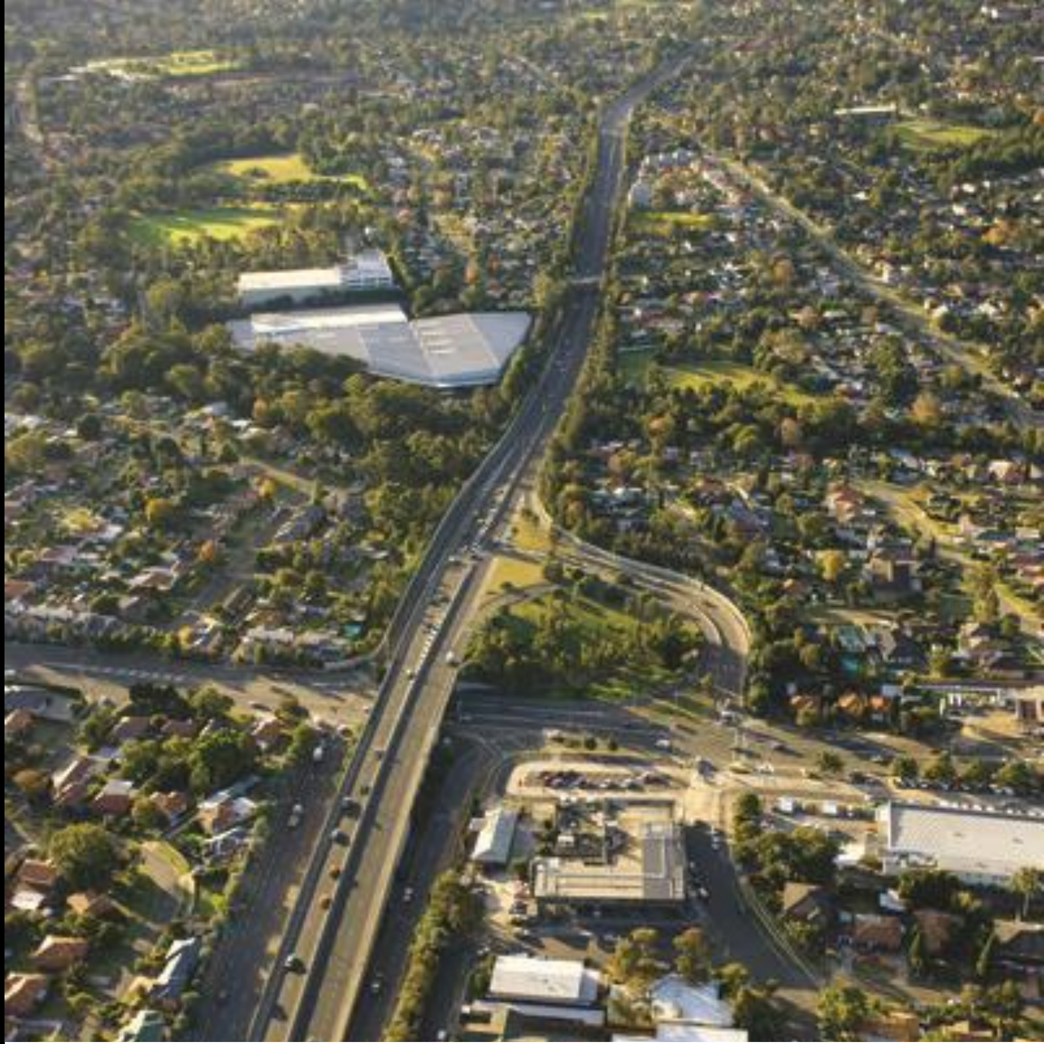
Consult Australia Future Leaders Project:

Infrastructure Australia – Climate Risk & Resilience Assessment for Nationally Significant Infrastructure



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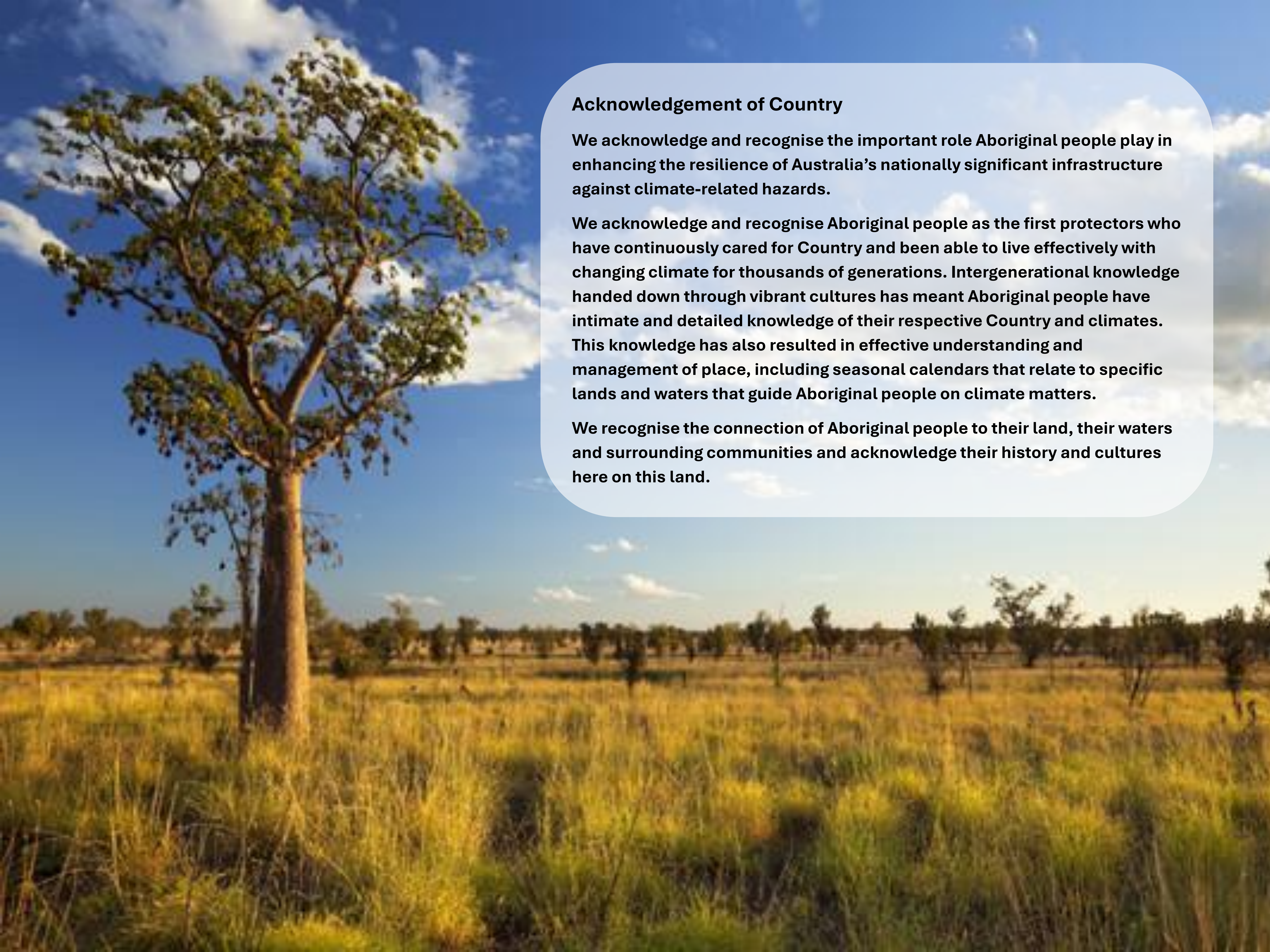
Infrastructure Australia



Acknowledgement of Country

We acknowledge and recognise the important role Aboriginal people play in enhancing the resilience of Australia's nationally significant infrastructure against climate-related hazards.

We acknowledge and recognise Aboriginal people as the first protectors who have continuously cared for Country and been able to live effectively with changing climate for thousands of generations. Intergenerational knowledge handed down through vibrant cultures has meant Aboriginal people have intimate and detailed knowledge of their respective Country and climates. This knowledge has also resulted in effective understanding and management of place, including seasonal calendars that relate to specific lands and waters that guide Aboriginal people on climate matters.

We recognise the connection of Aboriginal people to their land, their waters and surrounding communities and acknowledge their history and cultures here on this land.

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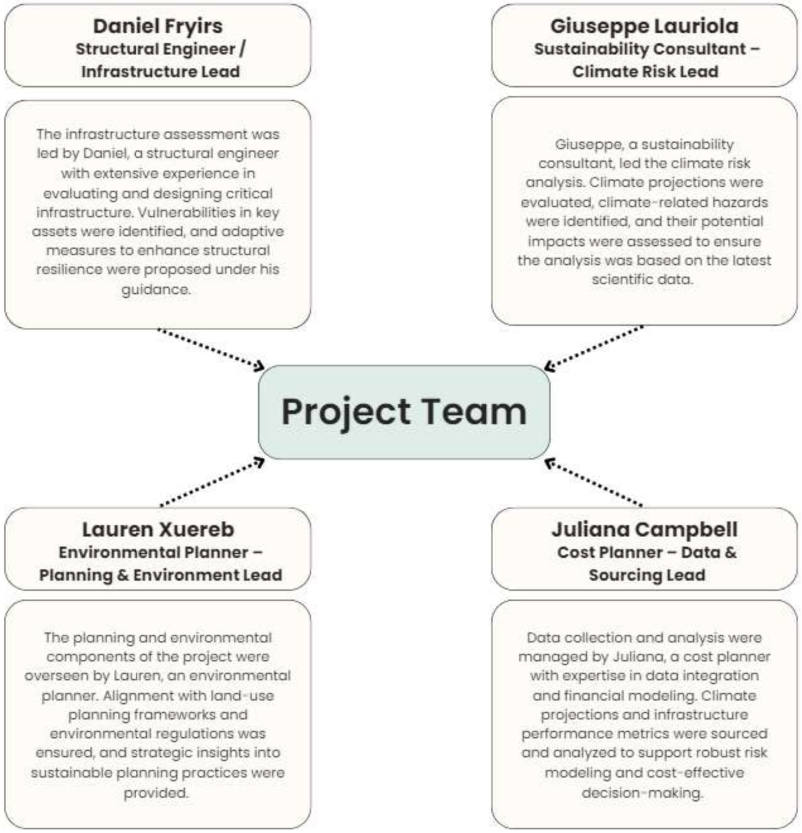
Executive summary

This report presents the Infrastructure Climate Risk Assessment (ICRA) framework, developed to enhance the resilience of Australia's nationally significant infrastructure against climate-related hazards. The framework integrates data from multiple sources to evaluate the vulnerability and criticality of infrastructure assets across key sectors, including transport, energy, water, and telecommunications. Using a robust risk scoring system, it quantifies exposure to risks such as bushfires, floods, and extreme heat, enabling the prioritisation of interventions to strengthen resilience.

Aligned with Infrastructure Australia's strategic goals, the framework supports evidence-based decision-making and investment planning. A proof-of-concept application demonstrates its practical value, offering clear insights to guide resilience-building initiatives. This approach highlights the importance of data-driven methodologies in safeguarding critical infrastructure and ensuring its long-term sustainability amid increasing climate risks.

The Leadership Team

The Climate Risk Assessment for Infrastructures in Australia was conducted by a multidisciplinary team, with each member contributing their expertise in key areas. Below is an introduction to the team and their leadership roles, highlighting their professional backgrounds and responsibilities:



Through their collective efforts, a comprehensive climate risk assessment was delivered, providing stakeholders with actionable insights to enhance the resilience of Australia's infrastructure.

Project Aim

The project is aimed at developing a comprehensive, data-driven framework for assessing the climate resilience and risk exposure of Australia's nationally significant infrastructure. In response to the increasing frequency and severity of natural hazards, existing gaps in data and methodologies are to be addressed through the creation of a robust risk assessment system.

This framework is intended to enable risks to be quantified across various sectors, investment priorities to be determined, and decision-making to be guided in enhancing infrastructure resilience against climate-related hazards. A focus is placed on the integration of diverse data sources, with practical applications to be demonstrated through a proof-of-concept approach, thereby supporting evidence-based policy development.

Methods

A framework for assessing infrastructure vulnerability to climate hazards in Australia is proposed to enhance resilience through an integrated scoring system. Infrastructure assets are scored based on their criticality and susceptibility to climate-related disasters, such as floods, bushfires, and extreme heat. The framework also incorporates the probability and impact of these events, using a quantitative method to measure risk exposure. These scores are combined into a single index, providing a comprehensive view of intersecting risks. This enables stakeholders to prioritise interventions, focusing on the most vulnerable or essential infrastructure to optimise resource allocation and strengthen resilience strategies.

Alignment with Infrastructure Australia Master Plan

The climate risk framework aligns with the Infrastructure Australia Master Plan's goals of enhancing sustainability, resilience, and risk management. It supports a systemic approach to resilience, recognising the interconnections between infrastructure, communities, and ecosystems, and applies a consistent national methodology for assessing and mitigating climate risks.

The framework integrates climate risk considerations into all stages of planning, providing a structured process to address risks and ensure long-term sustainability. It supports informed decision-making by accounting for evolving climate impacts, protecting critical assets, and extending their lifespan.

Collaboration is strengthened through consistent data use, shared tools, and coordinated vulnerability assessments, promoting transparency and aligning with stakeholder needs.

Embedding the framework within the Master Plan addresses immediate climate risks and supports Australia's long-term infrastructure resilience.

Background

As climate change accelerates, infrastructure systems worldwide face escalating risks from extreme weather events, rising temperatures, sea-level rise, and shifting precipitation patterns. These changes are more than environmental challenges; they pose significant risks to the functionality, reliability, and longevity of critical infrastructure across sectors like transport, energy, water, and telecommunications.

Communities are at the heart of these challenges. Disruptions to infrastructure can lead to power outages, water shortages, transportation delays, and communication failures, affecting daily life, livelihoods, and public health. Vulnerable populations, including low-income households, elderly individuals, and people who experience disabilities, are particularly susceptible to these impacts.

The Climate Council Compound Costs: How Climate Change is Damaging Australia's Economy (2019) report states that climate change presents a range of risks and impacts that are expected to negatively impact Australia's economy. These include property loss and damage, infrastructure and service costs, and risks to financial stability (Climate Council of Australia, 2019). The property market is expected to lose significant value due to climate change and extreme weather, with projections indicating a loss of $571 billion in value by 2030 (Climate Council of Australia, 2019). Additionally, the agricultural sector faces reduced yields and productivity, leading to economic instability and increased commodity prices. The financial sector is also at risk, with climate change posing substantial systemic economic risks. Direct macroeconomic shocks from climate change, such as reduced agricultural yields, damage to property and infrastructure, and commodity price hikes, are likely to lead to painful market corrections and could trigger serious financial instability in Australia and the region. The accumulated loss of wealth due to reduced agricultural productivity and labour productivity as a result of climate change is projected to exceed $19 billion by 2030, $211 billion by 2050, and $4 trillion by 2100 (Climate Council of Australia, 2019).

Preparing a framework to assess Australia's climate resilience needs

In Australia, the increasing frequency and intensity of extreme weather events, such as floods, bushfires, and heatwaves, highlight the urgent need for climate-resilient infrastructure. To address these challenges, a collaborative approach involving diverse stakeholders is essential. This includes local councils, government agencies, assets owners, private sector organisations, community members and groups, and Indigenous communities.

The framework outlined in this report is designed to be a practical tool for policymakers, engineers, and community leaders, enabling them to quantify risk, prioritise investments, and implement resilience strategies over the short, medium and long terms.

By focusing on proactive risk assessment and resilience planning, this report emphasises the importance of preparing infrastructure to withstand future climate conditions, ensuring the continued functionality of essential services and safeguarding communities against the growing impacts of climate change. Further, by prioritising the needs of communities and fostering collaboration among stakeholders, we can build a more resilient future.

The importance of gaining and maintaining social licence

The Australian government makes decisions on infrastructure spending through a structured process that involves evaluating the potential benefits and costs of proposed projects. This process ensures that taxpayer money is used efficiently and effectively to deliver the best value for money. Key considerations include the project's alignment with national priorities, its potential to stimulate economic growth, and its ability to enhance community resilience. For example, the Federal Budget for 2024-25 allocated $270.4 billion to infrastructure over four years, focusing on maintaining existing projects and addressing critical needs in transport, energy, and housing (Infrastructure Partnerships Australia, 2024). By rigorously assessing and prioritising investments, the government aims to ensure that infrastructure projects not only meet current demands but also contribute to long-term sustainability and resilience.

Maintaining social licence is crucial for government agencies. This means they must earn and sustain public trust and approval by acting responsibly and transparently. To achieve this, it is essential that their decisions are carefully informed by accurate and comprehensive data. By doing so, they can ensure that their actions are not only effective but also aligned with the values and expectations of the communities they serve.

Purpose and structure of this report

This report has been developed to meet the requirements of the assessment brief. It includes a data-driven framework that can be adopted by IA to assess climate risks to infrastructure and provide an analytical framework capable of assessing natural hazard and resilience risks to nationally significant infrastructure. This framework will contribute to providing evidence-based advice to all levels of government on future priorities for infrastructure investment to improve resilience outcomes.

An outline of the structure of this report, and how the outcomes of the assessment brief have been met, can be seen in Table 1 below.

TABLE 1 - REPORT STRUCTURE

#	Objective	Where addressed in this report
1	**Develop a robust risk assessment framework for infrastructure assets and networks. The framework should be designed to provide the basis for analysis, able to operate effectively across various geographic scales and must be adaptable for different infrastructure sectors.**	
	– Design and creation of a comprehensive risk assessment framework for assessing the resilience risk of infrastructure	Development of the Risk Framework
	– Specifying relevant infrastructure assets and networks – e.g., for transport, this may include road and rail networks, freight intermodal terminals, ports and airports, major bridges and tunnels.	Stage 2 – Infrastructure Assets & Network Identification
	– Developing a detailed risk taxonomy that aligns with leading risk assessment approaches. This may include: c Hazards – e.g., current and projected future frequency and severity of climate-related hazard events across Australia c Exposure – e.g., relationship between infrastructure assets/networks and the level of exposure to hazards. c Vulnerability – e.g., factors which affect the susceptibility of assets to hazard impacts (such as asset age, condition, value and utilisation) and factors related to wider economic, social or other community impacts of disruption to infrastructure (such as impacts on people movements and supply chains)	Stage 3 – Risk Assessment

#	Objective		Where addressed in this report
2.	**Identify and assess relevant data sources (with a focus on those in the public domain) and align these to the assessment framework to demonstrate where existing public or other data can be used to support risk analysis and identify any critical data gaps.**		
	–	Conduct a comprehensive review of data sources relevant to the risk assessment framework, evaluating the quality and relevance of identified sources for considering hazards and risk at a national level	Climate risk and resilience assessment and data
	–	Identifying strengths, weaknesses, areas for improvement and key gaps or limitations in the availability of useful data to support the framework.	Climate Risk Analysis
	–	Clearly indicate whether data sources are publicly available or would need to be acquired (e.g., on-request or on a paid, commercial basis)	Stage 1 – Climate Change Risk Mapping and Appendix A – Database Scoring
	–	Infrastructure Australia has provided a list of known (primarily public) data sources in the Appendix	N/A
3.	**Develop a methodology to integrate diverse data sources, where available, to quantify the overall risk to infrastructure based on multiple dimensions of risk.**		
	–	Conduct an evaluation of the risk assessment framework and identified data sources, identifying recommendations for further development.	Conclusion
	–	Develop a risk analysis methodology or model to quantify the severity and likelihood of each risk factor.	Stage 3 – Risk Assessment
	–	This is expected to include a standardised scoring system to facilitate comparative analysis and aggregation of risk ratings. This should enable an overall quantification or index of risk based on a range of factors related to the range and combination of hazard types, vulnerabilities (e.g., to assets, networks, communities or supply chains), and degree of exposure over time, allowing for relative comparisons to a reasonable degree of spatial granularity in providing a national analysis.	Stage 3 – Risk Assessment
	–	Provide supporting rationale and assumptions for the analytical approach to quantification of risk, ensuring consistency and reflecting the relative impact or significant of each risk factor across different infrastructure types	Stage 3 – Risk Assessment
	–	Subject to data quality and availability, project teams may make adjustments to the risk analysis framework. Gaps in data are expected, so teams should be clear about where these exist and how your approach has managed and responded to these.	Gaps
4.	**Demonstrate how the proposed approach would apply in practice by developing an initial 'proof-of-concept' application of the risk assessment framework and methodology**		
	–	This would include application of the proposed risk framework and analysis methodology in a defined geographic area (e.g., a sub-region within a state), based on integrating and analysing available data to evaluate risk to infrastructure.	Stage 4 – Case Study
	–	This should be used to demonstrate the validity of the approach and the practical insights this could deliver for senior government decision-makers to inform potential priority areas for investment to enhance resilience outcomes.	Stage 4 – Case Study
	–	Apply the risk analysis model to assess the resilience of the transport infrastructure assets within a selected geographic area and provide a concise report	Stage 4 – Case Study

Climate Risk in Australia

Australia is increasingly exposed to significant climate risks that threaten its infrastructure, ecosystems, and communities. Rising temperatures, prolonged droughts, intensifying storms, and other climate-related events are posing unprecedented challenges. As climate change accelerates, these risks are expected to worsen, directly impacting essential infrastructure systems, such as transportation, energy, water supply, and communication networks, with wide-reaching consequences. This section outlines the primary types of climate risks facing Australia, emphasising their current magnitude and potential direct and indirect impacts under projected climate scenarios.

Heatwaves & Extreme Temperatures

Heatwaves and extreme temperatures are among the most pressing climate risks for Australia. Average temperatures have risen by approximately 1.5°C since 1910 (Figure 2), and heatwaves are becoming more frequent, intense, and prolonged (CSIRO, 2024). This will put a severe strain on energy grids due to increased demand for cooling, damage transport infrastructure as asphalt melts and rail tracks buckle, and heighten health risks, particularly for vulnerable populations. Prolonged high temperatures also threaten ecosystems, notably causing coral bleaching in the Great Barrier Reef (Australian Institute of Marine Science, 2024). With projected temperature increases, the frequency and intensity of heatwaves are expected to continue rising, creating substantial risks for infrastructure, health, and biodiversity.

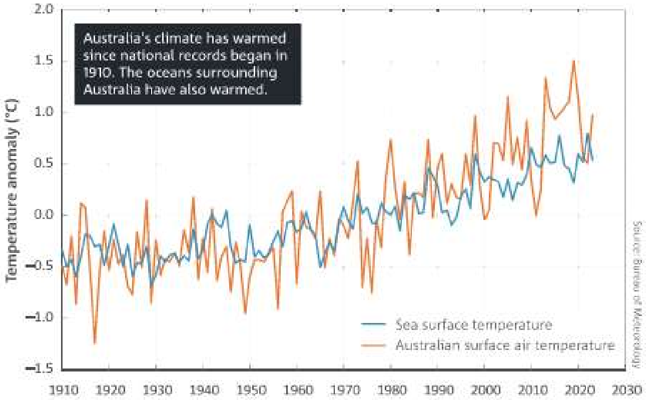


FIGURE 1 SEA SURFACE AND AUSTRALIAN SURFACE AIR TEMPERATURE TREND SINCE 1910 (SOURCE: 2022 STATE OF THE CLIMATE REPORT)

Bushfires

Bushfires also pose a severe risk, with the length and severity of the bushfire season increasing in recent years. The devastating 2019–2020 "Black Summer" fires, which burned over 18 million hectares, caused significant loss of life and extensive property damage. Infrastructure, including power lines, transport networks, and homes, is increasingly at risk, especially as fire-prone conditions become more common (UNEP, 2020). Bushfire smoke also affects air quality, exacerbating respiratory and cardiovascular conditions across affected areas. Moreover, fires destroy habitats, threaten biodiversity, and destabilise ecosystems. With climate change intensifying temperatures and decreasing cool-season rainfall, southern and eastern Australia are likely to experience more frequent and severe bushfires, underscoring the urgent need for resilient infrastructure and disaster preparedness (Figure 3).

