APPENDIX H

INLAND RAIL

Climate change assessment – additional information

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

ARTC

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

APPENDIX H Climate change assessment - additional information

This appendix provides additional information to support Chapter D4 (Climate change) including: a detailed description of the methodology; existing and future climate scenarios; risk narratives adopted for the proposal; climate change risk assessment; and adaptation measures proposed and adopted for the proposal.

Climate change risk assessment

The climate change risk assessment identifies risks and risk mitigation measures associated with the predicted impacts of climate change on the design, construction, and operation of the proposal. The objectives of this assessment are to:

- identify significant potential impacts of climate change on the proposal's infrastructure and service delivery
- assess the level of associated risks.

This assessment considers the impact of climate change on the proposal rather than the impact of the proposal on future climate change. The approach to the climate change risk assessment and adaptation planning process is consistent with the approach outlined in the *Draft Technical Guide for Climate Change Adaptation for the State Road Network* (Roads and Maritime, 2015) and conforms to the following standards and guidelines:

- *AS/NZS ISO 31000-2009 Risk management – principles and guidelines* (Standards Australia, 2009)
- *AS 5334-2013 Climate change adaptation for settlements and infrastructure – a risk based approach* (Standards Australia, 2013).

The assessment involved:

- understanding the climate change context with reference to relevant legislation framework, the proposal scope of works, geographic context, historical climate conditions and climate change projections, and the ISCA climate change credit requirements (ISCA, 2016)
- undertaking a climate change risk assessment by developing risk narratives for the proposal, identifying risk causes and impacts according to the ARTC climate change risk framework, and assessing risks with business-as-usual (BAU) risk controls in place
- proposing climate resilience measures and climate change adaptations for the treatment of priority climate change risks.

Methodology

Review of existing climate data

Historical climate conditions and climate change projections for the study area were reviewed, based on available Bureau of Meteorology (BoM) data.

The climate change risk assessment considers a number of climate variables and extreme weather events that have the potential to impact infrastructure associated with the proposal.

Historical weather records were analysed from the following BoM stations representing each end of the alignment at Narromine and Narrabri:

- Narromine – represented by Trangie Research Station Automatic Weather Station (AWS) (BoM 51049), located 35 kilometres north-west of Narromine (note that the stations in Narromine itself have insufficient historical data). Data has been captured from 1969 to present.

- Narrabri – represented by Narrabri West Post Office (BoM 53030) for data from 1962 up to 2002, and by Narrabri Airport AWS (BoM 54038) from 2002 to present.

Develop climate projections

To determine the potential implications of climate change for the design and operation of the proposal and assess the risk and vulnerability of the proposal to climate change, it is necessary to develop projections of the future climate in the study area along the proposal site.

Climatic data was obtained from Trangie Research Station AWS (BoM 51049), Narrabri West Post Office (BoM 53030) and Narrabri Airport AWS (BoM 54038) described in the previous section.

The Intergovernmental Panel on Climate Change (IPCC) has developed four scenarios for global climate change that relate to how the world may respond to the challenge of a changing climate, and the need to continue to produce and use energy and resources.. The IPCC's *Fifth Assessment Report AR5* (IPCC, 2013) provides a summary of climate change modelling undertaken by leading international climate research organisations. . Outputs for Australia are published on the Climate Change in Australia (CCIA) website. The outputs include consolidated projections from General Circulation Model (GCM or global climate model) runs for the 21st century under a range of greenhouse gas emissions and Representative Concentration Pathway (RCP) scenarios and include data for a wide range of climate parameters, including rainfall, temperature and wind speed

The climate change factors used for the current risk assessment were derived using the Climate Futures Tool (Clarke et al., 2011) and Climate Change in Australia (CCIA) modelling data from CSIRO and BoM.

To develop projections for the study area, the RCP scenarios were adopted for three timeframes. A moderate RCP (RCP4.5) and an extreme RCP (RCP8.5) were each used for 2030, 2070 and 2090 scenarios, to reflect the more pronounced level of uncertainty as the timescale of the projection is extended.

The climate projection scenarios adopted for the proposal are listed in Table H.1.

Generally, under any scenario, the extent of climate change is projected to increase over time, and the changes are more uncertain for longer-term projections. Given the anticipated design life of track formation/concrete sleepers and structures (50 years and 100 years respectively), both scenarios are considered appropriate for the assessment.

Table H.1 Climate change project scenarios based on two different RCP scenarios and three different timeframes reflecting general operational time for the proposed rail infrastructure

SCENARIO DESCRIPTOR	RCP SCENARIO	TIMEFRAME REFLECTING OPERATING LIVES ALONG THE ALIGNMENT		
		2030	2070	2090
Slower emission reductions that stabilise the CO_2 concentration at about 540 ppm by 2100	RCP4.5 Intermediate emission scenario	Assets and systems with shorter operating lives such as signalling and communications systems and level crossings.	Assets and systems with longer operating lives such as rail tracks and underground drainage.	Permanent assets, which are on-going features of the proposal, such as bridges and embankments.
Assumes little curbing of emissions and increases leading to a CO_2 concentration of about 940 ppm by 2100	RCP8.5 High emission scenario			

Risk assessment

The risk assessment is based on ARTC's climate change risk assessment framework. Risk likelihood was assessed cumulatively over the applicable asset life, rather than the chance of occurrence of the hazards in any given year. The risk assessment included climate change projection scenarios while allowing for BAU risk controls for natural hazards.

