ARTC

CABRAMATTA LOOP PROJECT

TECHNICAL REPORT

TECHNICAL REPORT 12 —

CLIMATE CHANGE
RISK ASSESSMENT

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Australian Rail Track Corporation Cabramatta Loop Project

Environmental Impact Statement

Technical Report 12 - Climate Change Risk Assessment

August 2019

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

Table of contents

Table index

Figure index

Appendices

Definitions

Term	Definition
Adaptation	Changes made in response to the likely threats and opportunities arising from climate variability and climate change.
Adaptive capacity	Ability of a system to respond to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
ARTC	Australian Rail Track Corporation
AWS	Automatic Weather Station
BOM	Bureau of Meteorology
Climate scenario	Coherent, plausible description of a possible future state of the climate.
CO_2	Carbon dioxide
Consequence	Outcomes of an event affecting objectives.
Control	Measure that is modifying a risk.
CSIRO	Commonwealth Science and Industrial Research Organisation
ECL	East Coast Low
EIS	Environmental Impact Statement
Impact	A threat or an opportunity that may arise as a result of either the weather or climate change both in the short and long term, and represents the fact that the issue is one that is constantly evolving.
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Area
Likelihood	Chance of something happening.
NARCliM	NSW and ACT Regional Climate Modelling
OEH	NSW Office of Environment and Heritage
OHW	Overhead wiring
ppm	Parts per million
Project	The construction and operation of the Cabramatta Loop
Project site	Refers to the area that would be directly disturbed by construction of the project (for example, as a result of ground disturbance and the construction of foundations for structures). It includes the location of construction activities, compounds and work site, and the location of permanent operational infrastructure.
RCP	Representative Concentration Pathway
Residual risk	Risk remaining after risk treatment (this can contain unidentified risk, and may be known as 'retained risk').
Resilience	Adaptive capacity of an organisation in a complex and changing environment.
Risk owner	Person or entity with the accountability and authority to manage the risk.
SEARs	Secretary's Environmental Assessment Requirements
Sensitivity	Degree to which a system is affected. Either adversely or beneficially, by climate-related stimuli.
SFAIRP	So Far As Is Reasonably Practicable
SiD	Safety in Design

Term	Definition
SSFL	Southern Sydney Freight Line
The project	The Cabramatta Loop Project
Vulnerability (to climate change)	Degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes.

Definitions for risk and climate terms provided are adapted from AS 5334-2013 Chapter 4 – Definitions.

Executive summary

Australian Rail Track Corporation (ARTC) proposes to construct and operate a passing loop for up to 1,300 metre length trains on the Southern Sydney Freight Line (SSFL) between Sydney Trains' Cabramatta and Warwick Farm stations. The Cabramatta Loop Project ('the project') would allow freight trains to pass and provide additional rail freight capacity along the SSFL.

ARTC requires an environmental impact statement (EIS) to support the application for planning approval of the project – including an assessment of the risk and vulnerability of the project to climate change, requiring quantification of specific climate change risks and incorporation of specific adaptation actions in design. Climate change poses a risk to new infrastructure developments including rail, road and bridge infrastructure and ancillary components.

In response, an initial climate change risk assessment was performed. The assessment was:

- Aligned with the Australian Standard AS 5334: 2013 Climate Change Adaptation for settlements and infrastructure as well as other relevant guidance.
- Performed using CSIRO projections for climate change relevant to the location of the proposed Cabramatta Loop, as well as a baseline for the measured historical climatic conditions at or near the site. CSIRO's projections are the most current and relevant projections available for the project site, and are based on the latest assessment report from the Intergovernmental Panel for Climate Change (IPCC).
- Informed by liaising with the reference designers to understand the context of the project, as well as identify and assess relevant risks related to climate change and identify appropriate adaptation actions in design.

This report provides the methodology, limitations and outcomes of the climate change risk assessment. In summary, a total of eleven climate change risks were identified for the Cabramatta Loop Project across climate hazards including extreme rainfall events, extreme heat and solar radiation, bushfire weather and storm events.

Risks were identified and assessed using ARTC's likelihood and consequence risk matrix – in summary as follows:

- Four Medium risks relating direct risks of wind and extreme storm impacts, and indirect risk of flooding to the road and cycleway which is not owned by ARTC.
- Seven Low risks relating to extreme heat impacts to rail track and signalling equipment, lightning and bushfire risk impacts to operations.
- No high or very high risks were identified.

This risk profile in part reflects that a range of adaptation actions are already incorporated into the reference design for the project. Seven further potential adaptations were identified and recommended (so far as is reasonably practicable). Three of these potential adaptations are relevant for consideration during detailed design, while others such as management protocols would ideally be implemented by the time the project is operational.

The following mitigation measures are recommended to manage climate change risk for the project:

1. ARTC will:
    a. Apply this climate change risk assessment and its existing control measures identified in Table 5.1 in implementing the project, or

b. In the event of design changes, during detailed design, review the climate change risks identified in this assessment in order to amend existing control measures or identify additional control measures to reduce the climate change related risks to the project with no 'very high' or 'high' residual climate related risks remaining.

2. ARTC will implement all potential adaptation measures identified in Table 6.1 so far as is reasonably practicable to reduce climate change risk.

3. In the event of significant new scientific climate change projections becoming available during detailed design, ARTC will review the relevant climate change risks and control measures identified in this assessment in order to confirm that there are no 'very high' or 'high' residual climate related risks remaining.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3.1 and the assumptions and qualifications contained throughout the Report.

1. Introduction

1.1 Overview

Australian Rail Track Corporation (ARTC) proposes to construct and operate a passing loop for up to 1,300 metre length trains on the Southern Sydney Freight Line (SSFL) between Sydney Trains' Cabramatta and Warwick Farm stations. The Cabramatta Loop Project ('the project') would allow freight trains to pass and provide additional rail freight capacity along the SSFL.

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 environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs), issued on 17 May 2018.

1.2 The project

1.2.1 Location

The project is generally located within the existing rail corridor between the Hume Highway and Cabramatta Road East road overbridges in the suburbs of Warwick Farm and Cabramatta. In addition, the project includes works to Broomfield Street adjacent to the rail corridor in Cabramatta.

The rail corridor is owned by the NSW Government (RailCorp) and leased to ARTC.

The location of the project is shown in Figure 1.1.

1.2.2 Key features

The key features of the project include:

- New rail track – providing a 1.65 kilometre long section of new track with connections to the existing track at the northern and southern ends
- Track realignment – moving about 550 metres of existing track sideways (slewing) to make room for the new track
- Bridge works – constructing two new bridge structures adjacent to the existing rail bridges over Sussex Street and Cabramatta Creek
- Road works – reconfiguring Broomfield Street for a distance of about 680 metres between Sussex and Bridge streets.

Ancillary work would include communication upgrades, works to existing retaining and noise walls, drainage work and protecting/relocating utilities. In addition, minor works in the form of new signalling would be installed at a number of locations within the rail corridor (indicative locations provided in the EIS).

The key features of the project are shown in Figure 1.2.

Further information on the project is provided in the EIS.

Figure 1.1 Location of the project

Figure 1.2 Key features of the project

1.2.1 Timing

Subject to approval of the project, construction is planned to start in early 2021, and is expected to take about two years. Construction is expected to be completed in early 2023.

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. Possession periods typically occur for 48 hours four times per year.

1.2.2 Operation

The project would operate as part of the SSFL 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 Broomfield Street would be restored, with one travel lane in each direction, kerb-side parking on both sides and a shared path on the western side of the street.

1.3 Purpose and scope of this report

The purpose of this report is to provide the outcomes of the initial assessment of the potential impacts of climate change to the project. This initial climate change risk assessment addresses the relevant SEARs for the EIS, as outlined in Table 1.1. This process provides a means to integrate consideration of climate change risk to ultimately guide the design of an asset which will be resilient to the future impacts of climate change throughout construction and operation.