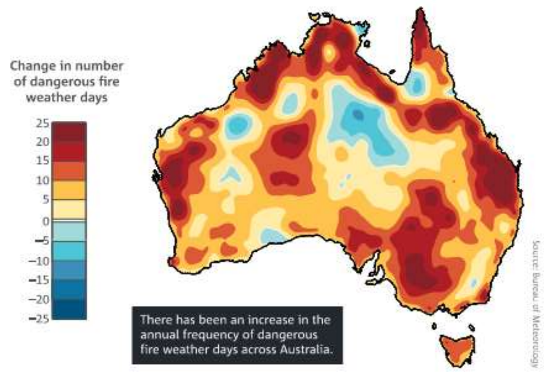


FIGURE **2** CHANGE IN NUMBER OF DANGEROUS FIRE WEATHER DAYS (SOURCE: 2022 STATE OF THE CLIMATE REPORT)

Flooding

Flooding represents another significant risk, particularly for communities and infrastructure located in flood-prone areas. Extreme rainfall events are becoming more common, increasing the frequency of riverine, coastal, and flash floods. This is especially pronounced in regions like Queensland and New South Wales. Floods damage buildings, roads, bridges, and agricultural areas, often resulting in billions of dollars in recovery costs. They also pose public health risks by contaminating water supplies and increasing the spread of waterborne diseases. The projected increase in both inland and coastal flood events, fuelled by climate change, will amplify the impacts on infrastructure and communities, particularly as sea levels continue to rise, intensifying coastal flooding and erosion.

Rising Sea Levels

Sea-level rise is a critical risk, exacerbating coastal erosion and saltwater intrusion into freshwater aquifers. Sea levels around Australia have risen by approximately 25 cm since 1880, and the rates are accelerating (Australia State of the Environment, 2021). Coastal infrastructure, including ports, airports, and residential areas, faces increasing vulnerability to erosion and inundation. Coastal ecosystems, such as wetlands and mangroves, are at risk, impacting biodiversity and natural coastal defences. With continued sea-level rise expected, the impacts on both built and natural environments will intensify, necessitating substantial adaptation and protection measures.

Water Supply & Drought

Australia’s water resources are also under threat from climate-driven drought and water scarcity, particularly in southern Australia. With cool-season rainfall declining, regions like the Murray-Darling Basin are increasingly affected by prolonged droughts (Murray Darling Basin Authority, 2024). Water shortages impact agriculture, energy production, and drinking water supplies, with significant economic and social consequences. Reduced water availability also stresses ecosystems dependent on regular rainfall, affecting biodiversity. As climate change drives more frequent and severe droughts, sustainable water management and infrastructure adaptations are essential to mitigate these impacts.

Extreme Weather

Storms and tropical cyclones remain a persistent threat, particularly in Australia's north. While the overall number of tropical cyclones may decrease, those that do occur are expected to be more intense, bringing higher rainfall and more damaging winds (Climate Council, 2024). Cyclones and severe storms disrupt infrastructure, damage crops, and increase risks to human lives. Intense storms with high winds and flooding also pose direct threats to buildings, energy systems, and transportation networks, leading to substantial recovery costs. The increased intensity of cyclones projected under climate change scenarios will likely lead to greater infrastructure damage and coastal impacts.

Waste Infrastructure

These climate-related risks also have a significant direct and indirect impacts on waste infrastructure. Extreme weather events can damage waste and recycling facilities, disrupt waste collection services, and lead to increased waste generation. For instance, bushfires can damage recycling facilities and generate large volumes of debris, while floods can contaminate waste and overwhelm waste management systems. The resulting strain on waste infrastructure can lead to air and water pollution, as well as increased greenhouse gas emissions. As climate change intensifies, it is crucial to consider the implications for waste management and develop resilient waste infrastructure systems to mitigate these risks.

Recognising Risk Impacts

These key climate risks underscore the urgent need for resilient infrastructure planning and proactive climate adaptation. As Australia faces an increasingly challenging climate, understanding and addressing these risks is critical for protecting communities, ecosystems, and the nation's economic stability. This report outlines each of these risks in detail, with a focus on assessing the vulnerability of Australia's infrastructure and developing strategic responses to safeguard it against future climate impacts.

State of the Climate

The CSIRO and Bureau of Meteorology have recently released the 8th biennial State of the Climate Report. These reports are intended to inform decision making by governments, industries and communities and highlight evolving trends in climate change impacts across Australia, revealing an intensification of certain risks and continued shifts in climatic conditions (Figure 3).

FIGURE 3 - KEY TRENDS IN CLIMATE EVENTS (SOURCE BUREAU OF METEOROLOGY AND CSIRO)

The 2024 report builds on the 2022 findings, highlighting a worsening trajectory for many climate risks, such as temperature extremes, sea-level rise, fire weather, and heavy rainfall (CSIRO, Australian Government Bureau of Meteorology, 2024). Each report underscores the urgent need for adaptive responses to these escalating impacts, which are projected to have substantial economic, environmental, and social consequences. This evolution reflects Australia's growing exposure to climate-related hazards, reinforcing the importance of climate resilience in infrastructure and community planning.

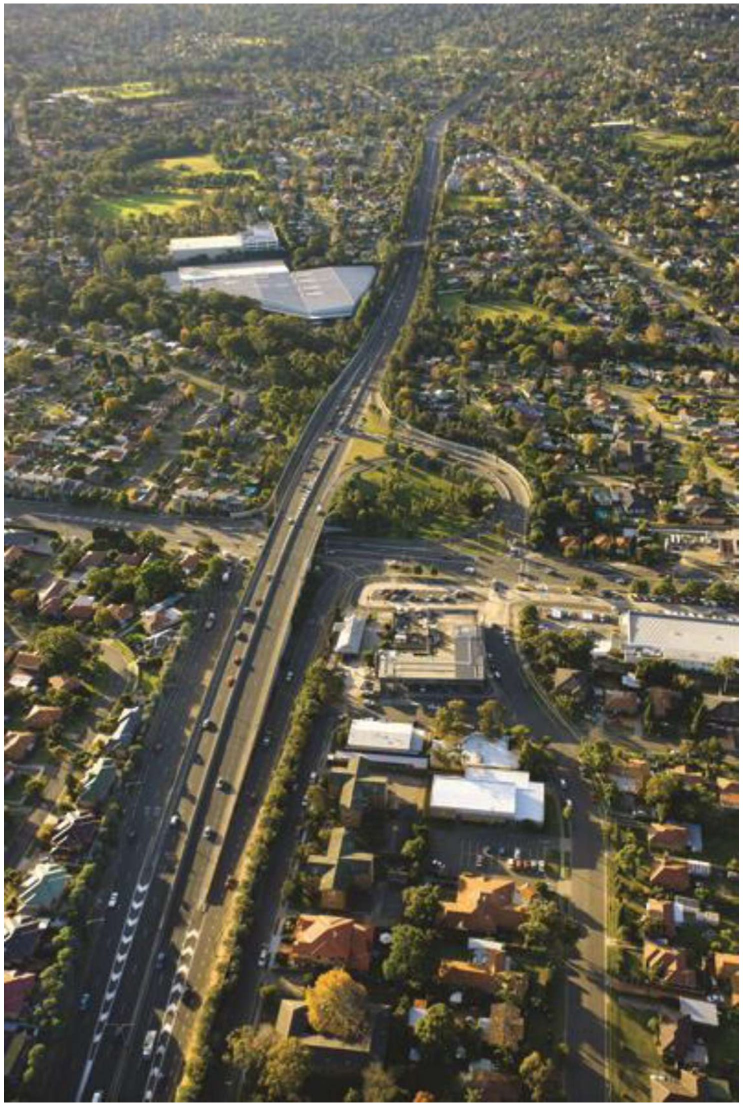


TABLE 2 TRENDS IDENTIFIED IN THE STATE OF THE CLIMATE 2022 AND 2024 REPORTS

We have undertaken an analysis between the 2022 and 2024 CSIRO reports, and have consolidated their notable findings in the following table.

Climate Aspect	State of the Climate 2022 Report	State of the Climate 2024 Report	Trend
Warming and Temperature Extremes	Australia had warmed by about 1.47°C since 1910, with record-breaking years contributing to a significant increase in extreme heat days.	Warming intensified to an average of 1.51°C since 1910. The report further emphasized an increasing frequency of heat extremes, with very hot days occurring six times more often than in the past.	Both reports underscore a rapid rise in temperature, but the 2024 report emphasizes an accelerated frequency of extreme heat, which directly impacts infrastructure, health, and ecosystems.
Rainfall Patterns and Drought	Continued reduction in cool-season (April to October) rainfall in southern Australia, particularly in the southwest and southeast. Northern Australia, in contrast, experienced increases in wet-season rainfall.	Reaffirmed these trends with greater detail, noting a 16% decline in southwest rainfall and a 9% decline in southeast rainfall since the 1970s. Northern wet-season rainfall was reported as 20% above the historical average since 1994.	The drying trend in southern Australia continues to intensify, signalling ongoing drought risk, while northern areas are experiencing increased rainfall, impacting water resource planning and agriculture.
Fire Weather	Highlighted an increase in extreme fire weather and a longer fire season across Australia, particularly in the south and east.	Expanded on the earlier findings, showing even more dangerous fire weather conditions. The report highlights an increased frequency of fire-conducive thunderstorms and fire-generated thunderstorms, particularly in southern Australia.	There is a trend toward more hazardous fire weather conditions, with climate change driving greater fuel availability and dryness, increasing the likelihood of larger, more intense fires.
Tropical Cyclones	Observed a decrease in tropical cyclone frequency in the Australian region but indicated an increase in intensity for those that do occur.	Reinforced the trend, noting a continued reduction in cyclone numbers but highlighting that the cyclones that do form are becoming more intense and bring heavier rainfall.	Cyclones are becoming less frequent but more powerful, contributing to a higher risk of damage to coastal and northern infrastructure when they occur.
Sea-Level Rise and Coastal Erosion	Reported a general trend of sea-level rise around Australia, especially affecting northern and southeastern coasts.	Highlighted an acceleration in sea-level rise, with particularly high rates observed around the northern and southeastern coasts. Coastal communities now face more frequent and severe inundation risks.	Sea levels are rising at an increasing rate, especially in certain regions, posing escalating risks of erosion and flooding to coastal infrastructure and communities.
Ocean Warming and Acidification	Noted warming sea surface temperatures and increased acidification, particularly impacting marine ecosystems like the Great Barrier Reef.	Reinforced these findings, adding that marine heatwaves are becoming more frequent, with five mass coral bleaching events occurring over the past decade. The report warns of even greater impacts on marine biodiversity and fisheries.	Warming and acidification are intensifying, threatening marine biodiversity and industries reliant on the health of ecosystems, such as tourism and fisheries.
Heavy Rainfall Events	Observed an increase in the intensity of short-duration heavy rainfall events, particularly in northern Australia, contributing to a higher flood risk.	Confirmed this trend, noting an 8-10% increase in daily and hourly extreme rainfall intensity for each degree of warming. This shift has major implications for flood management, especially in urban and coastal areas.	Short-duration heavy rainfall events are intensifying, driving up the frequency and severity of flash floods, which pose challenges to urban drainage systems and flood preparedness.

Development of the Risk Framework

The risk framework has been developed in accordance with ISO 31000, however it is noted that the scope of this document is limited to steps 1 to 4. It is recommended that Infrastructure Australia develop this methodology further to address all aspects of ISO 31000.

Step 1: Establish the Context
Define Scope and Objectives: Clarify the boundaries of the risk assessment (e.g., focus on specific infrastructure assets or regions).
Determine Stakeholders: Identify relevant stakeholders (e.g., government agencies, infrastructure owners, communities) and their roles in risk management.
Set Risk Criteria: Establish criteria for assessing risk (e.g., acceptable levels of risk, thresholds for climate impacts).
Step 2: Identify Risks
Data Collection: Gather data on climate hazards (e.g., temperature, rainfall, sea-level rise) and infrastructure assets (e.g., locations, design specifications, criticality).
Identify Potential Impacts: Map out climate hazards against asset vulnerabilities (e.g., flooding on transport infrastructure, heatwaves affecting energy networks).
Hazard Analysis: Use predictive models to understand the frequency and intensity of climate hazards and potential future trends.
Step 3: Analyse Risks
Assess Vulnerability and Exposure: Examine the susceptibility of infrastructure assets to identified climate hazards, considering factors like age, materials, and maintenance practices.
Risk Scoring and Mapping: Apply a scoring methodology (e.g., likelihood x impact) to quantify risks and create visualizations (e.g., GIS maps) of high-risk areas.
Step 4: Evaluate Risks
Compare Against Criteria: Assess if identified risks fall within acceptable risk levels. Highlight risks that exceed thresholds for further action.
Prioritise Risks: Rank risks based on their potential impact on infrastructure resilience and service delivery.

We recommend the following aspects of IS031000 be explored in-tandem with the suggestions identified through out exploration of Steps 1 to 4.

Step 5: Develop Risk Treatment Strategies
Adaptation and Mitigation Measures: Develop strategies to mitigate high-priority risks (e.g., upgrading infrastructure, relocating critical assets).
Cost-Benefit Analysis: Analyse the cost and effectiveness of proposed adaptation strategies to ensure resource efficiency.
Step 6: Implement Risk Management Plan
Develop an Action Plan: Create an implementation timeline, allocate responsibilities, and establish monitoring checkpoints.
Allocate Resources: Secure funding and resources for executing adaptation strategies.
Step 7: Monitor and Review
Performance Monitoring: Continuously monitor climate data and infrastructure conditions to assess the effectiveness of risk treatments.
Regular Updates: Periodically review the risk assessment framework and incorporate new data to adapt to evolving climate risks.
Step 8: Communicate and Consult
Engage Stakeholders: Maintain transparent communication with stakeholders about risks, treatments, and progress.
Report Findings: Share results and adjustments with relevant entities to build collective resilience and ensure ongoing alignment with risk management objectives.

Climate risk and resilience assessment and data

A comprehensive review of existing data sources was undertaken to assess their suitability for supporting the Climate Risk and Resilience Assessment. Using 13 weighted evaluation criteria, each data source was systematically scored to determine its relevance, quality, and practical usability. These criteria balanced aspects such as accuracy, coverage, and relevance with practical considerations like ease of use, accessibility, and cost, as detailed in Table 2. A full evaluation of the data sources can be found in Appendix A.

TABLE 3 DATA SOURCE ASSESSMENT CRITERIA WEIGHTING

Criteria	Weight	Reasoning
Age of Data	2	While it's important to have up-to-date data, some older data can still be valuable if it's the most recent available or if it provides historical context. Therefore, it has a moderate weight.
Source	3	The credibility and reliability of the data source are crucial. Data from reputable organizations (e.g., government agencies, UN bodies) is generally more trustworthy, hence a higher weight.
Ease of Use	2	User-friendliness is important for practical application, but it's not as critical as the accuracy or relevance of the data. Therefore, it has a moderate weight.
Coverage	3	Comprehensive coverage is essential for a thorough assessment. Data that covers all necessary geographical areas and time periods is highly valuable, hence a higher weight.
Accuracy	4	Accuracy is paramount for reliable risk assessments. Inaccurate data can lead to incorrect conclusions, so this criterion has a high weight.
Relevance	4	The relevance of the data to the specific hazards and risks being assessed is critical. Highly relevant data directly supports the assessment framework, hence a high weight.
Granularity	3	Detailed data allows for more precise analysis. While not as critical as accuracy or relevance, it is still very important, hence a moderate to high weight.
Format	2	The format of the data affects how easily it can be integrated into your systems. While important, it is less critical than the content of the data itself, hence a moderate weight.
Accessibility	2	Data that is easily accessible is more practical to use. However, it is less critical than the accuracy or relevance of the data, hence a moderate weight.
Cost	1	While cost is a consideration, it is often outweighed by the importance of the data's quality and relevance. Therefore, it has a lower weight.
Metadata	2	Comprehensive metadata helps in understanding the context and limitations of the data. It is important but not as critical as accuracy or relevance, hence a moderate weight.
Update Frequency	3	Regularly updated data ensures that the assessment is based on the most current information. This is important for maintaining the relevance and accuracy of the assessment, hence a higher weight.
Interoperability	2	The ability to combine data from different sources is important for comprehensive analysis. While important, it is less critical than the core content of the data, hence a moderate weight.

Data Findings

The assessment revealed that most data sources are recent, with many updated in 2023 or 2024, ensuring their currency. High credibility was maintained through reliance on reputable sources, such as government agencies and international organisations. Data scored well on ease of use, accessibility, and format, enabling seamless integration into the assessment framework. Furthermore, comprehensive geographic and temporal coverage was evident, with high accuracy and relevance to the specific hazards and risks under evaluation.

Despite the overall quality, minor gaps were identified. Some data sources lacked the granularity required for detailed local assessments, and while update frequency was generally high, a few sources were not updated frequently enough to capture the latest climate risks. Issues with data interoperability were noted, highlighting challenges in combining different sources. Additionally, although most data was publicly available, some valuable sources were restricted or behind paywalls, and certain geographic regions or infrastructure types were underrepresented.

To address these gaps, recommendations include supplementing with local data for improved granularity, prioritising frequently updated sources, and enhancing interoperability through standardised data integration tools. Expanding coverage to underrepresented areas and securing access to restricted data will further enhance the assessment. Ensuring comprehensive metadata across all sources will support accurate interpretation and application of the data.

Climate resilience of Nationally Significant Infrastructure

Climate resilience refers to the ability of infrastructure systems to anticipate, absorb, adapt to, and recover from climate-related shocks and stresses while maintaining their critical functions. In Australia, nationally significant infrastructure encompasses vital assets and networks that underpin the country's economy, security, and social well-being. These include infrastructure systems in transport, energy, water, telecommunications, and social services such as healthcare and education. Ensuring the resilience of such infrastructure is crucial as climate change intensifies the frequency and severity of natural hazards like bushfires, floods, extreme heat, and cyclones.

Nationally significant infrastructure is spread across diverse locations, from dense urban centres like Sydney and Melbourne to remote and regional areas such as the Pilbara and Northern Territory. The geographic spread means these assets face varied climate risks. Coastal cities, for example, are increasingly vulnerable to sea-level rise and storm surges, while inland regions contend with prolonged heatwaves and drought. Critical infrastructure like the Sydney Harbour Bridge, Melbourne's rail network, and Queensland's Bruce Highway are central to the nation's connectivity and economic activity but are also at risk from climate impacts.

Examples of infrastructure affected by climate events in Australia include the Queensland Rail network, which sustained significant damage during the 2019 floods, disrupting freight and passenger transport. Similarly, bushfires in 2019-2020 severely impacted power supply in New South Wales and Victoria, highlighting the vulnerability of energy infrastructure to extreme heat and fire. In contrast, some infrastructure systems have demonstrated resilience. For instance, Melbourne's water supply network has adapted to prolonged drought conditions through desalination plants and diversified water sources.

Resilient infrastructure not only minimises damage but also ensures rapid recovery and continuity of services. Investments in flood-resistant road designs, fire-hardened power lines, and climate-resilient telecommunications networks are examples of adaptive measures. These efforts reduce disruption, protect communities, and safeguard the economy, ensuring that nationally significant infrastructure remains robust in the face of a changing climate.

Risk Framework Feasibility Assessment

The project team has assessed a range of methodologies to assess the climate risk of infrastructure. Various methodologies are employed by both government and industry bodies around the world. The below table collates some of the more widely adopted methodologies, briefly discussing the methods and outcomes along with key risks and opportunities should any of these methodologies be employed. The project team has used this analysis to determine the framework methodology most suited to Infrastructure Australia's goals.

