality	Medium	1. No mitigation strategy has been identified for this. This is considered to be a secondary impact of bushfire.	Medium
Increased solar radiation 	Increased solar radiation identified as posing no adverse risks	None	None applicable	None

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Wind speed 	Impacts on amenity at Lake Jindabyne foreshore during strong wind days	Low	None applicable	Low

5.3 Risk mitigation – Zone 2, Alpine

A consolidated risk mitigation strategy for Zone 2 – Alpine region is as follows:

Table 11: Zone 2 - Alpine region - Risk mitigation strategies

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Temperature increase 	Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit	High	1. Consider alternative sources of water for snow making including water storage, and recycled water from new sewerage treatment systems, rather than direct extraction. 2. Consider substation and electricity network upgrades to support additional snow making equipment and demands. Other: Consider water licencing (DPE Water and Snowy Hydro) for the entire region/catchment and determine new allocations for each consumer to ensure upstream and downstream users are considered.	High
	Increased discrepancy between natural snow fields and artificial snow fields impacting on amenity and visitor experience	Extreme	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however no specific mitigation measure is proposed. This is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	Extreme

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term	Extreme	1. Resort operators to incorporate comfortable skier capacity and amenity assessments as per the Carrying Capacity Framework, including public reporting of conditions, and alignment with the KNP POM. 2. Implement the Carrying Capacity Framework in conjunction with a certified EMS to ensure user amenity is maintained. 3. Consider visitor number projections and revenue to match the levels necessary to maintain high amenity, including a transition to being a year-round tourism destination.	High
	Abandonment of snow infrastructure and rehabilitation of cleared areas at lower altitudes as visitors migrate to higher altitudes, with resort operators unable to fund reparations/restoration	High	1. Establish planning requirements to ensure that owners/operators are required to appropriately deal with the abandonment of ski infrastructure. 2. Consider bond / security type payments to ensure all infrastructure is removed (where appropriate - and not heritage listed) when no longer in use and cleared areas are rehabilitated. 3. Require rehabilitation management plans for rehab works at old infrastructure sites.	Medium
	Faster snow melt reducing snow coverage, leading to an increase in snow making and salt/environmental impacts, or reducing length and financial viability of snow season	Extreme	1. Implement an effective snow melt, salt, and environmental impact management plan, as part of a certified EMS. This includes ensure that new technologies for snow making are not approved until environmental impacts have been assessed to limit impacts on the environment and in particular water quality. 2. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	High

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	Over-investment in supporting infrastructure in the short term, to accommodate higher intensity use but then reducing ski areas	High	1. Clear rules to be established for approvals in the Regional-Precincts SEPP. 2. Establish planning requirements to ensure that owners/operators are required to appropriately deal with the abandonment of ski infrastructure. 3. Review economic, growth, and infrastructure planning modelling to ensure that a short term over investment does not occur, leaving stranded assets in place.	Medium
Increased hot days 	Heat stress for the community population and in particular visitors using active tourism offerings that could be susceptible to increased hot days (hiking and mountain biking events)	Extreme	1. Resort development planning to include green landscaping, tree canopies, and other natural ways to reduce heat island effect, while not increasing bushfire risk. 2. Provide adequate capacity for community heat stress respite e.g. free access to air conditioned/shaded spaces such as libraries, shopping, and community centres. 3. Design new buildings which are thermally resilient and therefore act as a first line of defence against heat stress. 4. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. 5. Ensure health and medical services and facilities have adequate capacity for heat stress related incidents.	High
	Increased water storage requirements and/or alternative water supplies where mains water is not connected, to cater for periods of high temperatures with increased water consumption	Medium	1. Design and construct new infrastructure capable of withstanding future climate change projected impacts. 2. Consider the provision of new supporting infrastructure to improve reliability, for example water storage, noting that space in the KNP/resorts will be limited for this. 3. Provide recycled water as an alternative supply source from new water treatment systems.	Low
	Heat stress and increased electricity demand and cost for buildings	Medium	1. Design new buildings which are thermally resilient and therefore act as a first line of defence against heat stress.	Medium

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
			2. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. 3. Design and construct new infrastructure capable of withstanding future climate change projected impacts.	
Reduced snow conditions 	Reduced winter tourism due to shorter and more intermittent snow seasons	Extreme	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	High
	Reduced tourism expenditure during winter impacting business financial viability and economic growth	Extreme	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	High
	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	Extreme	1. NPWS to develop and implement a management and mitigation plan, including smart technologies for monitoring, reporting and compliance. 2. Management and implementation plan to be shared with DPE and NPWS to inform the DCP.	Extreme
	Change in and loss of biodiversity and ecology, including loss of alpine flora and fauna, snow gum die back, flora/fauna	Extreme	1. NPWS to develop and implement a management and mitigation plan, including smart technologies for monitoring, reporting and compliance. 2. Management and implementation plan to be shared with DPE and NPWS to inform the DCP.	Extreme

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	loss/migration, and other sudden unforeseen impacts			
	Change in alpine scenic amenity (no snow), increase in weeds and shrubs, visitation is no longer to an alpine destination	High	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate. 2. Consider bond / security type payments to ensure all infrastructure is removed (where appropriate - and not heritage listed) when no longer in use and cleared areas are rehabilitated.	Medium
	Replacement of infrastructure at end of life neglected as the declining winter revenue means the resort operators see them as a stranded asset	High	1. Require operators to maintain infrastructure at the required condition to meet the Carrying Capacity and sustainability requirements, within the EMS. Consider bond/security payments or conditions where NSW Government will remediate and charge operators if requirements are not met. Clear and concise conditions will be required and legal advice sought. 2. Establish planning requirements to ensure that owners/operators are required to appropriately deal with ageing infrastructure at the end of its life.	Medium
	Potential increase in landslide frequency in good snow seasons due to variability	Low	None required.	Low
	Increase in visitor costs/pricing driven by a shorter snow season, with a reduced capacity for premium users only, deterring	Extreme	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	Medium

