CHAPTER 19

Climate Change Risk and Adaption

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

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19.1 Scope of chapter

The climate change risk assessment chapter is structured as follows:

- Section 19.1outlines how the Secretary's Environmental Assessment Requirements (SEARs) have been addressed in this chapter
- Section 19.2 describes the legislative, policy and management framework relevant to climate change and risk adaptation for the proposal
- Section 19.3 outlines the relevant guidelines and methodology used for the climate resilience assessment
- Section 19.4outlines the existing climate change drivers including policy context, local climate exposure, climate change projections and detailed climate variables
- Section 19.5 outlines the risks from climate change during construction and operation of the proposal
- Section 19.6outlines the adaptation options developed to address climate change risks, the residual risk assessment and details for SEARs compliance.

This chapter summarises the climate change risk assessment undertaken for the proposal. The climate change risk assessment addresses the SEARs as well as considers the requirements outlined in the *Infrastructure Sustainability (IS) Rating Scheme—version 1.2* for Cli–1 and Cli–2. More information on Cli–1 and Cli–2 is in Chapter 18: Sustainability and Appendix Q: Climate Change Risk Assessment Technical Report.

19.1.1 Secretary's Environmental Assessment Requirements

The SEARs for the proposal includes a key issue and desired performance outcome for designing, constructing and operating the proposal to be resilient to the future impacts of climate change. Table 19.1 identifies the two requirements and where the requirement has been addressed in this chapter.

TABLE 19.1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS COMPLIANCE

	Item 18: Climate Change Risk
Desired performance outcome	The proposal is designed, constructed and operated to be resilient to the future impacts of climate change.
Current guidelines	*Australian Government's Climate Change Impacts and Risk Management—A Guide for Business and Government (2006)* *AS/NZS 3100:2009 Risk Management—Principles and Guidelines* *Technical Guide for Climate Change Adaptation for the State Road Network* (RMS, in draft)

SEARs requirement	**EIS section**
Item 20.1 The Proponent must assess the risk and vulnerability of the proposal to climate change in accordance with the current guidelines.	Section 19.3.1 and Section 19.5 Appendix Q: Climate Change Risk Assessment Technical Report
Item 20.2 The Proponent must quantify specific climate change risks with reference to the NSW Government's climate projections at 10 km resolution (or lesser resolution if 10 km projections are not available) and incorporate specific adaptation actions in the design.	Section 19.4.1, Section 19.5 and Section 19.6 Appendix Q: Climate Change Risk Assessment Technical Report

19.2 Legislation, policies, standards and guidelines

This section describes the legislative, policy and management framework for the proposal relevant to climate change and risk adaption for the proposal. The legislation, policies and guidelines relevant to the proposal with respect to climate change are in Table 19.2.

TABLE 19.2 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 (2016)	In 2015, the Australian Government announced its commitment to a target of reducing greenhouse gas (GHG) emissions by 26–28 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* (Department of Foreign Affairs and Trade, 2016) include: ▸ 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.
Commonwealth	
Australian Government's *Direct Action Plan* (2014)	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.
Australian Government's *National Climate Resilience and Adaptation Strategy* (2015)	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.
State (NSW)	
Climate Change Policy Framework for NSW (Office of Environment and Heritage, 2016)	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 make NSW more resilient to a changing climate. In making NSW more resilient to a changing climate, the NSW Government's 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) (Roads and Maritime Services, 2015)	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 been referenced within the SEARs for the proposal.

19.3 Impact assessment methodology

19.3.1 Climate change risk assessment

As recommended through the SEARs requirements, the climate change risk assessment undertaken for the proposal follows the approach detailed within the draft *Technical Guide for Climate Change Adaptation for the State Road Network* (Roads and Maritime, 2015). It is recognised that this technical guide is one of the current guidelines for assessing risk and vulnerability for infrastructure projects and is noted as such in the SEARs.

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 *AS/NZS 3100:2009 Risk Management—Principles and Guidelines*. The guide references the identification of relevant climate variables and impacts (refer Section 19.4.1.1), undertaking a risk assessment (refer Section 19.5) and identifying and evaluating various risk treatments (adaptation options in Section 19.6) to address each risk. While the technical guide has also been developed considering existing roads and maritime processes, it aligns with the broader NSW Government initiatives and programs responding to climate change impacts. As such, it has been referenced within the SEARs for the proposal and used to guide the development of this assessment, as noted above.

