CHAPTER

22

Climate change

ARTC | INLAND RAIL
An Australian Government Initiative

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22 Climate change

This chapter details the climate change risk assessment of the Narrabri to North Star (N2NS) Phase 2—Moree to Camurra North project (the proposal). It assesses the potential impacts of climate change on the proposal and provides recommended adaptation and mitigation measures.

Table 22-1 identifies the two requirements within the Secretary's Environmental Assessment Requirements (SEARs) and where the requirements have been addressed. A full copy of the SEARs is provided in Appendix A: Secretary's Environmental Assessment Requirements.

TABLE 22-1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS FOR CLIMATE CHANGE

Key Issue		Requirement	Where addressed
11. Climate change and Sustainability	1	The risk and vulnerability of the project to climate change in accordance with the current guidelines.	Section 22.1 Section 22.4
	2	Climate change risks must be quantified with reference to the NSW Government's climate projections at 10 km resolution (or lesser resolution if 10 km projections are not available) or equivalent projection tool (such as the Climate Futures Tool from CSIRO and BoM (attenuated for project region) and incorporate specific adaptation actions in the design.	Section 22.5.2.2 Section 22.6 Section 22.7.1

22.1 Summary of impacts

A preliminary climate change assessment was undertaken to consider climate change risks, opportunities and adaptations to inform the design process. Extreme rainfall events, flooding, increased periods of drought, extreme heat and increase in bushfire and fire weather conditions are expected to present the highest risks in the future. Risks associated with these events involve:

- changing flood patterns and behaviour
- increased flooding, resulting in:
  - inundation of rail infrastructure, drainage systems and water sensitive assets (such as electrical equipment)
  - structural scouring
  - wash out of foundations
- increased incidents of extreme events (heat, rainfall and bushfire) resulting in:
  - impacts on power supply
  - network interruption
  - track buckling
  - disruption of service
  - increase in incidence of dangerous fire weather conditions and, possibly, uncontrollable fires resulting in:
  - damage to infrastructure
  - increased operational costs
  - power failure
  - stoppage of freight.

Further consideration of the potential for climate change risks will be undertaken to support detailed design. This will include a detailed climate change risk assessment, considering both direct and indirect risks.

Specific mitigation measures associated with managing climate change factors are detailed in section 22.7.3 and Chapter 27: Environmental Management.

22.2 Assessment approach

The climate change risk assessment addresses the SEARs and considers the requirements outlined in the *Infrastructure Sustainability (IS) Rating Scheme—version 1.2* (ISCA, 2016) for Cli-1 and Cli-2 Climate Change Adaptation. More information on the IS Rating Scheme is outlined in Chapter 23: Sustainability. This chapter includes:

- Section 22.3: Legislation, policies, standards and guidelines describing the legislative, policy and management framework for the proposal to climate change and risk adaptation
- Section 22.4: Impact assessment methodology describing the relevant guidelines and methodology used for the climate change adaptation assessment
- Section 22.5: Existing and future climate providing the existing drivers, including policy context, local climate exposure, climate change projections and detailed climate variables
- Section 22.6: Potential impacts of the risks from climate change during construction and operation of the proposal
- Section 22.7: Adaptation options developed to address climate change risks, the residual risk assessment and details for SEARs compliance.

22.3 Legislation, policies, standards and guidelines

This section describes the legislative, policy and management framework for the proposal relevant to climate change and risk adaptation for the proposal. The legislation, policies and guidelines relevant to the proposal are presented in Table 22-2.

TABLE 22-2 SUMMARY OF LEGISLATION, POLICIES, STRATEGIES OR GUIDELINES

Legislation, policy, strategy or guideline	Relevance to the proposal
International	
Paris Agreement under the United Nations Framework Convention on Climate Change	In 2015, the Australian Government announced its commitment to a target of reducing greenhouse gas (GHG) emissions by 26 to 28 per cent below 2005 levels by 2030, building on its previous target of 5 per cent below 2000 emission levels by 2020, irrespective of what other countries do. The Australian Government submitted this new target as its intended nationally determined contribution to the United Nations Framework Convention on Climate Change for negotiation at the 21st Conference of the Parties (COP21) held in Paris in December 2015. Key outcomes of the Paris Agreement include (Department of Foreign Affairs and Trade, 2016): ▸ a target to keep global temperature increase to well below 2 °C and pursue efforts to keep warming below 1.5 °C above pre-industrial levels ▸ all countries to set emissions reduction targets from 2020, with an agreement to review and strengthen targets every five years ▸ transparency and accountability rules to provide confidence in countries' actions and track progress towards targets ▸ promoting action to adapt and build resilience to climate impacts ▸ financial, technological and capacity building support to help developing countries implement the Agreement.
Australian Government	
Direct Action Plan	The plan sets out how the 2030 emissions reduction target will be achieved. The Emissions Reduction Fund, as part of the Direct Action Plan, aims to reduce Australia's GHG emissions by creating positive incentives to adopt better technologies and practices to reduce emissions.
National Climate Resilience and Adaptation Strategy	The strategy was released on 2 December 2015 and provides a set of principles to guide effective adaptation and build the resilience of communities, the economy and the environment. The guiding principles include priorities for shared responsibility, climate change risks factored into decision making, a risk-management approach based on the best available scientific data, assisting the vulnerable, collaboration with stakeholders, and the need to revisit decisions and outcomes over time.