TABLE **4** RISK FRAMEWORK METHODOLOGY COMPARISON

Risk Framework Methodology	Method	Outcome	Risks	Opportunities	Applications
Risk Scoring & Ranking	Assign a score to each infrastructure asset based on factors like exposure to climate hazards, vulnerability (e.g., age, condition), and criticality (importance to the community).	Produces a ranked list of assets from high to low risk, helping prioritize resources for those most at risk.	Risk scores can be oversimplified, missing context or nuances about specific hazards and vulnerabilities. Scoring models may vary in quality if not standardized, making it difficult to compare results across sectors or regions.	Provides an accessible and prioritized view of risk across multiple assets, facilitating quick decision-making. Can be adapted for various infrastructure types, promoting consistency in risk assessment.	Used in frameworks like the **National Disaster Risk Reduction Framework** in Australia and in countries like **New Zealand** and **Canada** for ranking infrastructure vulnerabilities
Historical Damage Cost Analysis	Analyse past costs of repairs and disruptions from climate events (e.g., floods, heatwaves) across infrastructure assets. Use this data to estimate potential future costs based on frequency and severity trends.	Provides an economic basis for risk, which helps in budgeting for maintenance, upgrades, or relocation.	Historical data may not accurately predict future risks, especially with escalating climate impacts. May neglect newer, lower-impact climate risks that have yet to cause damage but could pose future threats.	Enables cost-based risk assessments, grounding predictions in actual past costs, useful for budget planning. Encourages economic analysis of adaptation investments by comparing potential future costs.	Commonly used in **The United States** by agencies like **FEMA** to predict future damage costs and in Australia's **National Climate Resilience and Adaptation Strategy** to assess economic impacts
Probability x Impact Matrix	Use a matrix to assign each climate risk event (e.g., flood, wildfire) a probability score (likelihood of occurrence) and an impact score (extent of damage to infrastructure). Multiply probability and impact for a risk rating.	Yields a clear, comparable risk score across different hazards, making it easier to identify and prioritize risks.	Requires reliable data to estimate probabilities accurately; limited or inaccurate data can skew risk ratings. May oversimplify complex risks by reducing them to numerical scores, potentially overlooking cascading effects.	Produces a straightforward risk rating system, facilitating clear comparisons of different hazards. Allows for a multi-dimensional risk view by including probability and impact, enhancing planning.	Widely adopted in **ISO 31000:2018** for standardized risk management and used by infrastructure agencies in **Europe** and **Australia** to support climate resilience planning.
Vulnerability and Exposure Mapping	Map infrastructure assets alongside climate hazard data (e.g., flood plains, fire-prone areas) to visualize exposure levels. Combine with asset vulnerability data (age, resilience) to pinpoint high-risk areas.	Produces geographic insights into climate risk hotspots, which is useful for regional planning and resource allocation.	High-resolution mapping requires significant data, which may be lacking in some areas or assets. Can miss hidden vulnerabilities within mapped "low-risk" zones, leading to unexpected damages.	Identifies geographic risk concentrations, helping target adaptation resources to high-risk areas. Supports visual communication of risk to stakeholders, facilitating more engaging, data-driven planning.	Used in **Digital Earth Australia** for environmental and infrastructure monitoring and by **FEMA** in the United States for hazard mapping and community risk assessments **Climate Stress Testing.**
Climate Stress Testing	Use climate projections (e.g., increased rainfall or temperature) to simulate how infrastructure will respond under different climate scenarios. Measure changes in asset performance or lifespan.	Provides a resilience benchmark and helps gauge necessary adaptation measures to maintain functionality under future conditions.	**Complexity**: Stress testing requires sophisticated modeling and accurate climate projections, which can be technically demanding and resource-intensive. **Scenario Uncertainty**: Outcomes are highly dependent on chosen climate scenarios. Testing against unlikely extremes might lead to overinvestment or misallocation of resources.	**Future-Proofing Infrastructure**: Provides a benchmark for resilience, identifying vulnerabilities under various future scenarios to guide proactive adaptations. **Comprehensive Resilience Planning**: Helps test infrastructure across a range of possible future conditions, supporting decisions on materials, design standards, and location suitability.	**European Union:** Widely used in the EU's climate adaptation policies to test critical infrastructure against future climate scenarios. **Japan:** Adopted in national infrastructure standards, particularly for public works, to improve resilience to future climate risks, including earthquakes and typhoons.
Return on Investment (ROI) for Adaptation Measures	Calculate the potential cost savings from implementing adaptation measures (e.g., flood defenses) by comparing with projected damages if no adaptation is applied.	Quantifies the financial benefit of resilience investments, supporting cost-effective climate adaptation decisions.	**Short-Term Focus**: ROI calculations often focus on shorter time frames, potentially undervaluing long-term resilience benefits. **Potential for Underinvestment**: ROI may deprioritize essential adaptations if projected financial savings are not immediately evident, leading to underinvestment in critical resilience projects.	**Financial Justification**: Demonstrates the economic benefits of resilience investments, aiding in budget prioritization and supporting decision-makers with clear cost-benefit data. **Cost-Effective Adaptation**: Helps identify high-impact, low-cost interventions, optimizing resource allocation for maximum resilience gains.	**World Bank**: Used in climate investment frameworks to support funding decisions for infrastructure projects globally. **Public-Private Partnerships**: Frequently applied in public-private infrastructure projects to show financial returns on resilience investments, encouraging private sector engagement.
Reliability and Service Disruption Metrics	Track frequency and duration of service disruptions (e.g., power outages, road closures) due to climate events. Assess how climate impacts affect infrastructure reliability.	Indicates infrastructure resilience in practical terms, helping justify resilience upgrades to maintain service standards.	**Reactive Approach:** Metrics based only on past disruptions may miss pre-emptive measures for future risk, especially as climate impacts evolve. **Context Limitation:** Reliability data under current conditions might not accurately reflect performance under future, more severe scenarios.	**Real-Time Resilience Monitoring**: Offers practical, operational data on how infrastructure handles current climate events, identifying weak points that need immediate improvement. **Supports Maintenance Planning**: Reliability metrics can inform maintenance schedules and upgrades, helping ensure infrastructure remains functional during extreme weather events.	**Canada**: Used in Canada's National Adaptation Strategy to assess and track resilience in sectors like energy and transportation. **Australia's National Resilience Taskforce**: Applied in tracking infrastructure reliability and service continuity, particularly for transport and energy sectors.

Based on the initial brief from Infrastructure Australia, the method that best aligns is likely a combination of the Risk Scoring and Ranking approach with Vulnerability and Exposure Mapping. These methods address the need for a structured framework that can prioritise high-risk assets, be applied across various infrastructure types, and provide geographic insights into risk distribution.

How These Methods Align with the Brief

1. **Risk Scoring and Ranking**
   - **Alignment:** The brief emphasises developing a clear risk framework that identifies and prioritises infrastructure assets based on climate risk. The scoring and ranking approach enables structured prioritisation across multiple asset types by using a straightforward scoring system.
   - **Benefits:** By assigning scores based on hazard exposure, asset vulnerability, and criticality, this method helps highlight which assets are at the highest risk, supporting targeted resilience investment.
   - **Practicality:** This method is flexible and can be adapted to accommodate various infrastructure types and climate hazards, aligning with Infrastructure Australia's objective of a cross-sector risk assessment.
2. **Vulnerability and Exposure Mapping**
   - **Alignment:** The brief seeks to understand climate impacts across geographic areas and infrastructure types. Mapping vulnerability and exposure provides spatial insights into where infrastructure is most at risk, aligning with the need for a data-driven, visual approach to assessing risk distribution.
   - **Benefits:** This method enhances stakeholder engagement through geographic visualisation, making it easier for policy-makers and planners to see high-risk zones and prioritise resources accordingly.
   - **Applicability:** Mapping aligns with Infrastructure Australia's goals by integrating data on location, hazard types, and vulnerability, which is crucial for comprehensive risk assessments.

How They Work Together to Fulfill the Brief:
Using Risk Scoring and Ranking to quantify and prioritise risks, alongside Vulnerability and Exposure Mapping to visualise those risks geographically, provides a robust framework. This combined approach fulfills Infrastructure Australia's objectives of developing a risk assessment that is adaptable across sectors, data-driven, and informative for strategic planning and resource allocation.

Proposed Methodology: ICRA (Infrastructure Climate Risk Assessment)

Overview of the ICRA Methodology

In proposing a framework for assessing infrastructure vulnerability to climate hazards in Australia, we can enhance resilience by integrating a scoring system that evaluates both the criticality of infrastructures and their susceptibility to climate-related disasters. This approach entails scoring infrastructure assets based on their importance and vulnerability to identified climate hazards, such as floods, bushfires, and extreme heat. Simultaneously, the framework incorporates the probability and potential impact of these climate-related events, applying a rigorous quantitative method to measure risk exposure. By combining these scores into a single, mathematically derived index, we gain a comprehensive view of intersecting risks posed by climate change and infrastructure sensitivity. This integrated risk score allows stakeholders to prioritise interventions, targeting the most vulnerable or essential infrastructures for climate adaptation and mitigation efforts, thereby optimising resource allocation and strengthening resilience strategies (Figure 4).

Stage 1 – Climate Change Risk Mapping

Scoring climate risks in Australia involves evaluating both the likelihood of climate-related events, such as heatwaves, bushfires, floods, and cyclones, and the severity of their potential impacts on critical infrastructure. This dual assessment enables vulnerabilities to

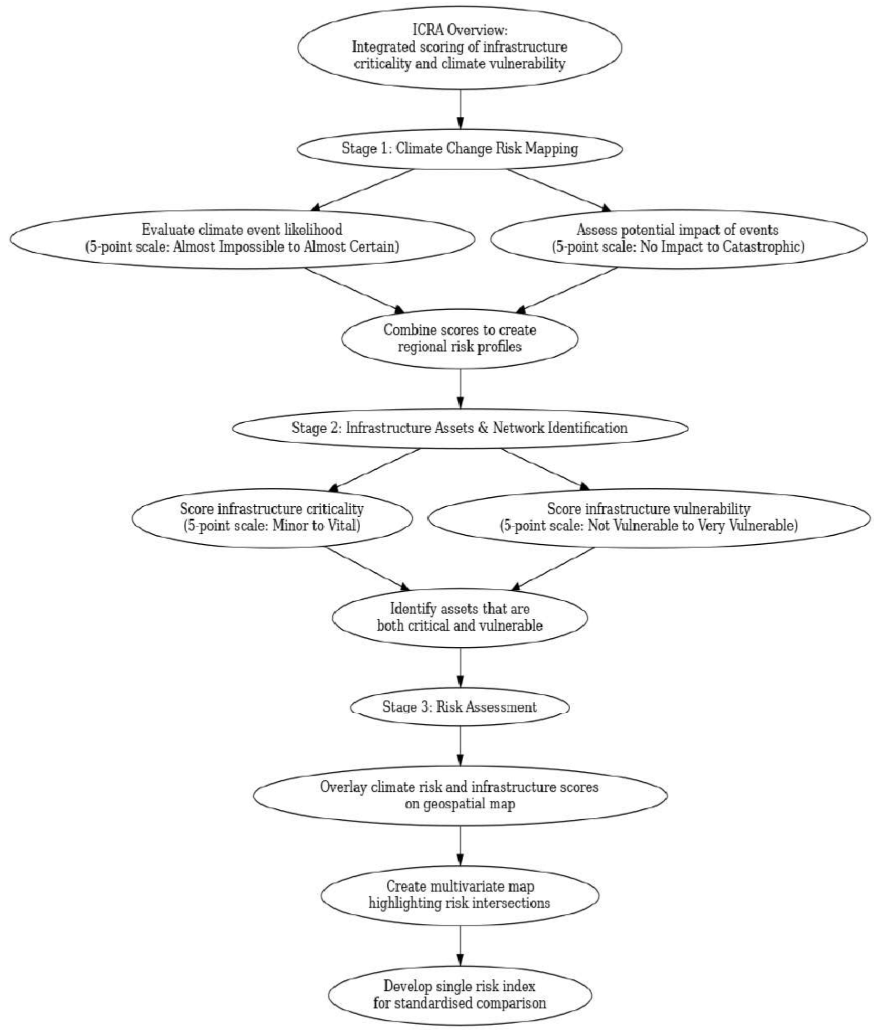


FIGURE 4 ICRA METHODOLOGY FLOWCHART

be identified across sectors including transport, energy, water supply, and public facilities like hospitals and schools. The process combines historical climate data and predictive models to estimate the probability of events, while impact assessments evaluate potential damage, economic losses, and service disruptions. These insights support the prioritisation of investments in resilient infrastructure and the implementation of adaptive measures to mitigate risks.

The scoring framework applies a standardised five-point scale to evaluate both the likelihood and impact of climate hazards. Likelihood scores range from "almost impossible" to "almost certain," reflecting the probability of events occurring under current and projected conditions. Similarly, impact scores range from "no impact" to "catastrophic impact," assessing the extent of damage and disruption to infrastructure systems. By combining these scores, comprehensive risk profiles are created for different regions and infrastructure types, providing valuable guidance for targeted resilience strategies and infrastructure planning across Australia's diverse landscapes.

Stage 2 – Infrastructure Assets & Network Identification

The next stage in the proposed climate risk assessment involves scoring infrastructure assets and systems across Australia based on their criticality and vulnerability to climate-related hazards. Criticality refers to the importance of an asset in maintaining essential services such as energy, water, transport, and telecommunications. Assets are ranked on a five-point scale, ranging from "minor" to "vital," based on the potential consequences of their disruption. This ensures that infrastructure with the greatest societal and economic importance is identified and prioritised.

Vulnerability assesses the susceptibility of infrastructure to climate hazards like extreme weather, sea level rise, and temperature fluctuations. Factors such as asset age, design, and geographic location are considered, with scores also assigned on a five-point scale from "not vulnerable" to "very vulnerable." By integrating these scores, a clear picture emerges of which assets are both highly critical and highly vulnerable. This approach enables targeted resilience measures to be implemented, ensuring that Australia's most essential and at-risk infrastructure is safeguarded against the growing impacts of climate change.

Stage 3 – Risk Assessment

The climate risk assessment methodology culminates in the integration of climate risk and infrastructure vulnerability scores to identify high-priority areas for intervention. By overlaying these datasets, a geospatial map is created to visually highlight regions where significant climate risks coincide with critical and vulnerable infrastructure.

To improve the utility of this analysis, a multivariate map is proposed, offering a more nuanced visualisation of risk intersections. Additionally, a single risk index will be developed to consolidate climate risk and infrastructure vulnerability into a standardised metric. This index simplifies comparisons across regions and infrastructure types, enabling policymakers to prioritise interventions effectively. By directing resources to areas with the highest risk scores, this approach supports the development of targeted strategies to enhance resilience and mitigate the impacts of climate change on Australia's infrastructure.

Stage 4 – Case Study

To demonstrate the practical application of the ICRA methodology, a case study was conducted on transport infrastructure in northern New South Wales. This region was selected due to its exposure to climate hazards such as flooding, bushfires, and extreme heat, which pose significant risks to transport networks. Using the ICRA framework, key transport assets, including highways, rail lines, and bridges, were assessed for their criticality and vulnerability to these hazards.

Stage 1 – Climate Change Risk Mapping

Climate risk scenario analysis and the identification of risks

The Current Scenario

Quantifying the current climate risk scenario in Australia requires a comprehensive assessment that integrates data from several key national resources, including the National Climate Risk Assessment (Department of Climate Change, Energy, the Environment and Water, 2024) and climate databases like the Climate Risk Map of Australia (Climate Council, 2022). These tools offer a detailed understanding of regional vulnerabilities and the likely impacts of climate-related hazards on infrastructure. Geoscience Australia's Natural Hazards and Scenarios provide critical data on hazard-prone areas, which, combined with scenario-based analyses, help project future impacts on essential infrastructure (Geoscience Australia, 2022). The Australian Disaster Resilience Knowledge Hub's Disaster Mapper (Australian Institute for Disaster Resilience, 2024) and the Australian Disaster Resilience Knowledge Hub (Australian Institute for Disaster Resilience, 2024), provide historical data on disaster events, offering valuable insights into patterns and recurrence intervals of hazards such as floods, bushfires, and cyclones.

Additionally, the Australian Flood Risk Information Portal compiles flood mapping and flood studies, essential for evaluating the risk to infrastructure in flood-prone areas, while Bushfire Boundaries data outlines areas historically affected by bushfires, a hazard that frequently disrupts transportation networks, power supplies, and community facilities (Geoscience Australia, 2024). Together, these resources provide a multi-layered view of climate risk, facilitating a data-driven approach to infrastructure resilience. By leveraging this information, Australia can more accurately prioritise and design adaptation measures that target the most at-risk infrastructure assets, enhancing the country's capacity to withstand and recover from climate-related disruptions.

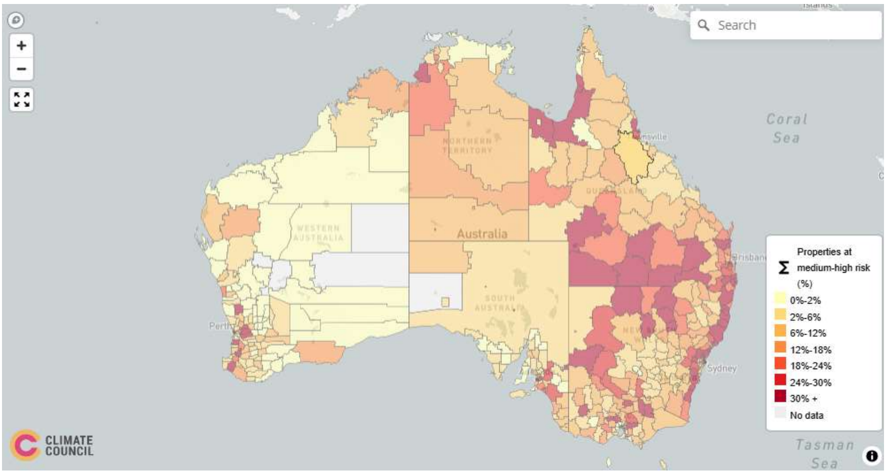


FIGURE 5 CLIMATE RISK MAP (CLIMATECOUNCIL.ORG.AU)

The Future Scenario

Quantifying climate change-related hazards for future climate conditions in Australia relies on projections from advanced climate models, such as those provided by Climate Change in Australia and NARCliM2.0 (NSW and ACT Regional Climate Modelling) (AdaptNSW, 2024). These resources offer high-resolution projections that help evaluate how climate-related hazards are likely to intensify under various emissions scenarios. By using downscaled models specific to Australia, Climate Change in Australia integrates national climate data with IPCC scenario pathways, offering insights into future extreme temperatures, rainfall patterns, bushfire risks, and sea-level rise across different regions. Similarly, NARCliM2.0 provides regional climate projections for New South Wales and the Australian Capital Territory, making it possible to predict hazards like intense storms, coastal erosion, and flooding at a local scale.

These projections suggest an increased frequency and intensity of extreme events in a warmer climate, such as more frequent heatwaves, greater rainfall variability, and a heightened risk of bushfires and coastal flooding. By analysing these data, Australia can assess which infrastructure assets are most vulnerable to future climate hazards, allowing for more targeted, resilient adaptation strategies. For example, models predict that parts of Australia's coastline, which host critical transportation and energy infrastructure, may face accelerated erosion and inundation under higher sea-level scenarios. Using projections from Climate Change in Australia and NARCliM2.0, planners can prioritise areas for climate adaptation measures, such as reinforcing flood defences, upgrading cooling systems for heat-sensitive infrastructure, and investing in bushfire-resistant materials, ensuring long-term resilience against climate impacts.

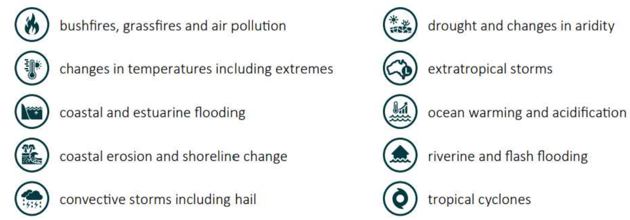


FIGURE **6** THE 10 PRIORITY HAZARDS AS DETERMINED BY THE NATIONAL CLIMATE RISK ASSESSMENT

Types of Risks / Hazards

Australia faces an array of climate-related hazards that increasingly threaten infrastructure, ecosystems, and communities. Understanding these hazards and their potential impacts on infrastructure, ecosystems, and communities is crucial for effective risk management and adaptation planning. The National Climate Risk Assessment identifies priority hazards that pose the most significant risks in the coming decades (Australian Government, Department of Climate Change, Energy, the Environment and Water, 2024). Understanding and characterising these hazards is critical to developing effective adaptation strategies and enhancing resilience. This section provides an overview of the key climate hazards identified in the National Climate Risk Assessment, focusing on their characteristics, current impacts, and projected future changes under climate change scenarios.

Bushfires, grassfires and air pollution

Bushfires are intense fires that spread rapidly across forests, grasslands, and other vegetation. Australia's hot, dry climate creates conditions conducive to bushfires, particularly during summer and autumn, with fires becoming more frequent and severe in recent years.

Bushfires damage properties, disrupt energy and communication networks, and release large amounts of carbon dioxide. Health impacts include respiratory issues due to smoke exposure. The 2019–2020 "Black Summer" fires destroyed over 18 million hectares, with significant economic losses and health impacts due to smoke exposure. The "Black Summer" fires were unprecedented, burning 6.82% of New South Wales' land area (Australian Institute for Disaster Resilience, 2020).

Climate change is projected to exacerbate bushfire risk, particularly in southeastern and southwestern Australia, where warmer temperatures and reduced rainfall will increase vegetation dryness and lengthen the bushfire season. The fire season is projected to lengthen, with more dangerous fire weather days and increased frequency of fire-generated thunderstorms. The risk of larger, more intense bushfires will grow, especially in southern regions.

Changes in temperatures including extremes

Extreme heat events, including heatwaves, are characterised by prolonged periods of excessively high temperatures that significantly exceed the historical average. Heatwaves have become more frequent, intense, and longer in duration due to climate change, making them one of Australia's most deadly climate hazards. Australia has seen a marked increase in the duration, frequency, and intensity of heatwaves since the 1910s. In 2019, there were 33 days with temperatures exceeding 39°C nationwide—more than the combined total from 1960 to 2018. These events are starting earlier in the year and lasting longer (CSIRO, 2024).

Heatwaves place immense stress on energy grids due to increased demand for cooling, reduce the efficiency of transport infrastructure, and cause adverse health outcomes, particularly for vulnerable populations like the elderly. High temperatures also impact ecosystems, contributing to events like coral bleaching in the Great Barrier Reef.

Heat extremes are expected to increase in both intensity and frequency. This trend will likely result in greater demand for cooling, increased infrastructure degradation, and severe public health implications.

Coastal and estuarine flooding

Coastal and estuarine flooding is driven by sea-level rise, storm surges, and tidal fluctuations. These events are particularly damaging in low-lying coastal and estuarine areas where land meets the sea.

Coastal flooding threatens critical infrastructure such as ports, airports, and coastal roads. Estuarine flooding can lead to saltwater intrusion into freshwater systems, damaging agricultural lands and affecting water supplies.

Sea levels are projected to continue rising, with extreme sea levels that previously occurred once in a century expected to become annual events by mid-century. This will increase the frequency of coastal inundation, particularly during storm surges, leading to significant damage to coastal infrastructure and ecosystems.

Coastal erosion and shoreline change

Sea-level rise, driven by thermal expansion and melting polar ice, contributes to coastal erosion and increases the risk of coastal flooding. Australia's extensive coastline makes it highly vulnerable to these impacts. Global sea levels have risen by approximately 25 cm since 1880, with an accelerated rise observed in recent decades. Australia's southeast coast has seen sea levels rise faster than the global average (State of the Environment, 2023).

Coastal infrastructure is increasingly threatened by erosion and storm surges. Key assets like roads, airports, and ports face significant damage from rising sea levels and extreme coastal events.

Sea levels are projected to continue rising, with extreme sea levels that previously occurred once in a century expected to happen annually by mid-century. This will increase the risk of coastal inundation and infrastructure damage.

Convective storms including hail

Hailstorms are severe weather events where frozen precipitation falls, often causing significant damage. Australia's eastern states are particularly prone to these storms. Hailstorms are common in Australia's eastern states, causing substantial damage to vehicles, roofs, and crops.

Hailstorms damage vehicles, rooftops, and crops, resulting in substantial economic losses. Major urban centers have experienced significant property damage due to large hail events.

Climate change may increase the intensity of hailstorms, leading to more frequent and severe damage to urban infrastructure and agriculture. The frequency of severe hail events is expected to increase, with a 40% rise in Australia, resulting in more frequent extreme hailstorms (UNSW Sydney, 2023).

Drought and changes in aridity

Drought refers to prolonged periods of below-average rainfall, resulting in water shortages that affect agriculture, industry, and households. Australia's already variable climate makes it particularly susceptible to drought, which has significant socio-economic implications.

Droughts lead to reduced agricultural yields, water shortages, and increased costs for water-dependent industries. They also impact energy generation, particularly hydropower, and exacerbate bushfire risk by drying out vegetation. The Murray-Darling Basin, one of Australia's most important agricultural regions, has been severely affected by recent droughts.

Climate change is expected to increase the frequency and intensity of droughts, particularly in southern Australia. Reduced rainfall during the cooler months will exacerbate water scarcity, challenging water management practices and increasing competition for limited resources.

Extratropical storms

Extratropical storms, which occur outside the tropics, bring heavy rain, strong winds, and can cover large areas. These storms often impact southern Australia, particularly during the winter months.

Extratropical storms can cause significant damage to infrastructure, including buildings, power lines, and transport systems. They also lead to coastal erosion and flooding in affected areas.

Climate change may increase the intensity of these storms, leading to more frequent high-impact weather events. Stronger extratropical storms will exacerbate risks to southern coastal regions, requiring increased resilience planning for critical infrastructure.