In addition to the technical guide, this climate change risk assessment has been conducted in line 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 *Infrastructure Sustainability Council of Australia (ISCA) Rating Tool* v1.2 Cli–1 and Cli–2 credits.

- The *ARTC Risk Assessment Framework*, in accordance with *Australian Standard (AS)/New Zealand Standard 3100:2009 Risk Management—Principles and Guidelines* as well as *International Standards Organization (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 *ISO31000:2009*
- *Climate Change Impacts and Risk Management—A Guide for Business and Government* (Department of Environment and Heritage, 2006)
- The *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.

A preliminary rating in accordance with these guidelines was undertaken and subsequently socialised, refined and updated based on feedback provided in a workshop held on 20 September 2018 with key stakeholders. A risk assessment was undertaken in accordance with Chapter 10: Assessment Methodology.

A description of the proposal is in Chapter 6: The Proposal and Chapter 7: Construction of the Proposal.

19.3.2 Limitations

ARTC does not own or operate rolling stock, nor does the proposal include rolling stock, therefore climate change impacts on rolling stock have not been considered in this report. In certain instances, where impacts to rolling stock would have an affect on operation or maintenance of the proposal (indirect impacts), consideration has been given in the risk assessment and through the identification of adaption responses.

19.4 Existing and future climate

In 2016, global temperatures were confirmed to have risen by 1 °C since pre-industrial levels. The *Paris Climate Change Accord* (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 increase, the Earth's climate and weather systems are experiencing considerable changes.

The State of the Climate 2014 (Bureau of Meteorology and CSIRO, 2014) confirms the long-term warming trend over Australia's land and oceans, showing that Australia's climate has warmed by 0.9 °C since 1910 (Ekström et al., 2015). 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.

19.4.1 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 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. Overall, average rainfall is around 700 mm (400 to 800 mm on average) per year and generally higher in summer, and relatively uniform across the other seasons. In summer, average temperatures (over 24 hours) across the north-west of the region range between 26–28 ˚C, with January generally being the hottest month, while average winter temperatures (over 24 hours) across the north-west region range between 12 ˚C and 14 ˚C, with July generally being the coldest. The areas surrounding the North Star to Border corridor can experience more than 50 days above 35 ˚C per year.

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

- In January 2011, extreme rainfall resulted in a flooding event (along the Macintyre and Dumaresq rivers) that caused the evacuation of nearly the entire towns of Boggabilla and Toomelah, which are located adjacent to the corridor (Sydney Morning Herald, 2011). This event also closed the Bruxner Way (just outside of Boggabilla) and resulted in delays and cancellations for regional trains and regional coach services.
- In January 2013, extreme rainfall caused a flooding event that closed the Newell Highway near Boggabilla, with no access from either NSW or Queensland (Northern Star, 2013). Furthermore, the Bruxner Way between Boggabilla and North Star was closed in both directions because of flood waters.
- In 2014, a heat wave resulted in temperatures exceeding 45 ˚C in Goondiwindi (45.9 ˚C), while a 2017 event resulted in a three-day stretch of at least 43 ˚C (The Courier-Mail, 2018; The Chronicle, 2017)
- In summer 2016–2017, the town of Moree set a NSW record with 52 consecutive days of temperatures exceeding 35 ˚C (Mashable, 2017).

19.4.1.1 Climate variables

Selecting relevant climate change variables is critical input to the climate change risk assessment process. Selection of these variables 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 in 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 19.3.

TABLE 19.3 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

Table notes:

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

19.4.1.2 Future climate

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 future-proofing Inland Rail, and the requirements of the climate change credits in the Infrastructure Sustainability (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; 2015), which provides projections at the 10 km resolution
- Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology Climate Futures (CSIRO and BoM, 2015), which supplements the information available from the NARCliM projections for a number of key climate variables.

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

Time scales

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 occurring between early 2021 and 2025 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 2025, 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.