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	tourism and driving a decline in amenity and visitation			
	Introduction of additional snow making facilities increases utility demand, greenhouse gas emissions, and salt and synthetic ingredient contamination/run off/ecology impacts	Medium	1. Infrastructure to be designed and constructed to cater for future climate change projections, and Carrying Capacity requirements. 2. Implement a plan of management and reporting via the Carrying Capacity Framework/EMS to ensure these risks are mitigated. 3. Appropriate site-specific controls need to be prepared as part of the DCP to ensure that stormwater runoff and sediment control, water management, water sensitive urban design etc. are prepared to manage development.	Medium
	Reduced financial viability of smaller businesses that have reduced capacity to respond to poor snow seasons	Extreme	1. Support small businesses in diversifying offerings in line with the transition to year-round activities. 2. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	High
	Unreliable snow making conditions, in particular during peak visitation, reducing visitor numbers	Extreme	1. The combined mitigation measures which aim to shift to year-round activities is expected to mitigate some of this risk by providing additional infrastructure and services, however this is one risk of a number relating to the declining snow field capacity which the Snowy Mountains SAP is unlikely to fully mitigate.	High
	Introduction of new infrastructure and at higher altitudes and associated impacts on the natural environment	High	1. Ensure infrastructure investment is modelled for the long term based on future projections, to avoid unnecessary and disruptive environmental impact, and eventual stranded assets. 2. All development to follow pre-determined design and development guidelines aligned with the SAP DCP, Master Plan, KNP Plan of Management, Carrying Capacity model, and EMS.	Medium

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	High	1. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas. 2. Integrated water management plan, incorporated into the Carrying Capacity model to be developed to place clear targets and supporting infrastructure plans in place for future demand and capacity changes. 3. Water hierarchy to be developed and governance structure implemented to ensure highest priority uses are catered for.	Medium
	Reduced water supply to resorts and increased water storage requirements	Medium	1. Infrastructure to be designed and constructed to cater for future climate change projections, and Carrying Capacity requirements. 2. Consider the provision of new supporting infrastructure to improve reliability, for example water storage, noting that space in the KNP/resorts will be limited for this. 3. Provide recycled water as an alternative supply source from new water treatment systems.	
	Low rainfall/drought periods impacting on soil conditions, and contributing to an increased bushfire risk	Medium	1. No specific mitigation strategy has been identified, as this is considered to be a contributary factor to the risks associated with Bushfire *(see Increased bushfire risk/intensity).*	Medium
Increased rainfall intensity 	Increased impact on local water treatment plant sizing and operating efficiency	Medium	1. Infrastructure sizing and demand to cater for future climate change projections, including the monitoring and upgrade of existing systems.	Low
	Increased erosion impacting built infrastructure (roads, pathways, trails)	Medium	1. Maintenance plans, governance and finance structure to be in place to allow incremental improvement in order to keep ahead of future climate change impacts. 2. New infrastructure construction should be designed to cater for future climate change impacts.	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Increased bushfire risk/intensity 	Increased risk ratings and fire life safety standards for new and replaced buildings and infrastructure	Extreme	1. Consider bushfire risk rating and resilience when designing and constructing all new buildings and infrastructure. 2. Include “build back better” requirements in the development assessment rules (Alpine SEPP and DCP) when restoring infrastructure after a bushfire event.	Medium
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	Extreme	1. Establish reasonable clear zones and ensure proper maintenance of vegetation build up beneath power lines or around significant assets. 2. Asset owners to undertake a network review of redundancy in power and water systems. Asset owners to model and understand how they would run their networks if certain connections were taken offline due to fire. Scenario analysis to be run and understood in case of emergencies. 3. Integration of recycled water networks to provide additional water supply if require for firefighting use. 4. Need to consider the resilience of planned infrastructure to natural hazard events, including the cost benefits of buildings and infrastructure to withstand bushfire inundation.	High
	Damage/loss of indigenous and non-indigenous heritage (buildings, natural landscape, features etc) due to repeated and uncontrolled bushfire impacts	High	1. Maintain a fire management and habitat management plan that reduces fire loading, and reduces the risk of human started fires.	High
	Loss of biodiversity and threatened species	High	1. No specific mitigation strategies have been proposed, as this is a secondary impact of large-scale bushfire occurrence.	High
	Visual amenity impact reducing tourism and visitation (directly as a result of a major bushfire, or indirectly as a result of clearing	High	1. Undertake new projects in previously developed areas, and areas which require smaller APZ’s.	Medium

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
	developable areas for fire safety zoning/RPZ)		2. Include requirements in the DCP for the development of new buildings and assets that minimise this risk impact. 3. Include requirements in the Development/Planning rules/SEPP to minimise this impact.	
	Increased bushfire waste and resource material recovery/disposal requirements	Low	None applicable	Low
	Access to the resorts is lost and/or reduced if bushfire cuts off access into and out of the alpine areas, and/or roads cannot cope with peak evacuation demand	High	1. Include the development of safe areas, areas of respite in resorts as a last resort measure if safe evacuation is not possible. 2. Ensure road networks have adequate capacity cater for a full evacuation during the summer months, at all points during the SAP development and growth cycle. 3. Implement smart technologies to support emergency services/evacuation plans and provide advanced notice, where possible.	Medium
	Increased demand emergency services and community service response resourcing, and supporting buildings and infrastructure	High	1. Develop and maintain additional emergency services infrastructure, buildings, equipment, and personnel to cater for the planned SAP area growth, and climate change projections.	Medium
	Reduced tourism due to increased bushfire risk, in particular in KNP during summer	High	1. Develop alternative visitation destinations and activities to still promote visitor attraction, in areas at lower risk to bushfire inundation, for example in the Jindabyne township and surrounds. 2. Implement the land management, and emergency services infrastructure/services measures, in order to minimise the perception of risk.	High

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
			3. Implement smart technologies to support emergency services/evacuation plans and provide advanced notice, where possible, to provide confidence to visitors that there safety is being planned for.	
	Changing conditions in insurance and affordability, particularly impacting on smaller businesses/lodges	High	1. Consider the development of alternative insurance offerings to businesses in the SAP boundary, recognising the lower risk profile compared to businesses that do not benefit from the SAP infrastructure investment and SEPP.	High
	Increased risk to tourists/campers/visitors in low communication areas (poor telecommunications)	Medium	1. Provide high quality networked communications systems with redundancy in the event of a critical emergency.	Low
	Reduced water availability and reliability for firefighting due to increase in utilisation and other climate change impacts	Medium	1. Infrastructure to be designed and constructed to cater for future climate change projections. 2. Consider the provision of new supporting infrastructure to improve reliability, for example water storage, noting that space in the KNP/resorts will be limited for this. 3. Provide recycled water as an alternative supply source from new water treatment systems. 4. Consider the provision of additional air support services for firefighting based at the Jindabyne airstrip.	Low
Increased solar radiation 	Increased risk of sun burn, particularly during ski season	Low	None applicable	Low

Climate change risk	Risk description	Far Future Risk Rating	Mitigation Measures	Residual Risk Rating
Wind speed 	Impacts on amenity and alpine experience during strong wind days	Low	None applicable	Low

6 Inputs to Master Plan

6.1 Introduction

The risk assessment and review process has identified a series of mitigation measures that will need to be implemented in order to reduce the risk impact resulting from climate change. The purpose of this section of the report was to summarise mitigation measures proposed for review and incorporation into the Master Plan teams, and where possible to allocate the lead role in actioning this to a Technical Consultant.