A high-level risk assessment was undertaken to determine how changing patterns of rainfall, hydrology, and extreme weather may impact on the future resilience of the proposal. Through discussions with the design team, workshop outputs, review of design drawings and documents, publications and case studies, potential risks to the construction and operation of the proposal were identified.

The risk rating classification is shown in Table H.2 and outlines the consequences related to each risk category.

The risk matrix adopted for this assessment is based on the ARTC climate change risk rating classification. Based on the assessment of likelihood and consequence, any foreseeable climate change impact can be assigned a risk level. This determines the significance of the environmental risk associated with a given impact. The risk assessment matrix is provided in Table H.3.

Assumptions

The following assumptions were made for the climate change risk assessment:

- climate change scenarios were based on publicly available projections
- the assessment of risks was qualitative not quantitative
- climate change projections were regional rather than localised
- the consequences and risks for infrastructure and service delivery were based on consideration of the proposal only, not the wider Inland Rail program.

Table H.2 Risk rating category and consequence classification

RISK CATEGORY			CONSEQUENCE				
			Not significant	Minor	Moderate	Major	Extreme
Safety category is focussed on impact to people.	S:	Safety	No Medical Treatment Required	Lost Time Injury (LTI) Results OR Medical Treatment Required	Serious Injury Occurs	Single Fatality Occurs	Multiple but Localised Fatalities Occur
Focussed on engineering impact(s) and satisfying objectives.	A:	Assets	Up to 6hrs Track Closure	>6hrs to 24hrs Track Closure	>24hrs to 48hrs Track Closure	>48hrs to 5 Days Track Closure	>5 Days Track Closure
Focussed on total outturn cost impact	F:	Financial	Up to 0.05% of Programme budget (ie to $5M in $10B)	>0.05% to 0.5% of Programme budget (ie>$5M to $50M in $10B)	>0.5% to 1.5% of Programme budget (ie>$50M to $150M in $10B)	>1.5% to 5% of Programme budget (ie>$150M to $500M in $10B)	>5% of Programme budget (ie>$500M in $10B)
			Up to 0.1% of project budget (eg to $100k in $100M)	>0.1% to 0.5% of project budget (eg >$100k-$500k in $100M)	>0.5% to 2.5% of project budget (eg >$500k-$2.5M in $100M)	>2.5% to 10% of project budget (eg >$2.5M-$10M in $100M)	>10% of project budget (eg >$10M in $100M)
Focussed on environment impact heritage, flora & fauna, archaeology & indigenous, pollution and amenity (public)	E:	Environment	Contained Environmental Damage - fully recoverable (no cost or ARTC action required)	Isolated Environmental Damage - minimal ARTC remediation required	Localised/Clustered Environmental Damage - requiring remediation	Considerable Environmental Damage - requiring remediation	Widespread Long Term or Permanent Environmental Damage - remediation required
Focussed on regulatory/legislation exposure Non-compliance & our licence to operate	R:	Regulatory	Minimal or no Regulatory Involvement	Notice to Produce Information	Improvement Notice or Threatened Action	Prohibition Notice or Fine(s)	Prosecution of the Company and/or its Office Holders

RISK CATEGORY			CONSEQUENCE				
			Not significant	Minor	Moderate	Major	Extreme
Focussed on reputational exposure Customer dissatisfaction, shareholder support, service quality & reliability, public image and stakeholder attitudes	R:	Reputation	Isolated event able to be resolved (up to 7 days)	Management intervention required (>7 days to 3 months)	Tactical (Business Unit/ Divisional) intervention required (>3 months to 18 months)	Strategic intervention required (>18 months to 3 years)	Corporate loss of Shareholder and/or Customer support (tangible business impact >3 years)
Focused on time-based impacts	S:	Schedule	Influences schedule up to 1% of Programme approved schedule period	Influences schedule >1% to 2.5% of Programme approved schedule period	Influences schedule >2.5% to 5% of Programme approved schedule period	Influences schedule >5% to 10% of Programme approved schedule period	Influences schedule >10% of Programme approved schedule period
			Influences schedule up to 2% of project approved schedule period	Influences schedule >2% to 5% of project approved schedule period	Influences schedule >5% to 10% of project approved schedule period	Influences schedule >10% to 20% of project approved schedule period	Influences schedule >20% of project approved schedule period

Table H.3 Climate change risk assessment matrix

LIKELIHOOD				CONSEQUENCES				
Description	**Frequency**	**Percentile**	**Likelihood**	**1 Not significant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Extreme**
Is expected to occur in most circumstances	Once per month	>90%	Almost Certain	Medium	Medium	High	Very High	Very High
Will probably occur in most circumstances	Between once a month and once a year	60%-90%	Likely	Low	Medium	High	Very High	Very High
Might occur at some time	Between once a year and once in five years	30%-<60%	Possible	Low	Low	Medium	High	High
Could occur at some time	Between once in five years and once in 20 years	10%-<30%	Unlikely	Low	Low	Low	Medium	Medium
May occur in exceptional circumstances	Once in more than 20 years	<10%	Rare	Low	Low	Low	Low	Medium

Existing environment and future climate

Existing environment

The existing climatic environment is described with reference to data from theTrangie Research Station AWS (BoM 51049), Narrabri West Post Office (BoM 53030) and Narrabri Airport AWS (BoM 54038) . The overall climate of the study area is characterised by hot summers and seasonal patterns in temperature and rainfall typical of inland NSW. At both ends of the proposal site, summer temperatures of 43°C or higher have been recorded during December and January.