This assessment is intended to identify potential vulnerabilities of the proposed asset from climate hazards and identify ways to address and minimise this vulnerability. Specifically, this report:

- Identifies the potential climatic events and hazards that could impact the proposed asset, based on its scale, location, asset components and design life
- Assesses climate change risk under two timeframes and emission scenarios to provide an indication of potential risks
- Links asset vulnerability associated with climate change to the design of the asset, and potential adaptation options to improve asset resilience.

Table 1.1 SEARs relevant to this assessment

Requirements	Where addressed in this report
3 (2) Assessment of Key Issues	
1. 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 and Section 5
(b) describe the legislative and policy context, as far as it is relevant to the issue	Section 3.1
(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	Chapter 5
(d) demonstrate how potential impacts have been avoided (through design, or construction or operation methodologies);	Refer to the EIS

Requirements	Where addressed in this report
(e) 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)	Chapter 5 and 6
11. Climate Change Risk: The project is designed, constructed and operated to be resilient to the future impacts of climate change.	
1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	Chapter 5
2. The Proponent must quantify specific climate change risks with reference to the NSW Government's climate projections at 10km resolution (or lesser resolution if 10km projections are not available) and incorporate specific adaptation actions in the design.	Chapter 4 Chapter 6

Climate change provides parameters for assessment in the flood modelling study (Technical Report 5 – Hydrology and flooding impact assessment), as outlined in SEAR 9 Flooding, which is directly assessed in the flood modelling report and summarised in this report where flooding risks due to climate change are discussed.

1.3.1 Assumptions and scope limitations

The following assumptions and limitations apply to this climate risk assessment:

- This climate change risk assessment is indicative of relevant risks based on emerging reference design at the time of the risk assessment.
- Analysis of climate change is based on best-available climate change projections at the time of assessment. Combined with a historic measured climatic baseline at or near the project site, these are the best available projections of likely future climatic conditions at the project site – as such, they have inherent uncertainties as to the likelihood of occurrence and intensity of events (refer Chapter 2). At later stages of design, updates to the climate change risk assessment should incorporate improved climate change projections that may have become available, and which may indicate a different risk profile for the project relating to climate change (this could lower or increase the inherent climate related risks to the project).
- Current NSW projections of 10 kilometre resolution were not available at the time of assessment, and therefore were not used – best available current climate projections at this time were used for this assessment and do not have this resolution. It is expected that NSW projections at 10 kilometre resolution (or similar) may become available at later stages of design – and if so, such projections with higher resolution should be used if this climate change risk assessment is updated during detailed design.
- This assessment has been performed in consultation with the project personnel listed in Appendix B.
- It is assumed that integration of this climate change risk assessment into the ongoing Safety in Design process will allow any specific adaptation actions which are not already implemented to be handed over to the project proponent to carry forward to detailed design, as part of the reference design risk documentation.
- This assessment is based on current, publicly available climate science, and is additionally informed by the flood modelling assessment performed to support the EIS.

1.4 Structure of this report

The structure of this report is outlined below:

Chapter 1 – provides an introduction to the report

Chapter 2 – provides context on the climate change risk assessment process and its uncertainties and interpretation

Chapter 3 – describes the specific methodology for the assessment, including the legislative and policy context for the assessment, and relevant guidelines

Chapter 4 – describes the existing climate as relevant to the assessment and quantifies climate change projections

Chapter 5 – assesses the risk and vulnerability of the project to climate change

Chapter 6 – provides recommended adaptation actions for consideration.

2. Assessing climate risk

This Chapter is intended to assist the reader to understand the climate change context for this assessment, including current practices and how to interpret climate change science in a risk assessment process.

2.1 Climate change context

There is a growing body of evidence that shows Australia's climate has changed and continues to change significantly, particularly driven by the work of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Bureau of Meteorology (BOM), and NSW Office of Environment and Heritage (OEH) in NSW. The anthropogenic climate changes which have been seen and are projected to occur place property, communities and infrastructure assets under risk. This can manifest itself in a number of ways, affecting physical asset life, life-cycle maintenance costs, operating costs and/or revenue. To add to the uncertainty, potential impacts influenced by climate change could be realised in either the short term or decades from today.

Infrastructure is designed to function and perform within the environment that it exists, and to respond to the variable weather conditions for which it has been designed. State, national and international design standards and codes of practice exist to provide the parameters necessary to ensure the desired reliability and level of resilience of various infrastructure components to extreme conditions.

The proposed asset is subject to climate change uncertainty, from the risks posed to a physical asset by climate hazards under the influence of climate change. For any asset to be resilient to the impacts of climate change, consideration must be made to the climate hazards which are applicable to the asset type and broader context, including periodic review to incorporate the latest climate science. The results of a climate change risk assessment at any stage of a design promotes resilience and consideration of adaptation, either through designed adaptations or in allowance for future adaptive capacity.

2.2 Publicly available climate data

The Intergovernmental Panel on Climate Change (IPCC) has developed four scenarios for global climate projections that relate to how the world may respond to the challenge of a changing climate, the need to continue to produce and use energy and resources, and the global greenhouse gas emissions that may occur. These scenarios incorporate diverging tendencies based on alternative economic, globalisation and environmental pathways. These have been modified through subsequent reports and renamed as Representative Concentration Pathways (RCPs) in the IPCC's Fifth Assessment Report.

The CSIRO and BOM released the Climate Change in Australia Technical Report in 2015, which links strongly to findings of the latest IPCC Fifth Assessment Report, and updates the projections previously outlined in the 2007 Technical Report. The 2015 Technical Report uses over 40 global climate models to produce climate change projections as they relate to IPCC RCP scenarios.

These RCPs are described according to CO_2 concentration levels, and may also be described by anomalies in global mean surface air temperatures for the period 2081-2100 relative to the average period 1986-2005, refer Table 2.1.

Table 2.1 Climate change emission scenarios

Global climate response	RCP scenario	Projected increase in global surface temperature by 2081 - 2100
Strong immediate response, emissions peak by 2020, with rapid decline in emissions thereafter from global participation and application of technologies	**RCP 2.6**, atmospheric concentration of CO_2 projected at approx. 420 ppm by 2100	Mean projected increase **1.0°C** Anomaly range +0.3 to 1.7°C
Slower response, emissions peak around 2040, then decline	**RCP 4.5**, atmospheric concentration of CO_2 projected at approx. 540 ppm by 2100	Mean projected increase **1.8°C** Anomaly range +1.1 to 2.6°C
Slow response, application of mitigation strategies and technologies	**RCP 6.0**, atmospheric concentration of CO_2 projected at approx. 660 ppm by 2100	Mean projected increase **2.2°C** Anomaly range +1.4 to 3.1°C
Little curbing of emissions, continuing rapid rise throughout the 21st century	**RCP 8.5**, atmospheric concentration of CO_2 projected at approx. 940 ppm by 2100 and continuing to increase	Mean projected increase **3.7°C** Anomaly range +2.6 to 4.8°C

Current atmospheric concentration of CO_2 is at approximately 410 parts per million (ppm), up from being stable at about 280 ppm prior to the industrial revolution, and increasing by approximately 2.5 ppm per year (US national Oceanic and Atmospheric Administration, 2018). Global mean atmospheric temperatures have increased approximately 0.9 degrees Celsius (°C) compared to pre-industrial levels(NASA, 2018), and Australia's climate has warmed in both surface air and surrounding sea surface temperatures by around 1°C since 1910 (CSIRO, 2016).

The latest credible climate projection data from the IPCC's current Fifth Assessment Report, upon which CSIRO data is based, covers uniform projections for most of Australia's central eastern seaboard, known as the 'East Coast cluster' which is further split into north and south sub-clusters. Sydney is part of the southern sub-cluster which extends from approximately the Queensland border down just short of Wollongong. More granular projections for different regions of New South Wales exist mapped by OEH (NSW and ACT Regional Climate Modelling or NARCliM), but are based on older global climate models as they have been based on the previous Fourth Assessment Report by the IPCC.