Detailed projections

A summary of the current climate science available for the *Central Slopes Cluster Report* (Ekström et al., 2015) using the representative concentration pathway 8.5 data, and the *New England North West Climate Change Snapshot* (OEH, 2014) using the *Special Report on Emissions Scenarios* A2 data, are provided in Table 19.4. The Representative Concentration Pathway (RCP) 8.5 data and *Special Report on Emissions Scenarios* (SRES) A2 data (Intergovernmental Panel on Climate Change, 2018) were used as current global emissions. The current trajectory suggests we are tracking along these scenarios and represents a worst-case scenario to help guide risk assessment and adaptation planning. Where relevant, projections for the RCP4.5 pathway have also been included for comparison (refer Appendix Q: Climate Change Risk Assessment Technical Report). RCP4.5 projections have been included to provide a range of future projections to help inform potential actions to address risk as well as highlight the difference in projections based on various scenarios.

TABLE 19.4 DETAILED CLIMATE CHANGE PROJECTIONS[1]

		NARCliM AdaptNSW (OEH)		Climate Futures CSIRO and BoM	
		2030	2070	2030	2090
Climate variable	Baseline data[2]	SRES A2[3] (high emissions)	SRES A2 (high emissions)	RCP 8.5[4] (high emissions)	RCP 8.5 (high emissions)
Average daily annual temperature	26–28 °C summer 12–14 °C winter	+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 (3.0 to 5.4)
Average maximum temperature	36 °C (summer)	+0.7°C (0.4 to 1.0)	+2.2 °C (1.9 to 2.7)	+1.2 °C (0.5 to 1.6)	+4.2 °C (3.2 to 5.5)
Average minimum temperature	4–6 °C (winter)	+0.7°C (0.5–1.0)	+2.3 °C (1.6–2.8)	+1.0 °C (0.7–1.4)	+4.1 °C (3.0–5.3)
Extreme heat days (above 35 °C)	50–60 days	+7 days (2–10 days)	+24 days (14–29 days)	+9 days (+4– +15)	+43 days (+27– +63)
Average annual rainfall	400–800 mm	+1.6% (-9%–13%)	+7.7% (-8%–24%)	-1.0% (-13%–8%)	-6.0 % (-23%–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[5] > 50)	3.3 days/year	+0.2 (-0.8 to 1.0)	+0.9 (-0.6 to 2.5)	+1.4 days (+0.7 to +2.5)	+4.5 days (+1.0 to +8.1)
Drought[6]	N/A	The time spent in drought and the occurrence of drought are both anticipated to increase in intensity and severity.			

Table notes:
1. Quantitative results presented as model median (50th percentile) value, with 10–90 percentile range in brackets.
2. NARCliM changes relative to 1990–2009 baseline, CSIRO and BoM changes relative to 1986–2005 baseline.
3. The SRES A2 is the high emissions trajectory resulting from the Intergovernmental Panel on Climate Change Fourth Assessment Report (2007).
4. The RCP 8.5 is the high emissions scenario resulting from the Intergovernmental Panel on Climate Change Fifth Assessment Report (2014).
5. The Forest Fire Daily Index (FFDI)(BoM) 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.

19.5 Potential impacts

There were 34 climate change risks identified as part of the risk assessment process for the proposal. Of these risks, two were identified as relevant to the construction process, while the remaining 32 were considered relevant to operation of the proposal. Table 19.5 presents the two construction risks as well as their risk rating, while Table 19.6 presents the 'very high', 'high' and 'medium' risks considered relevant to the operation phase of the proposal. Risks that were identified as being 'low' can be found in Appendix Q: Climate Change Risk Assessment Technical Report.

Risks have been grouped by the following climate variables:

- Extreme rainfall/flood events—14 risks
- Extreme heat—8 risks
- Bushfire events—7 risks
- Storm events and wind—3 risks
- Mean rainfall change/drought—2 risks.

19.5.1 Construction

Because of previous events experienced in and around the rail corridor, and observed and projected trends, risks to rail infrastructure by way of physical damage, delays in schedule and potential risks to human health and safety are likely. The increased frequency and intensity of extreme weather events, increased rainfall, bushfires and rising temperatures are already causing strain on existing rail networks and associated infrastructure. More extreme weather events are likely to damage rail infrastructure and, by 2030, design criteria for extreme events are likely to be exceeded more frequently (Thom et al., 2010).