Legislation, policy, strategy or guideline	Relevance to the proposal
State (NSW)	
Climate Change Policy Framework for NSW	The policy aims to maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate. The framework considers current and emerging policy settings both nationally and internationally. The framework sets out two aspirational long-term objectives; achieve net-zero emission by 2050 and making NSW more resilient to a changing climate. In making NSW more resilient to a changing climate, the NSW Government role includes: ▸ implementing policies to plan for climate change risks and provide targeted support ▸ assessing and effectively manage climate change risk to government assets and services ▸ advocating for action to support effective adaptation.
Technical Guide for Climate Change Adaptation for the State Road Network (draft)	The draft provides guidance for state road network projects that require climate change adaptation in response to changes in climate processes. While the technical guide has been developed considering existing roads and maritime processes, it aligns with the broader NSW Government initiatives and programs responding to climate change impacts and, as a result, has been referenced within the SEARs for the proposal.

22.4 Impact assessment methodology

22.4.1 Climate change risk assessment

The climate change risk assessment undertaken for the proposal follows the approach detailed in the draft *Technical Guide for Climate Change Adaptation for the State Road Network* (NSW Roads and Maritime Service (RMS), 2015). This technical guide is one of the current guidelines for assessing risk and vulnerability for infrastructure projects. While this guide was developed for use on motorway and road projects, the framework is applicable to all infrastructure projects (including freight rail), as the guide is focused on risk management and is closely aligned with *ISO 31000:2018 Risk management* (International Organization for Standardization (ISO), 2018).

The guide references the identification of relevant climate variables and impacts (refer section 22.5.2.1), undertaking a risk assessment, and identifying and evaluating various risk treatments (adaptation options in section 22.7) to address each risk. While the technical guide has been developed considering existing RMS processes, it aligns with the broader NSW Government initiatives and programs responding to climate change impacts and, as a result, has been referenced within the SEARs for the proposal and used to guide the development of this assessment.

In addition to the technical guide, this climate change risk assessment has been conducted in accordance with the following relevant standards and current guidelines. These additional standards and guidelines serve to not only complement the technical guide but also consider the requirements outlined within the ISCA Rating Tool v1.2 Climate Change Adaptation:

- *Inland Rail Climate Change Risk Assessment Framework, in accordance with Australian Standard (AS)/New Zealand Standard 31000:2009 Risk Management—Principles and Guidelines as well as International Standards Organisation (ISO)/International Electrotechnical Commission 31010 Risk Management—Risk assessment techniques*
- *AS 5334-2013 Climate change adaptation for settlements and infrastructure—A risk-based approach, following ISO 31000:2009* (Standards Australia, 2013)
- *Australian Government's Climate Change Impacts and Risk Management—A Guide for Business and Government* (Department of Environment and Heritage, 2006)
- *ARTC Risk Management Procedure* (PSK-PR-001) (ARTC, 2020a)
- *Infrastructure Sustainability Council of Australia: ISCA Climate Change Adaptation Guidelines* (Australian Green Infrastructure Council, 2011), which have been reviewed and used to guide, confirm and validate measures to mitigate and adapt to climate change risks.

22.4.1.1 Limitations

As the ARTC does not own and/or operate rollingstock, nor has the proposal included rollingstock, consideration of impacts resulting from climate change towards rollingstock has not been included in this chapter. In certain instances where impacts to rollingstock would have an impact on operation or maintenance of the proposal (indirect impacts), consideration was given in the risk assessment and through the identification of adaptation responses.

22.5 Existing environment

22.5.1 Existing and future climate

In 2016, for the first time, global temperatures were confirmed to have risen by 1 degree Celsius (°C) since pre-industrial levels. The *Paris Agreement Under the United Nations Framework Convention on Climate Change* (effective 4 November 2016) seeks to limit climate change to under 2°C with a target of 1.5°C (United Nations Framework Convention on Climate Change (UNFCCC), 2016). Seeking to achieve these targets presents a significant challenge and, even at 1°C, the Earth's climate and weather systems are experiencing considerable changes.