Ocean warming and acidification

Ocean warming refers to the increase in sea surface temperatures, while acidification results from higher levels of dissolved carbon dioxide. These changes are particularly impactful on marine ecosystems, including coral reefs.

Warmer waters cause coral bleaching, disrupt marine ecosystems, and threaten biodiversity, particularly in the Great Barrier Reef. Ocean acidification affects the health of shellfish, corals, and other marine organisms, impacting fisheries and coastal economies.

Continued ocean warming and acidification are expected to worsen, leading to more frequent marine heatwaves and further coral bleaching. The decline in marine health will impact coastal communities dependent on fishing and tourism, necessitating increased efforts in marine conservation and sustainable management.

Riverine and flash flooding

Riverine flooding occurs when rivers overflow their banks due to prolonged heavy rainfall, while flash flooding results from intense, short-duration rain events that overwhelm drainage systems. These are especially severe in urban areas where impervious surfaces limit water absorption.

Riverine and flash floods cause significant damage to buildings, roads, and transport infrastructure, disrupt supply chains, and lead to contaminated water supplies. Urban areas are particularly vulnerable due to dense infrastructure and limited drainage capacity.

Intensified rainfall due to climate change is expected to increase the frequency of riverine and flash floods. The intensity of extreme rainfall events could rise by approximately 7% per degree of warming, exacerbating urban flood risks (Bureau of Meteorology, Victorian Water and Climate Initiative, 2019).

Tropical cyclones

Tropical cyclones are intense storm systems characterised by strong winds, heavy rainfall, and storm surges. Although the overall frequency of cyclones in the Australian region may decrease, the intensity of those that do occur is expected to increase, leading to more severe impacts.

Cyclones cause widespread damage to infrastructure, disrupt transport and supply chains, and lead to significant economic losses. High winds and flooding associated with these storms can damage buildings, power lines, and agricultural lands.

Climate projections indicate a likely increase in the intensity of tropical cyclones, resulting in higher rainfall rates and stronger winds. This will heighten the risk to coastal infrastructure, particularly in northern Australia, where cyclones are most common.

Compound extreme events

Compound events occur when multiple climate hazards coincide, amplifying their impact. For example, heatwaves combined with droughts can severely stress water resources and increase bushfire risk. Compound events can overwhelm emergency response systems, disrupt infrastructure, and lead to cascading failures, especially when critical services like water, power, and transport are affected simultaneously. The likelihood of compound extreme events is expected to increase, driven by overlapping climate stressors. This will result in more complex challenges for managing infrastructure and community resilience.

Geographical Information

Australia’s federal structure comprises multiple geographical jurisdictions, each playing a distinct role in governance and policy implementation. These jurisdictions include six states—New South Wales, Victoria, Queensland, South Australia, Western Australia, and Tasmania—along with two mainland territories, the Australian Capital

Territory (ACT) and the Northern Territory. Each operates under its own constitution and legislative framework, while national responsibilities are managed by the federal government. This layered governance structure allows for policies and regulations to be adapted to the unique geographical, economic, and climatic conditions of each region.

Within these jurisdictions, local government areas are administered by councils responsible for community services, local infrastructure, and environmental management. The capacity and responsibilities of these councils vary significantly, with urban councils generally overseeing more complex systems than their rural counterparts. This localised governance ensures that service delivery and regulatory approaches can be tailored to the specific needs of diverse communities, though it often results in variations in implementation and resource allocation.

Jurisdictional diversity is particularly evident in the management of natural resources and environmental policies. For example, water rights are allocated differently across states due to variations in climate and water availability. Cooperative management frameworks, such as those governing the Murray-Darling Basin, enable multiple jurisdictions to collaborate in balancing environmental sustainability and agricultural needs. Similarly, land use planning and disaster risk reduction measures are shaped by local priorities and risk profiles, highlighting the importance of region-specific strategies.

Geographical jurisdictions are also essential in mapping climate risks and hazards, a critical component of resilience planning for nationally significant infrastructure. Tools like the Climate Council's Climate Risk Map of Australia (Climate Council, 2022) utilise jurisdictional boundaries to provide detailed, region-specific assessments of climate vulnerabilities. These maps highlight areas prone to bushfires, floods, extreme heat, and other climate hazards, supporting data-driven decision-making. By leveraging jurisdictional data, risk assessments can be tailored to the unique climatic and geographic challenges of each region, ensuring that adaptation and mitigation strategies are effectively targeted.

Climate Risk Analysis

Data availability & accuracy

In addressing the assessment brief, a comprehensive review of existing data was undertaken to assess the relevance of existing data sources to demonstrate where existing data sources can be used to support the risk analysis. 13 evaluation criteria were identified to do this. Each criterion was then assigned a specific weight based on its importance to the assessment, and data sources were scored accordingly. By systematically assessing each data source against these weighted criteria, we determined their suitability for supporting risk analysis and identify any critical data gaps. These weightings were chosen to balance the practical aspects of using the data (e.g. ease of use, format, accessibility) with the critical aspects of data quality (e.g. accuracy, relevance, coverage). The weighting ascribed to each criterion can be seen in Table 5. A detailed evaluation of these data sources can be seen in **Appendix A.**

TABLE 5 WEIGHTING OF FACTORS ADOPTED IN DATA EVALUATION

Criteria	Weight	Reasoning
Age of Data	2 / 5	While it's important to have up-to-date data, some older data can still be valuable if it's the most recent available or if it provides historical context. Therefore, it has a moderate weight.
Source	3 / 5	The credibility and reliability of the data source are crucial. Data from reputable organizations (e.g., government agencies, UN bodies) is generally more trustworthy, hence a higher weight.
Ease of Use	2 / 5	User-friendliness is important for practical application, but it's not as critical as the accuracy or relevance of the data. Therefore, it has a moderate weight.
Coverage	3 / 5	Comprehensive coverage is essential for a thorough assessment. Data that covers all necessary geographical areas and time periods is highly valuable, hence a higher weight.
Accuracy	4 / 5	Accuracy is paramount for reliable risk assessments. Inaccurate data can lead to incorrect conclusions, so this criterion has a high weight.
Relevance	4 / 5	The relevance of the data to the specific hazards and risks being assessed is critical. Highly relevant data directly supports the assessment framework, hence a high weight.
Granularity	3 / 5	Detailed data allows for more precise analysis. While not as critical as accuracy or relevance, it is still very important, hence a moderate to high weight.
Format	2 / 5	The format of the data affects how easily it can be integrated into your systems. While important, it is less critical than the content of the data itself, hence a moderate weight.
Accessibility	2 / 5	Data that is easily accessible is more practical to use. However, it is less critical than the accuracy or relevance of the data, hence a moderate weight.
Cost	1 / 5	While cost is a consideration, it is often outweighed by the importance of the data's quality and relevance. Therefore, it has a lower weight.
Metadata	2 / 5	Comprehensive metadata helps in understanding the context and limitations of the data. It is important but not as critical as accuracy or relevance, hence a moderate weight.
Update Frequency	3 / 5	Regularly updated data ensures that the assessment is based on the most current information. This is important for maintaining the relevance and accuracy of the assessment, hence a higher weight.
Interoperability	2 / 5	The ability to combine data from different sources is important for comprehensive analysis. While important, it is less critical than the core content of the data, hence a moderate weight.

Evaluation of data

The evaluation of data sources for the assessment reveals that most of the data is recent, with many sources updated in 2023 or 2024, ensuring the information is current and relevant (Age of data). The majority of the data comes from reputable and reliable sources such as government agencies, UN bodies, and well-known NGOs, which enhances the credibility of the information (Source). Data sources generally scored high in ease of use, indicating that they are user-friendly and accessible, facilitating their integration into the assessment framework (Ease of use). The data sources provide comprehensive coverage both geographically and temporally, ensuring that all necessary areas and periods are well-represented (Coverage). High accuracy scores across the board suggest that the data is precise and reliable, which is crucial for making informed decisions in the risk assessment (Accuracy). The data sources are highly relevant to the specific hazards and risks being assessed, ensuring that the information directly supports the objectives of the assessment (Relevance).

Most data sources offer a high level of detail, which is essential for conducting thorough and precise analyses (Granularity). The data is available in various formats, including PDFs, interactive maps, and CSV files, which are compatible with different tools and systems used in the assessment (Format). The majority of the data sources are publicly available and free, making them easily accessible for use in the assessment (Accessibility). Most data sources are free, which is beneficial for budget considerations and ensures that cost is not a barrier to accessing high-quality data (Cost). Comprehensive metadata is provided with most data sources, explaining the context, collection methods, and limitations, which aids in accurate interpretation and use of the data (Metadata). Regular updates are a common feature, ensuring that the data remains current and reflective of the latest information and trends (Update Frequency). High interoperability scores indicate that the data can be easily combined with other sources, facilitating a more integrated and comprehensive assessment (Interoperability). Overall, the evaluation reveals that the data sources are of high quality, relevant, and comprehensive, with only minor gaps in granularity and update frequency.

Gaps

Notwithstanding the above evaluation, the following gaps and areas for improvement have been identified:

1. Granularity

While many sources provide detailed data, some do not offer the level of granularity needed for specific local assessments. For example, national-level data might not be sufficient for detailed regional or local risk assessments. To address this gap, supplementing the national-level data with local data sources will enhance granularity. For example, we currently have the NARCLiM 2.0 data (for NSW and ACT), Queensland has their own equivalent data sets, and other states are working to develop something similar. What we have found is that though they are all downscaling the data and models provided by IPCC AR6 (CMIP6) (The Intergovernmental Panel on Climate Change, 2023), which is the latest science that we have, there are inconsistent approaches. For example, each platform provides different climate variables which makes it difficult to make comparisons and assessment especially when reviewing assets spread across states.

A standardised set of climate projection data at the national level will ensure that there is a consistent approach – climate change doesn't work by state boundaries, and it will ensure that we are all working together towards the same goal.

2. Update frequency

Although most sources are regularly updated, some might not be updated frequently enough to reflect the latest climate risks and resilience measures. Ensuring that data is current is crucial for accurate risk assessments. Therefore, prioritising data sources that are frequently updated or seek out additional sources that provide more current data.

There are limited resources on accurate and up-to-date flood mapping. For example, in NSW, most councils will have done their flooding assessments and there will be a portal to access this, or there is the SEED mapping but with the release of the new ARR Guidelines it is now all redundant. For critical infrastructure, it would be worthwhile investing in undertaking standardised detailed flooding assessments, especially for areas/regions that are susceptible to flooding. While it may seem like an initial cost, it can be valuable. For example, looking at the light rail in Sydney CBD – the tracks are easily flooded, and then the light rail either must travel at a slower pace, or cannot run at all.

3. Interoperability

Combining data from different sources can be challenging if they are not easily interoperable. Ensuring that data formats and structures are compatible is essential for seamless integration into assessment frameworks. To improve interoperability, it is recommended that data integration tools and standards to ensure compatibility between different data sets are used.

4. Coverage

While the coverage is generally good amongst the data sources evaluated, there might be specific areas or sectors that are underrepresented. For instance, certain types of infrastructure or specific geographic regions might not be as well covered. To expand coverage, additional data sources that cover underrepresented areas or sectors should be identified and included.

Engaging with local councils to identify the location and details of their assets is recommended here, as well as working with local councils to engage with their communities to understand the importance of each asset. This collaborative approach will ensure that the assessment considers local knowledge and priorities, leading to more accurate and relevant risk assessments.

Further, engaging with local Indigenous communities to incorporate their traditional knowledge and insights of climate events. Indigenous knowledge can provide unique perspectives on environmental changes, historical climate patterns, and the significance of certain assets. This collaborative approach will enhance the accuracy and relevance of the risk assessments by integrating diverse sources of information.

5. Metadata

Comprehensive metadata is crucial for understanding the context, collection methods, and limitations of the data. Ensuring that all data sources come with detailed metadata can help in accurately interpreting and using the data. To verify metadata, ensure that all data sources include comprehensive metadata and seek additional documentation if necessary.

The comprehensive evaluation of data sources highlights their overall high quality, relevance, and suitability for supporting the Climate Risk and Resilience Assessment. However, addressing identified gaps—such as limitations in granularity, update frequency, and coverage—will be essential to ensuring a robust and accurate analysis. Improvements in data interoperability, accessibility, and metadata quality will further enhance the integration and usability of data within the assessment framework. By prioritising these areas, a more comprehensive and reliable risk assessment can be achieved, providing critical insights to inform resilience strategies and infrastructure investment decisions.

Stage 2 – Infrastructure Assets & Network Identification

Typology mapping

Type of infrastructure assets & networks

Understanding the vulnerability of infrastructure to climate risks requires a clear characterisation of the various types of assets at risk. Infrastructure Australia, the national agency responsible for strategic planning and assessment of Australia's infrastructure needs, categorises infrastructure assets into several key sectors. This section characterises these asset categories, focusing on their critical functions, vulnerabilities to climate hazards, and potential adaptation strategies.

The 2021 Australian Infrastructure Plan from Infrastructure Australia (2021) adopts broad categorisation which has been adopted by the project team.

TABLE **6** INFRASTRUCTURE ASSET CATEGORISATION

Asset Category	Description	Asset Types
Transport Infrastructure	This category includes roads, bridges, railways, ports, and airports. Transport infrastructure is essential for the movement of people and goods, facilitating economic activity and social connectivity.	Roads Rail Port Airport Bridges Civil structures
Energy	This includes electricity generation facilities, transmission and distribution networks, and gas pipelines. Reliable energy supply is crucial for economic stability, healthcare, and essential services.	Power plants Transmission lines Wind farms Substations Solar plants Gas pipelines
Telecommunications and Digital	Encompasses telecommunications networks, including mobile networks, fiber-optic cables, satellite systems, and broadcasting facilities. These are essential for communication, emergency response, and digital connectivity.	Satellite dishes Communications towers Cables NBN
Water	Includes water supply systems, wastewater treatment plants, stormwater drainage systems, and irrigation networks. Water infrastructure ensures access to clean water and sanitation.	Dams Pipelines Desalination plants Wastewater treatment Sewerage treatment
Social Infrastructure	This includes hospitals, schools, public buildings, and community facilities. Social infrastructure supports essential services, such as healthcare, education, and social welfare.	Hospitals Education Parks Community and recreation centres Libraries
Waste	Includes waste processing facilities, landfills, recycling centers, and hazardous waste storage. This infrastructure is essential for maintaining public health and environmental sustainability.	Landfills Material Recovery facilities Resource recovery Specialised recycling plants Hazardous waste storage

Leveraging existing Data Aggregators

The Australian Government already has several location based tools for aggregating asset data. These tools are considered critical for determining where to direct funding, as the hazard likelihood can vary significantly across the continent. Two key data aggregators are the Digital Atlas of Australia (Geoscience Australia, 2024) and the National Map (Geoscience Australia, 2024).

The Digital Atlas of Australia

The Digital Atlas of Australia is an innovative platform developed by Geoscience Australia that brings together diverse national datasets into a centralised digital ecosystem. This initiative is part of the broader Australian Government's Data and Digital Government Strategy, which aims to enhance the management and accessibility of data as a critical national asset. By consolidating trusted data sources, the Digital Atlas plays a crucial role in supporting climate risk assessment, infrastructure planning, and resilience strategies.

The Digital Atlas integrates data related to Australia's geography, environment, economy, and demographics, allowing stakeholders to explore, analyse, and visualise complex datasets in a single platform. This integration is particularly valuable for climate risk assessments, as it provides decision-makers with a holistic view of how climate hazards interact with infrastructure systems and socio-economic conditions across the country. By connecting data that was previously fragmented across various agencies, the Atlas addresses long-standing challenges related to data silos, enabling more seamless and efficient analysis.

One of the most significant benefits of the Digital Atlas is its ability to enhance place-based decision-making. By providing high-quality geospatial data, the platform empowers planners and policymakers to develop targeted, evidence-based interventions that are tailored to the unique characteristics of specific regions. For example, stakeholders can use the Atlas to map climate hazards such as bushfires, heatwaves, floods, and sea-level rise, overlaid with the locations of critical infrastructure assets like transport networks, energy grids, and water systems. This spatial analysis helps to identify vulnerabilities and prioritise areas that require urgent investment in adaptation measures.

The Atlas also supports the development of a robust climate risk framework by providing access to newly created and previously inaccessible datasets. This wealth of information enables a deeper understanding of the interplay between climate hazards and infrastructure resilience, supporting more informed policy and investment decisions. Real-time data integration further enhances the platform's capabilities, allowing for dynamic monitoring of changing conditions and more timely responses to emerging threats.

Overall, the Digital Atlas of Australia represents a significant advancement in the use of digital technology to inform climate risk assessment and infrastructure planning. By enabling more efficient data sharing, improved collaboration, and deeper insights into place-based risks, the Atlas is a valuable tool for building a resilient future. As the platform continues to evolve, it will play an essential role in supporting Australia's efforts to mitigate the impacts of climate change and secure the sustainability of its critical infrastructure.

National Map

The National Map is another initiative by Geoscience Australia that serves as an interactive, digital mapping tool. It consolidates a wide range of national datasets into a central, interactive system, providing users with the ability to visualise geospatial data layers. This platform is essential for infrastructure planning, risk assessments, and climate resilience efforts.

The National Map supports data-driven decision-making by allowing users to access and analyse critical information on infrastructure assets, environmental hazards, and socio-economic factors. It facilitates comprehensive risk assessments by integrating data on historical climate events, projected changes, and asset vulnerabilities, thus supporting resilient infrastructure planning.

Asset Data availability

The data included in both the Digital Atlas and the National Map has been reviewed to assess what type of infrastructure asset information is currently included. This is used to identify gaps in the data that Infrastructure Australia will need to source in order to complete a climate hazard risk assessment.

TABLE 7 ASSET DATA GAP ANALYSIS

Asset Category	Asset Type	Included in the Digital Atlas	Included in the National Map
Transport	Roads	Yes	Yes
	Rail	Yes	Yes
	Tram Lines	Yes	No
	Seaports	Yes	Yes
	Airport	No	Yes
	Road Bridges	No	Yes
	Rails Bridges	No	Yes
	Road civil structures	No	No
	Rail civil structures	No	No
Energy	Power plants	Yes	No
	Oil Pipelines	Yes	Yes
	Gas Pipelines	Yes	Yes
	Electricity Transmission Lines	Yes	Yes
	Liquid Fuel Terminals	Yes	No
	Wind Farms	Yes	No
	Substations	Yes	Yes
	Solar Farms	Yes	Yes
	Petrol Stations	Yes	Yes
Communications	Satellite dishes	No	No
	Comms towers	No	No
	Cables	No	No
	NBN	No	Yes
Water	Dams	No	No
	Pipelines	No	Yes
	Desalination plants	No	No
	Wastewater treatment	No	Yes
	Sewerage treatment	No	No
Waste	Landfills	Yes	No
	Material Recovery facilities	Yes	No
	Resource recovery	Yes	No
	Specialised recycling plants	Yes	No
	Hazardous waste storage	Yes	No
Social	Hospitals	No	Yes
	Education	No	Yes
	Parks	No	Yes

Asset Category	Asset Type	**Included in** the **Digital Atlas**	**Included in** the **National Map**
	Community and recreation centres	No	Yes
	Libraries	No	Yes
	Fire Services	Yes	Yes
	Police Stations	Yes	Yes

While data between the two aggregators includes a significant degree of overlap neither system includes information on all key asset types. Further there are several asset types that to not appear to be included in either database, namely:

- Road and rail civil structures (e.g. retaining walls)
- Communication assets (other than NBN)
- Dams, Desalination Plants and Sewerage Treatment plants

If is recommended that IA invest in securing additional data on these assets and determine a methodology to incorporate both aggregators in order to feed into the proposed climate risk assessment.

Infrastructure Significance

Infrastructure assets are critical to the functioning of society, supporting essential services such as transportation, energy, water supply, and communications. Assessing the significance of these assets is crucial for effective planning, maintenance, and investment, especially in the context of increasing climate risks. There are a number of factors that can impact the significance of an asset which need to be considered when undertaking a climate risk assessment.

Assessing the significance of infrastructure assets is a multi-faceted process that requires a careful balance of financial, social, and strategic factors. By using a structured approach that considers replacement costs, community impact, owner priorities, and potential failure consequences, stakeholders can better prioritise investments and resilience measures. This ensures that critical infrastructure is maintained, upgraded, or protected to sustain essential services, particularly in the face of increasing climate risks.

Financial Value – Replacement Cost

One of the most straightforward metrics for assessing asset significance is its financial value, typically measured by the replacement cost. The higher the cost of replacing an asset, the greater its economic importance. This metric is particularly relevant for large-scale infrastructure like bridges, ports, and power plants, where replacement costs can reach billions of dollars.

Local Significance – Community Impact

Infrastructure assets play a vital role in supporting local communities. Roads, water supply systems, and public transport networks are crucial for the daily lives of residents. Assessing the local significance of an asset involves understanding its role in supporting community well-being, access to essential services, and economic activities. For instance, a bridge that connects isolated rural communities may be deemed highly significant due to its impact on mobility and access to healthcare.

Asset Owner Significance

The importance of an asset can also vary based on the priorities of the asset owner, which could be a government agency, private company, or local council. Owners may prioritise assets that are critical to their strategic objectives, such as those generating significant revenue or serving a large customer base. For example, utilities may prioritise maintaining energy infrastructure to ensure reliable service to consumers.

Cost of Failure

The cost of failure is a key metric in determining the significance of an asset. This includes not only the direct financial costs of repairing or replacing the asset but also indirect costs such as service disruptions, loss of revenue, and reputational damage. In some cases, the cost of failure may extend to legal liabilities if failures lead to property damage or personal injuries.

Maintenance Costs

An asset's maintenance requirements can significantly influence its overall significance. High maintenance costs may indicate the need for upgrades or replacement, especially if the asset is critical to service delivery. Conversely, assets with low maintenance costs but high failure consequences may be prioritised for proactive resilience measures to avoid future disruptions.

Cost of Life

The cost of life metric is essential for assets that, if compromised, could result in loss of life or severe injury. This is particularly relevant for infrastructure like bridges, tunnels, and transport systems, where failures can have catastrophic consequences. Ensuring the safety of such assets is often prioritised over economic considerations. In Australia, the Value of Statistical Life (VoSL) is determined by the Office of Impact Analysis.

Downstream Impacts

Infrastructure failures can have downstream impacts that extend beyond the immediate area. For example, a failure in a major transport corridor can disrupt supply chains, leading to economic losses across multiple sectors. Assessing the potential ripple effects of asset failures helps identify those with broader regional or national significance. Downstream impacts are often complex and difficult to quantify, and is only recommended for highly detailed assessments.

Redundancy

Redundancy refers to the presence of alternative systems or routes that can take over if an asset fails. Infrastructure with high redundancy may be considered less significant than those where failure would lead to severe service disruptions. For instance, if a region relies on a single water pipeline with no alternative supply, that pipeline would be of high significance due to its lack of redundancy.

Infrastructure Vulnerability

Assessing the vulnerability of infrastructure systems is a crucial step in understanding their exposure to climate-related risks. Vulnerability refers to the degree to which infrastructure assets, communities, or systems are susceptible to damage due to their physical characteristics, location, or socio-economic context. Identifying vulnerabilities is essential for prioritising resilience measures, especially as climate change intensifies the frequency and severity of extreme weather events. By understanding these vulnerabilities, stakeholders can develop targeted adaptation strategies to protect critical infrastructure and enhance community resilience in the face of future challenges.