TABLE 19.5 CLIMATE CHANGE RISKS TO PROPOSAL CONSTRUCTION (2030) PRIOR TO MITIGATION

Risk ID	Climate change risk	Likelihood	Consequence[1]	Risk rating	Risk type
R17	Extreme rainfall and flooding resulting in delays to construction schedule and cost impacts	Possible	Major	High	Direct
R21	Uncertainty of extreme rainfall events/flooding behaviour impacting on design conditions/requirements leading to a potential over or under design of infrastructure.	Rare	Major	Low	Indirect

Table note:
1. Primary consequence driver noted on workshop materials located in Appendix Q: Climate Change Risk Assessment Technical Report.

19.5.2 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 involve:

- Increased flooding resulting in inundation of track and trackside infrastructure (signalling/communications equipment and drainage basins)
- Increased incidents of extreme events (heat, rainfall and bushfire) on 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 19.6 presents the very high, high and medium risks (excluding low risks) identified to proposal operation before mitigation for the period of 2030. Low risks have been excluded as they do not require the same level of consideration as the very high, high and medium risks. The full risk register for both the 2030 and 2090 time scales can be found in Appendix Q: Climate Change Risk Assessment Technical Report.

TABLE 19.6 CLIMATE CHANGE RISKS TO PROPOSAL OPERATION (2030) PRIOR TO MITIGATION

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence[1]	Risk rating	Risk type
R1	Extreme heat	Risk to health and safety of staff working along the rail corridor through heat stress	Possible	Major	High	Direct
R2	Extreme heat	Risk to business continuity as a result of heat events (e.g. increased incidence of delayed service from trains breaking down and/or operational activities not being able to occur)	Likely	Minor	Medium	Direct
R3	Extreme heat	Increase in hot days resulting in track twisting (buckling) which could lead to derailment of trains along the rail line	Likely	Moderate	High	Direct
R6	Extreme heat	Increased occurrence of extreme heat impacting the ability to maintain equipment (e.g. accessibility to water resources)	Likely	Minor	Medium	Direct

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence[1]	Risk rating	Risk type
R11	Extreme rainfall and flood events	Risk to health and safety of staff (e.g. conductor, emergency crews) working along the rail corridor due to velocity and flow of flooding	Likely	Minor	Medium	Direct
R12	Extreme rainfall and flood events	Inundation of tracks causing potential isolation of assets due to flooding	Possible	Major	High	Direct
R13	Extreme rainfall and flood events	Inundation of adjacent road network and signalling equipment causing potential isolation of assets due to flooding	Likely	Major	Very high	Direct
R16	Extreme rainfall and flood events	Changed rainfall patterns and resulting runoff impacting drainage including civil drainage (surface) and overland flow along the corridor	Possible	Moderate	Medium	Direct
R18	Extreme rainfall and flood events	Extreme rainfall and flooding resulting in cost/time disruption to operation (increased frequency of repairs/outages/lost service revenue)	Unlikely	Major	Medium	Direct
R20	Extreme rainfall and flood events	Increase in extreme events increasing volume for runoff from catchment areas outside of the rail corridor	Possible	Moderate	Medium	Indirect
R22	Extreme rainfall and flood events	Extreme rainfall leading to faults/failure of power infrastructure resulting in interruptions to power supply with increased frequency and duration of power outages (particularly signalling and communications equipment)	Possible	Moderate	Medium	Indirect
R23	Extreme rainfall and flood events	Extreme rainfall leading to increased stormwater runoff, with potential damage and/or inundation of surrounding road infrastructure impacting the ability of emergency response/workers to reach the corridor	Possible	Moderate	Medium	Indirect
R32	Storm 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	Major	High	Direct
R34	Storm events	Storm events and subsequent higher winds resulting in service disruption (loss of freight, rolling stock, cessation of operation) including damage to infrastructure	Unlikely	Major	Medium	Indirect

Table note:
1. Primary consequence driver noted on workshop materials located in Appendix Q: Climate Change Risk Assessment Technical Report.