A selection of RCPs over different timeframes should be considered in climate change risk assessments using AS 5334, to acknowledge how different global responses may impact the assessment and subsequent adaptation measures.

2.3 Climate change uncertainty

Although climate projections represent the presently accepted forefront of climate change science, there is still a high level of uncertainty that exists regarding the climate changes that may actually eventuate. This uncertainty becomes more pronounced as the timescale of the projection is extended. Several areas of uncertainty exist which influence the accuracy of climate change projections, including:

- **Scenario uncertainty**, due to the uncertain future emissions and concentrations of greenhouse gases and aerosols, resulting from uncertainties regarding the current and future activities of humans.

- **Climate response uncertainty**, resulting from limitations to scientific understanding of the climate system and its representation in climate models, and consequently how much the climate will change due to increased atmospheric concentration of greenhouse gases. This includes natural variability uncertainty, stemming from unperturbed variability in the climate system.
- **Location specific uncertainties**, regarding the assignment of probability distributions to regional climate change projections, and projecting climate change at small spatial scales, particularly for coastal and mountainous areas.

The inevitability of uncertainty is stated within AS 5334, and it is recognised that decisions and adaptation planning processes should be flexible enough to cope with potential knowledge gaps.

2.4 Typical assessment method

Each climate risk to an asset is rated by identifying and assessing each of the following components:

- The **climate variable** (rainfall, temperature, sea level, high-wind days, etc.), considered in terms of how its patterns may change over time.
- The **impact of change** of that climate variable or a collection of variables in so far as how it may affect the integrity or reliability of some part or component of the infrastructure, or the asset as a whole, and how this may affect the infrastructure operations or reliability overall.
- The **vulnerability** of an asset, or the extent to which it may be able to cope with climate changes. It can be determined through a consideration of:
  - The sensitivities of the asset components to various climate variables, and whether environmental ‘thresholds’ exist beyond which an asset may become damaged or operate ineffectively or inefficiently;
  - The possible extent of changes in the climate and the frequencies, durations and severities of extreme weather events; and
  - The ability of the asset to cope with those changes, and how adaptable the current controls are to meeting new challenges.

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3. Methodology

This assessment is specific to climate change and the risks to the Cabramatta Loop Project posed by climate variables, and in principle follows the same process as for any type of risk as shown on Figure 3.1 below, derived from AS/NZS ISO 31000 – Risk management – Principles and guidelines.

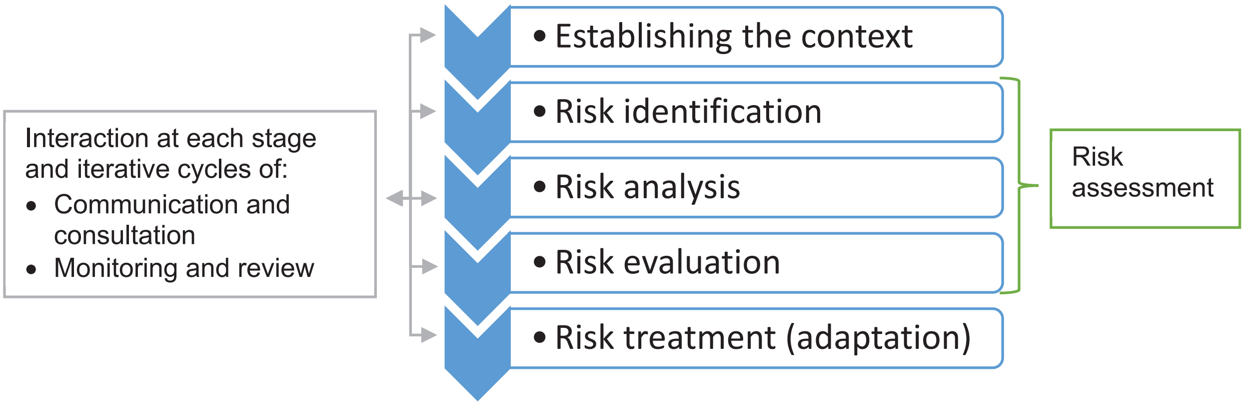

Figure 3.1 Risk management process (adapted from AS 5334-2013)

This report presents the first iteration of this process, incorporating the three steps defined as a risk assessment, in addition to a preliminary establishment of the context of the asset at this stage of planning and design, and consideration of potential treatment options to mitigate those risks identified.

3.1 Legislative and policy context

This climate change risk assessment broadly follows a typical risk assessment process in line with the Australian Standard AS 5334:2013 Climate change adaptation for settlements and infrastructure – A risk based approach (AS 5334) which in turn is aligned with AS/NZS ISO 31000:2009 – Risk Management – Principles and guidelines.

This assessment has been performed to address the requirements of the SEARs for climate change risk, which requires consideration of the guidelines listed in Table 3.1 below. These guidelines each describe slightly different ways of performing an assessment, in which case the date of production, and guidance of the Australian Standard for climate change adaptation has been taken into account to resolve any differences.

Table 3.1 Guidelines used in assessment (per SEAR 11)

Guideline	Influence on assessment method
Australian Government's Climate Change Impacts and Risk Management – A Guide for Business and Government (2006)	Broadly this guide aids businesses to describe, prioritise and integrate climate change risk into the decisions for a project. This risk assessment constitutes the "initial assessment" described in section 3.4 that quickly identifies and ranks risks, requiring further information to perform detailed treatment planning, due to the early stage of design of the Cabramatta Loop Project. This climate change risk assessment has been integrated into the existing Safety in Design process for the project per recommendations 31 and 33, therefore a workshop was not specifically performed for this task. A workshop was held as part of the Safety in Design process for reference design, at which risks identified by this initial assessment were discussed and validated.
AS ISO 31000:2018 Risk Management – Guidelines	AS ISO 31000:2018 provides a framework for an overarching risk management process which may be applied to climate change risk as to any other risk area. This climate change risk assessment follows the principles of ISO 31000, and steps through the process described in Chapter 6 of the standard up to 6.5.3, whereby this report describes the context, risk assessment and treatment, but not ongoing implementation, monitoring and review. However, inclusion of climate change risks described in this report into the Safety in Design hazard log promotes these remaining steps, as well as further consultation, into an iterative process as recommended by ISO 31000.
Technical Guide for Climate Change Adaptation for the State Road Network (Roads and Maritime Services, in draft)	The technical guide describes an appropriate risk screening, assessment, evaluation and adaptation process for road infrastructure. This guide also references the ARR design guidelines for flooding. It indicates that bridge structures typically have enough conservatism for wind loading under climate change by following Australian Standards. The guide suggests the use of CSIRO data, rather than higher resolution data provided by the NSW Government due to the climate science currency, as CSIRO data is based on the latest suite of Global Climate Models. This has been adopted for the detailed projection data for this assessment (refer section 3.4).

3.2 Asset context and design life

The types of infrastructure that are part of the project were used to determine the applicable climate variables for assessment, according to AS 5334. Additional context including whether the project site is flood-prone or bushfire-prone is also provided for context of the risks of the existing climate and environment.

The scope of the project includes; rail-bridge, retaining wall and noise wall structures, reconfigured road design, new and adjusted rail track and ancillary signalling and communication components as described in section 1.2. These infrastructure components are anticipated to commence operations in 2022, and with an anticipated design life of 25 to 100 years.

Design life of the varying infrastructure components was identified by project designers. The rail bridge structure and retaining wall structure are anticipated to have a 100 year design life, represented by 'structural components' in the figure below. The road design is anticipated to have a 25 years design life, and the noise wall is similar. Rail formation and track also have a shorter design life, as these components are maintained regularly and replaced as required based on performance in an asset maintenance schedule. Signals are also regularly maintained and replaced to meet the required operational standards. These are collectively represented by the 'road/rail components' label in the figure below and have only been assessed for the 2030 projections.

