BOTANY RAIL DUPLICATION

TECHNICAL REPORT

Technical Report 16 –
Climate Change Assessment

Botany Rail Duplication - Environmental Impact Statement

Technical Report 16 – Climate Change Assessment

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Glossary and abbreviations

AEP	Annual exceedance probability
ARTC	Australian Rail Track Corporation (the proponent)
BOM	Bureau of Meteorology
Botany Line	A dedicated freight rail line (operated by ARTC) that forms part of the Metropolitan Freight Network. The line extends from near Marrickville Station to Port Botany.
detailed design	The stage of design where project elements are design in detail, suitable for construction.
EIS, the	Botany Rail Duplication environmental impact statement
embankment	A raised area of earth or other materials used to carry a rail line in certain areas.
existing rail corridor	The corridor within which the existing rail infrastructure is located. In the study area, the existing rail corridor is the Botany Line.
impact	Influence or effect exerted by a project or other activity on the natural, built and community environment.
IPCC	Inter-governmental Panel on Climate Change
LGA	local government area
NARCLiM	The NSW and ACT Regional Climate Modelling
project site, the	The area that would be directly affected by construction (also known as the construction footprint). It includes the location of operational project infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the storage areas/compounds etc, that would be used to construct that infrastructure.
project, the	The construction and operation of the Botany Rail Duplication
RCP	Representative Concentration Pathways
Secretary's environmental assessment requirements (SEARs)	Requirements and specifications for an environmental assessment prepared by the Secretary of the Department of Planning and Environment under section 115Y of the *Environmental Planning and Assessment Act 1979* (NSW).
State significant infrastructure	Major transport and services infrastructure considered to have State significance as a result of size, economic value or potential impacts.

Executive summary

Climate change is having worldwide impacts on society, the economy and the environment. The Intergovernmental Panel on Climate Change (IPCC) predicts that even if greenhouse gas emissions are significantly reduced, global warming trends and other associated impacts from climate change will continue for centuries due to the long lag times associated with climate processes.

This climate change assessment is a preliminary assessment that aims to assess the potential risks to the project from future climate change and identify mitigation measures to make assets, and operation of these assets, more resilient in the future.

A risk assessment approach was used to assess the impacts of future climate change on the project. This risk assessment was carried out in accordance with *AS 5334 'Climate change adaptation for settlements and infrastructure – A risk based approach'*.

Climate projection data used to inform the risk assessment were sourced using the following hierarchy:

1. NSW and ACT Regional Climate Modelling project (NARCLiM) (where sufficient climate variable data exists).
2. CSIRO Climate Futures climate modelling projections for the East Coast Cluster (RCP 8.5) for variables not covered by NARCLiM.

No extreme risks were identified in the climate risk assessment. One high risk was identified in relation to the failure of communications and signalling systems caused by flooding as a result of an increase in rainfall intensity combined with sea level rise.

A range of medium risks were identified for the follow climate change variables:

- Increased rainfall intensity combined with sea level rise potentially resulting in:
  - localised flooding causing scour of the track formation and ballast
  - reduced performance of surface drainage systems caused by increased rainfall intensity contributing to localised flooding.
- Increases in average annual temperatures and the number of extreme heat days potentially resulting in:
  - track buckling increasing operational and maintenance costs, cause delays and potential derailments
  - more frequent malfunctioning of communication and signalling systems; therefore causing delays on the rail network
  - high demand on the wider electricity grid leading to a loss of signalling systems and therefore cause delays on the rail network
  - more frequent thunderstorms and associated lightning strikes resulting in damage and potential failure of signalling systems
  - maintenance staff unable to perform maintenance tasks due to extreme temperature events impacting on maintenance schedules.
- Increases in the frequency of extreme wind events resulting in:
  - damage to vegetation adjacent to the alignment which can become a hazard on the trail tracks.

The risks and potential adaptations outlined in this climate change assessment should be considered for implementation during detailed design and the preparation of operational procedures. The key treatments recommended include:

- allowing for an increase in rainfall intensity due to climate change when determining the location of critical rail system infrastructure such as rail system location cases
- allowing for an increase in rainfall intensity due to climate change when designing the drainage infrastructure
- designing ventilation systems for signalling equipment rooms/location cases that allow for increased temperatures due to climate change
- considering the impacts of extreme temperatures on the performance of the rail tracks and consider adjusting design specifications where required
- Limit outside exposure of cables where possible, ensure the installation of surge protection, and provide a redundant power source to reduce likelihood and impacts of lightning strikes to exposed cables.
- the preparation of operational and maintenance plans that consider potential impacts from climate change such as increases in temperatures, increases in rainfall intensity and increases in the frequency of high intensity east coast lows that result in damaging winds.

1. Introduction

1.1 Overview

1.1.1 Background

Australian Rail Track Corporation (ARTC) proposes to construct and operate a new second track within the existing Botany Line rail corridor between Mascot and Botany, in the Bayside local government area (LGA). The Botany Rail Duplication ('the project') would increase freight rail capacity to and from Port Botany. The location of the project is shown in Figure 1.1.

The project is State significant infrastructure in accordance with Division 5.2 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). As State Significant Infrastructure, the project needs approval from the NSW Minister for Planning and Public Spaces.

This report has been prepared to accompany the environmental impact statement (EIS) to support the application for approval of the project, and address the Secretary of the Department of Planning and Environment's environmental assessment requirements (the SEARs), issued on 21 December 2018.

1.1.2 Overview of the project

The project would involve:

- Track duplication – constructing a new track predominantly within the rail corridor for a distance of about three kilometres.
- Track realignment (slewing) and upgrading – moving some sections of track sideways (slewing) and upgrading some sections of track to improve the alignment of both tracks and minimise impacts to adjoining land uses.
- New crossovers – constructing new rail crossovers to maintain and improve access at two locations (totalling four new crossovers).
- Bridge works – constructing new bridge structures at Mill Stream, Southern Cross Drive, O'Riordan Street and Robey Street (adjacent to the existing bridges), and re-constructing the existing bridge structures at Robey Street and O'Riordan Street.
- Embankment/retaining structures – construction of a new embankment and retaining structures adjacent to Qantas Drive between Robey and O'Riordan streets and a new embankment between the Mill Stream and Botany Road bridges.

Further information on the key elements of the project is provided in the EIS.

Ancillary work would include bi-directional signalling upgrades, drainage work and protecting/relocating utilities.

Subject to approval of the project, construction is planned to start at the end of 2020, and is expected to take about three years for the main construction works to be undertaken. Construction is expected to be complete in late 2023 with commissioning activities undertaken in early 2024.

It is anticipated that some features of the project would be constructed while the existing rail line continues to operate. Other features of the project would need to be constructed during programmed weekend rail possession periods when rail services along the line cease to operate.

The project would operate as part of the existing Botany Line and would continue to be managed by ARTC. ARTC is not responsible for the operation of rolling stock. Train services are currently, and would continue to be, provided by a variety of operators. Following the completion of works, the existing functionality of surrounding infrastructure would be restored.

Key features of the project are shown on Figure 1.2.