The State of the Climate 2020 (Bureau of Meteorology, 2020) confirms the long-term warming trend over Australia's land and oceans, showing that Australia's climate has warmed on average by 1.44 ± 0.24°C since 1910. The *Intergovernmental Panel on Climate Change Fifth Assessment Report* (Intergovernmental Panel on Climate Change (IPCC), 2013) states with high confidence that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events. Other observed trends include an increase in record hot days, a decrease in record cold days and increases in extreme fire weather.

22.5.2 Observed local climate

The proposal is generally located within the New England North West region, characterised by a regional landscape, varying from rolling hills to broad floodplains, including the west-flowing Macintyre River.

According to the AdaptNSW *New England North West Climate Change snapshot* (Office of Environment and Heritage (OEH), 2014), the region is generally dry and hot, with much of the region being semi-arid.

Specific to the Moree Plains region, winter typically consists of cool, clear days and frosty nights with often a rapid transition of perhaps a month from summer to winter. Overall, the average rainfall is 585 millimetres (mm) per year and generally higher in summer due to the incidence of thunderstorms. Average maximum temperatures range from 17°C to 19°C in winter to 33°C in the summer months. Average minimum temperatures range from between 4°C and 5°C in winter to between 18°C and 20°C in summer. In winter, the minimum is below zero on an average of 10.4 days. In summer, on average, more than 25 days reach 35°C or higher. Additionally, winter frosts are quite common (average 8 to 13 days a month). Fogs are generally rare, with only one or two days per month recording fog from May to September.

Recent extreme events have been highlighted the area's exposure to climate change, including:

- 2019 was the driest year on record for Moree, with only 125.4 mm of rain recorded for the entire year. In addition, 2019 was Moree's warmest year in 131 years and the third hottest ever, with a mean daily maximum temperature of 29.3°C
- the highest temperature for Moree was recorded on 12 February 2017 of 47.3°C
- the highest daily rainfall was recorded on 31 January 2001 of 128.6 mm
- major floods have occurred in 1955, 1971, 1974, 1976, 2011 and 2012, each inundating the area around Moree for up to 1.5 days.

22.5.2.1 Climate variables

Selecting relevant climate change variables is critical input to the climate change risk assessment process. Selection of these is based on the following factors related to the broader context and nature of the proposal:

- the location of the proposal in an area projected for increased temperature and increased solar radiation
- the location of the proposal in an area subject to decreased annual rainfall resulting prolonged periods of drought
- the location of the proposal in an area projected for an increase in extreme rainfall with subsequent flooding of local waterways.

The climate variables relevant to the proposal are listed in Table 22-3.

TABLE 22-3 PRIMARY AND SECONDARY CLIMATE EFFECTS

Primary climate effect[1]	Secondary climate effect[2]
Mean surface temperature	Extreme temperature and heatwaves
Average annual rainfall	Bushfire weather
Solar radiation	Flood and flash-flood events
Extreme rainfall	Drought
Increased CO_2	Storm events and wind speed

1. Primary effects: those climate variables that are directly influenced or changed as a result of global warming or climate change, such as air and sea surface temperature, precipitation, wind and solar radiation.
2. Secondary effects: those variables that are derived from primary effects that are still influenced by a changing climate, such as increased risk of bushfire weather and drought.

22.5.2.2 Climate projection scenarios

To assess the level of climate change risks to the proposal, the current climate science and model projections have been investigated for the identified climate variables relevant to the proposal, based on available data sources. Reflecting ARTC's commitment to futureproofing Inland Rail, and the requirements of the climate change credits in the IS rating scheme, this climate change risk assessment has used two data sources for climate change projections:

- AdaptNSW and NSW and ACT Regional Climate Modelling (NARCliM) developed by the OEH (2014), which provides projections at the 10-kilometre (km) resolution
- Bureau of Meteorology (BoM) and Commonwealth Scientific and Industrial Research Organisation (CSIRO) Climate Futures (BoM and CSIRO, 2015), which supplements the information available from the NARCliM projections for a number of key climate variables.

The BOM and CSIRO present climate data through the Climate Futures tool in the form of cluster reports, which are regional, down-scaled climate projects across eight regions in Australia. Based on the location of the proposal, the *Central Slopes Cluster Report* (Ekstrom et al., 2015) has been used to inform this assessment.

22.5.2.3 Timescales

Rail infrastructure has a varied expected design life depending on the component. For the purposes of this assessment, it has been assumed that the following design lives would be applied to rail components:

- electrical, signalling and communications components—20 years
- earthworks—50 years
- concrete infrastructure (e.g. bridges, culverts, sleepers) and railway tracks—100 years.