Components need only be assessed for climate change risk at the time slices (or future time periods) which are appropriate. As such, 2030 and 2090 have been selected for this assessment to assess climate change risk for components with both short and longer design lives as shown in Figure 3.2 below. The selection of 2030 and 2090 therefore allows the assessment to consider both a short and long-term scenario and to allow an appropriate assessment of all asset components.

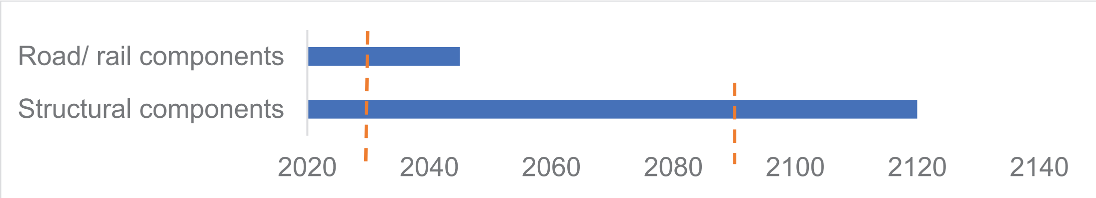

Figure 3.2 Time slices for asset component assessment

3.3 Climate baseline data

Bankstown Airport Automatic Weather Station (AWS) (006137) was selected as the most appropriate source for the climate baseline data for this assessment. Bankstown Airport is the closest weather station to the project, with a range of climate statistics available, including rainfall and temperature data across the whole of the 20 year baseline period. The climate change modelling from CSIRO has been developed based on a 20 year baseline period of 1986-2005, therefore in the selection of weather station data it is ideal to replicate this time period for baseline data. The use of an averaged baseline period allows climate to be more realistically captured to avoid representing weather fluctuations as the average climate.

Both averages and extremes during this baseline period were captured and supplemented with additional data outside the 1986-2005 period, and data from the broader Sydney Metropolitan region. Some climate variables were not recorded across the whole baseline period, where this occurs, all available years within this period were used to represent the average baseline.

3.4 Climate projection data

Both quantitative and qualitative data has been gathered to inform the assessment in line with the Australian Government's *Climate Change Impacts and Risk Management – A Guide for Business and Government* (2006).

Although OEH's NARCliM mapping for NSW provides downscaled projections at a 10 kilometre radius, this data is currently based on a previous iteration of recognised climate science (refer section 2.2) and therefore not recommended as a detailed projection source for climate change risk assessments (Roads and Maritime*,* in draft). In addition, NARCliM data was not available through the Climate Data Portal at the time of data collation for this assessment (November 2018). In this case the SEAR allows for use of climate data at lower than 10 km resolution where this data is not available (refer Table 1.1), and the NSW Government's climate change projections have been used to support the broader assessment of climate change risk as described below.

Accordingly, detailed climate change projection data has been sourced for this assessment from CSIRO's projections at the cluster scale, or sub-cluster where available. In addition, qualitative information has been provided for the purposes of the risk assessment from CSIRO's suite of tools and information for climate change risk assessments. AdaptNSW (OEH) Climate snapshots and profiles for Metropolitan Sydney have been used to supplement CSIRO data to provide a more granular projection of Sydney's future climate for variables which are not projected at sub-cluster scale such as hail and lightning. These climate snapshot documents are informed by the more granular 10 km resolution climate data provided by the NSW Government.

For the quantitative CSIRO and BOM data the two following projection scenarios were selected:

- Near term, moderate scenario using 2030 and RCP 4.5
- Long term, extreme scenario using 2090 and RCP 8.5.

Per the AS 5334, these projections are current, authoritative and credible. Each projection scenario represents an average period, with 2030 representing the average for years 2020-2039 and 2090 representing years 2080-2099.

It is good practice to use a projection which identifies the potential future climate beyond the life of the asset, however 2090 is the latest projection for which robust, publicly available data exists, which is earlier than the 100 year design life of some components of this project. In addition, the use of a long term extreme scenario such as 2090 with RCP 8.5 allows a conservative estimation of risk, which encourages the asset to be designed or considered with a worst case in mind so that risk is not downplayed, acknowledging that scenarios may transpire earlier than projected.

AS 5334 recommends using multiple emission scenarios for assets with a design life greater than 30 years. This allows the climate change risk assessment process to account for uncertainty of the global emission scenario that will actually transpire. The use of RCP 4.5 and 8.5 allows this breadth in consideration, with the use of two time slices to cut across the design life of the asset components as shown in Figure 3.2.

3.5 Initial assessment of climate risk

To ensure the appropriate assessment of, and adaptation to, climate change risks at a planning and early design stage for a proposed asset, a two-step approach was performed:

- An initial assessment of climate change risks was performed and identified in this report, in consultation with relevant designers
- Climate change risks identified were integrated into the overarching Safety in Design hazard log which is an ongoing record of project risks, and were subsequently discussed and validated at the Safety in Design workshop during reference design.

The use of this two-step process allowed an initial assessment of climate change risks or rapid appraisal with project designers, with broader interdisciplinary validation and discussion with ARTC at the Safety in Design workshop to inform the adoption of adaptation actions during reference design.

The initial risk assessment was performed with consideration of the asset context, baseline and projection data (including qualitative descriptions) for the future climate. Assessment was performed using the consequence and likelihood descriptors, and combined risk matrix provided by ARTC to align with other risk assessments for the project (refer Appendix A). Consequences include consideration of safety, operational, financial, environmental, regulatory, reputational, and schedule delay impacts to the project.

The initial risk assessment was performed in consultation with the following reference design team personnel, detailed in Appendix B:

- Project manager
- Design manager
- Systems & Safety Assurance Lead
- Flood modeller (for the EIS flooding impact assessment)
- Structural design lead

- Drainage design lead
- Geotechnical lead.

Consultation for the initial assessment consisted of short interviews to determine interdependencies with other disciplines and identification of likely areas of climate risk, current and potential controls (or adaptations).

3.6 Integration with design risk management

To allow the ongoing consideration of climate change risk and adaptation integration for the design process, the climate change risks identified in this initial assessment have been included into the Safety in Design risk documentation. This means that cross-disciplinary validation of risk levels initially identified and existing controls were reviewed and validated by design team members in a workshop process with ARTC, and subsequently reviewed before the end of reference design.

In addition, this allowed for potential controls to be reviewed in conjunction with ARTC, to implement any adaptation actions necessary for inclusion at reference design.

To align with the Safety in Design hazard log, climate change risks were described as follows:

- ‘Hazard’: a description of the climate variable change which is posing a risk to the asset eg lightning strike.
- ‘Risk’: description of the impact or event to a particular component eg lightning strike causes damage to electrical and signalling assets causing operational delay and cost.

This method allows the risks to the asset to be filtered to pair appropriate hazards and risks based on the climate changes to an applicable timeframe. For example, where asset components are only being assessed for 2030 (refer section 3.2), the ‘hazard’ has been phrased in terms of the specific climate projection for 2030, eg 4 per cent increase to 1 in 20 year rainfall event.

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4. Climate data

4.1 Asset context

4.1.1 Existing environment

At a local scale this project spans both the City of Fairfield local government area (Fairfield LGA) to the northern end, and the City of Liverpool local government area (Liverpool LGA) at the southern end. Each of these areas have maps or guidelines which interface with climate change risk. For example, Fairfield LGA has bushfire maps which are publicly available, while flood models from Liverpool LGA are being used for the flooding impact assessment for this project.