As climate change continues to intensify, the vulnerabilities of critical infrastructure are becoming increasingly apparent, requiring targeted adaptation strategies to ensure their resilience. Transport infrastructure, for instance, faces severe risks from heatwaves, flooding, storms, and bushfires, impacting roads, rail networks, and airports. Understanding these vulnerabilities is essential to prioritise resilience measures and safeguard essential services against future climate impacts. Table 6 outlines the key infrastructure asset categories, their primary vulnerabilities, and corresponding adaptation strategies.

TABLE 8 ASSET CATEGORY KEY VULNERABILITIES

Asset Category	Vulnerabilities	Adaptation Strategies
Transport Infrastructure	**Heatwaves**: High temperatures can cause road surfaces to soften, rail tracks to buckle, and airport runways to degrade, leading to disruptions. **Flooding**: Riverine, flash, and coastal flooding can inundate roads, railways, and airports, leading to significant damage and service disruptions. **Storms and Cyclones**: Strong winds and heavy rain can damage transport networks, particularly ports and coastal roads. **Bushfires**: Fires can destroy rail lines, roadways, and transport facilities, especially in rural and bushland areas.	Implementing heat-resistant materials for roads and rail tracks. Upgrading drainage systems to manage increased rainfall and reduce flooding risks. Strengthening coastal infrastructure to withstand storm surges and sea-level rise. Developing fire-resistant barriers and vegetation management around transport corridors.
Energy	**Heatwaves**: High temperatures increase energy demand for cooling, leading to potential grid overloads and outages. Heat can also reduce the efficiency of power generation and transmission. **Storms and Cyclones**: Strong winds and heavy rain can damage transmission lines, substations, and renewable energy facilities (e.g., solar farms and wind turbines). **Bushfires**: Fires can destroy power lines, substations, and other critical energy assets, leading to prolonged outages. **Sea-Level Rise**: Coastal energy infrastructure, such as power plants and gas terminals, is vulnerable to flooding and erosion.	Upgrading grid infrastructure to handle peak demand and extreme heat conditions. Strengthening poles and towers to withstand high winds and storms. Relocating critical energy assets away from fire-prone and flood-prone areas. Implementing sea walls and other protective measures for coastal energy facilities.
Telecommunications and digital	**Storms and Cyclones**: High winds and flooding can damage towers, cables, and satellite systems, leading to communication outages. **Bushfires**: Fires can destroy communication towers and underground cables, disrupting emergency services. **Heatwaves**: High temperatures can affect the performance of electronic equipment and increase cooling requirements for data centers.	Hardening communication infrastructure against wind and water damage. Deploying underground cables where feasible to reduce fire risk. Enhancing cooling systems for data centers to handle extreme heat. Building redundancies into networks to ensure service continuity during disasters.
Water	**Drought**: Reduced rainfall and prolonged droughts can lead to water shortages, affecting water supply for households, agriculture, and industry.	Diversifying water sources through desalination, recycling, and rainwater harvesting.

Asset Category	Vulnerabilities	Adaptation Strategies
	Flooding: Heavy rainfall and flash floods can overwhelm stormwater systems, damage water treatment plants, and contaminate water supplies. **Sea-Level Rise**: Coastal water infrastructure is at risk from saltwater intrusion, which can affect freshwater supplies and wastewater treatment facilities.	Strengthening stormwater systems to manage intense rainfall and reduce flooding. Protecting coastal water assets from sea-level rise through levees and barriers. Implementing efficient water management practices to reduce demand during droughts.
Social Infrastructure	**Heatwaves**: Increased temperatures can reduce indoor air quality and strain cooling systems in hospitals and schools. **Flooding**: Schools, hospitals, and public buildings in flood-prone areas face damage and service disruptions during extreme rainfall events. **Bushfires**: Social infrastructure located near bushland is at risk of fire damage, which can affect emergency response capabilities.	Retrofitting buildings with efficient cooling and ventilation systems to cope with extreme heat. Elevating or flood-proofing critical facilities in flood-prone areas. Creating firebreaks and using fire-resistant materials in the construction of buildings near bushfire zones. Enhancing emergency preparedness and evacuation plans for hospitals and schools.
Waste	**Flooding**: Waste management facilities are vulnerable to flood damage, leading to contamination and environmental hazards. **Storms**: High winds can damage waste processing equipment and structures, disrupting waste management services. **Heatwaves**: Extreme heat can impact the operation of waste processing facilities, increasing the risk of fires at landfills.	Relocating critical waste facilities away from flood-prone areas. Strengthening waste management infrastructure to withstand extreme weather events. Implementing fire prevention measures at landfills, such as monitoring systems and firebreaks.

Stage 3 – Risk Assessment

Quantification of Climate Risk

Scoring climate risks in Australia involves assessing both the likelihood of climate-related events, such as extreme heatwaves, bushfires, cyclones, and floods, and the potential severity of their impact on critical infrastructure. This evaluation helps identify vulnerabilities within transportation networks, energy grids, water supply systems, and essential public facilities like hospitals and schools. The process typically combines historical climate data and predictive models to estimate the probability of such events, while impact assessments focus on the extent of damage, economic loss, and service disruptions that could occur. By integrating these factors, organisations and governments can prioritise investments in resilient infrastructure, implement adaptive measures, and strengthen emergency response systems to mitigate long-term risks. This approach ensures that communities and economies are better prepared to withstand and recover from climate-induced disruptions.

The following sections will delve into the critical components of the Climate Risk and Resilience Assessment: Climate Risk Severity and Climate Risk Likelihood.

Likelihood

Likelihood, often referred to as probability in climate risk assessments, denotes the chances of climate-related hazards occurring and affecting infrastructure systems. In Australia, hazards such as floods, bushfires, cyclones, extreme heatwaves, and coastal erosion have varying probabilities depending on regional climate conditions and long-term trends influenced by climate change.

Likelihood is typically evaluated using historical data, predictive models, and climate projections. For planners and policymakers, recognising high-probability events—like recurrent heatwaves in urban areas—is vital for implementing preventive measures, such as enhancing cooling systems and upgrading transport networks. Meanwhile, low-probability but high-impact events, such as rare catastrophic floods, require robust contingency plans to minimise long-term damage. Understanding likelihood enables more precise risk forecasting and resource allocation, ensuring the resilience of infrastructure systems against anticipated climate threats.

The first step involves quantifying the likelihood or probability of a climate-related event occurring in the country. This risk assessment will consider both current climate conditions and future scenarios, ensuring that the potential impacts of climate change are fully integrated into the analysis. It is important to note that the probability of such events is closely linked to geographical location, as different regions within Australia face varying levels of exposure and vulnerability to climate hazards such as bushfires, floods, cyclones, and heatwaves.

Various tools and resources are available to support this process, including the Climate Risk Map of Australia provided by the Climate Council. This map offers a comprehensive view of both current and future risks and allows users to explore different emissions scenarios based on the Representative Concentration Pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC). The ability to visualise region-specific risks is particularly valuable for understanding how localised factors influence the probability and impact of climate events.

The risk scoring system will use a five-point scale to assess the likelihood of climate-related events, offering a standardised approach to evaluate their probability. The scale ranges from 1 to 5, where:

1: Almost impossible
The event is highly unlikely to occur under current or projected conditions. It may happen only in exceptional circumstances.
2: Unlikely
The event has a low probability of occurring but is not entirely out of the question. It might happen infrequently or under unusual conditions.
3: Possible
The event has a moderate chance of occurring. While not guaranteed, it could take place under typical conditions.
4: Likely
The event is expected to occur with some regularity. It is a probable outcome under current or projected scenarios.
5: Almost certain
The event is highly likely to occur. It is expected to happen frequently or inevitably given the current trends and conditions.

This structured framework allows for a consistent and location-sensitive assessment of climate risks, supporting targeted adaptation and resilience strategies across Australia's diverse landscapes.

Severity

Climate risk severity for infrastructure assets and networks reflects the potential scale and intensity of damage or disruption caused by climate-related hazards such as extreme weather events, flooding, heatwaves, and rising sea levels. The severity is determined by the magnitude of these hazards, the vulnerability of exposed infrastructure, and the system's capacity to absorb shocks or recover. High-severity risks can severely impact critical infrastructure, including transport systems, power grids, water networks, and communication channels, leading to cascading failures. These failures disrupt essential services, drive up repair and maintenance costs, and strain local and national economies. As climate change accelerates, the frequency and intensity of severe events are expected to rise, making it essential to prioritise resilience planning and strategic investments to mitigate the most severe impacts.

Climate-related hazards, such as extreme weather events, rising sea levels, and temperature fluctuations, have diverse impacts on various types of infrastructure. For instance, transportation networks like roads and bridges are particularly vulnerable to flooding and heatwaves, which can lead to structural damage and increased maintenance costs. Power infrastructure, including grids and generation facilities, faces risks from storms and high winds that can disrupt energy supply, while water and sanitation systems may experience strain from droughts or heavy rainfall, affecting their capacity to deliver essential services.

The second step involves understanding the different impacts that different climate-related hazards have on various infrastructure systems and assets.

Building on the findings from earlier chapters, the priority climate hazards for Australia have already been identified. This phase focuses on assessing how these hazards could affect different types of infrastructure, including transportation networks, energy systems, water supply, telecommunications, and public facilities. Each infrastructure type may experience varying degrees of impact depending.

The impact assessment will use a standardised scoring system ranging from 1 to 5:

1: No Impact
The hazard has negligible or no effect on the asset or system.
2: Minor Impact
Minor disruptions or damages occur, with limited functional or financial consequences.
3: Moderate Impact
Noticeable disruptions or damages that require repair but do not compromise overall system functionality.
4: Severe Impact
Significant damage or operational disruption, leading to partial loss of service or increased repair costs.
5: Catastrophic Impact
Complete failure or destruction of the asset or system, with widespread consequences and long-term recovery needs.

Scoring Climate Risk

Once the likelihood of a climate-related event occurring and its potential impact on various types of infrastructure assets and systems is determined, the final step in assessing and scoring climate risks involves synthesising this information. This process assigns a comprehensive risk score to each geographical region in Australia, taking into account not only the probability of such events but also the magnitude of their potential impact on different infrastructure types. The methodology ensures that the unique vulnerabilities of each infrastructure type are reflected in the scoring process.

Below is an expanded explanation of the scoring system:

1: Almost impossible and No Impact
Climate risks are extremely rare, with negligible likelihood of occurrence.
No anticipated impact on infrastructure functionality or service delivery.
2: Unlikely and Minor Impact
Climate risks are unlikely, with low probability of occurrence.
Minor damage or disruption, easily managed with minimal intervention.
3: Possible and Moderate Impact
Climate risks are possible, with occasional exposure to hazards.
Moderate damage or disruption, potentially requiring repairs or short-term service adjustments.
4: Likely and Severe Impact
Climate risks are likely, with regular or frequent exposure to hazards.
Severe damage or prolonged service disruptions, requiring significant intervention and resources.
5: Almost certain and Catastrophic Impact
Climate risks are almost certain, with regular and severe exposure to hazards.
Catastrophic impact, resulting in widespread service failure and long-term recovery efforts.

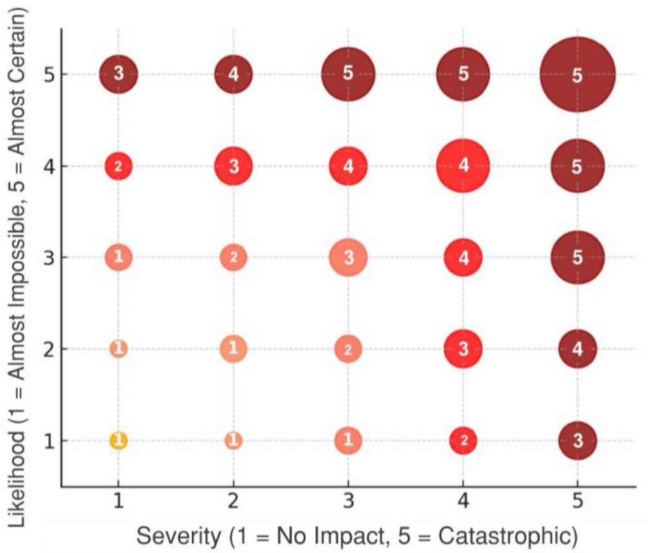


FIGURE 7 CLIMATE RISK MULTIVARIATE MATRIX

The end result is a collection of detailed risk maps, with each map corresponding to a specific type of infrastructure asset or system (unless certain types have identical risk profiles). These maps provide a visual representation of climate risks, highlighting areas where the likelihood of events such as floods, bushfires, or extreme heat is highest, and where the potential damage to infrastructure would be most severe.

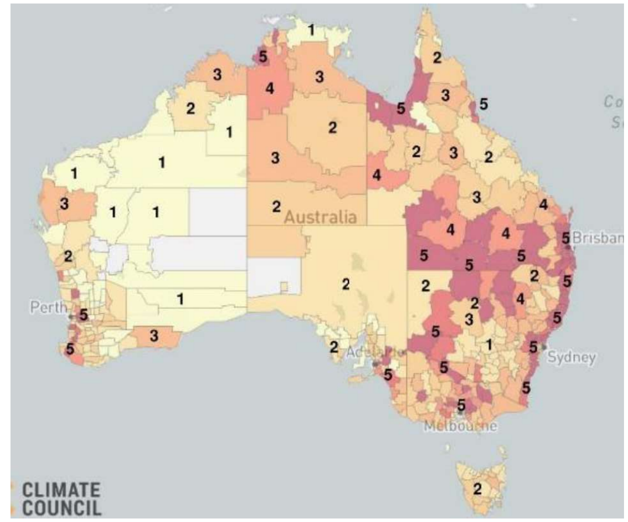


FIGURE 8 EXAMPLE OF THE SCORED CLIMATE RISK MAP

Quantification of Infrastructure Criticality and Vulnerability

The next step in the proposed methodology involves evaluating and assigning scores to infrastructure assets and systems across Australia, with a focus on their criticality and susceptibility to climate-related hazards. This process entails a comprehensive assessment of how essential these assets are to the functioning of society and the economy, as well as their level of exposure and sensitivity to risks such as extreme weather events, rising sea levels, and temperature fluctuations.

The criticality assessment will determine the importance of each infrastructure component in maintaining vital services, including energy supply, water distribution, transport networks, and telecommunications. Meanwhile, the vulnerability analysis will identify specific weaknesses or conditions that may increase the likelihood of damage or failure under climate stressors.

By combining these two dimensions—criticality and vulnerability—the methodology aims to prioritise infrastructure that requires immediate attention or investment in resilience measures. This ensures that the most vital and at-risk systems are safeguarded against the growing impacts of climate change, thereby supporting Australia's long-term sustainability and security.

Infrastructure Criticality

The criticality of infrastructures refers to the importance of specific systems, facilities, or assets in ensuring the functioning and stability of a society or economy. Critical infrastructures are those whose disruption, destruction, or failure would have a significant impact on public safety, security, health, or economic well-being.

Key Elements of Critical Infrastructure:

- Vital Functions: Infrastructures that support essential services such as energy, water, transportation, and communication.
- Interdependencies: Many critical infrastructures are interconnected. For example, the power grid supports telecommunications, and transportation systems rely on fuel supplies.
- Risk and Impact: The criticality of an infrastructure is often assessed based on the potential consequences of its failure. This includes:
    - Loss of life
    - Economic disruption
    - Environmental damage
    - National security threats

Infrastructure criticality will be evaluated using a five-point scale, ranging from 1 to 5. Each score reflects the level of importance and impact associated with the asset or system, as follows:

- **1: Minimal Criticality:** The infrastructure plays a minimal role in societal or economic functions. Its disruption would cause negligible impact, with little to no effect on public safety, essential services, or daily operations.
- **2: Low Criticality:** The infrastructure is of limited importance. Disruption would lead to minor inconveniences or delays, but alternative systems or workarounds are readily available, minimising the overall impact.
- **3: Moderate Criticality:** The infrastructure has a noticeable role in supporting societal or economic functions. Disruption could lead to moderate consequences, such as localised service interruptions or economic losses, but these can be managed within a reasonable timeframe.
- **4: High Criticality:** The infrastructure is critical to key operations. Its disruption would cause significant impacts, including widespread service interruptions, economic disruption, or public safety concerns. Recovery would require substantial effort and resources.
- **5: Extreme Criticality:** The infrastructure is essential for the functioning of critical services and systems. Disruption would result in severe, widespread consequences, potentially

endangering lives, compromising national security, or causing major economic and social instability.

This scoring system ensures a consistent and prioritised approach to identifying which assets require immediate attention for resilience and protection measures.

Vulnerability to Climate Hazards

Infrastructure systems worldwide face heightened vulnerability to climate-related hazards, including extreme weather events, rising sea levels, prolonged droughts, and temperature fluctuations. These hazards threaten critical infrastructure such as transportation networks, energy grids, water supply systems, and telecommunications. The impact of these risks is often severe, resulting in service disruptions, damage to assets, and significant economic and social consequences.

Ageing infrastructure is particularly susceptible, as it may not be designed to withstand the increasing intensity and frequency of climate-related events. For instance, roads and railways are prone to damage from flooding and extreme heat, while energy systems may face outages due to storms or high temperatures straining the grid. Water infrastructure is also vulnerable, with droughts and floods impacting supply and quality, posing risks to both human health and agricultural productivity.

Compounding these risks is the interconnectedness of modern infrastructure. Failures in one system can lead to cascading effects, where disruptions in energy supply, for example, can hinder the functioning of hospitals, transportation, and communication networks. Coastal infrastructure, including ports and urban developments, faces particular challenges from sea level rise and storm surges, which can result in long-term economic and operational disruptions.

Infrastructure vulnerability to climate hazards will be assessed using a five-point scale, from 1 to 5. Each score reflects the extent to which an asset or system is exposed to and affected by climate hazards, as follows:

- **1: Minimal Vulnerability** The infrastructure is largely resistant to climate hazards. Any impacts are negligible, with no significant effect on its functionality or service provision. Little to no adaptation or mitigation measures are required.
- **2: Low Vulnerability:** The infrastructure has some exposure to climate hazards but can largely maintain its functionality. Disruptions, if any, are minor and temporary, with readily available solutions or redundancies to restore normal operations.
- **3: Moderate Vulnerability:** The infrastructure is moderately exposed to climate hazards, with potential for noticeable impacts. Disruptions could result in temporary service interruptions or increased maintenance costs. Some adaptation measures are recommended to enhance resilience.
- **4: High Vulnerability:** The infrastructure is significantly exposed to climate hazards, with a high likelihood of severe impacts. Disruptions may cause prolonged service outages, increased repair costs, or reduced operational capacity. Urgent adaptation measures are necessary to mitigate risks.
- **5: Extreme Vulnerability:** The infrastructure is highly susceptible to climate hazards, with disruptions likely to have catastrophic impacts. Functionality could be severely

compromised, with widespread and prolonged consequences for services, safety, or economic stability. Immediate and extensive adaptation measures are critical.

This scoring framework enables prioritisation of infrastructure assets based on their vulnerability, ensuring resources are allocated effectively for resilience planning and hazard mitigation.

Scoring Infrastructure Criticality and Vulnerability

Scoring infrastructure criticality and vulnerability involves a systematic assessment of key assets and systems based on their importance and susceptibility to risks. Using a scale from A to E, this method evaluates both the criticality of an asset—its role in sustaining essential services—and its vulnerability to hazards such as extreme weather or system failures. Below is an expanded explanation of the scoring system:

- **A: Not Critical and Not Vulnerable**
  - Assets with minimal impact on overall system functionality if disrupted.
  - Limited exposure to hazards, with robust design and low sensitivity to external threats.
- **B: Low Criticality and Low Vulnerability**
  - Assets supporting non-essential functions or serving a small user base.
  - Low exposure to risks, or moderate exposure with strong protective measures in place.
- **C: Moderately Critical and Moderately Vulnerable**
  - Assets providing important but non-critical services, with potential for limited disruption impact.
  - Moderate exposure to hazards, with some mitigation strategies in place but room for improvement.
- **D: Highly Critical and Vulnerable**
  - Assets essential for maintaining key operations or services with high societal or economic dependence.
  - Significant exposure to risks, with existing vulnerabilities in design, location, or operational capacity.
- **E: Very Critical and Very Vulnerable**
  - Assets vital for public safety, economic stability, or large-scale service delivery (e.g., hospitals, major energy grids).
  - High exposure to severe risks, with limited capacity to withstand or recover from disruptions.

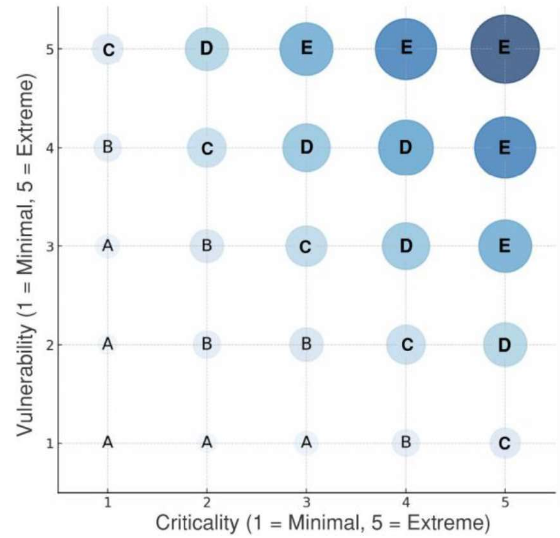


FIGURE 9 INFRASTRUCTURE MULTIVARIATE MATRIX

Once all assets are scored, they can be mapped to provide a clear visual representation of critical and vulnerable infrastructure.

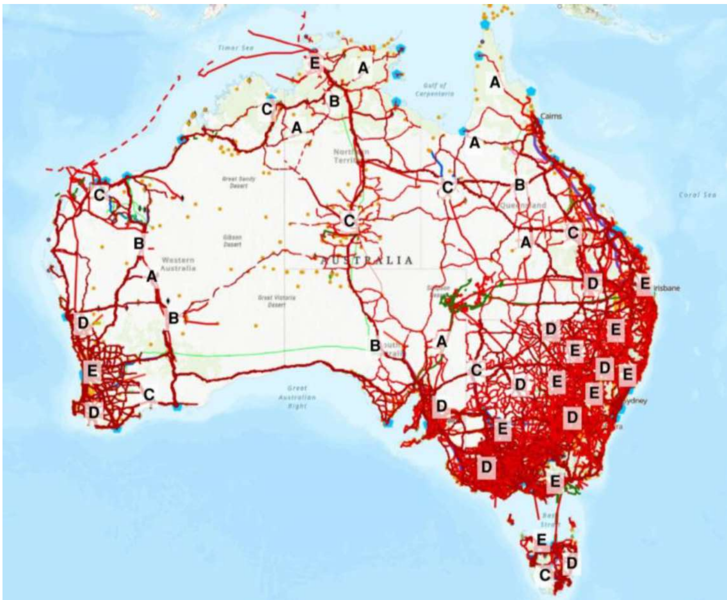


FIGURE 10 ***EXAMPLE OF THE SCORED INFRASTRUCTURE MAP***

Geospatial and Risk Score Synthesis

Climate Change Risk and Infrastructure Maps Overlay

The first two steps of the methodology focus on separately evaluating and scoring climate risks and infrastructure vulnerabilities. In **Step 1**, climate risks are assessed based on the probability of hazardous events and their potential impact on infrastructure systems, providing a spatial understanding of where and how climate change may pose significant threats. **Step 2** involves scoring infrastructure based on its criticality and vulnerability, identifying key assets whose failure would cause substantial disruptions to economic, social, or environmental systems. These steps form the foundation for **Step 3**, which overlays the two datasets to create an illustrated geospatial map. This map visually highlights regions where high climate risks intersect with critical and vulnerable infrastructure.