Figure 1.1 Botany Rail Duplication location

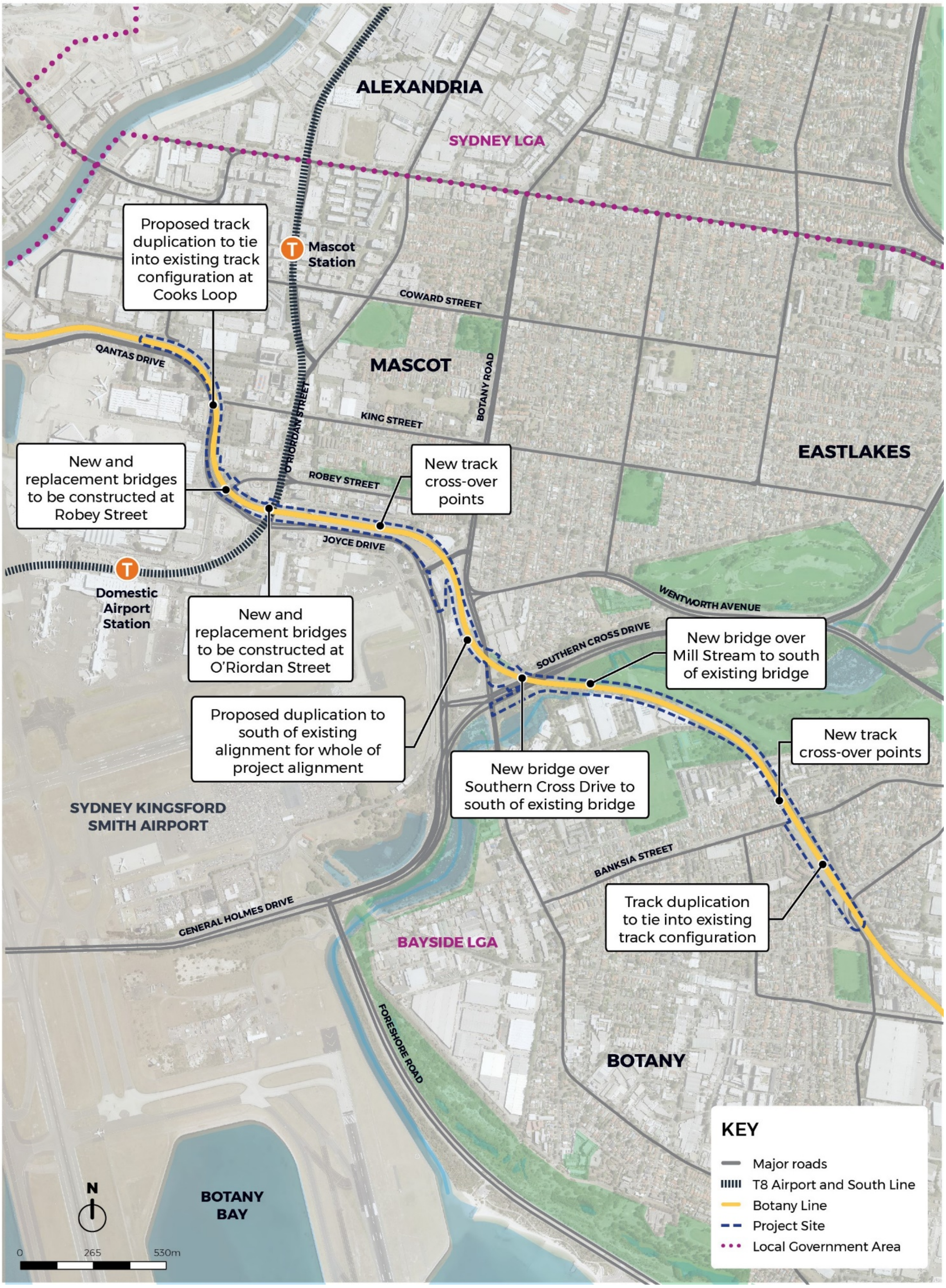

Figure 1.2 Botany Rail Duplication project overview

1.2 Purpose and scope of this report

The purpose of this report is to assess the potential risks to the project from future climate change and identify mitigation measures to make assets, and operation of these assets, more resilient in the future.

The report:

- describes the current and past climate of the project area
- describes the future climate change projections, for both the near and distant future
- assesses risk under future climate conditions through:
  - risk identification for key climate variables (e.g. extreme rainfall, temperature, wind speed and bushfires)
  - analysis of the risks
  - evaluation of the risks
- recommends measures to mitigate through the identification of climate adaptations in design and operation.

Unlike other impact assessments, this report focusses on the potential impacts *from* the environment (in this case through climate change) onto the project, rather than the potential impacts from the project *onto* the environment. This process enables future climate change to be considered during the design process to build more resilient infrastructure.

1.3 Structure of this report

The structure of the report is outlined below.

- Chapter 1 Introduction – provides an introduction to the report.
- Chapter 2 Legislative and policy context – describes the legislative and policy context for the assessment, and relevant guidelines.
- Chapter 3 Methodology – describes the risk assessment methodology.
- Chapter 4 Existing and future climate – establishes the existing climatic context and future climate change projections of the project area.
- Chapter 5 Climate change risk assessment – assesses risks for the project under future climate conditions, through risk identification, analysis and evaluation for key climate variables separated into:
  - impacts during construction
  - impacts during operation
  - cumulative impacts.
- Chapter 6 Management of impacts – provides management of impacts through risk treatment and identification of climate adaptation options in design and operation.
- Chapter 7 Conclusion – provides a conclusion of the assessment.

2. Legislative and policy context

This section summarises the legislation, guidelines and/or policies driving the approach to the assessment.

2.1 Relevant legislation, policies and guidelines

2.1.1 Commonwealth

National Climate Resilience and Adaptation Strategy (2015)

The Australian Government released a *National Climate Resilience and Adaptation Strategy* in 2015 that sets out how Australia will manage its risks and vulnerabilities to climate change and the Government's vision for a climate-resilient future. The strategy recommends the use of a risk management approach based on best available scientific data to guide climate resilience building and adaptation. This climate change assessment follows a best practice risk management framework and adopts the latest climate change projections for the region. This process is outlined in more detail in section 3 and section 4.

2.1.2 State

Environmental Planning and Assessment Act 1979

State significant infrastructure is regulated under the *Environmental Planning and Assessment Act 1979* (EPA Act), which requires proponents to apply to the NSW Minister of Planning for infrastructure approval, supported by a detailed EIS. This report forms part of the EIS for the project.

The NSW Department of Planning has issued project specific requirements (SEARs) setting out matters to be addressed in the EIS. SEARs relevant to climate change are listed in Table 2.1. These SEARs refer to the requirement to assess the risk and vulnerability of the project to climate change by quantifying specific climate change risks and incorporating specific adaptation actions in the design.

The NSW Climate Change Policy Framework (2016)

The NSW *Climate Change Policy Framework*, released in 2016, outlines NSW's long-term objectives to achieve net-zero emissions by 2050 and to make New South Wales more resilient to a changing climate. This framework guides NSW policy and programs.

The framework outlines that the NSW Government will implement policies and provide targeted information to assist in climate risk management. The release of the NSW and ACT Regional Climate Modelling project (NARCLiM) by the NSW Government allows projects such as the Botany Rail Duplication to understand the potential changes to the region's climate, to assess the associated climate change risks to the project and implement adaptation measures to build more resilient infrastructure. The NARCLiM climate change projections have been used to inform this assessment.

Sea Level Rise Policy Statement

The NSW Government released a *Sea Level Rise Policy Statement* in 2009. This policy statement recognises the long-term impacts of sea level rise and the potential social, economic and environmental impacts. The policy statement was prepared to assist councils, landowners, infrastructure providers and developers consider sea level rise in land use planning and development assessments. This policy statement was repealed in 2012 and the NSW Government announced that they would no longer prescribe state-wide sea level rise projections for use by councils. In the absence of a formal state government policy on sea level rise benchmarks to use in flood modelling assessments, the benchmarks prescribed in this policy statement have been adopted for assessing the impacts of sea level rise as outlined in the *Technical Report 6 – Flooding Impact Assessment.*

2.1.3 Standards and guidelines

The following international and Australian standards and guidelines have been used to guide this climate change assessment:

- *Australian Standard AS 5334-2013 'Climate change adaptation for settlements and infrastructure'* – provides guidance on managing climate change risks. AS 5334 follows the International Standard ISO 31000-2009 Risk Management. ISO 31000-2009 Risk Management – Principles and Guidance (adopted in Australia and New Zealand as AS/NZS ISO 31000:2009) provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and mitigations into their existing management and decision-making processes. AS 5334 has been adopted as the most relevant standard to follow for this assessment as it relates more specifically to climate change risks. It is considered that the report adheres to ISO31000:2009 by extension of adopting AS 5334.
- *Climate Change Impacts & Risk Management – A Guide for Business and Government* (DEH,2006) – provides guidance to integrate climate change impacts into risk management processes.
- *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007) – provides guidance on undertaking flood modelling sensitivity analysis to consider the potential impacts of climate change. The results of this modelling have been used to inform this climate change assessment. See *Technical Report 6 – Flooding Impact Assessment*.