Based on these design lives, construction of the proposal between early 2024 and 2027 and the latest available climate data, the time periods selected for assessment are 2030 (near future) and 2090 (far future). The year 2030 was considered appropriate for short-term impacts on construction of the proposal (assuming construction would be finished by 2027 with initial operation occurring soon after). Climate change projections for 2090 are considered relevant to longer term operation and maintenance of the proposal given the expected design life. Projections for 2070, where available, were included as a means of confirming long-term trends.

22.5.2.4 Detailed projections

A summary of the current climate science available for the proposal area is provided in Table 22-4. It is based on the *Central Slopes Cluster Report* using the Representative Concentration Pathway (RCP) 8.5 data, as well as the *New England North West Climate Change Snapshot* (OEH, 2014) using the *Special Report on Emissions Scenarios* (SRES) A2 data.

The RCP 8.5 data and SRES A2 data were used because the current global emissions trajectory suggests the planet is tracking along these scenarios and represents a pessimistic scenario (assuming no substantial reduction in current emission levels) to help guide risk assessment and adaptation planning. This is also a recommendation outlined in ARTC's *Climate Change Adaptation Framework*.

TABLE 22-4 DETAILED CLIMATE CHANGE PROJECTIONS

		NARCLiM AdaptNSW (OEH)		Climate Futures CSIRO and BoM	
		2030	2070	2030	2090
Climate Variable	Baseline Data[1]	SRES A2[2] (high emissions)	SRES A2 (high emissions)	RCP 8.5[3] (high emissions)	RCP 8.5 (high emissions)
Average daily annual temperature	26.6°C	0.7°C (0.5 to 1.0)	+2.2°C (1.8 to 2.6)	+1.1°C (0.7 to 1.5)	+4.2°C (3 to 5.4)
Average maximum temperature	17 to 19°C (winter) 33°C (summer)	+0.7°C (0.4 to 1.0)	+2.2 (1.9 to 2.7)	+1.2°C (0.5 to 1.6)	+4.2°C (3.2 to 5.5)
Average minimum temperature	4 to 5°C (winter) 18 to 20°C (summer)	+0.7 (0.5 to 1.0)	+2.3 (1.6 to 2.8)	+1°C (0.7 to 1.4)	+4.1°C (3 to 5.3)
Extreme heat days (above 35 °C)	25 days	+7 days (2 to 10)	+24 days (14 to 29)	+9 days (+4 to +15)	+43 days (+27 to +63)
Average annual rainfall	585 mm	+1.6% (-9 to 13%)	+7.7% (-8 to 24)	-1% (-13 to 8)	-6% (-23 to 18)
Extreme rainfall (>125 mm in 24 hours)	N/A	Extreme rainfall events to increase in intensity and severity.			
Fire weather (number of days/year FFDI[4] > 50)	2.2 days	+0.2 days (-0.8 to 1.0)	+0.9 days (-0.6 to 2.5)	+1.4 days (+0.7 to +2.5)	+4.5 days (+1.0 to +8.1)
Drought[5]	N/A	The time spent in drought and the occurrence of drought are both anticipated to increase in intensity and severity.			

1. Quantitative results presented as model median (50th percentile) value, with 10 to 90 percentile range in brackets.
2. NARCliM changes relative to 1990 to 2009 baseline, BoM and CSIRO changes relative to 1986 to 2005 baseline.
3. The SRES A2 is the high emissions trajectory resulting from the Climate Change Fourth Assessment Report (IPCC, 2007).
4. The RCP 8.5 is the high emissions scenario resulting from the Climate Change Fifth Assessment Report (IPCC, 2013).
5. The Forest Fire Daily Index (FFDI) combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50.
6. As drought conditions are directly linked to corresponding rainfall projections, there is uncertainty regarding these projections. Rainfall is dependent on local climate drivers, including topography, with most models showing contrasting patterns and trajectories.

22.6 Potential impacts

There were 45 climate change risks identified as part of the risk assessment process for the proposal. The climate change risks were extracted from the N2NS EIS (GHD, 2017) and adjusted to be specific to the proposal in accordance with the Inland Rail Climate Change Risk Assessment Framework. Of these risks, two were identified as relevant to the construction process, while the remaining 43 were considered relevant to operation of the proposal.

Risks have been grouped by the following climate variables:

- extreme rainfall/flood events—19 risks
- extreme heat—10 risks
- bushfire events—8 risks
- multi-hazards (flooding and warmer days)—1 risk
- solar radiation—1 risk
- storm events and winds—4 risks
- mean rainfall change/drought—2 risks.

22.6.1 Construction

Climate change risks that are associated with construction include (but are not limited to) risks to rail infrastructure by way of physical damage, delays in schedule, and potential risks to human health and safety. The increased frequency and intensity of extreme weather events, increased extreme rainfall events, increased bushfires and rising temperatures are already causing strain on existing rail networks and associated infrastructure. Table 22-5 outlines the climate change risk to the proposal in the near future prior to mitigation.