It is noted that a number of identified mitigation measures have already been documented in sufficient detail in the Technical Reports and Master plan such that no further action is required. These are summarised in Section 7 of this report, which schedules the Mitigation Measures that need to be followed through via the SAP Delivery Plans and DCPs and cannot be addressed by the Master Plan in itself.

6.2 Zone 1 Master Plan Inputs

The below Mitigation Measures for Zone 1 – Jindabyne township and sub-alpine region were provided to the Structure Plan/Master Plan teams and input into the final Master Plan.

Table 12: Zone 1 Structure Plan/Master Plan - Mitigation measures

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
Temperature increase 	Increased variability impacting ability to accurately calculate network demand and design infrastructure	1. Consultation required with industry bodies and government agencies to understand how they are responding to this. This includes improved modelling and assumptions, real-world monitoring and data reviews, and an agreed approach across government and industry.	1. Review industry engagement undertaken to date. 2. Undertake additional industry engagement and market sounding to determine potential further actions to inform the Delivery Plan.	WSP
Increased hot days	Heat stress for the community population, including residents and	1. Urban development planning to include green landscaping, tree canopies, and other natural ways to reduce heat island effect.	1. Review Public Space strategy and Structure Plan to check if adequate provisions have been made.	Jensen Plus

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
	visitors (relative heat wave impacts), serious injury or death. Increased demand and utilisation of public infrastructure for respite e.g. lake foreshore and public/community buildings.	2. Provide adequate capacity for community heat stress respite e.g. free access to air conditioned/shaded spaces such as community centres, libraries and shops.	2. Review Public Space strategy, Structure Plan, and Social Infrastructure study to check if adequate provisions have been made.	
	Reduced reliability and functionality of infrastructure services including sewage treatment, roads, public buildings, and electricity supply	1. Consider the provision of new supporting infrastructure to improve reliability, for example water storage, and energy storage systems such as batteries.	1. Review Technical Study reports and update if additional provisions are required.	WSP
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	1. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas.	1. Review Public Space strategy and Structure Plan to check if adequate provisions have been made.	Jensen Plus
Increased rainfall intensity 	Increased erosion impacting built infrastructure (roads, pathways, trails)	1. Need to understand the flood behaviour through FPCC mapping to ensure developable areas are not located in high-risk areas. 2. Flooding analysis required to indicate need for water storage and slow-release systems so that drainage lines and pits are not inundated.	1. Review Flooding Technical Report and determine if additional flood mapping is required. Review the Structure Plan to determine if developable areas are adequately provisioned outside of high-risk areas. 2. Review flooding analysis to establish the need if any for additional detention/storage and slow-release systems.	WSP

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
	Increased sediment and runoff impacting Lake Jindabyne water quality	1. Streets that do not have kerb and gutter or drainage systems to be upgraded to at least include vegetated swales that catch water and sediment.	1. Public Space study and Structure Plan to be reviewed to check if this is adequately provided for.	Jensen Plus
Increased bushfire risk/intensity 	Ash and debris entering waterways impacting on water quality and visual amenity	1. Strategic review of stormwater capture and gross pollutant filtration to be undertaken to understand the implications of attempting to filter inflows of additional ash and debris.	1. Infrastructure Study report to be reviewed and updated with recommendations as required.	WSP

6.3 Zone 2 Master Plan Inputs

The below Mitigation Measures for Zone 2 – Alpine region were provided to the Structure Plan/Master Plan teams and input into the final Master Plan.

Table 13: Zone 2 Structure Plan/Master Plan - Mitigation measures

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
Temperature increase 	Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit	1. Consider alternative sources of water for snow making including water storage, and recycled water from new sewerage systems, rather than direct extraction. 2. Consider substation and electricity network upgrades to support the additional snow making equipment and demands.	1. Document this in the Infrastructure Study report, utilising the new Carrying Capacity model to predict future snow making energy and water demands. 2. Update the Infrastructure Study report to take this into account.	WSP

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
	Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term	1. Adjust visitor number projections and revenue to match the levels necessary to maintain high amenity. 2. Review and adjust the economic report to model alternative scenarios whereby snow-based activities move elevation to the higher resorts. 3. Review and adjust the Transport infrastructure model whereby snow-based activities move elevation to the higher resorts, changing the pattern of road use.	1. Update economic modelling report with these new alternative scenarios and determine the impact. 2. As above. 3. Update the Transport Study with these new scenarios and determine the impact on the Structure Plan and Master Plan.	CIE CIE WSP
	Over-investment in supporting infrastructure in the short term, to accommodate higher intensity use, but then reducing again, to ski areas	1. Review economic, growth, and infrastructure planning modelling to ensure that a short term over investment does not occur, leaving stranded assets in place.	1. Review the economic model and report and update as required.	CIE
Increased hot days 	Increased water storage requirements and/or alternative water supplies where mains water is not connected, to cater for periods of high temperatures with increased water consumption	1. Consider the provision of new supporting infrastructure to improve reliability, for example water storage. 2. Provide adequate capacity for community heat stress respite e.g. free access to air conditioned/shaded spaces such as libraries, shopping, and community centres.	1. Review the Infrastructure Study and update to include requirements for measures to improve reliability as required. 2. Review Public Space strategy, Structure Plan, and Social Infrastructure study to check if adequate provisions have been made.	WSP

Climate change risk	Risk description	Mitigation Measures	Recommended action	Lead Technical Consultant
Reduced snow conditions 	Introduction of new infrastructure and at higher altitudes and associated impacts on the natural environment	1. Ensure infrastructure investment is modelled for the long term based on future projections, to avoid unnecessary and disruptive environmental impact, and eventual stranded assets.	1. Review economic modelling report and update as required.	CIE
Increased bushfire risk/intensity 	Access to the resorts is lost and/or reduced if bushfire cuts off access into and out of the alpine areas, and/or roads cannot cope with peak evacuation demand	1. Include the development of safe areas, areas of respite in resorts as a last resort measure if safe evacuation is not possible. 2. Ensure road networks have adequate capacity cater for a full evacuation during the summer months, at all points during the SAP development and growth cycle.	1. Review Structure Plan to check if this is adequately provisioned for. 2. Review Transport Study to check if this is adequately provisioned for.	Jensen Plus WSP
	Increased demand emergency services and community service response resourcing, and supporting buildings and infrastructure	1. Develop and maintain additional emergency services infrastructure, buildings, equipment, and personnel to cater for the planned SAP area growth, and climate change projections. 2. Consultation undertaken with RFS and NPWS (and other relevant agencies) about new methods/approaches that could be implemented to adequately maintain emergency services in the Alpine region.	1. Review Structure Plan to check if this is adequately provisioned for. 2. Review Infrastructure Study to check if this is adequately provisioned for. 3. Review Social Infrastructure study to check if this is adequately provisioned for.	Jensen Plus WSP Liesl Codrington