2.2 Secretary's environmental assessment requirements

The SEARs relevant to this climate change impact assessment, together with a reference to where they are addressed in this report, are outlined in Table 2.1.

Table 2.1 SEARs relevant to this assessment

Requirements		Where addressed in this report
3. Assessment of Key Issues (2) For each key issue the Proponent must:		
a)	describe the biophysical and socio-economic environment, as far as it is relevant to that issue;	Section 4.1
b)	describe the legislative and policy context, as far as it is relevant to the issue;	Section 2
c)	identify, describe and quantify (if possible) the impacts associated with the issue, including the likelihood and consequence (including worst case scenario) of the impact (comprehensive risk assessment), and the cumulative impacts;	Section 5
d)	demonstrate how options within the project potentially affect the impacts relevant to the issue;	Section 5
e)	demonstrate how potential impacts have been avoided (through design, or construction or operation methodologies);	Section 5 and 6
f)	detail how likely impacts that have not been avoided through design will be minimised, and the predicted effectiveness of these measures (against performance criteria where relevant); and	Section 5 and 6
g)	detail how any residual impacts will be managed or offset, and the approach and effectiveness of these measures.	Section 5 and 6

Requirements	Where addressed in this report
16. Climate Change Risk	
1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	Section 3, 4 and 5
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 3, 4 and 5

3. Methodology

This is a preliminary climate change risk assessment undertaken to inform the EIS that will be submitted under the EP&A Act for the approval of the project. The below methodology has been used to inform this climate change assessment. This methodology aligns with the process outlined in AS 5334 *Climate change adaptation for settlements and infrastructure – A risk based approach* and *Climate Change Impacts & Risk Management – A Guide for Business and Government* (DEH,2006). The methodology involves:

- establishing the context
- undertaking a risk assessment
- proposing risk treatment/adaptations.

3.1 Establish the context

To assess climate change risks and build resilient infrastructure it is important to consider the existing climate and define how this is likely to change in the future. The project's location as well as the different components of the project and their associated design life and vulnerability to climate change variables should be considered to understand how the asset will be impacted over time. Aspects of the function of the asset – in this case a rail freight track – as well as the ARTC 's operational role were defined to provide context to the risk assessment process.

The NSW and ACT Regional Climate Modelling project (NARCLiM) and the CSIRO Climate Futures produce climate change projections that can be used to assess the impacts of climate change in New South Wales. A review of these projections was undertaken to adopt climate change projections to inform this climate change assessment. Existing climate data collated from the Bureau of Meteorology and this process and details of the adopted projections are outlined in section 5.

When undertaking a climate change risk assessment, it is important to consider the design life of the different asset components. Asset components with a long design life (for example structures) need to consider far future climate change impacts and imbed adaptations in the design process. Asset components with a short design life may be replaced a number of times before far future impacts are anticipated to occur, therefore adaptation measures might not be necessary at this time but should be considered in future upgrades. For the Botany Rail Duplication concrete structural load bearing elements such as bridges, drainage structures and civil track formations were considered to have a long design life of approximately 80 to 100 years. The track consisting ballast, sleepers and steel rail were considered to have a design life of approximately 30–50 years and signalling infrastructure were considered to have shorter design life of approximately 20–30 years. Due to the varying design life of the projects components near future and far future climate change projections have been considered.

As potential climate change impacts discussed in this assessment relate to long term impacts based on the near and far future projections, impacts associated with the construction of the project are not assessed as they are temporary in nature and are projected to conclude within present day climate.

3.2 Risk assessment

Project specific potential climate change risks were identified and assessed using a risk assessment process.

The risk assessment process included:

- **Risk identification**: Risk statements/scenarios were developed for the project. These risks were identified by reviewing the design components of the project and considering the potential impacts that the different climate change variables may have on these components. These risks include direct risk as well as risk that may occur upstream or downstream but have the potential to impact the project, these risks are known as indirect risks.
- **Risk analysis:** The likelihood and consequence of these risks were then analysed. Criteria detailed in the *AS 5334* (refer Appendix A) were used to analyse the likelihood and consequence of these statements/ scenarios. During this process the components design life, the risk of exposure to the climate change projections adopted for the project as well as any existing controls that would already be in place to mitigate these risks were considered.
- **Risk evaluation:** By combining the outcomes of the likelihood and consequence rating for each risk statement/scenario an overall risk rating was assigned. The risk level matrix from the *AS 5334* (see Appendix A) was used to assign this risk rating.

3.3 Risk treatment/adaptation

Based on the results of the risk assessment process, risk treatments/adaptations were considered for extreme, high and medium risks. See section 5 for a list of potential risk treatments/adaptations that should be considered for implementation. Climate change impacts and risk treatments/adaptations should be revisited as the design progresses.

The risks assessment as well as the identification of potential adaptation measures was undertaken in consultation with a multidisciplinary team of designers and sustainability/environmental assessment specialists. A review of risks assessments undertaken for other similar asset types was also undertaken to inform this assessment.

4. Existing and future climate

4.1 Existing environment

This section describes the existing environment for the project and provides climate change context.

4.1.1 Australia

Climate change is having worldwide impacts on society, the economy and the environment. In Australia, the *CSIRO Climate Change in Australia 2015* publication, states: "Observed climate information indicates that Australian average surface air temperature has increased by 0.9°C since 1910, and many heat-related records have been broken in recent years. Sea level has risen about 20 cm over the past century." Figure 4.1 illustrates the average increase in temperatures across Australia as determined by the Bureau of Meteorology (BOM).