TABLE 22-5 CLIMATE CHANGE RISK TO PROPOSAL CONSTRUCTION (2030) PRIOR TO MITIGATION

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
IR CCR 20	Extreme rainfall	Extreme rainfall and flooding resulting in delays to construction schedule and cost impacts.	Possible	Major	High	Direct
IR CCR 21	Extreme rainfall	Uncertainty of extreme rainfall events/flooding behaviour impacting on design conditions/requirements. [Over or under design risks].	Rare	Major	Low	Indirect

22.6.2 Operation

Based on the climate change risk assessment for the proposal, extreme rainfall events, flooding and extreme heat will present the highest risk in both the near future and far future. Risks associated with these events include:

- increased flooding, resulting in inundation of track and trackside infrastructure (signalling/communications equipment and drainage basins)
- increased incidence of extreme events (heat, rainfall and bushfire) impacting power supply and demand (both internal and external to the rail corridor) and network (communications) interruption
- increased heat events leading to track buckling and subsequent disruption of service.

Table 22-6 presents the very high, high and medium risks (excluding low risks) identified to proposal operation before mitigation for the period of 2090. Low risks have been excluded as they do not require the same level of consideration as the very high, high and medium risks.

TABLE 22-6 CLIMATE CHANGE RISK TO PROPOSAL OPERATION (2090) PRIOR TO MITIGATION

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
IR CCR 2	Temperature	Risk to business continuity as a result of heat event (e.g. increased incidence of delayed services).	Almost certain	Minor	Medium	Direct
IR CCR 3	Temperature	Increase in hot days resulting in track twisting (buckling) that could lead to derailment of trains along the rail line.	Possible	Moderate	Medium	Direct
IR CCR 6	Temperature	Extreme heat leading to increased power demand and/or failure of power infrastructure (i.e. substations, LV/HV switchboards) resulting in interruptions to power mains supply with increased frequency and duration of power outages.	Likely	Minor	Medium	Indirect
IR CCR 7	Temperature	Increased incidences of extreme heat limiting the ability for ARTC to attract workers due to undesirable conditions.	Likely	Minor	Medium	Indirect
IR CCR 8	Temperature	Rollingstock or hot works igniting fire due to hot, dry and windy conditions.	Likely	Minor	Medium	Direct
IR CCR 10	Extreme rainfall	Risk to health and safety of staff (e.g. conductor, emergency crews) working along the rail corridor due to velocity and flow of flooding (e.g. flash flooding events).	Likely	Minor	Medium	Direct

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
IR CCR 11	Extreme rainfall	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage to scour.	Possible	Major	High	Direct
IR CCR 12	Extreme rainfall	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure reducing the safety of running conditions with resulting service disruption.	Possible	Major	High	Direct
IR CCR 13	Extreme rainfall	Increase in intense rainfall could result in overtopping leading to damaged infrastructure.	Possible	Major	High	Direct
IR CCR 14	Extreme rainfall	Longitudinal scour through water running along embankment, impacting on embankment.	Possible	Moderate	Medium	Direct
IR CCR 15	Extreme rainfall	Inundation of adjacent road network and signalling equipment causing potential isolation of assets due to flooding.	Likely	Minor	Medium	Direct
IR CCR 16	Extreme rainfall	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure, increasing maintenance and insurance premiums costs.	Almost Certain	Minor	Medium	Direct
IR CCR 17	Extreme rainfall	Inundation of adjacent road network impacting on ability of emergency response to reach the corridor.	Likely	Minor	Medium	Direct
IR CCR 18	Extreme rainfall	Water damage to signalling, substations and electrical circuitry may result in disruption to electricity supply, thereby impacting the functionality of level crossings, signals and utility supply.	Possible	Major	High	Direct/ indirect
IR CCR 22	Extreme rainfall	Extreme rainfall and flooding causing damage to non-rail structures potentially impacting operations.	Possible	Major	High	Direct
IR CCR 23	Extreme rainfall	Increase in intense rainfall could result in regional isolation and/or service interruption due to flooding along the 1,700 km route.	Possible	Major	High	Direct
IR CCR 24	Extreme rainfall	The projected periodic extreme dry and wet periods may increase the potential for erosion of substrate and ballast materials, causing increased washout. This could cause infrastructure instability, train derailment and disruption in the event of collapse.	Possible	Moderate	Medium	Direct
IR CCR 25	Extreme rainfall	Increased intense rainfall and flooding resulting in scour damage to adjacent properties.	Likely	Moderate	High	Direct
IR CCR 26	Extreme rainfall	Potential blockages of drainage infrastructure caused by the movement of debris during flood.	Likely	Minor	Medium	Direct
IR CCR 28	Extreme rainfall	Increased rainfall intensities leading to greater discharges, which leads to increased hydraulic impacts (e.g. afflux) on adjacent properties.	Possible	Major	High	Direct