Yearly average temperatures have trended upwards in the study area over the period of record by approximately 0.2-0.6°C per decade. Total annual rainfall has trended downwards over the same period, between 0-10mm per decade. Figure H.1 shows average maximum temperatures range between 15.4-33.4°C for Narromine, and 18-33.8°C for Narrabri. Average minimum temperatures range between 3.2-18.6°C in Narromine and 3.7-19.3°C for Narrabri.

The highest recorded rainfall occurs during December to February period. Narrabri experiences a higher volume of rainfall during summer than Narromine, however both locations have similar average temperature ranges. The general climatic conditions and the type of climate experienced have low variability.

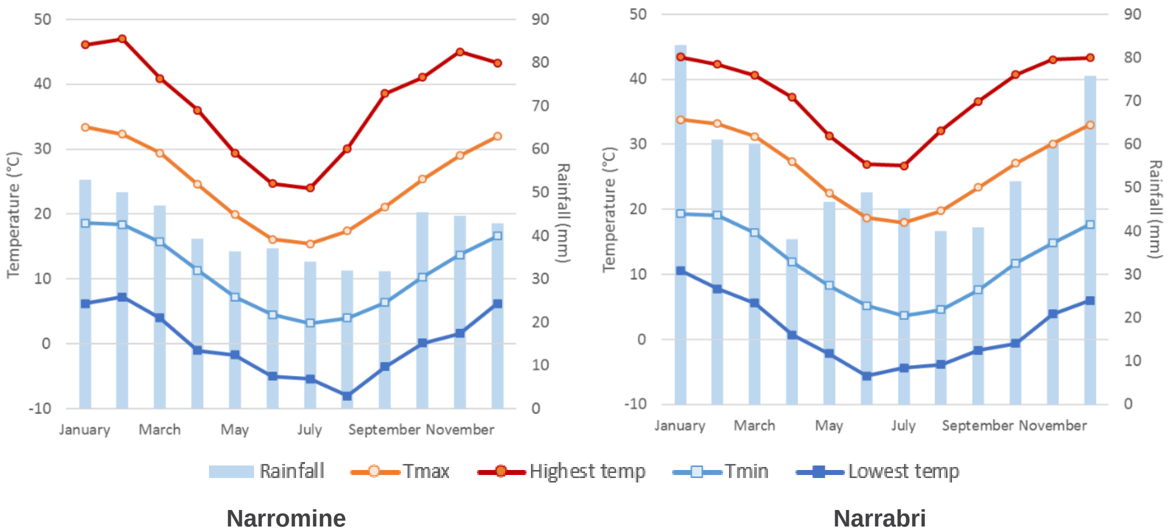

Figure H.1 Average climate conditions for the proposal representing Narromine and Narrabri

Climate projections

Climate change factors for annual average rainfall vary widely in 2070 and 2090 for the two RCP scenarios. Projected changes in average rainfall range vary between small increases and large decreases across 2070 and 2090, with a greater range of extremes for RCP8.5. The range in climate change factors for rainfall is similar for the two RCP scenarios. Climate change factors for temperature are more consistent.

The adopted climate change projections for the proposal are provided in Table H.4 and Table H.5.

Table H.4 Adopted climate change projections - Narromine

ATTRIBUTE	2030	2070[1]	2090[1]	SOURCE
Projected rainfall				
Mean annual rainfall (mm)	512	382 - 436	431 - 533	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
2.5% AEP daily rainfall event (mm)	124	136 - 141	143 - 148	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
Climate change factor for extreme rainfall events	+5.6%	+15.8%	+21.3%	Based on Australian Rainfall and Run-off projections.
Projected temperature				
Maximum projected temperature (°C)	46.5	49.2 – 50.1	50.0 – 51.3	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
Average maximum temperature (°C)	26.2	27.9 – 28.8	28.7 – 30.4	
Average annual temperature (°C)	19.1	21.1 – 21.9	22.2 – 23.1	
Average minimum temperature (°C)	12.1	14.4 – 14.9	15.6 – 16.1	
Minimum temperature (°C)	-6.9	-5.5 – -4.5	-4.9 – -3.0	
Average number of days per year in which freezing minimum temperatures are recorded	5.1	0.7 – 1.2	0.1 – 0.4	
Days/y Tmax8 ≥35°C	41.8	72.8 – 94.2	86.0 – 113.6	
Days/y Tmax8 ≥40°C	5.4	18.9 – 29.5	25.6 – 39.6	
Days/y Tmax8 ≥45°C	0.3	1.5 – 3.3	2.5 – 5.2	
Days/y Tmax8 ≥50°C	0.0	0.0 – 0.1	0.0 – 0.3	
Other climate/weather attributes				
Change in annual average potential evapotranspiration	3.6%	-	12.5%	Based on climate change projections for Southern Slopes cluster, www.climatechangeinaustralia.gov.au
Average relative humidity (%)	-0.8%	-	-2.4%	
Average wind speed (%)	+0.2%	-	+1.4%	
Atmospheric concentration of CO_2 (ppm)	449	677	936	Based on IPCC data (IPCC, 2013b) for RCP8.5. This is the atmospheric concentration of CO_2 rather than CO_2 equivalents.