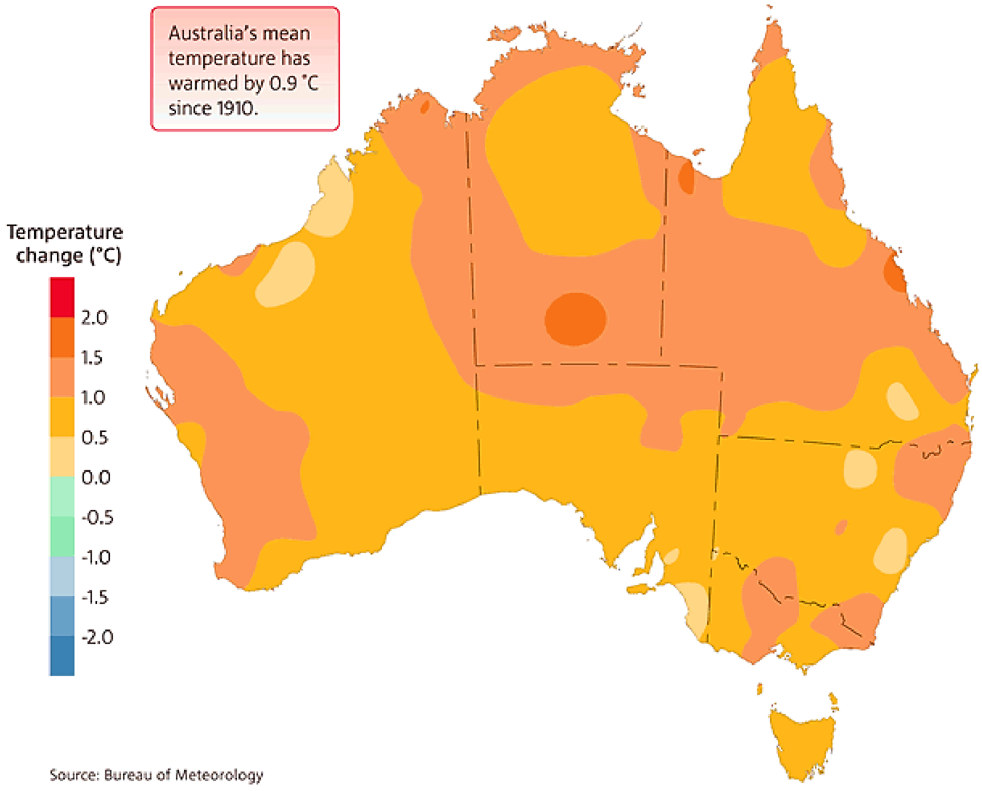

Figure 4.1 BOM mean temperature increase since 1910

The Intergovernmental Panel on Climate Change (IPCC) predicts that even if greenhouse gas emissions are significantly reduced, global warming trends and other associated impacts from climate change will continue for centuries due to the long lag times associated with climate processes.

Public policy and the design life of infrastructure demands an iterative appraisal of an asset's risk and resilience, so that its vulnerability and capacity to adapt to climate risks are understood and appropriate adaptations are planned for and implemented. Climate risks are reduced through the preparation of climate change assessments, such as this report. By using traditional risk management techniques to classify risks, adaptation strategies can be developed to futureproof the asset.

4.1.2 Local environment

The closest BOM weather station to the project is the Sydney Airport weather station, located within a 4 km distance of the project. This station is considered to be representative of the project area due to its close proximity to the project. Figure 4.2 illustrates historic climate data for the Sydney Airport AMO station from 1939 to 2018 (temperature) and 1929 to 2018 (rainfall). The data shows that on average the highest mean rainfall occurs in June and majority of the average rainfall falls in the first six months of the year. The highest recorded daily rainfall was 216.2 mm which occurred on 3 Feb 1990. The highest mean maximum temperatures during summer range from 25.9°C and 26.6°C and during winter range from 17.1°C and 18.4°C. The highest temperature recording during this time period was 46.4°C, which occurred on 18 January 2013.

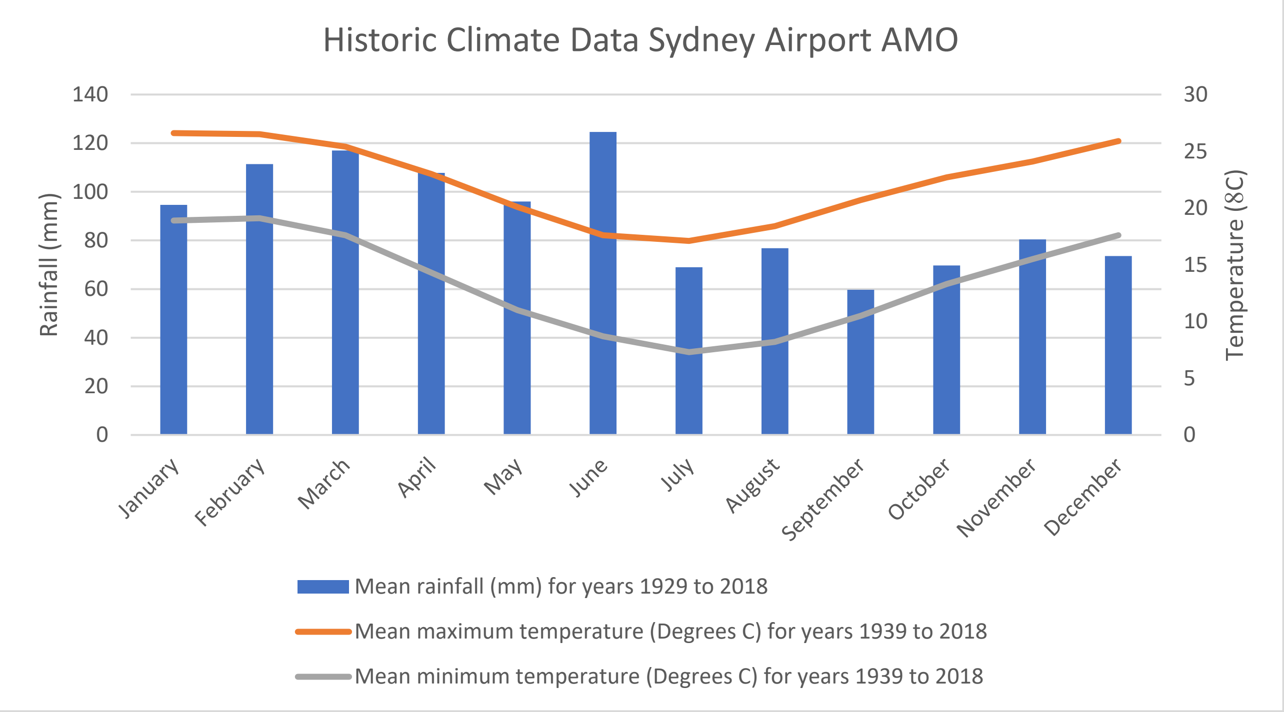

Figure 4.2 Historic climate data for Sydney Airport AMO (BOM, 2018)

4.2 Future climate projections

4.2.1 Climate projection data

Data used for the climate change risk assessment has been sourced using the following hierarchy:

1. NSW and ACT Regional Climate Modelling project (NARCLiM).
2. CSIRO Climate Futures climate modelling projections for variables not covered by NARCLiM.

Historical data has been sourced from Bureau of Metrology reporting on historical changes to Australia's climate.

The Metropolitan Sydney Climate Change Snapshot (OEH, 2014), used to inform this assessment, summarises NARCLiM projections for the Metropolitan Sydney Region, and are therefore at a lesser resolution than 10 km. After a review of more detailed mapping provided in *The Metropolitan Sydney Climate Change Snapshot* the projections adopted are considered to be representative of the changes anticipated at the location of the project, therefore meeting the 10 km resolution required by the SEARs.

For climate change variables not covered by NARCLiM, CSIRO projections provided in the *East Coast Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Report* (Dowdy, A et al. 2015) have been adopted. Projections are not available from the CSIRO at a resolution of 10 km, however these projections are the best available projections for the wider East Coast Cluster Region that Sydney is located within.

NARCLiM projections have been adopted to align with the SEARs requirement to utilise NSW Government projections to identify climate change risks. NARCLiM and CSIRO projections are considered appropriate projections to use as they are reliable sources of climate change projections that utilise global climate change modelling undertaken by the IPCC. Projections are also available for multiple timescales and between both data sources covers a wide range of climate change variables.

Due to the long design life of the project, when assessing the potential impacts from climate change, impacts in the near future (2030) and far future (2070) were considered. These are the two timeframes for climate change projections produced by NARCLiM.

4.2.2 Climate modelling

State governments and the CSIRO use global climate models and Intergovernmental Panel on Climate Change (IPCC) greenhouse gas concentration pathways to provide climate projections for each Australian region.

The IPCC has published four greenhouse gas concentration trajectories known as Representative Concentration Pathways (RCPs) which are used for climate modelling and research (see Table 4.1).