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
IR CCR 29	Decrease in average rainfall	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying, reducing integrity of tracks, bridges, embankments and signalling infrastructure with potential structural failure.	Unlikely	Major	Medium	Direct
IR CCR 30	Decrease in average rainfall	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying causing increases in monitoring and maintenance programs.	Likely	Minor	Medium	Direct
IR CCR 31	Extreme weather events	Damage to tracks/siding, electrical, communications infrastructure and other structures due to higher wind speeds and falling debris requiring repair and/or replacement and an increase in capital costs.	Possible	Moderate	Medium	Direct
IR CCR 32	Extreme weather events	Storm events resulting in closure of rail line (due to damage to communications equipment, for safety purposes or loss of power supply/increased frequency and duration of power outages) with subsequent delays.	Possible	Moderate	Medium	Direct/indirect
IR CCR 33	Extreme weather events	Storm events and subsequent higher winds resulting in derailment (loss of freight, rollingstock, cessation of operation) including damage to infrastructure.	Possible	Moderate	Medium	Direct/ indirect
IR CCR 36	Harsher fire weather conditions	Bushfire damaging rail infrastructure including trackside infrastructure (e.g. signals, communications equipment requiring increased operational costs).	Possible	Moderate	Medium	Direct
IR CCR 38	Harsher fire weather conditions	Bushfire events leading to damage to power supply infrastructure or a need to cut supply resulting in interruptions to power supply (particularly signalling and communications equipment) with increased frequency and duration of power outages.	Possible	Moderate	Medium	Indirect
IR CCR 41	Harsher fire weather conditions	Bushfire event along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and CFA access/egress points.	Possible	Major	High	Indirect
IR CCR 42	Harsher fire weather conditions	Bushfire event along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent impacts on customers good not being delivered.	Likely	Minor	Medium	Indirect
DJV CRR 02	Temperature	Structural materials may be affected by the extreme heat, leading to structural fatigue.	Unlikely	Major	Medium	Direct

22.7 Mitigation and adaptation

22.7.1 Climate adaptation actions

Table 22-7 outlines associated mitigation and adaptation measures to reduce the impact of climate change risks to the proposal. For the most part, identified measures include a combined approach that addresses the avoidance of risk, designing out risk where possible and practicable, and procedures for the management of risks that may be unavoidable.

The adaptation options identified below have been either integrated into the design and current procedures (referred to as 'current' in the optimal scale column) or are scheduled (referred to as 'planned' in the optimal scale column) to be addressed in future phases. All adaptation options are related to the climate change related risks outlined in the *N2NS Phase 2 Climate Change Risk Assessment*.

TABLE 22-7 ADAPTATION OPTIONS ASSOCIATED WITH THE N2NS PHASE 2 CLIMATE CHANGE RISK ASSESSMENT

Adaptation options	Optimal scale	Applicable risk ID
Design and construction		
Ensure that design and procurement of trackside equipment (e.g. signals, communication relay points) account for an increase in ambient temperatures and extreme heat days.	Current	DJV CCR 02 IR CCR 6
Consider the use of elastic fasteners and/or heavier sleepers to account for potential track buckle.	Current	IR CCR 3
Provide shade for trackside equipment (double-ventilated signal boxes and/or double-skinned enclosures) and/or specify material and colour selection to reduce heat load.	Planned	Opportunity
Consider the use of lighter coloured ballast or painted rails to reduce trackside temperature.	Current, infrequentl y applied	IR CCR 8
Locate electrical equipment and supporting infrastructure outside of bushfire-prone areas, where reasonable and feasible, to reduce risk of damage from bushfire.	Current	IR CCR 38 IR CCR 36
Include allowance for climate change in the design criteria for flooding based on a 10 per cent increase in rainfall events, particularly around track-side stormwater infrastructure, in accordance with the *Practical Consideration of Climate Change* (DECC, 2007).	Current	IR CCR 28 IR CCR 23 IR CCR 15 IR CCR 13 IR CCR 12 IR CCR 11
Undertake sensitivity testing in line with climate change scenario planning for RCP 8.5 by reviewing implications of 20 per cent increases in rainfall (in accordance with the *Australian Rainfall and Runoff (ARR) Guidelines,* (Geoscience Australia, 2019).	Current	IR CCR 28 IR CCR 23 IR CCR 15 IR CCR 13 IR CCR 12 IR CCR 11
Implement flood mitigation measures along the rail corridor, including the locating of critical electrical systems (signalling, communications huts, etc.) above potential flood zones.	Current	IR CCR 22 IR CCR 18 IR CCR 15
Design site grading to direct flooding into drainage infrastructure.	Planned	Opportunity
Design culverts and drainage to be concrete-lined to reduce potential for damage.	Current	IR CCR 14
Apply a 15 per cent hydrological blockage factor for drainage structures.	Current	IR CCR 26
Incorporate additional drainage network features and flood protection measures (e.g. larger drainage network, additional pits, larger pipe diameters, larger sumps, etc.) to mitigate a potential increase in flood risks.	Current	IR CCR 28
Establish vegetation clearance zones across the corridor to minimise vegetation (debris and bushfire risk).	Current	IR CCR 36 IR CCR 31
Backup power supply and/or built-in system redundancy (in case of substation failure) provided as standard to ensure continuous operation of electrical systems, including signalling and communications equipment along the corridor.	Current	IR CCR 38 IR CCR 18
Incorporate solar PV and battery storage as built-in redundancy to ensure ongoing operation of signalling and communications equipment in the event of power failure.	Current	Opportunity