Notes:
1. The ranges shown incorporate rainfall values for the 50th and 90th percentile climate models, selected on the basis of warming
2. Days/y Tmax ≥ - average number of days/y in which daily maximum temperature exceeds the benchmark temperature.

Table H.5 Adopted climate change projections – Narrabri

ATTRIBUTE	2030	2070[1]	2090[1]	SOURCE
Projected rainfall				
Mean annual rainfall (mm)	701	518 – 584	555 – 715	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
2.5% AEP daily rainfall event (mm)	168	184 – 190	193 – 200	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
Climate change factor for extreme rainfall events	+5.6%	+15.8%	+21.3%	Based on Australian Rainfall and Run-off projections.
Projected temperature				
Maximum projected temperature (°C)	47.8	48.2	50.9 – 51.6	Climate Change in Australia Climate Futures Tool – for Central Slopes sub-cluster
Average maximum temperature (°C)	26.7	28.0	29.8 – 30.7	
Average annual temperature (°C)	19.3	20.4	22.5 – 23.2	
Average minimum temperature (°C)	11.9	12.9	15.3 – 15.8	
Minimum temperature (°C)	-4.4	-2.9	-1.5 – -1.6	
Average number of days per year in which freezing minimum temperatures are recorded	10.0	4.3	0.7 – 1.0	
Days/y Tmax8 ≥35°C	45.4	54.3	96.4 – 122.9	
Days/y Tmax8 ≥40°C	3.8	4.8	20.3 – 36.9	
Days/y Tmax8 ≥45°C	0.0	0.0	1.1 – 2.6	
Days/y Tmax8 ≥50°C	0.0	0.0	0.0 – 0.0	
Other climate/weather attributes				
Change in annual average potential evapotranspiration	3.6%		12.5%	Based on climate change projections for Southern Slopes cluster, www.climatechangeinaustralia.gov.au
Average relative humidity (%)	-0.8%		-2.4%	
Average wind speed (%)	+0.2%		+1.4%	
Atmospheric concentration of CO_2 (ppm)	449	677	936	Based on IPCC data (IPCC, 2013b) for RCP8.5. This is the atmospheric concentration of CO_2 rather than CO_2 equivalents.

Notes:
1. The ranges shown incorporate rainfall values for the 50th and 90th percentile climate models, selected on the basis of warming.
2. Days/y Tmax ≥ - average number of days/y in which daily maximum temperature exceeds the benchmark temperature.

Risk narratives

Several key narratives have been identified in relation to different climate-related hazards that are rated as medium and above on the risk matrix. The following are risks prioritised for treatment by ARTC and the ISCA sustainability rating tools (extreme, high and medium priority risks) and include both short and long-term risks.

More intense river and stormwater flooding

Average annual rainfall is projected to decline and extreme rainfall events may intensify due to warming of the atmosphere and the associated increase in water holding capacity. Overland flows and fluvial (waterway) flooding could increase, which could directly impact N2N infrastructure such as culverts, rail embankments, rail lines, rail bridges.

More intense drought

Declining average annual rainfall can exacerbate droughts and loss of ground cover during droughts could create dust issues along the alignment and increase erosion during any excess rain or flood event. Examples of low and medium level risks identified include structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying (especially periods where there is a swift transition from dry to wet), reducing integrity of tracks, bridges, embankments and signalling infrastructure with potential structural failure.

Increased occurrence of extreme weather events

Intense frontal weather systems affecting south-eastern Australia during summer could increase and increased frequency and intensity of storm events and subsequent higher winds could result in damage to rail line communication equipment, loss of power supply, damage to signage and level crossings, all of which could lead to delays and safety issues for trains and motorists.

More extreme high temperatures

The frequency and severity of extreme heat events are projected to increase as a direct result of climate change which could lead to train operation and infrastructure being impacted during summer. Extreme heat events could damage tracks and signalling infrastructure, as well as electronic controls, which could lead to delayed services, failure of power supply and potentially hot works igniting due to hot, dry and windy conditions.

Increased bushfires and fire weather conditions

Incidences of dangerous fire weather conditions and potentially uncontrollable bush or grass fires could increase due to longer, drier and hotter summer periods. Bushfires pose risks to the proposal infrastructure as well as access roads around the Pilliga State Forest. Rail infrastructure such as signals, communication equipment could be damaged by bushfires and power supply could be interrupted as a result. The disruption could impact efficient freight delivery if service is forced to wait or stop.

Summary of risk assessment results

Table H.6 outlines the number of inherent risks (risks only treated with BAU controls) identified by the current climate change risk assessment, based on climate-related risk narratives and at varying level of risk based on a 2090 scenario. Table H.7 shows the results of the risk assessment for the 2090 inherent risks for the proposal.