Cabramatta Creek runs east-west, roughly intersecting the project site in half (refer Figure 1.1) which thus poses the potential for both flooding, and a vegetation buffer which could carry a bushfire. The project site has been known to flood, in particular the cycleway and Broomfield Street, both as a result of limited stormwater drainage and from Cabramatta Creek flooding. Some vegetation along Cabramatta Creek has been mapped in a number of vegetation classes on the bushfire prone land map (Fairfield City Council 2017).

The project site falls within Greater Western Sydney region of metropolitan Sydney and as such experiences a number of shocks and stresses which threaten the area. For example shocks which impact Greater Western Sydney include bushfire, flooding and extreme heat events (Resilient Sydney, 2018). Urban heat island effect is a climatological phenomenon which exacerbates the extreme temperature stress experienced in built environments. Fairfield City Council and Liverpool City Council are both part of the Western Sydney Regional Organisation of Councils (WSROC) which identifies urban heat as a major concern for western Sydney, and this is the current subject of much research and policy discussions. The large scale urban development occurring in western Sydney is predicted by OEH to exacerbate the temperature increases already projected (WSROC, 2016).

4.2 Climate baseline

Per AS 5334, the following climate variables are applicable for a climate change risk assessment to rail, bridge and road infrastructure:

- Rainfall: annual average rainfall, extreme rainfall (flooding) and drought
- Temperature: Extreme temperature events and solar radiation
- Wind: Gales and extreme wind events, storms (snow, hail, dust, lightning) and cyclones
- Soil: moisture, salinity, stability and pH
- Bushfire risk
- Coastal processes: sea level rise, storm surge and storm tide.

The selection of the above variables allows quantification of specific climate risks posed to the asset by relevant climate variables, as required by the SEARs.

Baseline climate data for these variables over the 1986-2005 period at Bankstown Airport AWS is provided in Table 4.1 to give an indication of the current climate with the shift that is projected to occur, along with some climate extremes also summarised in section 4.2.1.

4.2.1 Past extremes

As climate change projections typically apply a projected average to a baseline average, it can be easy to underestimate extreme conditions which have and could occur. Climate change projections indicate that extreme events are likely to be more frequent or more intense in the future.

The following climate extremes have already occurred at or near the project site:

- Temperature high of 46.1°C (Bankstown Airport AWS, 18 Jan 2013)
- Highest daily rainfall event of 243 mm (Bankstown Airport AWS, 6 Aug 1986)
- Maximum wind gust of 134 km/h (Bankstown Airport AWS, 15 Nov 1979)
- Extreme hail events, including extremely large hailstones in Cabramatta eg 20 Dec 2018 (ABC News, 2018)
- 15 hail events were recorded within a 5 kilometre radius of Cabramatta between 1986 and 2017 in the BOM Severe Storms Archive (BOM 2018).

4.3 Climate projections

4.3.1 Qualitative projections

A descriptive picture of the future climate is helpful for those assessing climate risk to consider the broad differences between current conditions and what is projected to occur.

The key messages for the East Coast south sub-cluster as presented on CSIRO's Climate Change in Australia sub-cluster projection summary tool (CSIRO and BOM, 2015c) are as follows:

- Average temperatures will continue to increase in all seasons (*very high confidence*)
- More hot days and warm spells are projected with *very high confidence*. Fewer frosts are projected with *high confidence*
- Decreases in winter rainfall are projected with *medium confidence*. Other changes are possible but unclear
- Increased intensity of extreme rainfall events is projected, with *high confidence*
- Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*)
- A harsher fire-weather climate in the future (*high confidence*)
- On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years and for rainfall.

The future climate of one place may be likened to that of the current climate of another known location. CSIRO's Climate Analogues tool projects that by 2030 under a RCP 4.5 emission scenario Sydney's climate will look similar to that of current day Newcastle, while 2090 under RCP 8.5 is likened to the climate of Brisbane.

4.3.2 Quantitative projection data

The following table indicates the baseline and detailed projection data used for this assessment, with sources provided in the table notes below. The changes to climate variables projected represent risk sources for the proposed asset.

Table 4.1 Detailed projection data

Variable		Current climate		Climate change projections				
	Climate variable	Annual historical trend Bankstown Airport AWS	Baseline period	Reported as	General trend	Near term, moderate scenario 2030, RCP 4.5	Long term, extreme scenario 2090, RCP 8.5	Source
Temperature	Mean maximum daily temperature (°C) - Annual	23.2	1986-2005	Absolute change	↑	+0.9 (0.6 to 1.2) ie 24.1°C (23.8 to 24.4)	+3.8 (3 to 4.9) ie 27°C (26.2 to 28.1)	1
Temperature	Mean maximum daily temperature (°C) – Summer (DJF)	27.6	1986-2005	Absolute change	↑	+1 (0.5 to 1.5) ie 28.6°C (28.1 to 29.1)	+3.8 (2.8 to 4.5) ie 31.4°C (30.4 to 32.1)	1
Temperature	Days p.a. over 35°C	8.1	1986-2005	New value	↑	11.9 days	25.4 days	2
Temperature	Days p.a. over 40°C	1.0	1986-2005	New value	↑	1.4 days	5.7 days	2
Temperature	Highest temperature for years 1986 to 2005 (°C)	44.8 18 January 2003	Discrete event	Absolute change	↑	+0.9 (0.5 to 1.7) ie 45.7°C (45.3 to 46.5)	+3.7 (2.4 to 5.2) ie 48.5°C (47.2 to 50)	3
Temperature	Highest temperature on record (1968 to 2018) (°C)	46.1 18 January 2013	Discrete event	Absolute change	↑	n/a		
Temperature	Mean daily solar exposure (MJ/(m*m))	16.5	1990-2005	Percentage change	↑	+0.5% (-0.5 to 1.9) ie 16.6 MJ/(m*m) (16.4 to 16.8)	+1.3% (-1.2 to 3.4) ie 16.7 MJ/(m*m) (16.3 to 17.1)	1
Rainfall	Annual average rainfall (mm)	856.2	1986-2005	Percentage change	↓	-3% (-10 to 6) ie 830.5 mm (770.6 to 907.6)	-3% (-20 to 16) ie 830.5 mm (685 to 993.2)	1
Rainfall	Highest daily rainfall (mm) for years 1986 to 2005 (also record for all years 1968 to 2018)	243 6 August 1986	Discrete event	Percentage change	↓↑ Seasonal variation	-1.8% (-26.2 to 11.7) ie 238.6 mm (179.3 to 271.4)	-8.9% (-40.3 to 18.3) ie 221.4 mm (145.1 to 287.5)	3
Rainfall	1 in 20 year wettest day	n/a	n/a	Percentage change	↑	+4.0% (-9.7 to 15.9)	+25.7% (7.1 to 43.3)	4
Rainfall	Drought	n/a	n/a	Qualitative	↑	Greater time spent in drought		8

Variable		Current climate		Climate change projections				
	Climate variable	Annual historical trend Bankstown Airport AWS	Baseline period	Reported as	General trend	Near term, moderate scenario 2030, RCP 4.5	Long term, extreme scenario 2090, RCP 8.5	Source
Daily conditions	Soil moisture	n/a	n/a	Percentage change	↓	-2.1% (-10.2 to 2)	-8.7% (-15.4 to 2.4)	1
Daily conditions	Evapotranspiration	n/a	n/a	Percentage change	↑	+3.4% (2.3 to 4.4)	+14.3% (10.1 to 18.1)	1
Daily conditions	Avg. 9 am wind speed (km/h)	9.2	1986-2005	Percentage change	↓	-1.1% (-2.9 to 0.5) ie 9.1km/h (8.9 to 9.2)	-1.1% (-6.9 to 4.2) ie 9.1km/h (8.6 to 9.6)	1
Daily conditions	Avg. 3 pm wind speed (km/h)	18.2	1986-2005	Percentage change	↓	-1.1% (-2.9 to 0.5) ie 18km/h (17.7 to 18.3)	-1.1% (-6.9 to 4.2) ie 18km/h (16.9 to 19)	1
Storm events	Maximum wind gust for years 1968 to 2018 (km/h)	134 15 November 1979	Discrete event	Percentage change	↓	n/a	-2.5% (-6.5 to 2.5) ie 130.7km/h (125.3 to 137.4)	7
Storm events	Hail	5.2 hail events per year (Sydney city)	1990-2007	Qualitative	↑	Increase in hail days per year		6
Storm events	Lightning	20-25 thunder days per year (Sydney area)	n/a	Percentage change	↑	5-6% increase per °C warming		6
Storm events	East coast lows	10 per year	n/a	Qualitative	↑↓	Projections vary based on season, intensity and type of storm		6
Storm events	Severe fire danger days per year	1.2	1986-2005	New value	↑	1.3 to 1.4	1.6 to 4.0	5
Sea conditions	Sea level rise (m)	n/a	1986-2005	Relative change	↑	+0.14	+0.85	9
Sea conditions	Storm surge	n/a	n/a	Qualitative	↑	Dependant on east coast low activity (above), typically more extreme sea level events are projected		10