Table 4.1 RCPs and global warming

Scenario		Global warming mean and likely range by 2100 (°C)
RCP 2.6	Emissions peak 2010–2020, then decline substantially	1.0°C (0.3 to 1.7)
RCP 4.5	Emissions peak around 2040, then decline before stabilising prior to 2100	1.8°C (1.1 to 2.6)
RCP 6.0	Emissions peak around 2080, then decline and stabilise after 2100	2.2°C (1.4 to 3.1)
RCP 8.5	Emissions continue to rise throughout the 21st century	3.7°C (2.6 to 4.8)

The NARCLiM projections adopted for this assessment relate to an earlier release of climate models by the IPCC. It adopts a single emissions scenario known as the A2 scenario. This A2 scenario has a similar trajectory to RCP 8.5 therefore for the purpose of this assessment, RCP 8.5 has been adopted for variables where CSIRO projections have been used.

Flood modelling undertaken for the project that was used to inform this assessment adopted a more conservative sensitivity analysis approach to assess the impacts of climate change. Details of this model and how it relates to the climate change projections adopted for the project is outlined in more detail in section 4.3.

It should be noted that this exercise is a risk management process and like all other risk management processes it should be subject to review, adjustment and update over time as required to consider the risk at a certain point in time.

4.2.3 Climate change projections

This section describes the climate change projections adopted for the assessment. Climate change projections have been provided for variables considered relevant to the project and where reliable projection data is available. Other secondary and flow on effects have been considered under these variables in this risk assessment process.

The baseline (actual) climate that these projections relate to is the period of 1990–2009 (Office of Environment and Heritage (2014)). The NARCLiM projections provide two timescales for climate change projections; the years 2030 and 2070. These have been used to assess the near future and far future impacts on the project.

Air temperature

The Sydney area is predicted to continue to warm throughout the 21st century at a rate that directly aligns with increases in global greenhouse gases. Maximum surface air temperatures in the metropolitan Sydney region are projected to increase by 0.3–1.0°C in the near future (2030), and by 1.6–2.5°C in the far future (2070). Minimum temperatures are also projected to rise by 0.6°C in the near future (2030) and 2°C in the far future (2070) (Office of Environment and Heritage, 2014). All models show there are no declines in maximum temperatures across Metropolitan Sydney.

Days in which the maximum temperature is over 35°C are projected to increase across Sydney by an average of eleven days per year by 2070. The greatest increases are seen in the central part of greater Sydney from Picton to north of Wiseman's Ferry and out to Katoomba. These regions are projected to have an additional 15 hot days per year. While the remainder of Sydney will see at least four additional hot days per year.

Little change to solar radiation is projected in the near future with some increase projected in the far future during winter and spring (Dowdy, A. et al. 2015)

Increased temperatures may also increase the frequency of thunderstorms and associated lightning strikes that are common occurrences on the east coast of NSW. Currently there are no projections provided by NARCLiM or the CSIRO in relation to changes to the frequency or intensity of thunderstorms and/ or lightning strikes. A report published by the NSW Government Department of Environment, Climate Change and Water in 2010, *Climate Change and Water titled Impacts of Climate Change on Natural Hazard Profiles,* outlines that the changes to the frequency of lightning strikes are uncertain, however some studies have suggested a 5–6% change in global lightning frequency for every 1°C of global temperature change. In the absence of NARCLiM and CSIRO data these projections have been adopted as the potential risk of increased lightning strikes is considered a key risk for the project.

Precipitation and rainfall intensity increase

Sydney's rainfall is projected to decrease in spring in the near future, however the projections are less clear in the far future. Sydney's rainfall is projected to increase in autumn in the near future and far future (Office of Environment and Heritage, 2014). In the long-term rainfall is projected to decrease in winter and increase in summer.

Through understanding of physical processes and climate change modelling there is a high confidence that the intensity of heavy rainfall events will increase. In a warming climate, heavy rainfall events are expected to increase in intensity, mainly due to a warmer atmosphere being able to hold more moisture (Sherwood et al., 2010).

To undertake the risk assessment, the flood sensitivity analysis scenarios modelled for the *Technical Report 6 – Flooding Impact Assessment* have been used for rainfall intensity and sea level rise. These scenarios are outlined in section 4.3.

Sea level rise

Sea levels are projected to increase in the near and far future with very high confidence. In the near future (2030), the projected range of sea level rise for the region is 0.08–0.18 metres above 1986–2005 levels, with only minor differences between RCPs. Sea levels are projected to increase by 0.4–0.55 metres above 1986–2005 levels by 2070 and up to 0.9 metres by the end of the century. This projection for 2070 was interpreted from the *East Coast Cluster Report (*Dowdy, A. et al. 2015) to allow for alignment with the NARCLiM projection timeframes.

To undertake the risk assessment the flood sensitivity analysis scenarios modelled for *Technical Report 6 – Flooding Impact Assessment* have been used for rainfall intensity and sea level rise. These scenarios are outlined in section 4.3.

Bushfire risk

Sydney is expected to experience an increase in average and severe fire weather in the near and far future. This is projected mainly in the summer and spring in the far future (Office of Environment and Heritage, 2014). These changes are projected in spring, when prescribed burning is often undertaken as well as during summer which is the peak fire risk season.

The project is located in an urban area, bordering the Sydney Airport and the industrial, commercial and residential suburbs of Mascot, Botany and Tempe and is not located within a bushfire prone area. NSW Rural Fire Service Building Construction and Design requirements, Planning for Bush Fire Protection 2006, are therefore not applicable to the project. There is however the risk of the project being affected by smoke if fires were to break out in fire prone area such as Botany Bay National Park and the Royal National Park.

Average and extreme wind

The projections outline with high confidence that little change in mean surface wind speed is likely to occur under all RCPs in the near future. There is medium confidence that this will still be case in the far future. Decreases are also suggested for extreme wind speeds, particularly for the rarer extremes. Overall, scientific literature suggests a decline in the number of east coast lows (Dowdy, A, et al 2015) and therefore a decrease in the number of storm events that result in windy conditions. However, when these are events are considered on a scale of intensity, projections show a substantial increase in the frequency of high wind storms, particularly in the summer months, compared to low and mid-level events (Office of Environment and Heritage, 2016).

4.3 Climate change flood modelling

Flood modelling was undertaken by Lyall & Associates to assess the potential impacts of increases in rainfall intensity and sea level rise due to climate change on the project (see *Technical Report 6 – Flooding Impact Assessment*). This flood modelling was undertaken in accordance with the NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007) where sensitivity analysis is undertaken for scenarios representative of potential near-medium future and far future climates within the design life of the project. The scenarios modelled were:

- **Scenario 1** – based on an assumed 10 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.4 metres.
- **Scenario 2** – based on an assumed 30 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.9 metres.

A detailed methodology of the modelling that was undertaken is outlined in the *Technical Report 6 – Flooding Impact Assessment.*

Rainfall intensity and sea level rise projections are not available from NARCLiM. Under the CSIRO projections for the 2090-time period maximum 1-day rainfall events are projected to increase by a range of 2 to 22 per cent under the RCP 8.5 scenario. Sea level rise the two scenarios outlined above aligns within *The NSW Government Sea Level Rise Policy Statement* and the CSIRO projections for RCP 8.5 sea level rise. The above sensitivity analysis scenarios are therefore considered conservative scenarios to assess the potential impacts of future rainfall intensity and sea level rise.