However, the overlapping maps alone can be difficult to interpret, as they present a complex visualisation without clearly indicating which specific infrastructures require urgent attention. To address this challenge, additional steps are proposed as part of a comprehensive risk assessment methodology: creating a multivariate map that incorporates and combines the two layers of data resulting from Steps 1 and 2 and developing a single risk index.

These steps aim to enhance the interpretability and utility of the overlay maps, supporting policymakers and planners in developing targeted, evidence-based strategies to strengthen Australia's infrastructure resilience in the face of climate change.

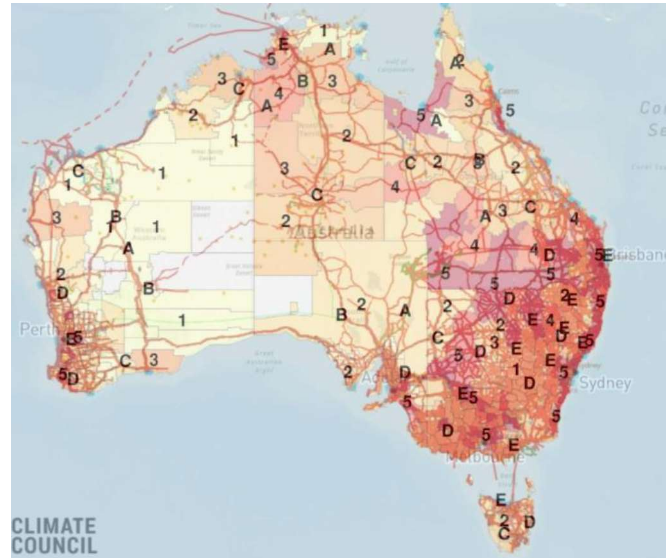


FIGURE 11 ***EXAMPLE OF THE SCORED OVERALL RISK MAP***

Climate Change Risk and Infrastructure Scores Overlay – The Multivariate Map

The next step in the climate risk assessment methodology involves creating a multivariate map that integrates the data from the first two steps: climate risk scores and infrastructure vulnerability scores. Unlike a simple overlay, which merely combines these two layers visually, a multivariate map incorporates them in a way that highlights the complex interplay between climate risks and infrastructure vulnerabilities. This approach provides a richer and more nuanced visualisation, allowing stakeholders to better understand the spatial relationships and interactions between these factors.

By using advanced geospatial analysis techniques, multivariate mapping can reveal patterns and hotspots that might otherwise remain hidden. For instance, areas with moderate climate risks might emerge as critical when combined with highly vulnerable infrastructure, while regions with high climate risks but resilient infrastructure may not require immediate intervention. This level of detail is invaluable for prioritising resources and planning targeted mitigation strategies. Ultimately, multivariate mapping supports more informed decision-making by providing a clearer picture of where climate risks and infrastructure vulnerabilities converge most critically.

Building on the insights gained from multivariate mapping, the next step in the methodology is to mathematically develop a single risk index. This index aims to quantify the intersecting scores into a single, standardised metric.

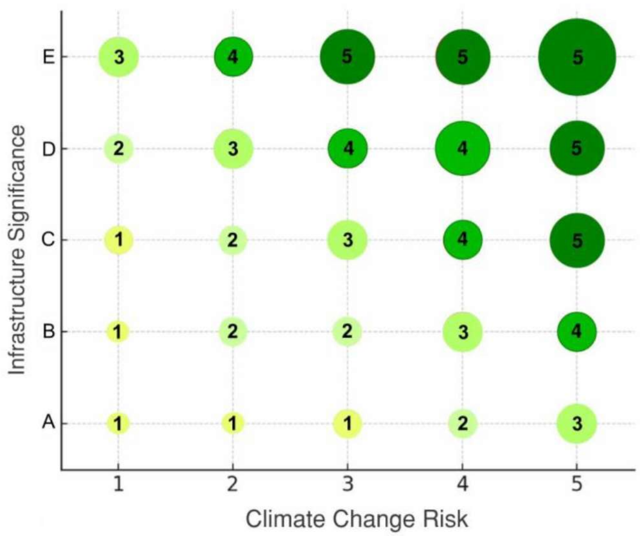


FIGURE 12 OVERALL RISK MULTIVARIATE MATRIX

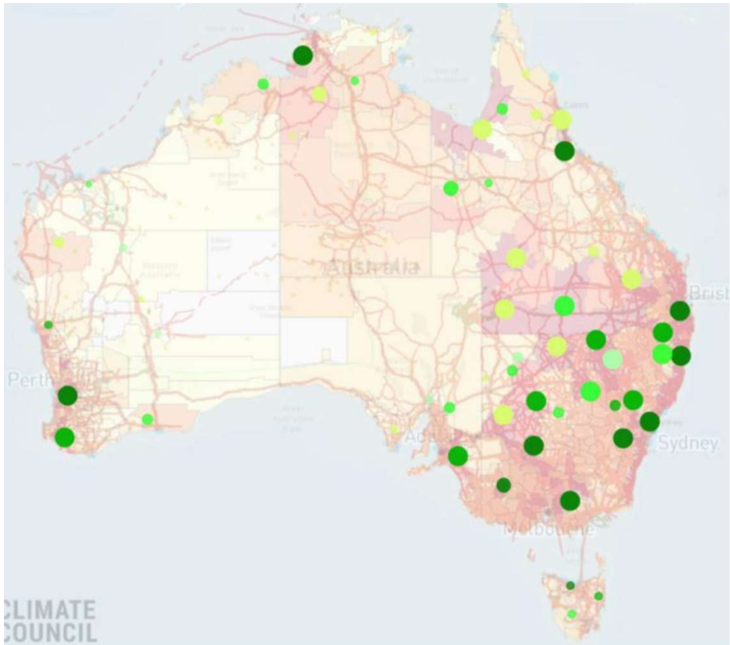


FIGURE 13 EXAMPLE OF THE RESULTING MAP

Development of the Overall risk

Development of the Overall Risk Index

The final step in the climate risk assessment methodology is the development of a mathematically derived single risk index, designed to consolidate the complex interplay of climate risks and infrastructure vulnerabilities into a single, standardised metric. This index integrates the probability and impact of climate hazards (Step 1) with the criticality and vulnerability of infrastructure assets (Step 2), providing a comprehensive measure of overall risk. The primary goal of this step is to simplify the decision-making process, allowing policymakers, planners, and stakeholders to easily compare and prioritise risks across different regions and types of infrastructure.

By reducing multiple layers of data into a single value, the risk index facilitates a clearer understanding of where resources and interventions should be directed. For instance, regions with high index scores would indicate areas where climate risks and infrastructure vulnerabilities intersect most critically, signalling a need for urgent action. Conversely, lower scores may identify areas where resilience measures are already effective or where immediate intervention is less critical. This standardised approach ensures consistency in risk evaluation, making it easier to rank and compare diverse infrastructure systems, from transport networks to energy grids, within a single framework.

Moreover, the single risk index supports long-term resilience planning by offering a scalable tool that can be updated as new data becomes available or as risks evolve due to changing climate conditions. It also provides a clear communication tool for stakeholders, translating complex risk assessments into a format that is both accessible and actionable. Ultimately, the development of a single risk index enhances the methodology's ability to guide evidence-based decision-making, ensuring that limited resources are allocated where they will have the greatest impact on mitigating climate risks and enhancing infrastructure resilience.

Identification of the Overall Risks and Vulnerabilities

To mathematically combine the two scores—climate risk and infrastructure criticality and vulnerability—into a single risk index, we propose the following formula:

Formula for the Single Risk Index (SRI)

$$SRI = w_1 \times CR + w_2 \times ICV$$

Where:

SRI = Single Risk Index (composite score)

CR = Climate Risk score (ranked 1 to 5, where 5 represents the highest climate risk)

ICV = Infrastructure Criticality and Vulnerability score (ranked similarly, where 5 represents the most critical and vulnerable infrastructure)

w_1 and **w2** = Weighting factors for CR and ICV, respectively, which reflect their relative importance in the overall risk assessment. These weights can be adjusted based on policy priorities, expert judgment, or empirical data.

Explanation:

1. **Climate Risk Score (CR):** Captures the likelihood and severity of climate hazards such as floods, heatwaves, or cyclones. A

higher score indicates higher probability and impact of these hazards in a specific region.

2. **Infrastructure Criticality and Vulnerability Score (ICV):** Measures the importance of infrastructure systems and their susceptibility to climate hazards. Critical infrastructures (like hospitals, transport hubs, or power plants) that are also vulnerable would have higher scores.
3. **Weighting Factors (w_1 and w2):** These allow flexibility to account for different stakeholder perspectives. For example, if climate risk is deemed more critical than vulnerability in a specific policy context, w_1 could be set higher than w_2. Commonly, these weights could be normalised so that $w_1+w_2=1$.

Regions or infrastructure assets with high Single Risk Index (SRI) values should be prioritised for intervention, as they represent the critical intersections where climate risks and infrastructure vulnerabilities are most acute. These high-priority areas highlight the need for immediate action to mitigate potential disruptions and enhance resilience. Additionally, the flexibility of the weighting factors within the SRI formula allows for customisation, enabling organisations to adjust the index to reflect specific risk appetites or regional priorities. This adaptability ensures that the methodology remains relevant and responsive to diverse contexts, providing a tailored approach to risk management and resource allocation.

Prioritisation of risks

The development of a single risk index is the final step of this comprehensive climate risk assessment methodology, offering a powerful tool for consolidating complex datasets into a single, standardised value. By integrating climate risk scores and infrastructure vulnerability scores, the index provides a clear, comparable metric that simplifies the often-daunting task of prioritising infrastructure for risk mitigation. This step is vital for decision-makers, as it offers a straightforward yet robust framework to guide the allocation of resources, design preventive measures, and implement targeted resilience strategies.

A key advantage of the single risk index is its consistency. By applying a uniform scale across different regions and infrastructure types, organisations can systematically evaluate and compare risks, ensuring that resources are directed where they are most needed. This not only improves efficiency but also helps to future-proof critical infrastructure against escalating climate threats.

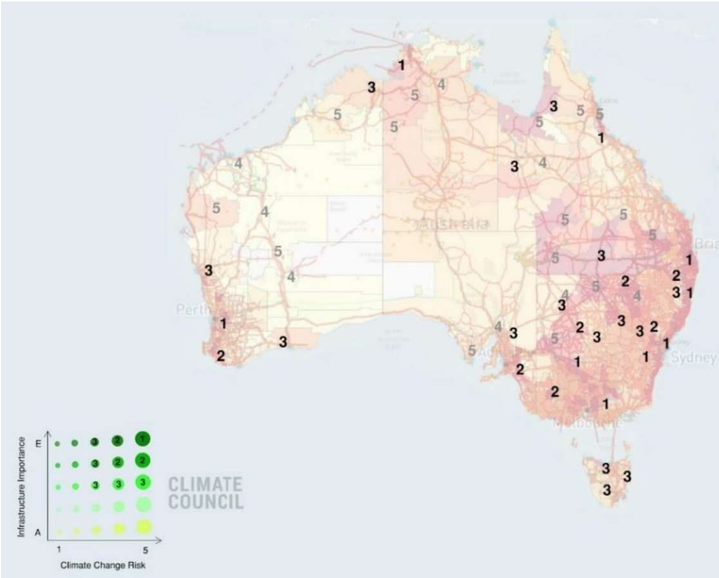


FIGURE 14 EXAMPLE OF THE SINGLE-INDEX MAP

Furthermore, the index supports transparent and effective communication of risk levels to a wide range of stakeholders, including policymakers, infrastructure managers, and local communities. By translating complex risk assessments into a comprehensible and actionable format, it fosters a shared understanding of potential climate-related threats. This collective awareness is essential for driving collaborative efforts, securing stakeholder buy-in, and developing coordinated resilience plans.

Ultimately, this methodology provides a holistic approach to managing climate risks, equipping organisations with the tools necessary to safeguard Australia's critical infrastructure in an era of increasing uncertainty.

Stage 4 – Case Study

The following section provides a worked example of the Risk Framework logic developed and discussed within this report. In order to show this simplistically, the project team has elected to focus on transport infrastructure. The selection of transport infrastructure aligns with both the Infrastructure Australia suggestion as well as the project teams' expertise. The following asset types are hence considered:

- Roads
- Rail
- Port
- Airport
- Bridges
- Civil structures

Hazard Impact

Each of these assets is assessed on the basis of the impact of the difference climate hazards that may occur. Impacts are given a score of 1 to 5 in line with the risk methodology. The justification of the impacts is based on the following criteria and tabulated below. It is expected that a similar justification and rating be developed for all asset types by Infrastructure Australia.

- **Bushfire**: High impact on rail networks and roads due to damage from fire and heat. Moderate impact on airports, which may face temporary closures due to smoke and visibility issues.
- **Extreme Temperatures**: Significant impact on roads (softening asphalt), rail tracks (buckling), and airports (affecting runway surfaces).
- **Flooding**: Critical impact on roads, rail, bridges, and airports due to inundation, structural damage, and service disruptions.
- **Storms**: Ports and airports are particularly vulnerable to storms due to exposure to wind and rain, which can disrupt operations.
- **Drought**: Lower impact on transport infrastructure but can affect ports (water levels for shipping) and civil structures reliant on water supply.
- **Extratropical Storms**: Ports, bridges, and civil structures face high risks due to high winds and heavy rainfall associated with these storms.
- **Ocean Warming & Acidification**: Ports are most affected due to rising sea levels and changes in marine conditions, while other assets are less directly impacted.
- **Tropical Cyclones**: Severe impact on all exposed infrastructure, particularly in coastal areas, due to high winds, storm surges, and flooding.

TABLE 9 IMPACT OF CLIMATE HAZARDS ON TRANSPORT INFRASTRUCTURE

Climate Hazard / Infrastructure asset	Road	Rail	Port	Airport	Bridge	Civil Struct-ure
Bushfire	4	5	3	3	4	3
Extreme Temperatures	4	4	3	4	4	3
Flooding	5	5	5	5	5	5
Storms	4	3	5	5	4	3
Drought	2	2	3	2	3	2

Extratropical Storm	4	4	5	4	4	4
Ocean Warming & Acidification	1	1	5	4	2	2
Tropical Cyclones	5	4	5	5	5	4

Hazard Likelihood

In order to further refine the assessment process, the project team has elected to focus on the Northern Rivers area of New South Wales. This area is known to experience several of the key hazard types relevant to Transport Infrastructure. The hazard likelihood is determined in this example with reference to the Climate Map of Australia, and assessed at both the 2030 and 2100 timesteps to assess increase in risk profile. This is tabulated in Table 10. The Northern Rivers region comprises the following Local Government Areas (LGAs).

- Ballina Shire Council
- Byron Shire Council
- Clarence Valley Council
- Kyogle Council
- Lismore City Council
- Richmond Valley Council
- Tweed Shire Council

The impact assessment above has been used to refine which hazard types should be considered further, namely flooding, bushfires, extreme wind and heatwaves. For each of the LGAs listed above the hazard likelihood is assessed for these key hazard types. The likelihood is assessed at both the 2030 and 2100 projected impacts assuming a moderate level of emissions. The data has been determined through the use of both the Climate Risk Map and the NARCliM2.0 Database.

TABLE 10 HAZARD LIKELIHOOD VALUES DEVELOPED FOR THE NORTHERN RIVERS REGION

	Riverine Flooding		Bushfire		Surface Water Flooding		Extreme Wind		Heatwaves	
LGA	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**
Ballina Shire Council	5	5	3	3	1	1	1	1	2	3
Byron Shire Council	1	1	5	5	1	1	1	1	2	3
Clarence Valley Council	5	5	4	4	1	1	1	1	2	3
Kyogle Council	2	2	5	5	1	1	1	1	2	3
Lismore City Council	3	3	5	5	1	1	1	1	2	3
Richmond Valley Council	2	2	2	2	1	1	1	1	2	3
Tweed Shire Council	5	5	3	3	1	1	1	1	2	3

TABLE 11 ASSET CRITICALITY MATRIX FOR TRANSPORT ASSET TYPES

Asset / Importance level	1 (Low)	2 (Moderate-Low)	3 (Moderate)	4 (High)	5 (Critical)
Roads	Local access roads with minimal traffic and limited impact on the economy or community access.	Minor roads that primarily serve residential areas or small local businesses, with moderate traffic volumes.	Collector roads that connect local roads to major highways and support moderate levels of traffic, including public transport and commercial vehicles.	Arterial roads that carry significant traffic volumes, connecting regional centres and supporting economic activities, such as transport of goods and services.	Major highways, motorways, and roads that serve as vital transport corridors for interstate and international trade, emergency response, and critical infrastructure access.
Rail	Branch lines serving local, low-density areas with minimal economic impact.	Secondary rail lines supporting regional passenger services with moderate traffic volumes.	Key commuter lines that connect suburban areas to city centres; significant for daily public transport.	Major freight corridors and high-traffic intercity passenger routes; crucial for economic activities and logistics.	Primary national rail corridors essential for interstate freight, bulk goods transport, and national supply chain continuity.
Port	Small, local ports with limited commercial or recreational activity.	Regional ports handling moderate cargo volumes, primarily supporting local industries.	Ports serving as regional logistics hubs with significant but not national-scale cargo handling.	Major commercial ports critical for regional economies, handling significant import/export volumes.	Key national ports that are vital for international trade, supporting bulk goods, container shipping, and essential imports/exports.
Airport	Small regional airports primarily serving general aviation and limited commercial flights.	Airports supporting regional air travel with moderate passenger and cargo volumes.	Significant domestic airports serving major cities and supporting high passenger traffic.	Major airports with a mix of domestic and international flights, critical for economic activity.	Primary international airports serving as major national gateways, essential for global connectivity, emergency response, and high-volume cargo.
Bridges	Supporting Low importance road or rail	Supporting Moderate-Low importance road or rail	Supporting Moderate importance road or rail	Supporting High importance road or rail	Supporting Critical importance road or rail
Civil structures	Supporting Low importance road or rail	Supporting Moderate-Low importance road or rail	Supporting Moderate importance road or rail	Supporting High importance road or rail	Supporting Critical importance road or rail

Asset Importance

Each asset is given a unique asset tag so as to track the risk profile and provide adequate cross referencing. These asset tags can be used to link where the asset data has been sourced from and additional relevant information such as asset owner or condition. The adopted tagging for this exercise is shown in Figure 15. The asset tags also assist with locating the asset within a particular LGA. This step is critical for assigning the appropriate hazard likelihood. Asset locations have been determined through the use of the National Map.

Each of the assets require a significance value in order to feed into the risk assessment. The criteria adopted to determine this significance is tabulated in Table 11, and is largely based on the redundancy aspect of the asset described in Section 7.3. This could be expanded to consider more aspects of asset importance which would allow a more refined assessment. The adopted Asset Importance values have been mapped as shown in Figure 16.

Asset Vulnerability

In this exercise it is noted that the asset vulnerability has been randomly assigned for each asset. Asset vulnerability needs to consider a range of asset data that the project team does not have direct access to. Key elements that need to feed into this assessment include

- Material of construction
- Elevation (mountainous or low lying region)
- Direct proximity to bushland
- Existing asset condition

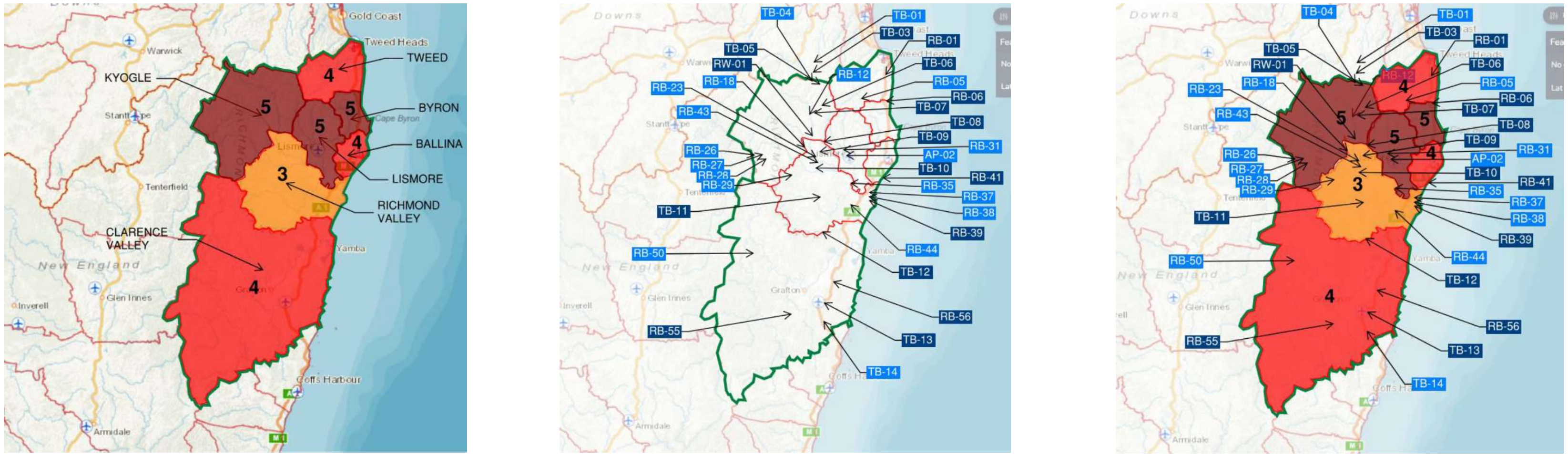
Infrastructure Australia should have access to this date through the asset authorities, who can assist with determining their individual asset vulnerabilities. It is recommended that asset owners be included in the risk assessment process as they would have the knowledge and information required to fine-tune the inputs.

Climate Risk and Criticality/Vulnerability Scores

Using the assigned values for hazard impact and likelihood with the asset importance and vulnerability the Climate Risk (CR) and Infrastructure Criticality / Vulnerability (ICV) scores are determined for each asset and each hazard type.

Each of these scores have been calculated in a spreadsheet database. The full table has been provided in Appendix B. Extracts of this table are included below.