19.6 Adaptation options

19.6.1 Climate adaptation actions

Table 19.7 outlines associated mitigation and adaptation measures to reduce the impact of climate change risks to the proposal. In some instances, a changing climate can result in beneficial outcomes, including fewer impacts to track from rapid heating and cooling resulting from increased temperature changes; however, 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 or are scheduled to be addressed in future phases ('planned'). It is noted that recommended future actions ('potential actions') have been identified in Appendix Q: Climate Change Risk Assessment Technical Report and will be considered as relevant as the proposal progresses. This appendix presents a full list of adaptation options.

TABLE 19.7 CURRENT AND PLANNED ADAPTATION OPTIONS

Adaptation options	Timing
Maintenance program to be developed/operational policy updated to avoid outdoor works during hotter times (where practicable)	Planned
Implement high temperature stop-work threshold if not already considered within existing ARTC operational framework	Planned
Reduce train speeds during days where trackside temperature exceeds 35 ˚C	Current
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	Planned
Consider the use of elastic fasteners and/or heavier sleepers to account for potential track buckle	Current
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
Consider the use of lighter coloured ballast or painted rails to reduce trackside temperature	Current, infrequently applied
Locate electrical equipment and supporting infrastructure outside of bushfire-prone areas where reasonable and feasible to reduce risk of damage from bushfire	Current
Include allowance for climate change in the design criteria for flooding based on a 10% increase in rainfall event, particularly around track-side storage detention basins/stormwater infrastructure, in accordance with the NSW Office of Water guide *Practical Consideration of Climate Change* (Office of Water, 2007)	Current
Undertake sensitivity testing 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 2019* (OEH, 2019)	Current
Implement flood-mitigation measures along the rail corridor, including the locating of critical electrical systems (signalling, communications huts, etc.) above potential flood zones and increasing the design height of bunds	Current
Design site grading to direct flooding into onsite detention and other stormwater channels/drainage infrastructure	Current
Design culverts and drainage to be concrete-lined to reduce potential for damage	Current
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

Adaptation options	Timing
Investigate the inclusion and development of an early flood warning system (e.g. flood gauges, trackside monitors) to alert ARTC to impending flooding	Planned
Develop or update emergency response procedures to respond to extreme weather events	Planned
Establish vegetation clearance zones across the corridor to minimise vegetation (debris and bushfire risk)	Current
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
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
Engage with local emergency services to discuss and coordinate emergency response procedures	Planned

19.6.2 Residual risk assessment

A residual risk assessment for the proposal was undertaken to apply the relevant adaptation measures identified in the above section for all very high and high risks (refer Appendix Q: Climate Change Risk Assessment Technical Report). An excerpt of the residual risk assessment can be found below in Table 19.8. In addition, adaptation actions identified contributed towards treating all 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. As a result of these adaptation measures, no residual very high or high risk ratings remain for the proposal.

While uncertainty regarding future climate projections exists, particularly to 2090, the 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.

TABLE 19.8 RESIDUAL RISK ASSESSMENT—EXCERPT

Risk ID	Risk statement	2030 Risk Rating	2090 Risk Rating	Adaptation options	Responsibility	Timing	2030 (L)	2030 (C)	2030 Residual Risk Rating	2090 (L)	2090 (C)	2090 Residual Risk Rating
R1	Risk to health and safety of staff working along the rail corridor through heat stress	High	Very High	Maintenance program to be developed/operational policy updated to avoid outdoor works during hotter times (where practicable) Implement high temperature stop-work threshold if not already considered within existing ARTC operational framework	ARTC	Review of ARTC operating procedures Temperature thresholds Extreme heat events	Possible	Minor	Low	Likely	Minor	Medium
R23	Extreme rainfall leading to increased stormwater runoff, with potential damage and/or inundation of surrounding road infrastructure impacting the ability of emergency response/workers to reach the corridor	Medium	High	Engage with local emergency services to discuss and coordinate emergency response procedures	ARTC/FFJV	Design Review Review of ARTC operation and maintenance procedures	Possible	Minor	Low	Likely	Minor	Medium