4.4 Summary of climate change projections

Table 4.2 Key climate change projections

	2030	2070	Source
Projected temperature changes			
Maximum Temperature	Maximum temperatures are projected to increase in the near future by 0.7°C (0.3–1.0°C)	Maximum temperatures are projected to increase in the far future by 1.9°C (1.6–2.5°C)	NARCLiM
Minimum Temperatures	Minimum temperatures are projected to increase in the near future by 0.6°C (0.4–0.8°C)	Minimum temperatures are projected to increase in the far future by 2.0°C (1.4–2.5°C)	NARCLiM
Hot days	The number of hot days will increase in the near future	The number of hot days will increase in the far future	NARCLiM
	Average change +4 hot days per annum above 35°C	Average change +11 hot days per annum above 35°C	NARCLiM
Cold nights	The number of cold nights will decrease in the near future	The number of cold nights will decrease in the far future	NARCLiM
	Average change of 5 fewer cold nights per annum below 2°C	Average change of 12 fewer cold nights per annum below 2°C	NARCLiM
Projected rainfall changes			
Mean Rainfall	Rainfall is projected to decrease in spring and increase in autumn	Rainfall is projected to decrease in spring and winter. Rainfall is projected to increase in summer and autumn	NARCLiM
Rainfall Intensity	The intensity of rainfall events is projected to increase in the far future*		CSIRO
Projected sea level rise changes			
	Sea level is projected to increase 0.08 to 0.18 m above 1986–2005 levels in the near future*	Sea level is projected to increase 0.4–0.55 m above 1986–2005 levels in the far future*	CSIRO
Projected forest fire danger index (FFDI) changes			
	Average fire weather is projected to increase in spring in the near future	Severe fire weather days are projected to increase in summer and spring in the near future	NARCLiM
Projected wind speed changes			
	Minimal change in mean surface wind speed with an increase in the frequency of high intensity east coast lows that result in damaging winds in the near future.	Minimal change in mean surface wind speed with an increase in the frequency of high intensity east coast lows that result in damaging winds in the far future.	NARCLiM CSIRO
Lightning			

	2030	2070	Source
	The frequency of lightning strikes is predicted to increase in the near and far future.		Department of Environment, Climate Change and Water

**Refer to section 4.3 for an explanation of how rainfall intensity and sea level rise has been considered for this assessment.*

Source: NARCLiM projections from Metropolitan Sydney Climate Change Snapshot, OEH, 2013

Source: CSIRO projections from East Coast Cluster Report, Dowdy, A et al. 2015

5. Climate change risk assessment

The climate risk assessment is a critical step in preparing the climate change assessment. The climate change risk assessment and risk management approach aligns with the process outlined in AS 5334 *Climate change adaptation for settlements and infrastructure – A risk based approach* and *Climate Change Impacts & Risk Management – A Guide for Business and Government* (DEH,2006).

5.1 Assessment of construction impacts

The potential climate change impacts discussed in this assessment relate to long term impacts based on the near and far future projections. Due to the short-term timeframes of construction (three years) the potential climate change impacts are considered to be minimal and therefore the focus of this assessment is the potential operational impacts. Assessment of operational impacts

This section outlines the key operational climate change risks to the project from each climate variable and the potential treatment options/adaptation measures to reduce these risks.

A range of potential risks were discussed with design and project team during the preparation of this assessment, however risks considered to have very low or negligible risk profiles have not been included in the risk assessment tables outlined below. These additional risks included:

- flooding and wind impacts to bridge structures – the height of the proposed bridges and current design codes are considered adequate to mitigate potential risks to these asset types
- increased rainfall intensity impacting the stability of retaining wall structures – these structures would be designed to drain any excess water to alleviate pressure build up from increased soil moisture levels. Additionally, design codes also mitigate these loading risks by prescribing the consideration of extreme water table levels
- corrosion impacts due to sea level rise – Due to the location of the site away from coastal areas and the weir located in Mills Stream these risks are likely to be very low. Flood modelling used to inform this assessment combined sea level rise and increased rainfall intensity, however the impacts noted in the risk assessment are considered to be predominately from rainfall intensity rather than sea water ingress
- increased temperatures causing thermal expansion of steel elements resulting in structural fatigue – design codes adopted on the project are considered adequate to address this risk.

The risk ratings were determined by using qualitative descriptions of consequences and likelihood provided in *AS 5334 – Climate change adaptation for settlements and infrastructure – A risk based approach.* These risk matrices are provided in Appendix A. A revised risk rating has also been provided to illustrate the residual risk if the proposed treatment/ adaptation measures were implemented.

5.1.1 Extreme rainfall combined with sea level rise

Rainfall events are predicted to become more intense, increasing the likelihood of flooding. Sea levels are also anticipated to rise and with the increase in intensity of storm events, more frequent storm surges are anticipated to be experienced in coastal areas. Section 4.3 outlines the climate change flood modelling scenarios used to inform this assessment that considered combined impacts from rainfall intensity and sea level rise. As outlined in the *Technical Report 6 – Flooding Impact Assessment,* due to the location of the proposed works, the potential impacts are primarily due to increases in rainfall intensity.

See Table 5.1 for the assessment of potential impact to each project component.

Table 5.1 Risk assessment matrix – extreme rainfall combined with sea level rise

Project component	**Risk variable/ hazard**	**Risk statement/scenario**	**Consequence**	**Likelihood**	**Risk rating**	**Potential treatment (adaptation measures) to reduce risk to be considered during detailed design**	**Residual consequence**	**Residual likelihood**	**Residual risk rating**
Track	Increase in rainfall intensity combined with sea level rise	Localised flooding resulting in overtopping of the rail tracks on the future UP and DN Botany Line between O'Riordan and General Holmes Drive and the future UP Botany Line between Southern Cross Drive and Banksia Street. *Scenario 1: 1%AEP +10% increase in rainfall intensity and 0.4 metres increase in sea level rise* *Scenario 2: 1%AEP +30% increase in rainfall intensity and 0.9 metre increase in sea level rise* *Direct risk on Operations*	Moderate	Very Unlikely	Low	▪ With current ARTC controls to slow trains during periods of flooding this risk is considered an acceptable risk and no adaptations are proposed.	Moderate	Very Unlikely	Low

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Track formation	Increase in rainfall intensity combined with sea level rise	Localised flooding causing scour of the track formation and ballast of the future UP and DN Botany Line between O'Riordan and General Holmes Drive and the future UP Botany Line between Southern Cross Drive and Banksia Street requiring the replacement of ballast and increasing the need for maintenance. *Scenario 1: +10% increase in rainfall intensity and 0.4 metres increase in sea level rise* *Scenario 2: +30% increase in rainfall intensity and 0.9 metre increase in sea level rise* *Direct risk on Operations & Maintenance*	Moderate	Possible	Medium	▪ Undertake inspections after flooding events to determine whether minor maintenance is required.	Moderate	Unlikely	Medium
Access road	Increase in rainfall intensity combined with sea level rise	Flooding of the corridor access road near Southern Cross Drive and between Botany Road and Southern Cross Drive resulting in it to be inaccessible for maintenance vehicles during significant rainfall events *Scenario 1: +10% increase in rainfall intensity and 0.4 metres increase in sea level rise* *Scenario 2: +30% increase in rainfall intensity and 0.9 metre increase in sea level rise* *Direct risk on Operations & Maintenance*	Insignificant	Possible	Low	▪ This risk is considered an acceptable risk as it is considered unlikely that maintenance activities would occur during significant flooding events, therefore the access roads would not need to be accessible during these times.	Insignificant	Possible	Low

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Drainage	Increase in rainfall intensity combined with sea level rise	Reduced performance of surface drainage systems caused by increased rainfall intensity contributing to localised flooding. *Scenario 1: +10% increase in rainfall intensity and 0.4 metres increase in sea level rise* *Scenario 2: +30% increase in rainfall intensity and 0.9 metre increase in sea level rise* *Direct risk Operations & Maintenance*	Moderate	Possible	Medium	▪ Design of drainage systems to consider the increase in rainfall intensity due to climate change ▪ Undertake regular inspections to ensure drainage systems aren't obstructed and can operate at design capacity.	Moderate	Very Unlikely	Low
Signalling, electrical assets and power supply	Increase in rainfall intensity combined with sea level rise	Flooding of the rail corridor resulting in damage to communication and signalling equipment and requiring the potential replacement of equipment and causing disruptions to services. *Scenario 1: 1%AEP +10% increase in rainfall intensity and 0.4 metres increase in sea level rise* *Scenario 2: 1%AEP +30% increase in rainfall intensity and 0.9 metre increase in sea level rise* *Direct risk Operations & Maintenance*	Major	Possible	High	▪ Locate new rail systems infrastructure (e.g. location cases, signal huts) above predicted climate change flood levels ▪ Cable routes to be placed outside climate change flood inundation zones where feasible.	Major	Very Unlikely	Medium

5.1.2 Temperature

Average annual temperatures are predicted to rise in the near and far future. The number of extreme heat days (days over 35 degrees) are also expected to increase. See Table 5.2 for an assessment of potential impact to each project component.