Source references:

1 CSIRO BOM 2015, Climate Change in Australia Projections Cluster Report - East Coast, Appendix Table 1c

2 BOM data for Bankstown Airport AWS, calculated applying CSIRO projected annual maximum temperature projections to baseline data

3 CSIRO BOM, Climate Change in Australia Extremes Data Explorer, applicable seasonal projection used
4 CSIRO BOM, Climate Change in Australia Extremes Data Explorer, annual projection
5 CSIRO BOM 2015, Climate Change in Australia Projections Cluster Report - East Coast, Appendix Table 2, Projections for Richmond
6 State of NSW and Department of Environment, Climate Change and Water 2010, Impacts of Climate Change on Natural Hazards Profile, Sydney/Central Coast Region
7 CSIRO BOM 2015, Climate Change in Australia Projections Cluster Report - East Coast, estimate from Figure 4.4.2 for maximum daily wind speed
8 CSIRO BOM 2015, Climate Change in Australia Projections Cluster Report - East Coast, section 4.3.2
9 CoastAdapt (2017) Projections for Sydney LGA
10 CSIRO BOM 2015, Climate Change in Australia Projections Cluster Report - East Coast, section 4.10.1
NB: Severe fire danger days per year based on Forest Fire Danger Index >50. Based on three climate models.

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5. Initial risk assessment

5.1 Climate change risks

The proposed asset facilitates a second rail track for the SSFL to allow additional freight movements. As such, the nature of the existing infrastructure is not changing, with bridge, road, noise wall and SSFL infrastructure already in place between Cabramatta and Warwick Farm stations. In addition, it is likely that a more recent design according to current standards and engineering practices may increase the resilience of the assets compared to the existing infrastructure. More recent designs are typically more resilient to climate change, with periodic updates to standards and engineering practice taking into account more recent climate baselines as the operating environment.

This initial climate change risk assessment identified eleven climate hazards and associated risks which are applicable to the project. A summary of the climate change risks identified, including the existing controls and initial assessment of consequence and likelihood, is provided in Table 5.1 below. Current control measures were identified which describe the controls and adaptation measures incorporated within the scope of reference design, which addresses the requirement of the SEARs to incorporate climate change risk mitigation in design. Additionally, potential controls were identified which represent adaptation actions which could be implemented at detailed design, or operation, these are discussed further in Chapter 6. These potential controls may serve to reduce the residual risk, as shown in Table 5.1.

Four medium risks were identified relating to flooding and storms. These risks are discussed further in section 5.2. No high or very high risks were identified, in part reflecting the effective adaptation measures already identified and implemented as part of reference design.

Typically impacts identified have consequences for operational delay to the asset, financial implications or safety risk, in line with ARTC's risk matrix, refer Appendix A.

Table 5.1 Climate risk assessment summary

Hazards	Risk	Existing control measures	ARTC initial risk rating			Potential control measures including existing ARTC operational procedures	ARTC residual risk rating			Comments
			Consequence	Likelihood	Risk rating		Consequence	Likelihood	Risk rating	
Extreme wind	Noise wall collapse due to extreme wind event causing fatality, environmental damage or cost	1. Noise wall designed to Australian wind code AS1170.2 resulting in design wind gust velocity of 143 km/h (greater than maximum projected wind gust of 137.4 km/h)	**5 – Extreme**	**E – Rare**	**MED – 5E**	None identified	**5 – Extreme**	**E – Rare**	**MED – 5E**	Applicable to 2030 scenario
4% increase to 1 in 20 year rainfall	Cabramatta Creek floods rail track causing operational delay	1. Ballasted track provides drainage for rainfall 2. Detailed modelling shows immunity to more than 1 in 200 year event	**2 – Minor**	**E – Rare**	**LOW – 2E**	None identified	**2 – Minor**	**E – Rare**	**LOW – 2E**	Applicable to 2030 scenario
4% increase to 1 in 20 year rainfall	Rail track floods due to poor drainage causing operational delay	1. Ballasted track provides drainage for rainfall 2. Current stormwater flows to be matched (at a minimum)	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	None identified	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	Applicable to 2030 scenario

Hazards	Risk	Existing control measures	ARTC initial risk rating			Potential control measures including existing ARTC operational procedures	ARTC residual risk rating			Comments
			Consequence	Likelihood	Risk rating		Consequence	Likelihood	Risk rating	
4% increase in 1 in 20 year rainfall	Broomfield Street becomes flooded due to poor drainage causing reputational damage, damage to houses, road closure or serious injury (Indirect risk to ARTC)	1. Design will match current stormwater flow rates 2. Flood modelling has been performed to assess flood risk for a range of scenarios including climate change	**4 – Major**	**D – Unlikely**	**MED – 4D**	1. ARTC to consult with asset owner, Fairfield City Council, regarding the drainage design	**4 – Major**	**D – Unlikely**	**MED – 4D**	Applicable to 2030 scenario
4% increase in 1 in 20 year rainfall	Cabramatta Creek floods cycleway causing serious injury to cyclists (Indirect risk to ARTC)	No project controls at this stage.	**3 – Moderate**	**C – Possible**	**MED – 3C**	1. ARTC to consult with asset owner, Fairfield City Council, regarding the drainage design	**3 – Moderate**	**C – Possible**	**MED – 3C**	Applicable to 2030 scenario
Higher extreme heat and solar radiation	Rail track buckling causing delays and increased management effort and cost	1. Concrete sleepers in design to reduce movement 2. Creep heat monitoring is standard rail design practice	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	1. Heat affects are currently managed via an operational procedure, the Area Stability Maintenance Plan, guided by ANG-210 – this includes a measure that speed restrictions are put in place n extreme heat based upon the neutral temperature of the rail.	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	Applicable to 2030 scenario

Hazards	Risk	Existing control measures	ARTC initial risk rating			Potential control measures including existing ARTC operational procedures	ARTC residual risk rating			Comments
			Consequence	Likelihood	Risk rating		Consequence	Likelihood	Risk rating	
Higher extreme heat and solar radiation	Signalling equipment loses efficiency causing increased energy consumption, reduced design life and cost of replacement	1. Critical signalling equipment (Point machines and interlocking) rated to operate up to 70°C	**1 – Not significant**	**D – Unlikely**	**LOW – 1D**	1. Re-specification of equipment at end of design life to account for climate change	**1 – Not significant**	**D – Unlikely**	**LOW – 1D**	Applicable to 2030 scenario
Intense storms	More intense storms disrupt operations of paths, rail track or road from fallen debris blocking access or drainage	1. Flooding analysis has been performed to consider the flood profile of the project and the surrounding environment. 2. Noise wall provides some protection to track infrastructure	**2 – Minor**	**B – Likely**	**MED – 2B**	1. Implementation of an appropriate maintenance regime to limit blocked drainage in line with ARTC's existing Major Periodic Maintenance regime	**2 – Minor**	**C – Possible**	**LOW – 2C**	Applicable to 2030 and 2090 scenarios
Lightning strikes	Lightning strike causes damage to electrical and signalling assets, causing operational delay and cost	1. Bonding of equipment to rails and cross-bonding of all current and proposed tracks reduces effects of lightning strikes	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	None identified	**2 – Minor**	**D – Unlikely**	**LOW – 2D**	Applicable to 2030 and 2090 scenarios