Table H.6 Number of climate change risks for each climate-related risk narrative

CLIMATE-RELATED RISK NARRATIVE	LOW RISKS (2090)	MEDIUM RISKS (2090)	HIGH RISKS (2090)	VERY HIGH RISKS (2090)
More intense river and stormwater flooding	4	7	5	1
More intense drought	1	1		
Increased occurrence of extreme weather events	2	2		
More extreme high temperatures	4	4		
Increased bushfires and fire weather conditions	4	3	1	
Total	**15**	**17**	**6**	**1**

Table H.7 Climate change risk impact and current adaptation inherent in design/operations, under a 2090 scenario

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
Temperature increase - more hot days and warm spells	Increased hot spells and heat waves leads to more frequent heat stress or heat related illness for staff or visitors working along the rail corridor.	Direct	Pre work brief Monitoring and responding to extreme weather events Access to corridor Night working across the Nullarbor Heat stress training Hazards and new miss reporting First aid training	C	2					1		2	Low – 2C
	Increased risk to business continuity as a result of increased heat events (eg increased incidence of delayed services).	Direct	Monitoring and responding to extreme weather events Business continuity plans for each site ETM-06-08 Managing Track Stability ETM-06-08F-01 Misalignment/Buckle Report ETI-06-07 Responding to Buckles Put speed restrictions in place (more cautious in Jan and Feb due to uncertainty of how work upgrades will perform)	A		1	2					2	Med – 2A

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in hot days results in track twisting (buckling) which could lead to derailment of trains along the rail line.	Direct	Monitoring and responding to extreme weather events ETM-06-08 Managing Track Stability ETM-06-08F-01 Misalignment/Buckle Report ETI-06-07 Responding to Buckles Put speed restrictions in place (more cautious in Jan and Feb due to uncertainty of how work upgrades will perform) Stop operations in peak heat Ongoing review of stress free setting for track	C	3	3	1					3	Med – 3C
	Decreased efficiency and more frequent outages of electrical (track switches, signalling, etc) and communication systems.	Direct	Standards and type approvals Redundancies and continuity plans Run under degraded conditions as per ARTC standards	B		1	1					1	Low – 1B

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increased extreme temperature and solar exposure may lead accelerated degradation of materials and reduced life of structures (bridges, crossings, track) and specialist equipment (communications towers, signalling) resulting in increased capital cost due to the need for more frequent repairs and maintenance.	Direct	Type approval process General standards	B			1					1	Low – 1B
	Increased extremes of heat leads to increased power demand and/or failure of power infrastructure (ie substations, LV/HV switchboards) resulting in interruptions to mains power supply with increased frequency and duration of power outages.	Indirect	Redundancies and continuity plans Business continuity plans Remote sensing and remote monitoring Run under degraded conditions as per ARTC standards There is backup for critical systems (eg solar and battery), however no Uninterrupted Power Supply (UPS) for level crossings	B		2						2	Med – 2C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increased incidence of extreme heat limiting the ability for ARTC to attract workers due to undesirable conditions.	Indirect	Staff survey and feedback process	C			2					2	Low – 2C
	Increased extreme heat/ hot spells leads to rolling stock or hot works igniting fire due to hot, dry and windy conditions.	Direct	Hot works procedure during extreme temperature (total fire ban, hot works application to go through) Welders qualified for managing heat and hot works (with rural fire brigade) Monitoring of noise and temperature of wheels and brake assembly. If temperature reaches a certain limit it will alert operating staff	B	2	2				2		2	Med – 2B

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
Increased intensity of extreme rainfall events	Increased frequency of extreme rainfall events leads to flash flooding events, which increases risk to health and safety of staff (eg conductor, emergency crews) working along the rail corridor due to velocity and flow of flooding.	Direct	Monitoring and responding to extreme weather events procedure (code red, amber and black procedure). Assessment is looking at 1/200 and 1/500 floods (in accordance with the SEARs) as proxies for climate change	B	2							2	Med – 2B
	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage due to scour.	Direct	Monitoring and responding to extreme weather events procedure Inland Rail hydrological risk assessment framework inclusive of climate change impacts ARR16 modelling approach. Sensitivity analysis as part of the hydrological risk assessment framework Modelling verification in areas requiring flood works permits. Greenfield projects undertaking sensitivity analysis and risk modelling so design can be adjusted for climate change (if deemed necessary)	B	3	3	1			1		3	High – 3B

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	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.	Direct	Monitoring and responding to extreme weather events procedure Inland Rail hydrological risk assessment framework inclusive of climate change impacts Culverts will not have consideration of climate change built in	B	3	3						3	High – 3B
	Increase in intense rainfall could result in overtopping leading to damaged infrastructure.	Direct	Track level will have mitigation built in, with protection of 1/100 flood to top of formation (this doesn’t include ballast and track). Free board will include consideration of climate change, and based on the change from baseline conditions will require a freeboard ‘test’ to be undertaken. The results of this are considered in the final alignment height. Assessment is looking at 1/200 and 1/500 floods (in accordance with the SEARs) as proxies for climate change.	B		4	3					4	V High – 4B

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	More intense extreme rainfall events leads to longitudinal scour through water running along embankment, impacting on embankment.	Direct	Inland Rail hydrological risk assessment framework inclusive of climate change impacts Sensitivity analysis as part of the hydrological risk assessment framework Embankments – designed for some displacement of materials. Post flood checks will be undertaken when safe.	B	3	3	3					3	High – 3B
	Increased extreme rainfall results in inundation of adjacent road network and signalling equipment causing potential isolation of assets due to flooding.	Direct	Run under degraded conditions as per ARTC standards	B	2	2						2	Med – 2B
	More intense extreme rainfall events leads to flooding of tracks and assets, inundation of drainage infrastructure, increasing maintenance and insurance premiums costs.	Direct	Monitoring and responding to extreme weather events procedure Inland Rail hydrological risk assessment framework inclusive of climate change impacts	A			2					2	Med – 2A