Table 5.2 Risk assessment matrix – temperature

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Track	Extreme high temperatures	Track buckling and potential derailment of trains. *+11 hot days per annum above 35°C* *Direct risk Operations & Maintenance*	Major	Unlikely	Medium	▪ When specifications are prepared for the stressing of steel rail to account for likely temperature variations, the neutral point should be adjusted to cater for increases in average maximum temperatures due to climate change. ▪ Undertake routine maintenance checks of the track, especially during and after periods of extreme heat.	Major	Very Unlikely	Medium

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Track	Extreme high temperatures	Increasing the risk of track buckling and therefore increasing the frequency of when operational controls such as reducing track speeds and increasing inspections of the rail track need to be put in place. *+11 hot days per annum above 35°C* *Direct risk Operations*	Moderate	Likely	Medium	▪ When specifications are prepared for the stressing of steel rail to account for likely temperature variations, the neutral point should be adjusted to cater for increases in average maximum temperatures due to climate change. ▪ Undertake routine maintenance checks of the track, especially during and after periods of extreme heat.	Moderate	Possible	Medium

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Signalling, electrical assets and power supply	Increased mean maximum temperature and extreme high temperatures	More frequent malfunctioning of communication and signalling systems resulting in delays on the rail network. *+ 1.9°C increase in average mean temperature* *+11 hot days per annum above 35°C* *Direct Risk Operations and Maintenance*	Moderate	Possible	Medium	▪ Select equipment to ensure resilience to the projected temperature changes over the design life of the equipment, especially equipment that would likely be in use for more than 30 years ▪ Design ventilation systems for signalling equipment rooms/location cases to account for increased temperatures due to climate change ▪ Consider monitoring temperature in equipment rooms over an extended period to inform decision making of whether further mitigation is required ▪ Review climate projections when signalling infrastructure is replaced to account for far future climate change projections.	Moderate	Very Unlikely	Low

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Signalling, electrical assets and power supply	Extreme high temperatures	High demand on the wider electricity grid leading to blackouts of the overall network as well as critical infrastructure back up supply. This would cause disruption to signalling systems and therefore cause delays on the rail network. *+11 hot days per annum above 35°C* *Indirect Risk Operations and Maintenance*	Moderate	Unlikely	Medium	▪ Connect to existing system at the site where UPS changeovers are provided to bridge power supply when changing from electricity network to critical infrastructure back up supply. This will reduce risk of power failure.	Moderate	Very Unlikely	Low
Signalling, electrical assets and power supply	Extreme high temperatures	Increased frequency of thunderstorms and associated lightning strikes resulting in damage and potential failure of signalling systems. *Indirect Risk Operations and Maintenance*	Moderate	Unlikely	Medium	▪ Limit outside exposure of cables where possible to reduce likelihood of lightning strikes to exposed cables. ▪ Ensure the installation of surge protection, and provide a redundant power source as back up to reduce impacts from lightning strikes to exposed cables. ▪ Reduce the number of signalling cabinets where possible to reduce the amount of exposed cabling.	Moderate	Very Unlikely	Low

Project component	**Risk variable/ hazard**	**Risk statement/scenario**	**Consequence**	**Likelihood**	**Risk rating**	**Potential treatment (adaptation measures) to reduce risk to be considered during detailed design**	**Residual consequence**	**Residual likelihood**	**Residual risk rating**
Operation	Extreme high temperatures	Maintenance staff unable to performance maintenance tasks due to extreme temperature events impacting on scheduled maintenance. *+11 hot days per annum above 35°C* *Direct Risk Operations and Maintenance*	Minor	Likely	Medium	■ Regular checks of weather forecasts to be undertaken to plan maintenance works around extreme heat events.	Minor	Possible	Low
Operation	Extreme high temperatures	Extreme heat resulting in heat stress and adverse health effects for maintenance staff. *+11 hot days per annum above 35°C* *Direct Risk Operations and Maintenance*	Moderate	Possible	Medium	■ Preparation and implementation of Operational Work, Health and Safety Management Plans that consider the increase of extreme heat days and the impacts on operation and maintenance staff. Awareness and education initiatives around personnel wellbeing and safety should be implemented	Moderate	Unlikely	Medium

5.1.3 Average and extreme wind

Average wind speeds are projected to increase marginally in the far future. However, the frequency of high intensity east coast lows that result in damaging winds is projected to increase. See Table 5.3 for an assessment of potential impact to each project component.

Table 5.3 Risk assessment matrix – wind speed

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Ancillary infrastructure (signals, fencing, lights etc)	More frequent extreme wind events	Increased likelihood of damage to signalling infrastructure, lighting and large billboards that span across the corridor resulting in debris on the rail line causing delays. *Direct Risk Operations and Maintenance*	Minor	Possible	Low	▪ Operational management plans to include requirement that track side infrastructure and overhead billboards are inspected regularly, particularly after strong wind events to fix any loose elements.	Minor	Unlikely	Low
Landscaping	More frequent extreme wind events	Damage to vegetation adjacent to the alignment which can become a hazard on the trail tracks. *Direct Risk Operations and Maintenance*	Moderate	Unlikely	Medium	▪ Operational management plans to include requirements that vegetation and mature trees adjacent the corridor is regularly maintained and the track inspected after strong wind events	Moderate	Very Unlikely	Low

5.1.4 Bushfire

Climatic changes such as changing rainfall patterns, extreme heat and wind speed are predicted to increase the likelihood of severe bushfires. Although not a direct risk to the project, this have the potential to result in indirect risks associated with upstream infrastructure. See Table 5.4 for an assessment of potential impact to each project component.

Table 5.4 Risk assessment matrix – bushfire

Project component	Risk variable/ hazard	Risk statement/scenario	Consequence	Likelihood	Risk rating	Potential treatment (adaptation measures) to reduce risk to be considered during detailed design	Residual consequence	Residual likelihood	Residual risk rating
Operational	Increased frequency of bushfires	Increased frequency of bushfires in bushland areas causing smoke to be blown towards the asset and lead to low visibility for drivers as well as adverse health impacts for operational and maintenance staff. *Indirect risk Operations and Maintenance*	Minor	Unlikely	Low	▪ This risk is considered an acceptable risk	Minor	Unlikely	Low
Signalling, electrical assets and power supply	Increased frequency of bushfires	Increased frequency of bushfires leading to damage of the electricity grid resulting in blackouts of the overall network as well as critical infrastructure back up supply. This would cause disruption to signalling systems and therefore cause delays on the rail network. *Indirect risk Operations and Maintenance*	Moderate	Very Unlikely	Low	▪ This risk is considered an acceptable risk	Moderate	Very Unlikely	Low

5.2 Summary of key findings

No extreme risks were identified in the climate risk assessment. One high risk was identified in relation to the failure of communications and signalling systems caused by flooding as a result of an increase in rainfall intensity combined with sea level rise.