Hazards	Risk	Existing control measures	ARTC initial risk rating			Potential control measures including existing ARTC operational procedures	ARTC residual risk rating			Comments
			Consequence	Likelihood	Risk rating		Consequence	Likelihood	Risk rating	
Increased bushfire weather	More frequent bushfires impact operations of SSFL	1. Additional loop provided by project allows adaptive SSFL management	**2 – Minor**	**C – Possible**	**LOW – 2C**	1. Implementation of an appropriate bushfire management plan in line with ARTC's current policies	**2 – Minor**	**C – Possible**	**LOW – 2C**	Applicable to 2030 and 2090 scenarios

The Safety in Design hazard log includes additional information to the initial climate change risk assessment recorded above. Hazard reference code, source (Climate change risk assessment), owner, package (Reference Design), location, SFAIRP justification statement and hazard status are also included for each risk in the Safety in Design hazard log. For tracking purposes, Table 5.1 presents the outcome of the initial climate change risk assessment at the time of preparation for contribution to the EIS, while the Safety in Design hazard log presents the up to date record of risks which will be assessed for incorporation into design and tracked throughout the reference design, showing final status of each hazard as 'closed out for design' or 'transferred' for future stages of the project.

5.2 Additional climate risks considered

A number of risks were discussed with design team members and ruled out, due to having low or no risk, and as such not requiring further assessment. These discussions are outlined below to provide additional information as to why these were not assessed as climate change risks during this risk assessment.

Bridge structures are not typically at risk from flooding or wind impacts due to the conservatism of the design standards (RMS, draft). This was further confirmed by the opinion of the structural lead for the project and has accordingly not been identified as a risk to the project.

Design team members consulted did not consider there to be any risks to the retaining wall structures as a result of climate change (such as structural collapse due to sudden increase in soil moisture from extreme rainfall events), as the retaining walls are intended to be drained structures, and are not made to hold moisture. Design codes consider and mitigate structural loading risks due to high soil moisture by incorporating extreme water table levels in the standards that are applied to design a retaining wall.

Hail was not considered to be a risk to the particular structural scope of the project. Climate change projections for this variable are uncertain due to modelling limitations, but would likely pose a higher risk to buildings than the types of infrastructure proposed.

The flood modelling performed for the EIS flooding impact assessment (Technical Report 5 – Hydrology and flooding impact assessment) indicated that sea level rise and storm surge do not pose a risk to the project, as these variables do not influence far enough up the George's River to influence the flood risk for the project.

5.3 Principle risks identified

5.3.1 Flooding

The flood risk of the project has been assessed regarding both the project and the surrounding environment as part of the EIS and reference design (Technical Report 5 – Hydrology and flooding impact assessment). The risk of Cabramatta Creek flooding has been considered in addition to the risk of flash flooding and stormwater capacity.

Climate change has been assessed within the Hydrology and flooding impact assessment (Technical Report 5) for the EIS by increasing the modelled runoff from rainfall in the 100 year event by 10 per cent, accounting for increased rainfall expected in the future. This is greater than the 4 per cent increase to the 1 in 20 year rainfall event which is projected for 2030.

The immunity of the rail line is greater than a 1 in 200 year event. Modelling of the 1 in 500 year event indicates the potential for overtopping of the rail track further south of the rail bridge around Jacquie Osmond Reserve and just north of the car yard. However, as the track does have immunity during the 1 in 200 year event, the rail line has flood immunity for the 100 year event as well as the 100 year event with 10 per cent rainfall increase to account for climate change. As the relevant infrastructure (Broomfield Street and the cycleway) which has been identified as vulnerable to flooding has a design life in the order of 25 years, 2090 rainfall projections have not been specifically assessed for these components. Direct flooding risks to the project were assessed as Low with no additional adaptation measures identified (refer Table 5.1).

The flood modelling determined that there is significant flooding for Broomfield Street for the 1 in 100 year event with 10 per cent addition for climate change (Technical Report 5 – Hydrology and flooding impact assessment). This includes inundation to houses and unsafe velocity flows on some parts of the street. Due to existing stormwater capacity constraints the immunity for

Broomfield Street is less than the 10 per cent Annual Exceedance Probability (more frequent than 1 in 10 years), and the flood immunity for the cycleway is assessed as the same (in light of the detailed modelling not covering events more frequent than this).

A 1 in 20 year rainfall event with 4% increase due to climate change would likely cause flash flooding on Broomfield Street and the cycleway, and these were both assessed as Medium risks (refer Table 5.1). These are indirect risks to ARTC which will not be the asset owner or operator of Broomfield Street or the cycleway at the end of the project. The risk already exists and is experienced in the area due to the level of the asset in the landscape and the capacity of existing infrastructure.

The project does not alter the risk – ARTC proposes to match the existing infrastructure capacity, noting that engineering controls to reduce the risk of significant flooding of Broomfield Street and the cycleway are not reasonably feasible. Management controls for these risks would be recommended. It is Fairfield City Council that as the owner and operator of these assets will continue to operate such management controls with ARTC having limited remit to implement management controls for these risks. The recommended control measure in this case is for ARTC to agree an acceptable level of risk for these assets with Fairfield City Council as the asset owner/operator in light of the flood modelling results, which requires appropriate recognition and handover of risk.

5.3.2 Storms

Extreme wind and storms were rated as medium risks due to the safety consequences of these events. For example the risk of noise wall collapse would be Rare, but walls have been known to fall and cause fatality in exceptional circumstances. Generally, appropriate maintenance regimes may mitigate storm activity more broadly, ensuring that the potential for debris and blocked drains is kept to a minimum. ARTC currently has a policy *Monitoring and Responding to Extreme Weather Events*, which provides direction around inspection frequencies for various extreme weather alerts including wind and rainfall events. Adoption of this policy in the management of the proposed asset would provide mitigation to storm event impacts in line with ARTC current practices.

The most difficult climate change risks to anticipate and manage occur where multiple events coincide. For example, although flooding has been shown to be a Low risk for the proposed rail line, if maintenance schedules allow debris to block drainage systems then the controls cannot be relied upon, and the risk of flooding would become heightened. This has been reflected in the storm risk identified in Table 5.1, where debris and high intensity rainfall are likely to coincide.

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6. Recommended adaptation measures

It is worth noting that climate change itself as a risk source is not under the control of the asset owner or operator. Nevertheless, controls or adaptations may be implemented to reduce the likelihood or the consequences of extreme climate events which may transpire as a result of climate change. Typically there is a lag between climate change science and incorporation of the newly observed climate data into Australian Standards, therefore designing to standards cannot be wholly relied upon to ensure climate change risk is mitigated, without some further consideration.

Risks identified in this assessment were all Medium or Low, considering current controls that have been applied or planned for reference design as required by the SEARs. As such, these risks may be considered as tolerable by ARTC and other project stakeholders. Some risks are more appropriate for treatment during design such as drainage sizing which is difficult and costly to upgrade later, while adaptive management may be more appropriate for other types of risks.

The potential adaptations identified as part of this risk assessment are summarised in Table 6.1 below for consideration, along with the initial risk rating for each risk. ARTC is not the owner/operator of Broomfield Street or the cycleway and therefore has limited capacity for adaptation measures, as risk is most appropriately treated by a party who has the authority and ability to manage the risk.