The CR and ICR can be mapped using the location data in order to visually determine areas of significant risk that require further examination.



a. Mapping of CR - Bushfire 2030

b. Mapping of ICV

c. Overlay of CR and ICR

FIGURE 15 CR AND ICV MAP OVERLAY EXAMPLE

TABLE 12 CLIMATE RISK CALCULATION EXAMPLE

Infrastructure Type	Impact on infra.	LGA	Bushfire Likelihood (2030)	Climate Risk
Road	4	**Ballina Shire**	3	**4**
Rail	5	**Byron Shire**	5	**5**
Port	3	**Clarence Valley**	4	**4**
Airport	3	**Kyogle**	5	**5**
Rail Bridge	4	**Lismore City**	5	**5**
Road Bridge	4	**Richmond Valley**	2	**3**
Civil Structures	3	**Tweed Shire**	3	**3**

TABLE 13 AIRPORT CRITICALITY AND VULNERABILITY CALCULATED FOR AIRPORTS EXPOSED TO BUSHFIRE

Asset Tag	Asset type	ASSET IMPORTANCE	VULNERABILITY	
			Bushfire	
AP-01	Airport	**2**	**4**	**C**
AP-02	**Airport**	**2**	**5**	**D**
AP-03	Airport	**2**	**2**	**B**
AP-04	Airport	**2**	**2**	**B**

Single Risk Index

Now that the risk values have been determined for each asset in the region this can be manipulated to determine a range of methods to visualise risk as well as assist with prioritisation of control implementation.one method is to adopt a Single Risk Index (SRI).The SRI is determined for each asset, assuming equal weighting of the CR and ICV which can be used to filter critical assets.

Further Interrogation of Data

For a more refined method to determine asset risk the following multivariate tool has been adopted. This tool uses the CR and ICV for each asset and each hazard type to assign a combined risk value between 1 and 25.

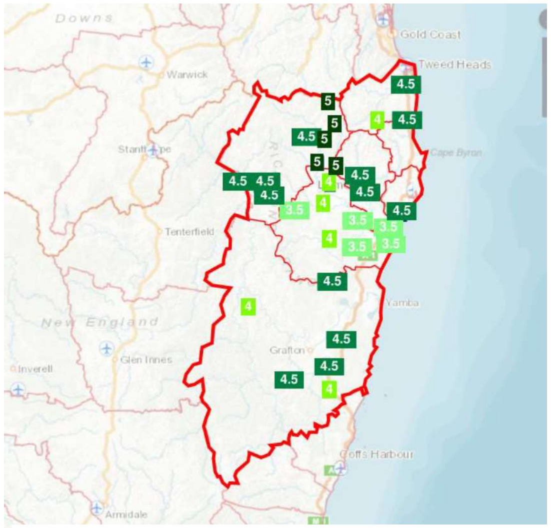


FIGURE 16 MAPPING OF HIGH VALUE SRI

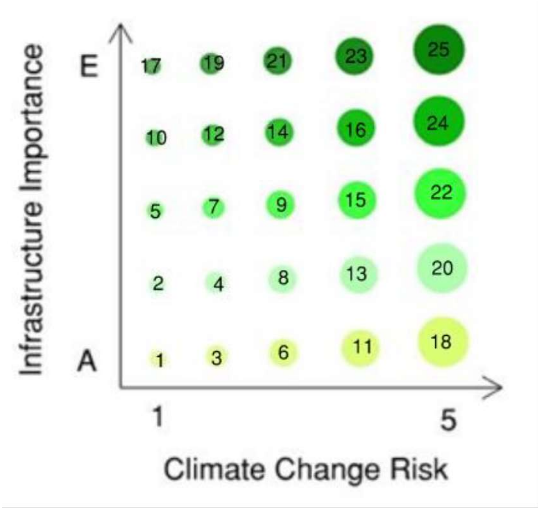


FIGURE 17 MULTIVARIATE SCORING TOOL

The multivariate scores for all assets in the region can be combined in various methods that are used to interrogate data. Firstly the scores for each hazard type are combined at both the 2030 and 2100 time steps. This is helpful to determine trends in hazard types and assess which hazards should be mitigated in the short term and which hazards are likely to become a bigger issue and will require mitigation in the future. From the data for this region it is clear that bushfire and flooding are the most pressing however extreme temperature is expected to become a more prevalent issue in the future.

TABLE 14 SUM OF MULTIVARIATE SCORES AGAINST HAZARD TYPES

Hazard type	Sum of Multivariate Scores	
	Year 2030	Year 2100
Bushfire	2472	2472
Extreme Temperature	1679	2183
Flooding	2545	2545
Extreme Winds	1606	1606

The scores can also be combined relative to either the area (i.e. LGA) or the asset type. This data manipulation can be used to determine where to prioritise spending and what types of assets are most at risk. This assessment suggests that investment should be focussed in the Clarence Valley Council and Kyogle Council LGAs. Risk mitigation should be adopted for roads and road bridges in these regions for bushfire and flooding hazard types for the greatest risk reduction. It is noted that these values are potentially skewed by the quantity of road and bridges assets relative to other asset types in the region, which may require further manipulation to normalise the results.

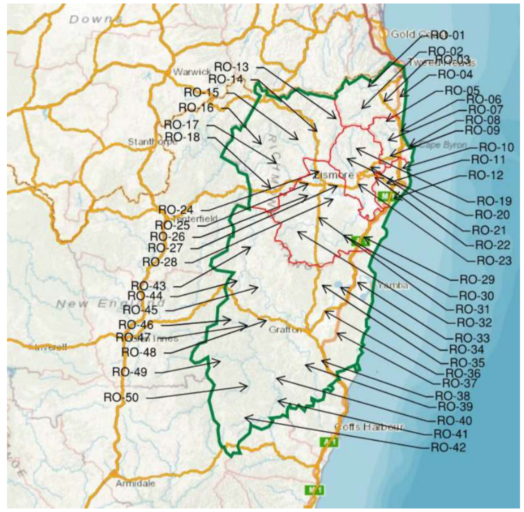
TABLE 15 SUM OF MULTIVARIATE SCORES BY LGA

Total Score by LGA	Number of assets	Sum of climate risk score 2030	Sum of climate risk score 2100
Ballina Shire Council	6	422	446
Byron Shire Council	7	399	430
Clarence Valley Council	32	2101	2216
Kyogle Council	37	2225	2376
Lismore City Council	16	1081	1129
Richmond Valley Council	22	1271	1353
Tweed Shire Council	13	803	856

TABLE 16 SUM OF MULTIVARIATE SCORES BY ASSET TYPE

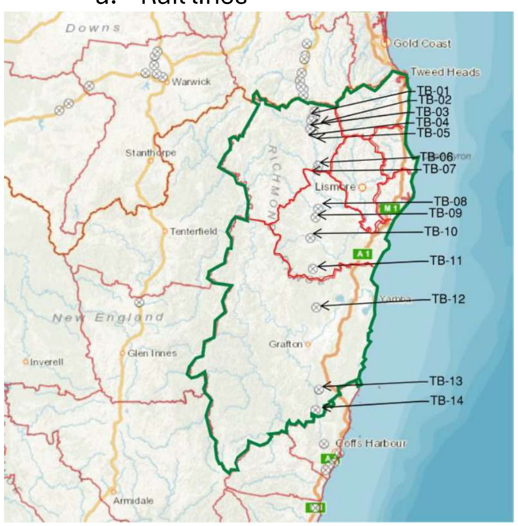
Total Score by asset type	Number of assets	Sum of climate risk score 2030	Sum of climate risk score 2100
Road	50	3333	3507
Rail	8	373	410
Port	0	0	0
Airport	4	197	218
Road Bridge	57	3312	3548
Rail Bridge	14	1087	1123

a. Rail lines

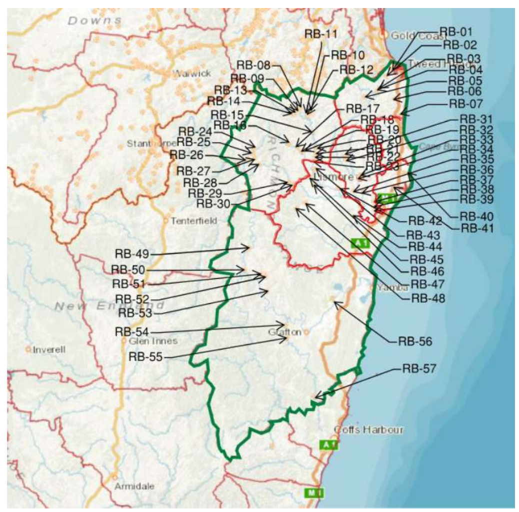


b. Roads

c. Airports



d. Rail Bridges



e. Road Bridges

FIGURE 18 ASSET TAGGING

f. Rail lines

g. Roads

h. Airports

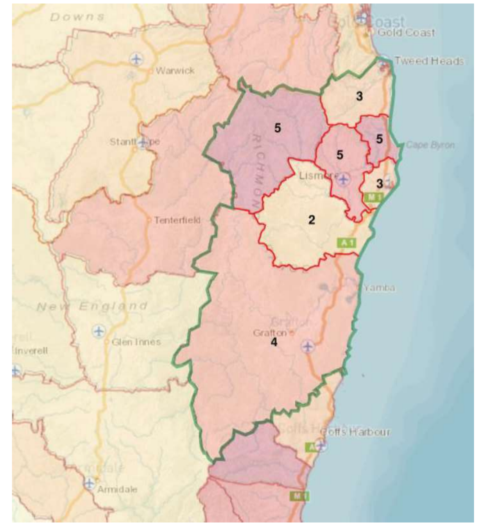
i. Rail Bridges

j. Road Bridges

FIGURE 19 MAPPING OF INFRASTRUCTURE ASSET IMPORTANCE

a. LGAs

b. Riverine Flooding



c. Bushfire

d. Extreme Wind

e. Coastal Inundation

f. Extreme Temperature

FIGURE 20 HAZARD LIKELIHOOD - 2030

Conclusion

The proposed Infrastructure Climate Risk Assessment (ICRA) framework represents a transformative approach to addressing the critical challenges posed by climate change to Australia's nationally significant infrastructure. By integrating diverse data sources and employing a standardised risk scoring methodology, the framework provides a comprehensive, scalable, and adaptable tool for assessing vulnerability and resilience across key infrastructure sectors. This ensures a cohesive response to the previously fragmented and inconsistent data landscape, aligning with Infrastructure Australia's strategic objectives and supporting informed decision-making.

The proof-of-concept application highlights the framework's practical utility, showcasing its ability to identify high-risk assets and prioritise resilience investments. By focusing resources on the most vulnerable areas, the framework empowers stakeholders to implement targeted, cost-effective measures that enhance the longevity and reliability of critical infrastructure. Furthermore, its flexibility allows it to remain relevant in the face of evolving climate risks, ensuring that infrastructure planning and adaptation strategies are continually refined.

This data-driven framework not only strengthens the resilience of infrastructure systems but also safeguards communities, supports economic stability, and promotes sustainable development. By adopting such an innovative approach, Australia positions itself to better navigate the growing challenges of climate change, ensuring a more secure and resilient future for its people and economy.

Recommendations

The report has highlighted several areas where it is recommended that Infrastructure Australia develop further.

Asset Data Gaps

If is recommended that IA invest in securing additional data on these assets and determine a methodology to incorporate both aggregators in order to feed into the proposed climate risk assessment.

- Road and rail civil structures (e.g. retaining walls)
- Communication assets (other than NBN)
- Dams, Desalination Plants and Sewerage Treatment plants

ISO 31000 Compliance

The scope of this document does not address all aspects of compliance with ISO 31000. It is recommended that IA action the remaining steps 5 to 8 detailed in Section 4.

Asset Vulnerability

Asset owners should be consulted when determining asset vulnerability. Asset vulnerability is a measure of the individual assets exposure to a particular hazard. Key inputs to consider are:

- Material of construction
- Elevation (mountainous or low lying region)
- Direct proximity to bushland
- Existing asset condition

Development of online tool

The penultimate tool for this framework is envisaged as an online tool that would be available to all asset owners. This would provide equitable access to all stakeholders and allow for additional inputs to be provided and incorporated. The tool would be similar in operation to the National map and could be an additional layer added to this interface to allow for visualisation of climate risk. By making the tool available for all stakeholders it is expected that additional data would be provided to Infrastructure Australia and allow for more refined assessments to take place.

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Appendices

Appendix A – Database Scoring

Data Source	Type	Summary	Age of Data (Weight: 2)	Source (Weight: 3)	Ease of Use (Weight: 2)	Coverage (Weight: 3)	Accuracy (Weight: 4)	Relevance (Weight: 4)	Granularity (Weight: 3)	Format (Weight: 2)	Accessibility (Weight: 2)	Cost (Weight: 1)	Metadata (Weight: 2)	Update Frequency (Weight: 3)	Interoperability (Weight: 2)	Overall Score	Link
Digital Atlas of Australia	Database (Online)	An online geospatial platform that presents national datasets from across the Australian Government. Includes interactive data on Australia's transport network and Australia's physical infrastructure – including roads, railways and ports.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://digital.atlas.gov.au/
National Exposure Information System	Database (Online)	The Buildings capability is a unique product of the National Exposure Information System (NEXIS) developed by Geoscience Australia (GA). It is used to estimate the cost and characteristics of the people, buildings and infrastructure potentially impacted by a man-made or natural hazardous event. NEXIS sources location-based data about buildings, demographics, community infrastructure, land use and agricultural commodities, then uses spatial modelling to develop a nationally consistent exposure profile.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://www.ga.gov.au/scientific-topics/national-location-information/nexis
Climate Risk Map of Australia	Database (Online)	The Climate Council's Climate Risk Map of Australia is an interactive map of climate vulnerable places in Australia.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://www.climatecouncil.org.au/resources/climate-risk-map/
The Australian Disaster Resilience Index	Database (Online)	The Australian Disaster Resilience Index is a snapshot of the capacities for disaster resilience in Australian communities. Understanding these capacities, and how they differ from place to place, will help communities, governments and industry work together to cope with and adapt to natural hazards such as bushfires, floods, storms and earthquakes.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://adri.bnhcrc.com.au/#!/
Geoscience Australia Natural Hazards and Scenarios	Database (Online)	Geoscience Australia develops national scale hazard, exposure and vulnerability data and information so that we are better prepared for, and can respond to, the consequences of hazards. Over time, this portal (or persona) will grow over time with new data and information	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://portal.ga.gov.au/persona/hazards
The Australian Disaster Resilience Knowledge Hub Disaster Mapper	Database (Online)	"Data and information on historical Australian natural and other disasters by location, type and year, with associated impact data (e.g., fatalities, insurance costs, homes destroyed)."	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://knowledge.aidr.org.au/disasters/
Australian Emergency Management Knowledge Hub disaster events	Database (Online)	CSV format list of all Australian Emergency Management Knowledge Hub disaster events, including disaster category, impacts and geographic co-ordinates.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://www.data.gov.au/data/dataset?tags=emergency
Australian Flood Risk Information Portal	Database (Online)	Central point of access to published flood studies and the associated spatial data.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://afrip.ga.gov.au/flood-study-web/#/search
Bushfire Boundaries data	Database (Online)	Interactive portal and data explorer of national bushfire boundary data.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://digital.atlas.gov.au/pages/8b124790a8f54ccd9b3288288e21cfd2
Global Infrastructure Risk Model and Resilience Index (GIRI)	Database (Online)	Measuring Risk and Resilence in Infrastructure Sector	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://giri.unepgrid.ch/
Global Resilience Index Initiative	Database (Online)	"Open data source. Provides filters for different hazards, return periods and infrastructure layers (roads, rail and power)"	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://resilient-planet-data.org/about
Doing Business	Database (Online)	Surveys conducted to estimate the reliability of infrastructure services supply	4 (8)	5 (15)	4 (8)	5 (15)	5 (20)	5 (20)	4 (12)	4 (8)	5 (10)	5 (5)	5 (10)	4 (12)	5 (10)	153	https://archive.doingbusiness.org/en/doingbusiness
Climate Change in Australia	Database (Online)	Explore what the climate models are projecting for Australia's future climate via a suite of tools	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://www.climatechangeinaustralia.gov.au/en/projections-tools/
NARCliM2.0	Database (Online)	NARCLiM 2.0 is the latest version of the NSW Australian Climate Modelling Project, which includes data for NSW and ACT, and is expanding to cover more regions such as South Australia. It uses the latest global climate models (CMIP6) and provides high-resolution data (20km for Australia and 10km for SE Australia) for two emission scenarios (SSP1 2.6 and SSP3 7.0)2. This data is crucial for assessing climate risks and planning for resilience.	5 (10)	5 (15)	5 (10)	1 (3)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	153	https://www.climatechange.environment.nsw.gov.au/news/get-ready-narclim2
National Map	Database (Online)	NationalMap is an online map-based tool to allow easy access to spatial data from Australian government agencies and is based on a fully open architecture. When you access data through it, you are typically accessing the data directly from the government department or agency who are the custodians of that data. NationalMap provides easy access to authoritative and other spatial data to government, business and the public facilitates the opening of data by federal, state and local government bodies provides an open framework of geospatial data services that supports commercial and community innovation	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://nationalmap.gov.au/about
World Bank Group climate change data	Database (Online)	The World Bank Group provides comprehensive climate change data through its Climate Change Knowledge Portal. This portal offers global, regional, and country-specific data related to climate change and development. The data is used to support climate and disaster risk screening for all IDA and IBRD operations, helping countries integrate climate action into their core development agendas.	5 (10)	5 (15)	5 (10)	5 (15)	5 (20)	5 (20)	5 (15)	5 (10)	5 (10)	5 (5)	5 (10)	5 (15)	5 (10)	165	https://climateknowledgeportal.worldbank.org/#country-map