A range of medium risks were identified for the follow climate change variables:

- Increased rainfall intensity combined with sea level rise potentially resulting in:
  - localised flooding causing scour of the track formation and ballast
  - reduced performance of surface drainage systems caused by increased rainfall intensity contributing to localised flooding.
- Increases in average annual temperatures and the number of extreme heat days potentially resulting in:
  - track buckling increasing operational and maintenance costs, cause delays and potential derailments
  - more frequent malfunctioning of communication and signalling systems; therefore causing delays on the rail network
  - high demand on the wider electricity grid leading to a loss of signalling systems and therefore cause delays on the rail network
  - more frequent thunderstorms and associated lightning strikes resulting in damage and potential failure of signalling systems
  - maintenance staff unable to performance maintenance tasks due to extreme temperature events impacting on maintenance schedules.
- Increases in the frequency of extreme wind events resulting in:
  - damage to vegetation adjacent to the alignment which can become a hazard on the trail tracks.

5.3 Cumulative impacts

Cumulative climate change impacts would typically occur where the project has interconnections with the surrounding area. Increased rainfall intensity is the main climate variable that would be most relevant when considering cumulative impacts as it has the potential to exacerbate any cumulative flooding impacts that may occur under climate change conditions.

The *Technical Report 6 – Flooding Impact Assessment* determined that under current climate conditions the project is likely to have minor or no cumulative impacts associated with other major projects in its vicinity due to the relative localised and minor nature of the project flooding impacts.

Section 3.7.2 of *Technical Report 6 – Flooding Impact Assessment* outlines that 0.5% and 0.2% annual exceedance probability (AEP) events were adopted as proxies for assessing the impact of the project on local flood behaviour under future climate change conditions. By comparing these results to current climate conditions, it was determined that there will be relatively minor increases in flood impacts caused by the project under future climate conditions.

6. Management of impacts

The mitigation measures that would be implemented to address potential climate change impacts are listed in Table 6.1.

Table 6.1 Mitigation measures

Stage	Impact	Measure
Design	Climate change resulting in a range of potential impacts to the asset that can be mitigated through design	Treatments/adaptation measures to mitigate any extreme, high and medium risks identified in the *Botany Rail Duplication EIS Technical Report 16 – Climate Change Assessment* should be implemented. At the end of detailed design there should be no residual extreme or high risks and treatment measures to address medium risks should be implemented where practicable.
Operation	Climate change resulting in a range of potential impacts to the asset that can be mitigated through operational procedures	ARTC's existing operational procedures should be implemented and amended (where relevant) to address relevant risks identified in the *Botany Rail Duplication EIS Technical Report 16 – Climate Change Assessment* that require action during the operational phase of the project.

7. Conclusion

This assessment evaluated the potential climate change risks to the project. No extreme risks were identified in this assessment. One high risk was identified in relation to the potential failure of communication and signalling systems caused by flooding as a result of an increase in rainfall intensity combined with sea level rise. A range of medium risks were also identified in relation to the combined impacts of increased rainfall intensity and sea level rise as well as temperature and wind.

The risks and potential adaptations outlined in this climate change assessment should be considered for implementation during detailed design and the preparation of operational procedures. The key treatments recommended include:

- allowing for an increase in rainfall intensity due to climate change when determining the location of critical rail system infrastructure such as rail system location cases
- allowing for an increase in rainfall intensity due to climate change when designing the drainage infrastructure
- designing ventilation systems for signalling equipment rooms/location cases that allow for increased temperatures due to climate change
- considering the impacts of extreme temperatures on the performance of the rail tracks and consider adjusting design specifications where required
- limit outside exposure of cables where possible, ensure the installation of surge protection, and provide a redundant power source to reduce likelihood and impacts of lightning strikes to exposed cables
- the preparation of operational and maintenance plans that consider potential impacts from climate change such as increases in temperatures, increases in rainfall intensity and increases in the frequency of high intensity east coast lows that result in damaging winds.

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Appendix A
AS 5334 – Climate change adaptation for settlements and infrastructure – A risk based approach

A1. AS 5334 – Climate change adaptation for settlements and infrastructure – A risk based approach

Table A.1, Table A.2 and Table A.3 sourced from AS 5334 – Climate change adaptation for settlements and infrastructure – A risk based approach, provides qualitative descriptions of consequences and likelihood, which combine under the risk ranking matrix.

A1.1 Consequence

Table A.1 Qualitative description of consequence AS 5334

Consequence	Adaptive capacity	Infrastructure, service	Social/cultural	Governance	Financial	Environmental	Economy
Insignificant	No change	No infrastructure damage, no change to service	No adverse human health effects	No changes to management required	Little financial loss or increase in operating expenses	No adverse effects on natural environment	No effects on the broader economy
Minor	Minor decrease to the adaptive capacity of the asset. Capacity easily restored.	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 10–20%. Need for new/modified ancillary equipment.	Short-term disruption to employees, customers or neighbours. Slight adverse human health effects or general amenity issues.	General concern raised by regulators, requiring response action	Additional operational costs Financial loss small, <10%	Minimal effects on the natural environment	Minor effect on the broader economy due to disruption of service provided by the asset

Consequence	Adaptive capacity	Infrastructure, service	Social/cultural	Governance	Financial	Environmental	Economy
Moderate	Some change in adaptive capacity. Renewal or repair may need new design to improve adaptive capacity.	Limited infrastructure damage and loss of service Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 20–50%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects	Investigation by regulators Changes to management actions required	Moderate financial loss 10–50%	Some damage to the environment, including local ecosystems. Some remedial action may be required	High impact on the local economy, with some effect on the wider economy
Major	Major loss in adaptive capacity. Renewal or repair would need new design to improve adaptive capacity.	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service. Early renewal of infrastructure by 50–90%.	Permanent physical injuries and fatalities may occur. Severe disruptions to employees, customers or neighbours.	Notices issued by regulators for corrective actions. Changes required in management. Senior management responsibility questionable.	Major financial loss 50–90%	Significant effect on the environment and local ecosystems. Remedial action likely to be required.	Serious effect on the local economy spreading to the wider economy
Catastrophic	Capacity destroyed, redesign required when repairing or renewing asset.	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service. Loss of infrastructure support and translocation of service to other sites. Early renewal of infrastructure by 90%.	Severe adverse human health effects, leading to multiple events of total disability or fatalities. Total disruption to employees, customers or neighbours. Emergency response at a major level.	Major policy shifts. Change to legislative requirements	Extreme financial loss > 90%	Very significant loss to the environment. May include localised loss of species, habitats or ecosystems. Extensive remedial action essential to prevent further degradation. Restoration likely to be required.	Major effect on the local, regional and state economies.

A1.2 Likelihood

Table A.2 Qualitative description of likelihood AS 5334

Likelihood	Description	Recurrent or event risks	Long term risks
Almost Certain	Could occur several times per year	Has happened several times in the past year and in each of the previous 5 years or Could occur several times per year	Has a greater than 90% chance of occurring in the identified time period if the risk is not mitigated
Likely	May arise about once per year	Has happened at least once in the past year and in each of the previous 5 years or May arise about once per year	Has a 60–90% chance of occurring in the identified time period if the risk is not mitigated
Possible	Maybe a couple of times in a generation	Has happened during the past 5 years but not in every year or May arise once in 25 years	Has a 40–60% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	Maybe once in a generation	May have occurred once in the last 5 years or May arise once in 25 to 50 years	Has a 10–30% chance of occurring in the future if the risk is not mitigated
Very Unlikely (Rare)	Maybe once in a lifetime	Has not occurred in the past 5 years or Unlikely during the next 50 years	May occur in exceptional circumstances, i.e. less than 10% chance of occurring in the identified time period if the risk is not mitigated

A1.3 Risk rating matrix

Table A.3 Risk rating matrix AS 5334

Likelihood	Consequences				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	Medium	High	Extreme
Possible	Low	Low	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Very Unlikely	Low	Low	Low	Medium	Medium

E = Extreme risk, requiring immediate action
H = High risk issue requiring detailed research and planning at senior management level
M = Moderate risk issue requiring change to design standards and maintenance of assets
L = Low risk issue requiring action through routine maintenance of assets

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