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	More intense extreme rainfall events leads to inundation of adjacent road network impacting on ability of emergency response to reach the corridor.	Direct	Out of inland rail control	B						2		2	Med – 2B
	Increased depth and duration of flooding results in water damage to signalling, substations and electrical circuitry. This may result in disruption to electricity supply thereby impacting the functionality of level crossings, signals and utility supply.	Direct/ Indirect	All signalling equipment installed above 1% AEP Monitoring and responding to extreme weather events Operational procedures when level crossings fail Redundancy through two power supplies, solar/batteries, with up to 48hrs power.	C		2	1					2	Low – 2C
	Extreme rainfall leading to flooding/standing water resulting in the increased presence/risk of disease and water-borne pathogens impacting the health and safety of employees.	Direct	Pre work brief Work method statements	D	2							2	Low – 2D

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increased frequency and intensity of extreme rainfall and flooding causing damage to non-rail structures potentially impacting operations.	Direct	Ability to comment on land developments on adjacent properties	C		3						3	Med – 3C
	Increase in intense rainfall could result in regional isolation and/or service interruption due to flooding along the 1,700 km route.	Direct	Inland Rail hydrological risk assessment framework inclusive of climate change impacts Property strategy to deal with severance issues	C			2					2	Low – 2C
	The projected periodic extreme dry and wet periods may increase the potential for erosion of substrate and ballast materials, causing increase washout. This could cause infrastructure instability, train derailment and disruption in the event of collapse.	Direct	Track inspection procedure Review and update in accordance with any updates to standards Embankments are designed for some displacement of materials. Post flood checks are undertaken when safe.	C		3	3			3		3	Med – 3C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increased intense rainfall and flooding resulting in scour damage to adjacent properties.	Direct	Agronomy assessment in hydrology design Consultation as part of EIS	B			2			3		3	High – 3B
	Climate change projects a greater incidence of flooding, greater afflux and potentially more debris as a result of temperature changes. Potential blockages of drainage infrastructure caused by the movement of debris during flood.	Direct	No climate change protection for culverts (this is standard). These will be slightly increased anyway to provide some additional capacity and to account for debris and blockage.	B		2						2	Med – 2B
	Increased rainfall leading to rise of groundwater resulting in reduced durability of materials.	Direct		D			2					2	Low – 2D

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increased rainfall intensities lead to greater discharges, which leads to increased hydraulic impacts (eg afflux) on adjacent properties.	Direct		B					3	3	3	3	High – 3B
Decrease in average rainfall	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying (especially periods where there is a swift transition from dry to wet), reducing integrity of tracks, bridges, embankments and signalling infrastructure with potential structural failure.	Direct	Basis of design Real time monitoring of track conditions	D		4	3					4	Med – 4D

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Decrease in average rainfall leads to deterioration of vegetation cover on embankments. This leads to greater erosion of embankments when cover not provided.		Vegetation management	C		2	2					2	Low – 2C
Increase in extreme weather events and storms	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.	Direct	Vegetation management Extreme weather redundancies	C			2					2	Low – 2C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in the frequency and intensity of storm events results 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.	Direct/Indirect	Monitoring and responding to extreme weather events procedure Land form procedure Run under degraded conditions as per ARTC standards	C		3						3	Med – 3C
	Increase in the frequency and intensity of storm events and subsequent higher winds resulting in derailment (loss of freight, rolling stock, cessation of operation) including damage to infrastructure.	Direct/Indirect	Monitoring and responding to extreme weather events procedure Run under degraded conditions as per ARTC standards	D		3	3			2		3	Low – 3D

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in the frequency and intensity of storm events and subsequent higher winds resulting in damage to level crossings and associated signage, resulting in safety issues for trains and motorists.	Direct	Monitoring and responding to extreme weather events procedure Run under degraded conditions as per ARTC standards	C	3					3		3	Med – 3C
Harsher fire-weather conditions	Increase in the frequency and intensity of bushfires resulting in limited visibility, which in turn results in increased risk of freight disruptions and/or cancellations.	Direct	Monitoring and responding to extreme weather events procedure Run under degraded conditions as per ARTC standards Emergency Service Bushfire Procedure ARTC Emergency management procedures/policies	C		2						2	Low – 2C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in the frequency and intensity of bushfires which cause greater than expected damage to rail infrastructure including trackside infrastructure (eg signals, communications equipment requiring increased operational costs).	Direct	Material durability Standards and type approvals (eg bury pipes not above ground) Vegetation management Emergency Service Bushfire Procedure ARTC Emergency management procedures/policies	C			3					3	Med – 3C
	Increased risk to health and safety of staff working along the rail corridor due to inhalation of bushfire smoke and proximity to flames.	Direct	Pre work brief Monitoring and responding to extreme weather events procedure Emergency Service Bushfire Procedure ARTC Emergency management procedures / policies	C	2							2	Low – 2C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
Harsher fire-weather conditions	Increased frequency and intensity of bushfire events leads 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.	Indirect	Redundancies built in	C		3						3	Med – 3C
	Increase in the frequency and severity of bushfire events results in regular use of rail corridor as access/egress by the surrounding community.	Indirect	Emergency Service Bushfire Procedure ARTC Emergency management procedures / policies	C		2				2		2	Low – 2C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in the frequency and intensity of bushfire events results in closure of surrounding road network, impacting emergency access, rescue, community evacuation or maintenance.	Indirect	Existing risk Monitoring and responding to extreme weather events procedure Under direction of EMS (signalling equipment is fire resistant) Reducing severance is considered in basis of design	E	4					4		4	Low – 4E
	Increase in the frequency and intensity of bushfire events along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and County Fire Authority access/egress points.	Indirect	Existing risk Monitoring and responding to extreme weather events procedure Under direction of EMS (signalling equipment is fire resistant) Reducing severance is considered in basis of design Increased clearance of corridor from 40m not considered due to other sustainability impacts	C		4						4	High – 4C