7 Inputs to Delivery Plan & DCP

7.1 Introduction

The ongoing development of the SAP and the initiation of all new supporting infrastructure projects and investor led projects, will be guided and driven by a number of key documents and plans and frameworks as follows:

- The final Snowy Mountains SAP Master Plan, Delivery Plans and Development Control Plans
- Planning Rules including the Activation Precincts SEPP, Alpine SEPP, and Snowy River LEP
- Design and development standards and guidelines
- Performance targets to be achieved including energy, water, waste, and environmental protection
- The proposed SAP Environmental Management System (EMS) framework.

The planning framework for Snowy Mountains SAP and integration with this Climate Change Adaptation Plan is as follows:

- **Zone 1** (covers Jindabyne Catalyst and Jindabyne Growth Precincts) - Delivery Plan/s will be developed by RGDC/DPE for the Jindabyne Catalyst Precinct, and an amendment to the Snowy River DCP will be developed by Council/DPE for the Jindabyne Growth Precinct.
- **Zone 2** (covers the Alpine precinct) - an Alpine DCP will be prepared by DPE for the Alpine Precinct.

The Delivery Plan and DCPs will be prepared following the release of the final Master plan and DPE have expressed the importance of ensuring that climate change risks and mitigation measures are fully recognised within it.

This section of the report therefore summarises the mitigation measures that need to be recognised and incorporated.

7.2 Governance

Throughout the development of the Structure Plan and Master Plan, and repeatedly voiced during the stakeholder engagement undertaken to develop this Climate Change Adaptation Plan, it has been made clear that climate change mitigation measures will only be followed through into action if there is a clear, strong, and fully funded governance structure and management systems in place. This will require existing management systems within NSW Government, NPWS and local council to be maintained, improved systems to monitor and plan for climate change be implemented to drive continual improvement, and an agency such as DPE or the Department of Regional NSW to take the lead in coordinating the governance structure and systems for the Snowy Mountains SAP.

The over-arching recommendation is that a formalised governance structure is in place, with supporting policy, planning and operational legislative requirements, monitoring, reporting and compliance mechanisms facilitating the implementation of the CCAP. The governance structure will require membership and investment from multiple agencies and businesses to be successful.

It is recommended that an Environmental Management System certified in accordance with ISO 14001 is in place for the SAP, encompassing the KNP PoM, Carrying Capacity Model, and KNP/Resort EMS frameworks, and this CCAP. This is considered to be an appropriate framework and mechanism for the ongoing management of climate change risks and the associated mitigation measures.

For further details refer to the Snowy Mountains SAP ESD Technical Report.

7.3 Zone 1 Inputs

The inputs required to the Delivery Plan and supporting documents for Zone 1 – Jindabyne township and sub-alpine region, are scheduled as follows:

Table 14: Delivery Plan Inputs - Zone 1 Jindabyne township and sub-alpine region

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
Temperature increase 	Increased utility infrastructure demand (electricity and water) during summer months, including energy use for cooling	1. Major infrastructure designs are to consider future expansions as demand increases. i.e. leaving space available at the substation site for future transformers or replacement, installing blank offtake valves on reservoir outlet pipes, so that additional reservoirs or pipe extensions can be connected easily to supplement supply as demand increases. 2. Asset operators are to regularly review the asset inspection and maintenance programs to respond to the changing environment, and system demands as the SAP development progresses. 3. The capacity of utility infrastructure (i.e. water and electricity networks) will need to be considered together with the anticipated growth as a result of the SAP as part of infrastructure planning.	1. Include guidance relating to these requirements in the Delivery Plan, DCP and associated design and development guidelines. 2. Include asset operator ongoing requirements in the Delivery Plan and DCP for new operators entering the precincts and embed in the EMS to cover all existing operators. 3. Include utility infrastructure growth planning in the Delivery Plan and DCP, noting that infrastructure demand calculators have been prepared by the Structure Plan technical team to assist with this. 4. Include new building design standards in the Delivery Plan and DCP, which can also be used to inform existing buildings and operations.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
		4. New buildings and systems are to be designed with energy efficiency and energy use intensity standards established to reduce demand through efficient/sustainable design. 5. Innovative, best practice designs examples are developed to provide industry and developers with practical examples of responding to temperature increases.	
	Increased variability impacting ability to accurately calculate network demand and design infrastructure	1. The capacity of utility infrastructure (i.e. water and electricity networks) will need to be considered together with the anticipated growth as a result of the SAP as part of infrastructure planning.	1. Include utility infrastructure growth planning in the Delivery Plan and DCP, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this.
	Potential disruption to sewerage treatment processes, particularly if settlement ponds are used	1. New water treatment systems are to be designed and sized to cater for future climate change projections and best practice standards will be applicable as existing assets are upgraded. 2. Incorporate a strategic review and program for existing system upgrades ahead of the climate change projections timeline.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.
	Change in species distribution in and around township, weed/pest invasions including mosquitos, decline in biodiversity and natural amenity including fishing	1. Develop a biodiversity and natural habitat management plan, including a governance and finance structure, and implement it. This includes options for biodiversity offset schemes to be developed as part of the Delivery Plan and DCP.	1. Develop this as part of the Delivery Plan and DCP, noting this will be complex and may take a significant period of time to fully develop, and so the Delivery Plan may just call for its development rather than fully developing it. Also include in the EMS.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
		2. Incorporate appropriate species selection, land and landscape specification requirements for the un-developed land uses surrounding the township.	2. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.
Increased hot days 	Heat stress for the community population, including residents and visitors (relative heat wave impacts)	1. Urban development planning to include green landscaping, tree canopies, and other natural ways to reduce heat island effect, while not increasing bushfire risk. 2. Provide adequate capacity for community heat stress respite e.g. free access to air conditioned/shaded spaces such as libraries, shopping, and community centres. 3. Design new buildings which are thermally resilient and therefore act as a first line of defence against heat stress. 4. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. 5. Implement a community resilience plan including networked communications, health and heat stress support programmes, particularly for those particularly vulnerable to heat stress. 6. Innovative, best practice designs examples are developed to provide industry and developers with practical examples of responding to increased hot days.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 2. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 3. Include new building design standards in the Delivery Plan. 4. Develop a community resilience plan to be included in the Delivery Plan and DCP.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
	Reduced reliability and functionality of infrastructure services including sewage treatment, roads, public buildings, and electricity supply	1. Implement an effective program of infrastructure monitoring, maintenance and upgrades. 2. Design and construct new infrastructure capable of withstanding future climate change projected impacts.	1. Encourage existing and new developments to implement an EMS which includes performance upgrades to improve resilience. 2. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.
	Increased algae and other reductions in Lake Jindabyne water quality and amenity.	1. Implement a Lake governance, management, and water treatment plan, in collaboration with Snowy Hydro, to manage water quality risks. Include smart technologies for monitoring, reporting and compliance.	1. Include requirements for management plan implementation in the Delivery Plan, DCP and EMS.
Reduced snow conditions 	Reduced snow melt and runoff of water catchments (Lake Jindabyne levels may be impacted)	1. Implement a Lake governance, management and water treatment plan to manage water quality risks. 2. Forecasts must be shared with Snowy Hydro, and their own information shared with the SMRC to understand the impact of reduced snow melt. Initiatives can then be planned to deal with this and understand how it impacts access to the lake, use of lake water, impact on flora and fauna etc.	1. Include requirements for management plan implementation in the Delivery Plan, DCP and EMS.
	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and	1. KNP to develop and implement a management and mitigation plan. 2. Management and implementation plan to be shared with RGDC to inform the Delivery Plan and DCP. 3. Implement a monitoring program for regional hydrology.	1. Include requirements in the Delivery Plan and DCP. 2. Include requirements in the Delivery Plan and DCP.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
	economy associated with the National Park		
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	1. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas. 2. Integrated water management plan, incorporated into the Carrying Capacity model to be developed to place clear targets and supporting infrastructure plans in place for future demand and capacity changes. 3. Water hierarchy to be developed and governance structure implemented to ensure highest priority uses are catered for. 4. Innovative, best practice designs examples are developed to provide industry and developers with practical examples of responding to reduced water availability.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 2. Develop integrated water management plan and include requirements in the Delivery Plan and DCP, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 3. Develop water hierarchy guidance and include requirements in the Delivery Plan and DCP.
	Reduced lake water levels impacting water quality, lake access, recreational uses and visual amenity	1. Implement a Lake governance, management and water treatment plan, in collaboration with Snowy Hydro, to manage water quality risks.	1. Include requirements for management plan implementation in the Delivery Plan, DCP and EMS.
Increased rainfall intensity 	Increased erosion impacting built infrastructure (roads, pathways, trails)	1. The delivery plans for the catalyst sites should provide guidelines for landscaping as well as stormwater management. Appropriate precinct-wide landscaping and stormwater management/infrastructure should also be considered (i.e. growth areas through LEP controls) as well.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
	Increased sediment and runoff impacting Lake Jindabyne water quality	1. Streets that do not have kerb and gutter, or drainage systems, to be upgraded at the least to include a vegetated swale that catches water and sediments and directs it into water ways. Best scenario, is the construction of drainage networks to capture all hard surface run off and eliminate over land flows into water ways. 2. Delivery Plan to include requirements for construction management plans will help manage sediment and runoff at the site level during construction. 3. Develop standardised Construction Environmental Management Plans (CEMP) templates to ensue information is recorded accurately and comprehensively.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 2. Include a requirement for Construction Environmental Management Plans (EMP) to be included in Delivery Plan.
Increased bushfire risk/intensity 	Increased risk ratings and fire life safety standards for new and replaced infrastructure	1. Consider bushfire risk rating and resilience when designing and building all new infrastructure. 2. Include “build back better” requirements in the development assessment rules (Delivery Plan and DCP) when restoring infrastructure after a bushfire event. 3. Innovative, best practice designs examples are developed to provide industry and developers with practical examples of responding to reduced water availability.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 2. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 3. As above
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	1. Establish reasonable clear zones and ensure proper maintenance of vegetation build up beneath power lines or around significant assets.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan and DCP action
		2. Installation of recycled water network and the Jindabyne sewer treatment plant to provide additional water supply if require for firefighting use. 3. Need to consider the resilience of planned infrastructure to natural hazard events, including the cost benefits of buildings and infrastructure to withstand bushfire inundation.	2. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines. 3. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.
	Ash and debris entering waterways impacting on water quality and visual amenity	1. Implement stormwater filtration infrastructure, noting it may not be practicable to fully filter under all circumstances, in which case this should be considered as per of the Lake management plan recommended.	1. Include guidance relating to these requirements in the Delivery Plan and DCP, and associated design and development guidelines.
	Adverse mental health and economic recovery impacts of repeated bushfires	1. Develop a community resilience and social infrastructure support plan, governance structure, and finance model to provide the necessary support.	1. Develop and incorporate a community resilience plan in the Delivery Plan, DCP and EMS.

7.4 Zone 2 Inputs

The inputs required to the Delivery Plan and supporting documents for Zone 2 – Alpine region, are scheduled as follows:

Table 15: Delivery Plan Inputs - Zone 2 Alpine region

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
Temperature increase	Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit	1. Consider water licencing for the entire region/catchment and determine new allocations for each consumer.	1. Develop a water licencing strategy for the SAP and include targets and requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
			been prepared by the Structure Plan technical team to assist with this.
	Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term	1. Resort operators to complete comfortable skier capacity and amenity assessments as per the proposed new Carrying Capacity model, including public reporting of conditions. 2. Implement the proposed new Carrying Capacity model in conjunction with a certified EMS to ensure user amenity is maintained.	1. To be completed to inform the DCP, with an ongoing requirement to keep thus updated as part of the EMS and new Carrying Capacity Framework. 2. Include the new Carrying Capacity model in the DCP and EMS.
	Abandonment of snow infrastructure at lower altitudes as visitors migrate to higher altitudes, with resort operators unable to fund reparations/restoration	1. Establish planning requirements to ensure that owners/operators are required to appropriately deal with the abandonment of ski infrastructure. 2. Consider bond / security type payments to ensure all infrastructure is removed (where appropriate - and not heritage listed) when no longer in use. 3. Require rehabilitation management plans for rehab works at old infrastructure sites. 4. Innovative, best practice design examples are developed to provide industry and developers with practical examples of creating adaptable infrastructure that responds to a changing climate and can be re-purposed or easily removed (e.g. touch the ground lightly).	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 2. Develop a strategy and governance model for this to be implemented via the new KNP PoM (supported by the DCP and EMS). 3. Include guidance relating to these requirements in the DCP, and associated design and development guidelines, and the EMS.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
	Faster snow melt reducing snow coverage, leading to an increase in snow making and salt/environmental impacts, or reducing length and financial viability of snow season	1. Implement an effective snow melt, salt, and environmental impact management plan, as part of a certified EMS.	1. Include guidance relating to these requirements in the DCP, and requirements in the EMS.
	Over-investment in supporting infrastructure in the short term, to accommodate higher intensity use but then reducing ski areas	1. Clear rules to be established for approvals in the Alpine SEPP. 2. Establish planning requirements to ensure that owners/operators are required to appropriately deal with the abandonment of ski infrastructure.	1. Clear rules to be included in the DCP/Alpine SEPP. 2. Clear rules to be included in the DCP/Alpine SEPP.
Increased hot days 	Heat stress for the community population and in particular visitors using active tourism offerings that could be susceptible to increased hot days (hiking and mountain biking events), resulting in serious injury or death	1. Resort development planning to include green landscaping, tree canopies, and other natural ways to reduce heat island effect, while not increasing bushfire risk. 2. Design new buildings which are thermally resilient and therefore act as a first line of defence against increased periods of and provide respite from heat stress. 3. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. 4. Innovative, best practice design examples are developed with practical examples of creating heat resilient infrastructure such as shaded outdoor	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 2. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 3. Include new building design standards in the DCP. 4. Include an upgrade program for existing buildings in the DCP, and guidance on how to upgrade the buildings to meet the future standards required.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
		environments, increased landscaping, and water refilling stations.	
	Increased water storage requirements and/or alternative water supplies where mains water is not connected, to cater for periods of high temperatures with increased water consumption	1. Design and construct new infrastructure capable of withstanding future climate change projected impacts. 2. Provide recycled water as an alternative supply source from new water treatment systems.	1. Include utility infrastructure growth planning in the DCP, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 2. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
	Heat stress and increased electricity demand and cost for buildings	1. Design new buildings which are thermally resilient and therefore act as a first line of defence against heat stress. 2. Develop an existing building upgrade programme to introduce an equivalent level of thermal resilience as new buildings. 3. Design and construct new infrastructure capable of withstanding future climate change projected impacts.	1. Include new building design standards in the DCP. 2. Include an upgrade program for existing buildings in the DCP, and guidance on how to upgrade the buildings to meet the future standards required. 3. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
Reduced snow conditions 	Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	1. KNP to develop and implement a management and mitigation plan. 2. Management and implementation plan to be shared with RGDC to inform the Delivery Plan.	1. Include requirements in the DCP. 2. Include requirements in the DCP.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
	Change in and loss of biodiversity and ecology, including loss of alpine flora and fauna, snow gum die back, flora/fauna loss/migration, and other sudden unforeseen impacts	1. KNP to develop and implement a management and mitigation plan. This includes options for biodiversity offset schemes to be developed as part of the Delivery Plan and DCP. All species included in the DCP should be from local native species suitable for the future climate. 2. Management and implementation plan to be shared with RGDC to inform the Delivery Plan.	1. Include requirements in the DCP. 2. Include requirements in the DCP.
	Replacement of infrastructure at end of life neglected as the declining winter revenue means the resort operators see them as a stranded asset	1. Require operators to maintain infrastructure at the required condition to meet the Carrying Capacity and sustainability requirements, within the EMS. 2. Establish planning requirements to ensure that owners/operators are required to appropriately deal with ageing infrastructure at the end of its life.	1. Include utility infrastructure maintenance requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 2. Include requirements in the DCP and EMS.
	Introduction of additional snow making facilities increases utility demand, greenhouse gas emissions, and salt and synthetic ingredient contamination/run off/ecology impacts	1. Infrastructure to be designed and constructed to cater for future climate change projections, and Carrying Capacity requirements. 2. Implement a plan of management and reporting via the Carrying Capacity model/EMS to ensure these risks are mitigated. 3. Appropriate site-specific controls need to be prepared as part of the DCP to ensure that stormwater runoff and sediment control, water management, water sensitive urban design etc. are prepared to manage development.	1. Include utility infrastructure requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 2. Include these requirements in the DCP, KNP PoM, EMS, and Regional-Precincts SEPP. 3. Include these requirements in the DCP, KNP PoM, EMS, and Regional-Precincts SEPP.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
	Introduction of new infrastructure and at higher altitudes and associated impacts on the natural environment	1. All development to follow pre-determined design and development guidelines aligned with the SAP Delivery Plan, Master Plan, KNP Plan of Management, Carrying Capacity model, and EMS. Includes appropriate provisions for zoning as well as ongoing maintenance.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
Reduced annual rainfall 	Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	1. Water sensitive urban design (WSUD) measures to be incorporated in all developable areas. 2. Integrated water management plan, incorporated into the Carrying Capacity model to be developed to place clear targets and supporting infrastructure plans in place for future demand and capacity changes. 3. Water hierarchy to be developed and governance structure implemented to ensure highest priority uses are catered for. 4. Innovative, best practice designs are developed with practical examples of creating water resilient infrastructure such as WSUD and drought tolerant plantings.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 2. Develop integrated water management plan and include requirements in the DCP, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 3. Develop water hierarchy guidance and include requirements in the DCP.
	Reduced water supply to resorts and increased water storage requirements	1. Infrastructure to be designed and constructed to cater for future climate change projections, and Carrying Capacity requirements. 2. Provide recycled water as an alternative supply source from new water treatment systems.	1. Include utility infrastructure requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 2. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
Increased rainfall intensity 	Increased impact on local water treatment plant sizing and operating efficiency	1. Infrastructure sizing and demand to cater for future climate change projections, including the monitoring and upgrade of existing systems.	1. Include utility infrastructure requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this.
	Increased erosion impacting built infrastructure (buildings, roads, pathways, trails)	1. Maintenance plans, governance and finance structure to be in place to allow incremental improvement in order to keep ahead of future climate change impacts. 2. New buildings and infrastructure construction should be designed to cater for future climate change impacts. 3. Innovative, best practice designs are developed with practical examples of mitigating increased erosion, with geotechnical requirements in the Alpine region set to the highest standard possible.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines and EMS. 2. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
Increased bushfire risk/intensity 	Increased risk ratings and fire life safety standards for new and replaced infrastructure	1. Consider bushfire risk rating and resilience when designing and building all new infrastructure. 2. Include “build back better” requirements in the development assessment rules (Regional-Precincts SEPP and Delivery Plan) when restoring infrastructure after a bushfire event. 3. Innovative, best practice designs are developed with practical examples of improving bushfire resilience. Refer RFS guidelines for Planning for Bushfire Protection.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 4. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
	Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications)	1. Establish reasonable clear zones and ensure proper maintenance of vegetation build up beneath power lines or around significant assets.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
		2. Asset owners to undertake a network review of redundancy in power and water systems. Asset owners to model and understand how they would run their networks if certain connections were taken offline due to fire. Scenario analysis to be run and understood in case of emergencies. 3. Installation of recycled water network and the Jindabyne sewer treatment plant to provide additional water supply if require for firefighting use. 4. Need to consider the resilience of planned infrastructure to natural hazard events, including the cost benefits of buildings and infrastructure to withstand bushfire inundation.	2. Include requirements for asset owners in the DCP for new businesses entering the SAP, and in the EMS for existing and new businesses and agencies. 3. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 4. Include guidance relating to these requirements in the DCP, and associated design and development guidelines.
	Damage/loss of indigenous and non-indigenous heritage (buildings, natural landscape, features etc) due to repeated and uncontrolled bushfire impacts	1. Maintain a fire management and habitat management plan that reduces fire loading and reduces the risk of human started fires. 2. Undertaken consultation with relevant community groups/stakeholders on how fire management plans can appropriately address any concerns they may have.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines, and a requirement in the EMS.
	Visual amenity impact reducing tourism and visitation (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/RPZ)	1. Undertake new projects in previously developed areas, and areas which require smaller RPZ's. 2. Include requirements in the Delivery Plan for the development of new buildings and assets that minimise this risk impact. 3. Include requirements in the Development/Planning rules/SEPP to minimise this impact.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 2. Include new building design standards in the DCP. 3. Include requirements in the Development/Planning rules/SEPP to minimise this impact.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
		4. Innovative, best practice designs are developed with practical examples of planning for increased bushfire frequency and impacts.	
	Reduced tourism due to increased bushfire risk, in particular in KNP during summer	1. Develop alternative visitation destinations and activities to still promote visitor attraction, in areas at lower risk to bushfire inundation, for example in the Jindabyne township and surrounds. 2. Implement the land management, and emergency services infrastructure/services measures, in order to minimise the perception of risk.	1. Include guidance relating to these requirements in the DCP, and associated design and development guidelines. 2. Include guidance relating to these requirements in the DCP, and associated design and development guidelines, and the EMS.
	Changing conditions in insurance and affordability, particularly impacting on smaller businesses/lodges	1. Consider the development of alternative insurance offerings to businesses in the SAP boundary, recognising the lower risk profile compared to businesses that do not benefit from the SAP infrastructure investment and SEPP.	1. Develop an alternative insurance model in conjunction with the insurance providers and implement as part of the Delivery Plan.
	Increased risk to tourists/campers/visitors in low communication areas (poor telecommunications)	1. Provide high quality networked communications systems with redundancy in the event of a critical emergency.	1. Include requirements relating to these requirements in the Delivery Plan, and associated design and development guidelines.
	Reduced water availability and reliability for firefighting due to increase in utilisation and other climate change impacts	1. Infrastructure to be designed and constructed to cater for future climate change projections. 2. Provide recycled water as an alternative supply source from new water treatment systems. 3. Consider the provision of additional air support services for firefighting based at the Jindabyne airstrip.	1. Include utility infrastructure requirements in the DCP and EMS, noting that infrastructure demand calculators and a carrying capacity calculator have been prepared by the Structure Plan technical team to assist with this. 2. Include requirements relating to these requirements in the DCP, and associated design and development guidelines.