Table 6.1 Summary of potential adaptation measures identified

#	Risk	Risk rating	Potential adaptation measures	Adaptation timing
1	Broomfield Street becomes flooded due to poor drainage causing reputational damage, damage to houses, road closure or serious injury (Indirect risk to ARTC)	Medium	1. ARTC to agree acceptable risk level with asset owner, Fairfield City Council	Detailed design
2	Cabramatta Creek floods cycleway causing serious injury to cyclists	Medium	1. ARTC to agree acceptable risk level with asset owner, Fairfield City Council	Detailed design
3	Rail track buckling from extreme heat and solar radiation causing delays and increased management effort and cost	Low	1. Management protocols to protect track in extreme heat events, using creep heat monitoring	Operation commencement
4	Signalling equipment loses efficiency from extreme heat and solar radiation causing increased energy consumption, reduced design life and cost of replacement	Low	1. Re-specification of equipment at end of design life to account for climate change	Operation (future upgrades)
5	More intense storms disrupt operations of paths, rail track or road from fallen debris blocking access or drainage	Medium	1. Implementation of an appropriate maintenance regime to limit blocked drainage in line with ARTC's existing Major Periodic Maintenance regime	Operation commencement
6	Lightning strike causes damage to electrical and	Low	1. Consider potential for lightning protection in light	Detailed design

#	Risk	Risk rating	Potential adaptation measures	Adaptation timing
	signalling assets, causing operational delay and cost		of broader SSFL asset protection	
7	More frequent bushfires impact operations of SSFL	Low	1. Implementation of an appropriate bushfire management plan in line with ARTC's current policies	Construction/ Operation

Of the seven adaptation or treatment actions, three are appropriate to consider during design (1, 2 and 6 above).

Three recommendations (3, 5 and 7 above) relate to the implementation of management plans or protocols to mitigate risk which should ideally be in effect by the commencement of operations.

One treatment identified (4 above) relates to future equipment upgrade, and to some extent may be equally said for all equipment and broader project upgrades, that climate change risk should be reconsidered at key trigger points such as infrastructure renewal, or major updates to climate change science and projections in Australia.

6.1 Recommended mitigation measures

Overall this risk assessment did not identify any high or very high risks, and the climate change risks presented to the proposed asset are relatively benign, given the scale and operations of the project.

Therefore the following mitigation measures are recommended to manage climate change risk:

1. ARTC will:
    a. Apply this climate change risk assessment and its existing control measures identified in Table 5.1 in implementing the project, or
    b. In the event of design changes, during detailed design, review the climate change risks identified in this assessment in order to amend existing control measures or identify additional control measures to reduce the climate change related risks to the project with no 'very high' or 'high' residual climate related risks remaining.
2. ARTC will implement all potential adaptation measures identified in Table 6.1 so far as is reasonably practicable to reduce climate change risk.
3. In the event of significant new scientific climate change projections becoming available during detailed design, ARTC will review the relevant climate change risks and control measures identified in this assessment in order to confirm that there are no 'very high' or 'high' residual climate related risks remaining.

6.2 Further considerations

The Safety in Design hazard log includes the risks identified in Table 5.1 and has been subject to a multidisciplinary workshop and interdisciplinary review of risks.

Operational recommendations may be considered by the project proponent as part of broader risk management processes, for incorporation and ongoing monitoring and review.

In the future, ARTC may wish to reassess climate change risk to the project at detailed design to improve the project's resilience in line with a broader sustainability strategy, this may include incorporation of climate change risk consideration into contractual requirements for detailed design, and review of climate change risk in light of any significant updates to climate change science or new best available climate change projections.

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Appendices

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Appendix A – ARTC Risk matrix and descriptors

Consequence descriptors

	Risk Category	Consequence				
	Descriptor	Not Significant	Minor	Moderate	Major	Extreme
	Level	1	2	3	4	5
Safety category is focussed on Impact to People	**S: Safety**	No Medical Treatment Required	Lost Time Injury Results (LTI) OR Medical Treatment Required	Serious Injury Occurs	Single Fatality Occurs	Multiple but Localised Fatalities Occur
Asset category is focussed on Operations Impact, Track, Systems (Hardware & Software) and Human Assets **Programme/Project** - Focused on engineering impact(s) and satisfying objectives	**A: Assets**	Up to 6hrs Unplanned Track Closure Minor impact on a programme/ project objective	>6hrs to 24hrs Unplanned Track Closure Minor impact on more than one programme/ project objective	>24hrs to 48hrs Unplanned Track Closure Significant impact on a programme/ project objective	>48hrs to 5 Days Unplanned Track Closure Severe impact on a programme/ project objective or significant impact on more than one objective	>5 Days Unplanned Track Closure Severe impact on more than one programme/ project objective
Focussed on Financial Impact Cash flow, liquidity, Capital, Asset Value, Procurement & Contracts related exposure **Programme/Project** - Focused on Total Outturn Cost Impact	**F: Financial**	Up to $250,000	Equal to or more than $250,000, up to $1m	Equal to or more than $1m, up to $2m	Equal to or more than $2m, up to $5m	Equal to or more than $5m
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 damage to the environment - remediation required

	Risk Category	Consequence				
	Descriptor	Not Significant	Minor	Moderate	Major	Extreme
	Level	1	2	3	4	5
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
Focussed on Reputational Exposure Customer Dissatisfaction, Shareholder Support, Service Quality & Reliability, Public Image and Stakeholder Attitudes	**R: Reputation**	Isolated event able to be resolved [<7Days]	Management intervention required [>7days but <3mths]	Tactical (Business Unit / Divisional) intervention required [>3 months but <18mths]	Strategic intervention required [>18mths but <3years]	Corporate Loss of Shareholder and/or Customer support (tangible business impact) >3years
Programme/Project - Focused on time based impacts	**S: Schedule**	Up to two weeks	Equal to or more than two weeks, up to 1 month	Equal to or more than 1 month, up to 3 months	Equal to or more than 3 months, up to 6 months	Equal to or more than 6 months

Combined risk matrix and likelihood descriptors

Likelihood		Consequence						
			Descriptor	Not Significant	Minor	Moderate	Major	Extreme
Description	Frequency of Occurrence	Descriptor	Level	1	2	3	4	5
Is expected to occur in most circumstances	Once per month	Almost Certain	A	MED - 1A	MED - 2A	HIGH - 3A	V HIGH - 4A	V HIGH - 5A
Will probably occur in most circumstances	Between once a month and once a year	Likely	B	LOW - 1B	MED - 2B	HIGH - 3B	V HIGH - 4B	V HIGH - 5B
Might occur at some time	Between once a year and once in five years	Possible	C	LOW - 1C	LOW - 2C	MED - 3C	HIGH - 4C	HIGH - 5C
Could occur at some time	Between once in 5 years and once in 20 years	Unlikely	D	LOW - 1D	LOW - 2D	LOW - 3D	MED - 4D	MED - 5D
May occur in exceptional circumstances	Once in more than 20 years	Rare	E	LOW - 1E	LOW - 2E	LOW - 3E	LOW - 4E	MED - 5E

Appendix B – Consultation record

Consultation record

Name	Company	Project role	Title
Andrew Priory	GHD	Flood modeller	Water Resources Engineer
Daniel Green	GHD	Design manager	Senior Civil/ Environmental Engineer
Jorge Pautasso	GHD	Structural Lead	Senior Technical Director - structures
Lewis Schneider	GHD	Drainage designer	Civil Engineer
Mike Parsons	GHD	Project manager	Technical Director – Project management/ civil
Steve Amoroso	GHD	Geotechnical Lead	Technical Director - Geotechnics
Stuart Healy	GHD	Systems & Safety Assurance Lead	Project Engineer - Signalling/ Systems

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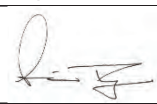
Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	H Urwin	Leon Olsen		S Page		08/08/2019

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CABRAMATTA LOOP PROJECT

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 5 — TECHNICAL REPORT