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
	Increase in the frequency and intensity of bushfire events along the Inland Rail corridor resulting in more frequent stoppage of freight along the rail and subsequent impacts on customers good not being delivered.	Indirect	Monitoring and responding to extreme weather events procedure Under direction of EMS (signalling equipment is fire resistant)	B						2		2	Med – 2B
Multi-hazard (flooding and warmer days)	Changing climatic conditions leading to changing farming practices, as well as the spread of weeds and water-borne pathogens reducing the productivity of farms; subsequently the demand for ARTCs services.	Indirect	Agronomist assessment	B			1					1	Low – 1B

CLIMATE HAZARD	RISK IMPACT DESCRIPTION	DIRECT/ INDIRECT RISK	ADAPTATION INHERENT IN DESIGN/OPERATIONS (INCLUDING ARTC OPERATIONAL PROCEDURES)	2090 INHERENT RISK									
					Consequence								
				Likelihood	Safety	Assets	Financial	Environmental	Regulator	Reputational	Schedule	Max Consequence	Initial risk
Multi-hazard (increased CO_2, humidity and temperature)	Changing climatic conditions leading to increased carbonation of concrete structures resulting in exposure of reinforcement requiring extensive remediation. Structures do not last as long as projected resulting in increased maintenance costs.	Indirect	ARTC standard designs	B		1	1					1	Low – 1B

Climate change adaption measures

Based on the identified risks and potential impacts, appropriate adaptation measures and/or design strategies are recommended. Adaptation responses can be grouped according to the type of treatment. Depending on the level, type and certainty of specific climate risks, adaptation can be either reactionary or precautionary. Development of adaptation responses should be both relevant and targeted.

The framing process for identifying 'adaptations' or 'resilience measures' (based on Smit et al., 2000) considers four main questions:

- adaptation to what?
- who or what adapts?
- how does adaptation occur?
- how effective is the adaptation?

Adaptation measures considered during reference design

The following climate change considerations have been implemented during the reference design:

- consideration of climate and weather events to avoid an increase in flood risk to neighbouring properties and the environment for extreme rainfall and weather events both now and in the future including extreme rainfall events including the one in two thousand and one in ten thousand events
- consideration of climate change in modelling to inform design of drainage and waterways including the following:
  - application of the latest *Australian Rainfall and Runoff Interim Climate Change Guidelines* (Engineers Australia: Water Engineering, 2014):
  - assessment of impacts associated with the 1% Annual Exceedance Probability (AEP) to determine the sensitivity of the design to potential changes in the rainfall intensity
  - where new track is to be constructed in greenfield areas, track crossing and longitudinal drainage shall have capacity to convey the 1% annual exceedance probability without over topping formation
  - where enhancement or upgrading to existing track is to be undertaken, no worsening of the existing track flood immunity will occur
- consideration and implementation of adaptation options associated with the direct and indirect impacts of climate change and natural disaster events to reduce the potential for service disruption.

Table H.8 details the mitigation measures identified for each climate change related risk with a medium rating or higher that are proposed to be undertaken during detailed design, construction and operation. It is proposed that these would be reviewed and adapted as appropriate as the design progresses.

Table H.8 Climate change adaptation measures

STAGE	RISK	ADAPTATION MEASURE
Detailed design/pre-construction	Increase in hot days results in track twisting (buckling) which could lead to derailment of trains along the rail line.	Design for future extreme temperatures (eg turn outs and grade separations). Instrument the track.
	Decreased efficiency and more frequent outages of electrical (track switches, signalling, etc) and communication systems.	Ensure that specifications for temperature tolerance of electrical and electronic equipment allows for future climate change (taking into account its intended lifespan).
	Increased extremes of heat lead to increased power demand and/or failure of power infrastructure (ie substations, LV/HV switchboards) resulting in interruptions to mains power supply with increased frequency and duration of power outages.	Future proof to ensure alternative power sources are possible.
	Increased extreme heat / hot spells leads to rolling stock or hot works igniting fire due to hot, dry and windy conditions.	Review wayside device placement and strategy for the life of the asset to include more at certain key points in the network.
	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage due to scour.	Design for retrofit upgrade (eg raising track, glued ballast) to allow for re-analysis in 30 years' time when there will be additional rainfall and runoff data. Review risks in line with updates to the ARR guideline (about every 30 years)/or in line with an extreme flooding event (eg overtopping, 1% event becomes a 5% event). Then multi-criteria analysis to determine what actions to take to reduce risk (being completed as part of the design process, but an ongoing requirement). Include RCP8.5 in flooding and hydrology assessments to assess impacts of climate change (being completed as part of the initial design work).
	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.	
	Increase in intense rainfall could result in overtopping leading to damaged infrastructure.	
	More intense extreme rainfall events leads to longitudinal scour through water running along embankment, impacting on embankment.	
	Increased extreme rainfall results in inundation of adjacent road network and signalling equipment causing potential isolation of assets due to flooding.	As above, plus option of solar back-up on most level crossings and minimisation of number of level crossings.