5 - highest weight
4
3
2
1 - lowest weight

Appendix B – Proof of Concept Data Table

Note: used random number generator here

Asset Tag	LGA	Asset type	ASSET IMPORTANCE	IMPACT ON INFRASTRUCTURE				Hazard likelihood - 2030				Hazard likelihood - 2100				Asset Vulnerability				Impact / likelihood (2030)				Impact / likelihood (2100)				Criticality / Vulnerability				Criticality / Vulnerability (Numerical)				Multivariate Score (2030)				Multivariate Score (2100)				Total Climate risk score 2030	Total Climate risk score 2100
				Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones	Bushfire	Extreme Temperature	Flooding	Tropical Cyclones		
AP-01	Tweed Shire Council	Airport	2	3	4	5	5	3	2	5	1	3	3	5	1	4	2	3	2	3	3	5	3	3	4	5	3	C	B	B	B	3	2	2	2	9	8	20	8	9	13	20	8	45	50
AP-02	Lismore City Council	Airport	2	3	4	5	5	5	2	3	1	5	3	3	1	5	1	3	2	5	3	5	3	5	4	5	3	D	A	B	B	4	1	2	2	24	6	20	8	24	11	20	8	58	63
AP-03	Ballina Shire Council	Airport	2	3	4	5	5	3	2	5	1	3	3	5	1	2	4	3	4	3	3	5	3	3	4	5	3	B	C	B	C	2	3	2	3	8	9	20	9	8	15	20	9	46	52
AP-04	Clarence Valley Council	Airport	2	3	4	5	5	4	2	5	1	4	3	5	1	2	3	1	4	4	3	5	3	4	4	5	3	B	B	A	C	2	2	1	3	13	8	18	9	13	13	18	9	48	53
RB-01	Tweed Shire Council	Road Bridge	5	4	4	5	5	3	2	5	1	3	3	5	1	5	5	2	5	4	3	5	3	4	4	5	3	E	E	D	E	5	5	4	5	23	21	24	21	23	23	24	21	89	91
RB-02	Tweed Shire Council	Road Bridge	3	4	4	5	5	3	2	5	1	3	3	5	1	1	1	1	5	4	3	5	3	4	4	5	3	A	A	A	E	1	1	1	5	11	6	18	21	11	11	18	21	56	61
RB-03	Tweed Shire Council	Road Bridge	4	4	4	5	5	3	2	5	1	3	3	5	1	1	4	4	4	4	3	5	3	4	4	5	3	B	D	D	D	2	4	4	4	13	14	24	14	13	16	24	14	65	67
RB-04	Tweed Shire Council	Road Bridge	3	4	4	5	5	3	2	5	1	3	3	5	1	2	2	5	2	4	3	5	3	4	4	5	3	B	B	E	B	2	2	5	2	13	8	25	8	13	13	25	8	54	59
RB-05	Tweed Shire Council	Road Bridge	5	4	4	5	5	3	2	5	1	3	3	5	1	2	1	4	1	4	3	5	3	4	4	5	3	D	C	E	C	4	3	5	3	16	9	25	9	16	15	25	9	59	65
RB-06	Tweed Shire Council	Road Bridge	5	4	4	5	5	3	2	5	1	3	3	5	1	3	5	1	2	4	3	5	3	4	4	5	3	E	E	C	D	5	5	3	4	23	21	22	14	23	23	22	14	80	82
RB-07	Tweed Shire Council	Road Bridge	2	4	4	5	5	3	2	5	1	3	3	5	1	1	4	5	3	4	3	5	3	4	4	5	3	A	C	D	B	1	3	4	2	11	9	24	8	11	15	24	8	52	58
RB-08	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	4	2	1	2	5	3	4	3	5	4	4	3	C	B	A	B	3	2	1	2	22	8	11	8	22	13	11	8	49	54
RB-09	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	1	2	1	5	3	4	3	5	4	4	3	B	A	B	A	2	1	2	1	20	6	13	6	20	11	13	6	45	50
RB-10	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	2	3	5	5	3	4	3	5	4	4	3	B	B	B	D	2	2	2	4	20	8	13	14	20	13	13	14	55	60
RB-11	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	3	4	3	5	3	4	3	5	4	4	3	A	B	C	B	1	2	3	2	18	8	15	8	18	13	15	8	49	54
RB-12	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	4	4	3	5	3	4	3	5	4	4	3	D	C	C	B	4	3	3	2	24	9	15	8	24	15	15	8	56	62
RB-13	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	2	5	3	5	3	4	3	5	4	4	3	B	B	D	B	2	2	4	2	20	8	16	8	20	13	16	8	52	57
RB-14	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	3	2	3	5	3	4	3	5	4	4	3	B	B	B	B	2	2	2	2	20	8	13	8	20	13	13	8	49	54
RB-15	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	4	1	3	5	5	3	4	3	5	4	4	3	C	A	B	D	3	1	2	4	22	6	13	14	22	11	13	14	55	60
RB-16	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	5	1	4	5	3	4	3	5	4	4	3	B	D	A	C	2	4	1	3	20	14	11	9	20	16	11	9	54	56
RB-17	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	2	2	3	5	3	4	3	5	4	4	3	A	B	B	B	1	2	2	2	18	8	13	8	18	13	13	8	47	52
RB-18	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	3	5	1	5	3	4	3	5	4	4	3	D	B	D	A	4	2	4	1	24	8	16	6	24	13	16	6	54	59
RB-19	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	2	5	5	5	3	4	3	5	4	4	3	A	B	D	D	1	2	4	4	18	8	16	14	18	13	16	14	56	61
RB-20	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	4	3	1	1	5	3	4	3	5	4	4	3	C	B	A	A	3	2	1	1	22	8	11	6	22	13	11	6	47	52
RB-21	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	5	1	3	5	3	4	3	5	4	4	3	A	D	A	B	1	4	1	2	18	14	11	8	18	16	11	8	51	53
RB-22	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	2	2	4	5	5	3	4	3	5	4	4	3	B	B	C	D	2	2	3	4	20	8	15	14	20	13	15	14	57	62
RB-23	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	5	2	3	5	3	4	3	5	4	4	3	D	D	B	B	4	4	2	2	24	14	13	8	24	16	13	8	59	61
RB-24	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	4	2	4	5	3	4	3	5	4	4	3	A	C	B	C	1	3	2	3	18	9	13	9	18	15	13	9	49	55
RB-25	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	2	1	4	5	3	4	3	5	4	4	3	A	B	A	C	1	2	1	3	18	8	11	9	18	13	11	9	46	51
RB-26	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	4	4	2	5	3	4	3	5	4	4	3	D	C	C	B	4	3	3	2	24	9	15	8	24	15	15	8	56	62
RB-27	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	2	2	1	5	3	4	3	5	4	4	3	D	B	B	A	4	2	2	1	24	8	13	6	24	13	13	6	51	56
RB-28	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	1	5	4	5	3	4	3	5	4	4	3	D	A	D	C	4	1	4	3	24	6	16	9	24	11	16	9	55	60
RB-29	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	5	3	3	5	5	3	4	3	5	4	4	3	D	B	B	D	4	2	2	4	24	8	13	14	24	13	13	14	59	64
RB-30	Kyogle Council	Road Bridge	2	4	4	5	5	5	2	2	1	5	3	2	1	1	2	1	2	5	3	4	3	5	4	4	3	A	B	A	B	1	2	1	2	18	8	11	8	18	13	11	8	45	50
RB-31	Lismore City Council	Road Bridge	3	4	4	5	5	5	2	3	1	5	3	3	1	4	5	2	1	5	3	5	3	5	4	5	3	D	E	B	A	4	5	2	1	24	21	20	6	24	23	20	6	71	73
RB-32	Lismore City Council	Road Bridge	3	4	4	5	5	5	2	3	1	5	3	3	1	1	4	1	1	5	3	5	3	5	4	5	3	A	D	A	A	1	4	1	1	18	14	18	6	18	16	18	6	56	58
RB-33	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	1	4	1	5	5	3	5	3	5	4	5	3	B	D	B	E	2	4	2	5	20	14	20	21	20	16	20	21	75	77
RB-34	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	2	5	5	2	5	3	5	3	5	4	5	3	C	E	E	C	3	5	5	3	22	21	25	9	22	23	25	9	77	79
RB-35	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	4	4	2	4	5	3	5	3	5	4	5	3	D	D	C	D	4	4	3	4	24	14	22	14	24	16	22	14	74	76
RB-36	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	1	4	1	5	5	3	5	3	5	4	5	3	B	D	B	E	2	4	2	5	20	14	20	21	20	16	20	21	75	77
RB-37	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	3	4	3	1	5	3	5	3	5	4	5	3	D	D	D	B	4	4	4	2	24	14	24	8	24	16	24	8	70	72
RB-38	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	3	1	1	1	5	3	5	3	5	4	5	3	D	B	B	B	4	2	2	2	24	8	20	8	24	13	20	8	60	65
RB-39	Lismore City Council	Road Bridge	4	4	4	5	5	5	2	3	1	5	3	3	1	5	3	3	2	5	3	5	3	5	4	5	3	E	D	D	C	5	4	4	3	25	14	24	9	25	16	24	9	72	74
RB-40	Ballina Shire Council	Road Bridge	5	4	4	5	5	3	2	5	1	3	3	5	1	1	3	4	5	4	3	5	3	4	4	5	3	C	E	E	E	3	5	5	5	15	21	25	21	15	23	25	21	82	84
RB-41	Ballina Shire Council	Road Bridge	5	4	4	5	5	3	2	5	1	3	3	5	1	3	4	5	4	4	3	5	3	4	4	5	3	E	E	E	E	5	5	5	5	23	21	25	21	23	23	25	21	90	92
RB-42	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	2	3	2	5	3	3	4	3	3	4	4	3	B	C	B	E	2	3	2	5	8	9	13	21	8	15	13	21	51	57
RB-43	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	4	1	5	1	3	3	4	3	3	4	4	3	D	A	E	A	4	1	5	1	14	6	23	6	14	11	23	6	49	54
RB-44	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	4	1	3	1	3	3	4	3	3	4	4	3	D	A	C	A	4	1	3	1	14	6	15	6	14	11	15	6	41	46
RB-45	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	2	5	1	1	3	3	4	3	3	4	4	3	B	E	A	A	2	5	1	1	8	21	11	6	8	23	11	6	46	48
RB-46	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	2	1	4	4	3	3	4	3	3	4	4	3	B	A	D	D	2	1	4	4	8	6	16	14	8	11	16	14	44	49
RB-47	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	1	3	2	3	3	3	4	3	3	4	4	3	A	C	B	C	1	3	2	3	6	9	13	9	6	15	13	9	37	43
RB-48	Richmond Valley Council	Road Bridge	3	4	4	5	5	2	2	2	1	2	3	2	1	1	1	5	3	3	3	4	3	3	4	4	3	A	A	E	C	1	1	5	3	6	6	23	9	6	11	23	9	44	49
RB-49	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	2	3	1	5	4	3	5	3	4	4	5	3	B	C	A	E	2	3	1	5	13	9	18	21	13	15	18	21	61	67
RB-50	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	4	5	5	2	4	3	5	3	4	4	5	3	D	E	E	B	4	5	5	2	16	21	25	8	16	23	25	8	70	72
RB-51	Clarence Valley Council	Road Bridge	2	4	4	5	5	4	2	5	1	4	3	5	1	1	2	5	2	4	3	5	3	4	4	5	3	A	B	D	B	1	2	4	2	11	8	24	8	11	13	24	8	51	56
RB-52	Clarence Valley Council	Road Bridge	2	4	4	5	5	4	2	5	1	4	3	5	1	4	5	5	3	4	3	5	3	4	4	5	3	C	D	D	B	3	4	4	2	15	14	24	8	15	16	24	8	61	63
RB-53	Clarence Valley Council	Road Bridge	2	4	4	5	5	4	2	5	1	4	3	5	1	1	4	1	4	4	3	5	3	4	4	5	3	A	C	A	C	1	3	1	3	11	9	18	9	11	15	18	9	47	53
RB-54	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	2	5	2	2	4	3	5	3	4	4	5	3	B	E	B	B	2	5	2	2	13	21	20	8	13	23	20	8	62	64
RB-55	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	5	3	5	4	4	3	5	3	4	4	5	3	E	C	E	D	5	3	5	4	23	9	25	14	23	15	25	14	71	77
RB-56	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	5	2	2	1	4	3	5	3	4	4	5	3	E	B	B	A	5	2	2	1	23	8	20	6	23	13	20	6	57	62
RB-57	Clarence Valley Council	Road Bridge	3	4	4	5	5	4	2	5	1	4	3	5	1	2	3	4	5	4	3	5	3	4	4	5	3	B	C	D	E	2	3	4	5	13	9	24	21	13	15	24	21	67	73
TB-01	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	2	5	1	3	5	3	4	3	5	4	4	3	D	E	C	E	4	5	3	5	24	21	15	21	24	23	15	21	81	83
TB-02	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	1	1	4	1	5	3	4	3	5	4	4	3	C	C	E	C	3	3	5	3	22	9	23	9	22	15	23	9	63	69
TB-03	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	3	2	4	1	5	3	4	3	5	4	4	3	E	D	E	C	5	4	5	3	25	14	23	9	25	16	23	9	71	73
TB-04	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	2	4	5	2	5	3	4	3	5	4	4	3	D	E	E	D	4	5	5	4	24	21	23	14	24	23	23	14	82	84
TB-05	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	3	5	3	4	5	3	4	3	5	4	4	3	E	E	E	E	5	5	5	5	25	21	23	21	25	23	23	21	90	92
TB-06	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	4	2	3	2	5	3	4	3	5	4	4	3	E	D	E	D	5	4	5	4	25	14	23	14	25	16	23	14	76	78
TB-07	Kyogle Council	Rail Bridge	5	4	4	5	5	5	2	2	1	5	3	2	1	3	3	2	4	5	3	4	3	5	4	4	3	E	E	D	E	5	5	4	5	25	21	16	21	25	23	16	21	83	85
TB-08	Richmond Valley Council	Rail Bridge	5	4	4	5	5	2	2	2	1	2	3	2	1	3	3	3	4	3	3	4	3	3	4	4	3	E	E	E	E	5	5	5	5	21	21	23	21	21	23	23	21	86	88
TB-09	Richmond Valley Council	Rail Bridge	5	4	4	5	5	2	2	2	1	2	3	2	1	3	5	3	5	3	3	4	3	3	4	4	3	E	E	E	E	5	5	5	5	21	21	23	21	21	23	23	21	86	88
TB-10	Richmond Valley Council	Rail Bridge	5	4	4	5	5	2	2	2	1	2	3	2	1	5	4	1	1	3	3	4	3	3	4	4	3	E	E	C	C	5	5	3	3	21	21	15	9	21	23	15	9	66	68
TB-11	Richmond Valley Council	Rail Bridge	5	4	4	5	5	2	2	2	1	2	3	2	1	3	4	2	3	3	3	4	3	3	4	4	3	E	E	D	E	5	5	4	5	21	21	16	21	21	23	16	21	79	81
TB-12	Clarence Valley Council	Rail Bridge	5	4	4	5	5	4	2	5	1	4	3	5	1	3	2	4	3	4	3	5	3	4	4	5	3	E	D	E	E	5	4	5	5	23	14	25	21	23	16	25	21	83	85
TB-13	Clarence Valley Council	Rail Bridge	5	4	4	5	5	4	2	5	1	4	3	5	1	3	4	5	1	4	3	5	3	4	4	5	3	E	E	E	C	5	5	5	3	23	21	25	9	23	23	25	9	78	80
TB-14	Clarence Valley Council	Rail Bridge	5	4	4	5	5	4	2	5	1	4	3	5	1	2	1	2	2	4	3	5	3	4	4	5	3	D	C	D	D	4	3	4	4	16	9	24	14	16	15	24	14	63	69
RW-01	Kyogle Council	Rail	3	5	4	5	4	5	2	2	1	5	3	2	1	5	2	3	5	5	3	4	2	5	4	4	2	E	B	C	E	5	2	3	5	25	8	15	19	25	13	15	19	67	72
RW-02	Richmond Valley Council	Rail	3	5	4	5	4	2	2	2	1	2	3	2	1	2	1	2	4	4	3	4	2	4	4	4	2	B	A	B	D	2	1	2	4	13	6	13	12	13	11	13	12	44	49
RW-03	Clarence Valley Council	Rail	3	5	4	5	4	4	2	5	1	4	3	5	1	2	4	2	1	5	3	5	2	5	4	5	2	B	D	B	A	2	4	2	1	20	14	20	3	20	16	20	3	57	59
RW-04	Tweed Shire Council	Rail	1	5	4	5	4	3	2	5	1	3	3	5	1	1	3	2	2	5	3	5	2	5	4	5	2	A	A	A	A	1	1	1	1	18	6	18	3	18	11	18	3	45	50
RW-05	Byron Shire Council	Rail	1	5	4	5	4	5	2	1	1	5	3	1	1	1	2	5	4	5	3	3	2	5	4	3	2	A	A	C	B	1	1	3	2	18	6	9	4	18	11	9	4	37	42
RW-06	Byron Shire Council	Rail	1	5	4	5	4	5	2	1	1	5	3	1	1	2	1	4	2	5	3	3	2	5	4	3	2	A	A	B	A	1	1	2	1	18	6	8	3	18	11	8	3	35	40
RW-07	Lismore City Council	Rail	1	5	4	5	4	5	2	3	1	5	3	3	1	4	4	4	1	5	3	5	2	5	4	5	2	B	B	B	A	2	2	2	1	20	8	20	3	20	13	20	3	51	56
RW-08	Richmond Valley Council	Rail	1	5	4	5	4	2	2	2	1	2	3	2	1	3	4	5	2	4	3	4	2	4	4	4	2	A	B	C	A	1	2	3	1	11	8	15	3	11	13	15	3	37	42
RO-01	Tweed Shire Council	Road	3	4	4	5	5	3	2	5	1	3	3	5	1	5	4	1	4	4	3	5	3	4	4	5	3	E	D	A	D	5	4	1	4	23	14	18	14	23	16	18	14	69	71
RO-02	Tweed Shire Council	Road	3	4	4	5	5	3	2	5	1	3	3	5	1	2	3	3	1	4	3	5	3	4	4	5	3	B	C	C	A	2	3	3	1	13	9	22	6	13	15	22	6	50	56
RO-03	Tweed Shire Council	Road	4	4	4	5	5	3	2	5	1	3	3	5	1	5	1	3	1	4	3	5	3	4	4	5	3	E	B	D	B	5	2	4	2	23	8	24	8	23	13	24	8	63	68
RO-04	Tweed Shire Council	Road	5	4	4	5	5	3	2	5	1	3	3	5	1	2	2	3	3	4	3	5	3	4	4	5	3	D	D	E	E	4	4	5	5	16	14	25	21	16	16	25	21	76	78
RO-05	Byron Shire Council	Road	3	4	4	5	5	5	2	1	1	5	3	1	1	4	2	4	2	5	3	3	3	5	4	3	3	D	B	D	B	4	2	4	2	24	8	14	8	24	13	14	8	54	59
RO-06	Byron Shire Council	Road	5	4	4	5	5	5	2	1	1	5	3	1	1	5	3	3	5	5	3	3	3	5	4	3	3	E	E	E	E	5	5	5	5	25	21	21	21	25	23	21	21	88	90
RO-07	Byron Shire Council	Road	3	4	4	5	5	5	2	1	1	5	3	1	1	1	4	4	5	5	3	3	3	5	4	3	3	A	D	D	E	1	4	4	5	18	14	14	21	18	16	14	21	67	69
RO-08	Byron Shire Council	Road	4	4	4	5	5	5	2	1	1	5	3	1	1	1	2	3	3	5	3	3	3	5	4	3	3	B	C	D	D	2	3	4	4	20	9	14	14	20	15	14	14	57	63
RO-09	Byron Shire Council	Road	4	4	4	5	5	5	2	1	1	5	3	1	1	4	2	3	4	5	3	3	3	5	4	3	3	D	C	D	D	4	3	4	4	24	9	14	14	24	15	14	14	61	67
RO-10	Ballina Shire Council	Road	5	4	4	5	5	3	2	5	1	3	3	5	1	1	1	3	2	4	3	5	3	4	4	5	3	C	C	E	D	3	3	5	4	15	9	25	14	15	15	25	14	63	69
RO-11	Ballina Shire Council	Road	4	4	4	5	5	3	2	5	1	3	3	5	1	4	2	4	4	4	3	5	3	4	4	5	3	D	C	D	D	4	3	4	4	16	9	24	14	16	15	24	14	63	69
RO-12	Ballina Shire Council	Road	5	4	4	5	5	3	2	5	1	3	3	5	1	4	4	3	1	4	3	5	3	4	4	5	3	E	E	E	C	5	5	5	3	23	21	25	9	23	23	25	9	78	80
RO-13	Kyogle Council	Road	3	4	4	5	5	5	2	2	1	5	3	2	1	5	5	5	5	5	3	4	3	5	4	4	3	E	E	E	E	5	5	5	5	25	21	23	21	25	23	23	21	90	92
RO-14	Kyogle Council	Road	5	4	4	5	5	5	2	2	1	5	3	2	1	5	3	5	1	5	3	4	3	5	4	4	3	E	E	E	C	5	5	5	3	25	21	23	9	25	23	23	9	78	80
RO-15	Kyogle Council	Road	3	4	4	5	5	5	2	2	1	5	3	2	1	4	1	1	3	5	3	4	3	5	4	4	3	D	A	A	C	4	1	1	3	24	6	11	9	24	11	11	9	50	55
RO-16	Kyogle Council	Road	3	4	4	5	5	5	2	2	1	5	3	2	1	2	5	3	3	5	3	4	3	5	4	4	3	B	E	C	C	2	5	3	3	20	21	15	9	20	23	15	9	65	67
RO-17	Kyogle Council	Road	3	4	4	5	5	5	2	2	1	5	3	2	1	3	3	4	4	5	3	4	3	5	4	4	3	C	C	D	D	3	3	4	4	22	9	16	14	22	15	16	14	61	67
RO-18	Kyogle Council	Road	4	4	4	5	5	5	2	2	1	5	3	2	1	4	5	1	4	5	3	4	3	5	4	4	3	D	E	B	D	4	5	2	4	24	21	13	14	24	23	13	14	72	74
RO-19	Lismore City Council	Road	3	4	4	5	5	5	2	3	1	5	3	3	1	1	3	3	1	5	3	5	3	5	4	5	3	A	C	C	A	1	3	3	1	18	9	22	6	18	15	22	6	55	61
RO-20	Lismore City Council	Road	3	4	4	5	5	5	2	3	1	5	3	3	1	5	2	5	4	5	3	5	3	5	4	5	3	E	B	E	D	5	2	5	4	25	8	25	14	25	13	25	14	72	77
RO-21	Lismore City Council	Road	4	4	4	5	5	5	2	3	1	5	3	3	1	5	3	2	2	5	3	5	3	5	4	5	3	E	D	C	C	5	4	3	3	25	14	22	9	25	16	22	9	70	72
RO-22	Lismore City Council	Road	4	4	4	5	5	5	2	3	1	5	3	3	1	5	5	3	1	5	3	5	3	5	4	5	3	E	E	D	B	5	5	4	2	25	21	24	8	25	23	24	8	78	80
RO-23	Lismore City Council	Road	4	4	4	5	5	5	2	3	1	5	3	3	1	1	3	4	2	5	3	5	3	5	4	5	3	B	D	D	C	2	4	4	3	20	14	24	9	20	16	24	9	67	69
RO-24	Richmond Valley Council	Road	5	4	4	5	5	2	2	2	1	2	3	2	1	2	1	1	5	3	3	4	3	3	4	4	3	D	C	C	E	4	3	3	5	14	9	15	21	14	15	15	21	59	65
RO-25	Richmond Valley Council	Road	4	4	4	5	5	2	2	2	1	2	3	2	1	4	4	5	1	3	3	4	3	3	4	4	3	D	D	E	B	4	4	5	2	14	14	23	8	14	16	23	8	59	61
RO-26	Richmond Valley Council	Road	3	4	4	5	5	2	2	2	1	2	3	2	1	2	5	4	4	3	3	4	3	3	4	4	3	B	E	D	D	2	5	4	4	8	21	16	14	8	23	16	14	59	61
RO-27	Richmond Valley Council	Road	4	4	4	5	5	2	2	2	1	2	3	2	1	4	2	4	5	3	3	4	3	3	4	4	3	D	C	D	E	4	3	4	5	14	9	16	21	14	15	16	21	60	66
RO-28	Richmond Valley Council	Road	3	4	4	5	5	2	2	2	1	2	3	2	1	2	5	2	1	3	3	4	3	3	4	4	3	B	E	B	A	2	5	2	1	8	21	13	6	8	23	13	6	48	50
RO-29	Richmond Valley Council	Road	5	4	4	5	5	2	2	2	1	2	3	2	1	5	1	5	1	3	3	4	3	3	4	4	3	E	C	E	C	5	3	5	3	21	9	23	9	21	15	23	9	62	68
RO-30	Richmond Valley Council	Road	3	4	4	5	5	2	2	2	1	2	3	2	1	4	4	4	5	3	3	4	3	3	4	4	3	D	D	D	E	4	4	4	5	14	14	16	21	14	16	16	21	65	67
RO-31	Richmond Valley Council	Road	5	4	4	5	5	2	2	2	1	2	3	2	1	3	4	5	5	3	3	4	3	3	4	4	3	E	E	E	E	5	5	5	5	21	21	23	21	21	23	23	21	86	88
RO-32	Richmond Valley Council	Road	3	4	4	5	5	2	2	2	1	2	3	2	1	5	5	3	1	3	3	4	3	3	4	4	3	E	E	C	A	5	5	3	1	21	21	15	6	21	23	15	6	63	65
RO-33	Clarence Valley Council	Road	5	4	4	5	5	4	2	5	1	4	3	5	1	2	5	5	1	4	3	5	3	4	4	5	3	D	E	E	C	4	5	5	3	16	21	25	9	16	23	25	9	71	73
RO-34	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	5	3	4	4	3	5	3	4	4	5	3	A	E	C	D	1	5	3	4	11	21	22	14	11	23	22	14	68	70
RO-35	Clarence Valley Council	Road	5	4	4	5	5	4	2	5	1	4	3	5	1	2	1	1	4	4	3	5	3	4	4	5	3	D	C	C	E	4	3	3	5	16	9	22	21	16	15	22	21	68	74
RO-36	Clarence Valley Council	Road	5	4	4	5	5	4	2	5	1	4	3	5	1	3	2	2	5	4	3	5	3	4	4	5	3	E	D	D	E	5	4	4	5	23	14	24	21	23	16	24	21	82	84
RO-37	Clarence Valley Council	Road	4	4	4	5	5	4	2	5	1	4	3	5	1	5	5	5	3	4	3	5	3	4	4	5	3	E	E	E	D	5	5	5	4	23	21	25	14	23	23	25	14	83	85
RO-38	Clarence Valley Council	Road	5	4	4	5	5	4	2	5	1	4	3	5	1	5	4	5	3	4	3	5	3	4	4	5	3	E	E	E	E	5	5	5	5	23	21	25	21	23	23	25	21	90	92
RO-39	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	5	5	5	2	4	3	5	3	4	4	5	3	E	E	E	B	5	5	5	2	23	21	25	8	23	23	25	8	77	79
RO-40	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	5	2	5	4	3	5	3	4	4	5	3	A	E	B	E	1	5	2	5	11	21	20	21	11	23	20	21	73	75
RO-41	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	3	4	4	5	4	3	5	3	4	4	5	3	C	D	D	E	3	4	4	5	15	14	24	21	15	16	24	21	74	76
RO-42	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	5	1	5	2	4	3	5	3	4	4	5	3	E	A	E	B	5	1	5	2	23	6	25	8	23	11	25	8	62	67
RO-43	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	2	4	2	4	3	5	3	4	4	5	3	A	B	D	B	1	2	4	2	11	8	24	8	11	13	24	8	51	56
RO-44	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	5	2	5	4	4	3	5	3	4	4	5	3	E	B	E	D	5	2	5	4	23	8	25	14	23	13	25	14	70	75
RO-45	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	2	2	4	2	4	3	5	3	4	4	5	3	B	B	D	B	2	2	4	2	13	8	24	8	13	13	24	8	53	58
RO-46	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	4	2	3	4	3	5	3	4	4	5	3	A	D	B	C	1	4	2	3	11	14	20	9	11	16	20	9	54	56
RO-47	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	2	5	1	2	4	3	5	3	4	4	5	3	B	E	A	B	2	5	1	2	13	21	18	8	13	23	18	8	60	62
RO-48	Clarence Valley Council	Road	5	4	4	5	5	4	2	5	1	4	3	5	1	3	2	1	3	4	3	5	3	4	4	5	3	E	D	C	E	5	4	3	5	23	14	22	21	23	16	22	21	80	82
RO-49	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	1	3	4	4	3	5	3	4	4	5	3	A	A	C	D	1	1	3	4	11	6	22	14	11	11	22	14	53	58
RO-50	Clarence Valley Council	Road	3	4	4	5	5	4	2	5	1	4	3	5	1	1	1	1	5	4	3	5	3	4	4	5	3	A	A	A	E	1	1	1	5	11	6	18	21	11	11	18	21	56	61