Adaptation options	Optimal scale	Applicable risk ID
Engagement with stakeholders.	Current	IR CCR 25 IR CCR 7
Engage with local emergency services to discuss and coordinate emergency response procedures, including (but not limited to) temperature, high wind and container topple.	Planned	Opportunity
Operational		
Reduce train speeds during days where trackside temperature exceeds 35°C as outlined in *Speed Restrictions during hot weather* (ANGE 210) (ARTC, 2020b).	Current	IR CCR 2 IR CCR 3
Maintenance program has developed operational policy to avoid outdoor works during hotter times (i.e. over 35°C) (where practicable).	Current	IR CCR 8
Maintenance program has developed operational policy to monitor bushfire risk.	Current	IR CCR 42 IR CCR 41
Implement threshold for a high winds, rainfall and storms to stop work if not already considered within existing ARTC operational framework.	Current	IR CCR 33 IR CCR 32 IR CCR 16 IR CCR 12 IR CCR 11 IR CCR 10
Real-time monitoring of track conditions.	Current	IR CCR 30 IR CCR 29 IR CCR 24

22.7.2 Residual risk assessment

A residual risk assessment for the proposal was undertaken to apply the adaptation measures identified in section 22.7.1 to applicable risks, including all risks with an initial rating of very high or high. In addition, adaptation actions identified have contributed towards treating most medium risks, resulting in a number of those risks having their corresponding residual risks revised to low. Adaptation measures have been specifically identified and incorporated in the design to address specific climate change risks, which satisfies the SEARs.

The implemented adaptation measures identified as part of this climate change risk assessment would result in a lowering of residual risks to the rail corridor across future scenarios. As a result of these adaptation measures, no residual very high risk ratings remain for the proposal; however, Table 22-8 shows that one risk remains rated high in the 2030 timeframe, and Table 22-9 indicates that 10 risks carry this same rating for 2090.

Nine of the high-rated residual risks in 2090 related to flooding due to increased intensity of extreme rainfall events. To manage these risks, the following measures should be undertaken:

- Review risks in line with updates to the ARR guideline (about every 30 years) or in line with an extreme flooding event (e.g. overtopping, 1% event becomes a 5% event). Then undertake a multi-criteria analysis to determine what actions to take to reduce risk.
- Reassess rainfall data and re-run models to check what impacts are now likely to affect adjacent properties (number of properties in the 1% annual exceedance probability (AEP) floodplain may change). Monitor long-term performance of hydrology and, if necessary:
  - increase rail level
  - provide additional scour protection of rail embankments and cross drainage structures
  - provide additional cross drainage structures to provide more flow capacity in flood events.

The remaining high-rated residual risk in 2090 is related to bushfires. Adaptation measures have been applied to this risk, which include early warning and monitoring systems; however, the risk remains high, as if the event occurs, the freight will be stopped.

TABLE 22-8 HIGH-RATED RISK TO PROPOSAL CONSTRUCTION (2030) FOLLOWING APPLICATION OF ADAPTATION MEASURES

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
IR CCR 20	Extreme rainfall	Extreme rainfall and flooding resulting in delays to construction schedule and cost impacts	Possible	Major	High	Direct