Climate change risk	Risk description	Mitigation Measures	Delivery Plan action
			3. Develop a strategy for future firefighting services support and include in the DCP.

8 Summary and conclusion

The climate change risk assessment highlighted the complex and diverse nature of the Snowy Mountains SAP, that there are multiple parties involved in the ongoing management of climate change risks and that the Snowy Mountains SAP incorporates a number of precincts and sub-precincts that are impacted by climate change to varying degrees. Due to this assessment focussing on the Master Plan and associated Delivery Plan/s and Development Control Plan/s, there are a number of climate change risks which are unable to be mitigated by actions identified in this plan. These risks will require an across government and industry approach to ensure that climate change impacts are planned for and responded to consistently.

The risk assessment identified a number of high and extreme climate change risks which require adequate mitigation measures to be implemented. However, a number of the climate change impacts are significant enough to remain at a high or extreme level, even if all practicable mitigation measures are implemented as part of the Master Plan and associated Delivery Plan/s and Development Control Plan/s. These include climate change events such as:

- **Temperature rises are predicted to radically impact on the existing snow-based economies**. Although the Snowy Mountains SAP is supporting a transition to being a year-round destination with the aim to mitigate this impact as far as possible, the effectiveness of this mitigation measure will need to be monitored over time. In addition, increased weather variability is expected which can lead to more extreme weather conditions in the short term, such as the increased snow season length and snow cover currently being experienced, while the longer-term trend of declining snow conditions continues. The key risk is that current snow conditions will create a sense of complacency for operators in the Snowy Mountains SAP, and a number of poor snow seasons due to weather variability could be unsustainable for businesses and resorts.
- **Community growth and resilience, and flora, fauna, biodiversity, and human safety resulting from a loss of snow cover**. The impact of climate change on the community and environment is expected to be significant and a number of protected flora and fauna in the alpine region area are at risk due to being dependent on alpine conditions. Many of these risks are outside the scope of this plan, require ongoing monitoring and governance systems to plan for and respond to climate change over time, and will require a multi-agency response.
- **An increase in bushfire frequency and intensity**. An increase in average and extreme fire weather days is expected to impact the alpine areas and Kosciuszko National Park in particular, with human safety and infrastructure at risk from increased bushfire frequency and intensity. In addition, many of the mitigation measures identified in the risk assessment require ongoing governance systems and resources to be implemented.

Throughout the development of the Structure Plan and Master Plan, and repeatedly voiced during the stakeholder engagement undertaken to develop this Climate Change Adaptation Plan, it has been made clear that climate change mitigation measures will only be followed through into action if there is a clear, strong, and fully funded governance structure and management systems in place. This will require existing management systems within NSW Government, NPWS and local council to be maintained, improved systems to monitor and plan for climate change be implemented to drive continual improvement, and a lead agency such as DPE or RGDC to coordinate the governance structure and systems for the Snowy Mountains SAP.