STAGE	RISK	ADAPTATION MEASURE
	Increased depth and duration of flooding results in water damage to signalling, substations and electrical circuitry. This may result in disruption to electricity supply thereby impacting the functionality of level crossings, signals and utility supply.	Investigate potential to future proof power supply design to allow for replacement and upgrade to more resilient technology.
	The projected periodic extreme dry and wet periods may increase the potential for erosion of substrate and ballast materials, causing increase washout. This could cause infrastructure instability, train derailment and disruption in the event of collapse.	Install track inspections and monitoring stations to check in on these changes especially in vulnerable areas. Install proximity sensors.
	Climate change projects a greater incidence of flooding, greater afflux and potentially more debris as a result of temperature changes. Potential blockages of drainage infrastructure caused by the movement of debris during flood.	Account for climate change throughout the design process (design with climate change in for critical assets/infrastructure). Climate change projections should be fed into flooding and hydrology assessments to determine additional impacts. Climate change has been factored into early assessments of flooding and hydrology.
	Increased rainfall intensities lead to greater discharges, which leads to increased hydraulic impacts (eg afflux) on adjacent properties.	Reassess rainfall data throughout the design process and re-run models to check what impacts are now likely to affect adjacent properties (number of properties in the 1% AEP floodplain may change). Climate change has been factored into early assessments of flooding and hydrology.
	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying (especially periods where there is a swift transition from dry to wet), reducing integrity of tracks, bridges, embankments and signalling infrastructure with potential structural failure.	Design of critical infrastructure to consider encapsulating materials inside to prevent impacts. Geotechnical analysis and design should adopt a conservative approach.
	Increase in the frequency and severity of bushfire events results in regular use of rail corridor as access/egress by the surrounding community.	Fencing strategy to be determined in detailed design stages.
	Increase in the frequency and intensity of bushfire events along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and County Fire Authority access/egress points.	Implement grade separations in high risk areas (over bridge).

STAGE	RISK	ADAPTATION MEASURE
Operation	Increased hot spells and heat waves leads to more frequent heat stress or heat related illness for staff or visitors working along the rail corridor.	Learning from other locations to ensure a consistent approach across the Australian Network (eg expanding night works). Apply learnings from hazard and near miss reporting. Development of a climate change monitoring and adaptation management plan. This document will set a framework for addressing all climate change impacts into the future.
	Increased risk to business continuity as a result of increased heat events (eg increased incidence of delayed services).	During operations consider impacts on contracting and reliability criteria, adjusting level of service offering.
	Increase in hot days results in track twisting (buckling) which could lead to derailment of trains along the rail line.	Ensure stress free temperature is monitored and issues are identified early. Recognising trigger points for speed restrictions when temperature is reached in the rail. Ensure and enforce high quality of the build / welds and track adjustment. Install Stress Free Temperature monitoring instrumentation to the rails.
	Increased extremes of heat lead to increased power demand and/or failure of power infrastructure (ie substations, LV/HV switchboards) resulting in interruptions to mains power supply with increased frequency and duration of power outages.	Review and retrofit for new technologies and improvements (ongoing), keep up to date. Consider asset replacement time horizons to ensure appropriateness and suitability for service. Forward maintenance strategy (trial, test and approval) and non-mandated review periods.
	Increased incidence of extreme heat limiting the ability for ARTC to attract workers due to undesirable conditions.	Attractive salary and workforce reward systems (competition with other industries ie mining companies in parts of the country). Note: this will be a common issue for many companies in response to heat so there will likely be an industry wide response.
	Increased extreme heat / hot spells leads to rolling stock or hot works igniting fire due to hot, dry and windy conditions.	Stipulate requirements around rolling stock in customer contracts (however avoid excluding those who cannot afford new stock).
	Increased frequency of extreme rainfall events leads to flash flooding events, which increases risk to health and safety of staff (eg conductor, emergency crews) working along the rail corridor due to velocity and flow of flooding.	Connect with and learn from emergency services, establish communications channels and procedures. Increase training on emergency event response.

STAGE	RISK	ADAPTATION MEASURE
	The projected periodic extreme dry and wet periods may increase the potential for erosion of substrate and ballast materials, causing increase washout. This could cause infrastructure instability, train derailment and disruption in the event of collapse.	Routine LIDAR runs to determine mass/soil changes/movements.
	Increased intense rainfall and flooding resulting in scour damage to adjacent properties.	Collect baseline photographic evidence of current conditions (visual monitoring / dilapidation survey) pre construction. Especially useful for new greenfield sites. Cameras on monitoring vehicles/trains (AK cars – three monthly). Updating commissions and operational monitoring. – mobile video cameras on drones and GPS spot checks.
	Increased rainfall intensities lead to greater discharges, which leads to increased hydraulic impacts (eg afflux) on adjacent properties.	Renegotiation of insurance premiums (where impacts may be foreseeable).
	Increase in the frequency and intensity of bushfire events along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and County Fire Authority access/egress points.	Expand early warning network for fire (currently mainly used for flood). Trains advised to not leave major centres and if no assessment is possible then the network is shut down (more difficult in fire due to uncertainty of fire behaviour, this should improve with time with real-time data collection). Development of a Bushfire Management Plan for operational purposes.

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