TABLE 22-9 HIGH-RATED RISKS TO PROPOSAL OPERATION (2090) FOLLOWING APPLICATION OF ADAPTATION MEASURES

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating
IR CCR 11	Extreme rainfall	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage to scour.	Possible	Major	High
IR CCR 12	Extreme rainfall	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure reducing the safety of running conditions with resulting service disruption.	Possible	Major	High
IR CCR 13	Extreme rainfall	Increase in intense rainfall could result in overtopping leading to damaged infrastructure.	Possible	Major	High
IR CCR 18	Extreme rainfall	Water damage to signalling, substations and electrical circuitry may result in disruption to electricity supply thereby impacting the functionality of level crossings, signals and utility supply.	Possible	Major	High
IR CCR 22	Extreme rainfall	Extreme rainfall and flooding causing damage to non-rail structures potentially impacting operations.	Possible	Major	High
IR CCR 23	Extreme rainfall	Increase in intense rainfall could result in regional isolation and/or service interruption due to flooding along the 1,700 km route.	Possible	Major	High
IR CCR 28	Extreme rainfall	Increased rainfall intensities leading to greater discharges, which leads to increased hydraulic impacts (e.g. afflux) on adjacent properties.	Possible	Major	High
IR CCR 41	Harsher fire weather conditions	Bushfire event along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and NSW Rural Fire Service (NSE RFS) access/egress points.	Possible	Major	High

22.7.3 Summary of mitigation measures

The measures outlined in Table 22-10 would be implemented to mitigate the potential land use and property impacts of the proposal.

TABLE 22-10 SUMMARY OF MITIGATION MEASURES

Ref	Impact	Mitigation measures	Timing
CC-1	Extreme temperature	Design and procurement of trackside equipment (e.g. signals, communication relay points) would account for an increase in ambient temperatures and extreme heat days.	Detailed design, pre-construction and construction

Ref	Impact	Mitigation measures	Timing
CC-2	Extreme temperature	The use of elastic fasteners and/or heavier sleepers to account for potential track buckle would be considered.	Detailed design, pre-construction and construction
CC-3	Extreme temperature	Shade for trackside equipment would be provided (double-ventilated signal boxes and/or double-skinned enclosures), and/or specify material and colour selection to reduce heat load.	Detailed design, pre-construction and construction
CC-4	Extreme temperature	The use of lighter coloured ballast or painted rails to reduce trackside temperature would be considered.	Detailed design
CC-5	Severe bushfire	Electrical equipment and supporting infrastructure would be located outside of bushfire-prone areas, where reasonable and feasible, to reduce risk of damage from bushfire.	Detailed design, pre-construction and construction
CC-6	Extreme rainfall	An allowance for climate change would be included in the design criteria for flooding based on a 10% increase in rainfall event, particularly around track-side storage stormwater infrastructure, in accordance with the Practical Consideration of Climate Change (Department of Environment and Climate Change (DECC), 2007).	Detailed design, pre-construction and construction
CC-7	Extreme rainfall	Sensitivity testing would be undertaken in line with climate change scenario planning for RCP 8.5 by reviewing implications of 20% and 30% increases in rainfall (in accordance with the Australian Rainfall and Runoff Guidelines, (Geoscience Australia, 2019)).	Detailed design, pre-construction and construction
CC-8	Extreme weather events	Vegetation clearance zones would be established across the corridor to minimise vegetation (debris and bushfire risk).	Detailed design, pre-construction and construction
CC-9	Extreme weather events	Backup power supply and/or built-in system redundancy (in case of substation failure) would be provided as standard to ensure continuous operation of electrical systems, including signalling and communications equipment along the corridor.	Detailed design, pre-construction and construction
CC-10	Extreme weather events	Solar PV and battery storage would be incorporated as built-in redundancy to ensure ongoing operation of signalling and communications equipment in the event of power failure.	Detailed design, pre-construction and construction
CC-11	Extreme weather events	Local emergency services would be engaged with to discuss and coordinate emergency response procedures, including (but not limited to) temperature, high wind and container topple.	Detailed design, pre-construction and construction
CC-12	Temperature	Train speeds would be reduced during days where trackside temperature exceeds 35°C, as outlined in Speed Restrictions during hot weather (ANGE 210—Chapter 22).	Operation
CC-13	Temperature	Maintenance program/operational policy would be developed to avoid outdoor works during hotter times (i.e. over 35°C) (where practicable)—refer to Monitoring and responding to Extreme Weather Events (OPE-PR-014, Chapter 22).	Construction and operation
CC-14	Harsher fire weather conditions	Maintenance program/operational policy would be developed to monitor bush fire risk—refer to Monitoring and responding to Extreme Weather Events (OPE-PR-014, Chapter 22).	Operation
CC-15	Extreme weather events	Thresholds for high winds, rainfall and storms would be implemented to stop work if not already considered within existing ARTC operational framework—refer to Monitoring and responding to Extreme Weather Events (OPE-PR-014 – Chapter 22). ARTC will work towards minimising future risk in emergencies and engage with local governments and the Local Disaster Management Groups.	Operation