To achieve this, the over-arching recommendation is that a formalised governance structure is in place, with supporting policy, planning and operational legislative requirements, monitoring and reporting mechanisms facilitating the implementation of the Climate Change Adaptation Plan. The governance structure will require membership and investment from multiple agencies, organisations, and businesses to be successful, including DPE, RGDC, Council, Snowy Hydro, the resorts, and businesses within the SAP.

It is recommended that an Environmental Management System certified in accordance with ISO 14001 is considered for the SAP, encompassing the Kosciusko National Park Plan of Management, Carrying Capacity Framework, the Kosciusko National Park /Resort Environmental Management System frameworks, and this Plan. This is an appropriate framework and mechanism for the ongoing management of climate change risks and the associated mitigation measures. However, the current approach is to have an EMS in place for the Alpine Precinct and it is recommended that a governance structure is implemented to manage climate change risks and impacts across the entire Snowy Mountains SAP to ensure learnings and mitigation measures are coordinated across the Snowy Mountains SAP.

In order to assist with providing some focus for the Delivery Plan and DCP development, the top climate change impacts resulting from this risk assessment are summarised below:

Table 16: Top climate change impacts

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
Temperature increase 	Increase of 2.0 to 2.5°C	1. Change in species distribution in and around township, weed/pest invasions including mosquitos, decline in biodiversity and natural amenity including fishing	1. Increased utility infrastructure demand (electricity and water) for snow making, noting that Perisher Village is already at its water licence limit. 2. Decreased snow fields resulting in increased intensity of use of areas with snow, impacting amenity and user experience. This will also impact on SAP development infrastructure modelling and sizing, as lower-altitude locations lose snow-based visitation to higher-altitude locations in the mid-term 3. Faster snow melt reducing snow coverage, leading to an increase in snow making and salt/environmental impacts, or reducing length and financial viability of snow season
Increased hot days	12 to 32 days above 35°C	1. Heat stress for the community population, including residents and visitors (relative heat wave impacts)	1. Heat stress for the community population and in particular visitors using active tourism offerings that could be susceptible to increased hot days (e.g. hiking and mountain biking events).

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
		2. Increased demand and utilisation of public infrastructure for respite e.g. lake foreshore and public/community buildings	
Reduced annual rainfall 	10% reduction in average rainfall	1. Reduced water availability and potential conflicts with water use for hydro generation and other uses (e.g. snow making, consumption, water licences downstream of the township)	1. Reduced water availability and increased water storage requirements for alpine areas not connected to a mains water supply.
Reduced snow conditions 	60% reduction of suitable snowmaking conditions, a reduction of 35 to 40 days	1. Reduced winter tourism due to shorter and more intermittent snow seasons 2. Reduced tourism expenditure during winter impacting business financial viability and economic growth 3. Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park	1. Changed regional hydrology (rain instead of snow) and subsequent runoff in winter instead of spring, leading to ecosystems and threatened species disruption, recreational and social values and economy associated with the National Park. 2. Change in and loss of biodiversity and ecology, including loss of alpine flora and fauna, snow gum die back, flora/fauna loss/migration, and other sudden unforeseen impacts. 3. Introduction of additional snow making facilities increases utility demand, greenhouse gas emissions, and salt and synthetic ingredient contamination/run off/ecology impacts.
Increased bushfire risk/intensity 	1 to 2 day increase in extreme fire weather days per annum, occurring in spring and summer.	1. Increased risk ratings and fire life safety standards for new and replaced infrastructure. 2. Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications).	1. Increased risk ratings and fire life safety standards for new and replaced infrastructure. 2. Damage/loss of utility infrastructure (electricity, water pumping stations, telecommunications).

Climate change risk	Climate change projection 2070	**Zone 1 – Jindabyne and surrounds** Most significant impacts	**Zone 2 – Alpine region** Most significant impacts
		3. Repeated bushfires and visual amenity impact reducing tourism, visitation and economic growth (directly as a result of a major bushfire, or indirectly as a result of clearing developable areas for fire safety zoning/RPZ) 4. Adverse mental health and economic recovery impacts of repeated bushfires	3. Damage/loss of indigenous and non-indigenous heritage (buildings, natural landscape, features etc) due to repeated and uncontrolled bushfire impacts. 4. Reduced tourism due to increased bushfire risk, in particular in KNP during summer. For example, tourist evacuation orders have been issued in the past significantly impacting the tourism industry. 5. Increased risk to tourists/campers/visitors in low communication areas (poor telecommunications).

The risk assessment and review process has identified a series of mitigation measures that will need to be implemented in order to reduce the risk impact resulting from climate change. These mitigation measures have been reviewed as part of the development of the final Master Plan however some impacts cannot be mitigated through the Master Plan and will require ongoing review and integration into supporting design and planning frameworks for the Snowy Mountains SAP. This includes integrating applicable parts of this Climate Change Adaptation Plan and zones into the following precinct Delivery Plans and DCPs.

- **Zone 1** (covers Jindabyne Catalyst and Jindabyne Growth Precincts) - Delivery Plan/s will be developed by RGDC/DPE for the Jindabyne Catalyst Precinct, and an amendment to the Snowy River DCP will be developed by Council/DPE for the Jindabyne Growth Precinct.
- **Zone 2** (covers the Alpine precinct) - an Alpine DCP will be prepared by DPE, with support from NPWS, for the Alpine Precinct.

The ongoing development of the SAP and the initiation of all new supporting infrastructure projects and investor led projects will be guided and driven by a number of key documents and plans and frameworks as follows:

- The Snowy Mountains SAP Master Plan, Delivery Plans and Development Control Plans
- Kosciuszko National Park Plan of Management (KNP PoM)
- Existing frameworks of governance agencies including NPWS, DPE and Council
- Planning Rules including the Precincts-Regional SEPP and Snowy River LEP
- Design and development standards and guidelines, and conditions of consent for development applications

- Performance targets to be achieved including energy, water, waste, and environmental protection
- The proposed SAP Environmental Management System (EMS) framework.

We reinforce the importance of ensuring that climate change risks and mitigation measures are fully recognised within the Delivery Plan/s and Development Control Plan/s and that an effective governance structure is implemented to integrate climate change into all of the above documents and associated plans.

It is recommended that this plan and referenced data sources and information are reviewed regularly or in the event of a change in policy or process to ensure current projects and investments are planning for future climate condition based on the latest available information.