Prepared for
Major Projects Canberra
ABN: 66 676 633 401

# Climate and Natural Hazards Assessment

## Technical Report - Light Rail City to Commonwealth Park

15-Dec-2022
Light Rail City to Commonwealth Park

aecom.com

Delivering a better world

# Climate and Natural Hazards Assessment

Technical Report - Light Rail City to Commonwealth Park

Client: Major Projects Canberra

ABN: 66 676 633 401

Prepared by

**AECOM Australia Pty Ltd**
Civic Quarter, Level 4, 68 Northbourne Avenue, GPO Box 1942 ACT 2601, Canberra ACT 2601, Australia
T +61 2 6100 0551 www.aecom.com
ABN 20 093 846 925

15-Dec-2022

Job No.: 60656949

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

# Table of Contents

# List of Acronyms

| Acronym | Definition |
|---|---|
| **ACT** | Australian Capital Territory |
| **AEP** | Annual Exceedance Policy |
| **AS** | Australian Standard |
| **BoM** | Bureau of Meteorology |
| **CLR** | Canberra Light Rail |
| **CMTEDD** | Chief Minister, Treasury and Economic Development Directorate |
| **CNHA** | Climate and Natural Hazards Assessment |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **FFDI** | Forest Fire Danger Index |
| **GHG** | Greenhouse Gas |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IS** | Infrastructure Sustainability |
| **ISC** | Infrastructure Sustainability Council |
| **ISO** | International Standards Organisation |
| **MPC** | Major Projects Canberra |
| **NARCliM** | NSW and ACT Regional Climate Modelling |
| **NZS** | New Zealand Standard |
| **OEH** | Office of Environmental Heritage |
| **ONRSR** | Office of the National Rail Safety Regulator |
| **PMF** | Probable Maximum Flood |
| **PPE** | Personal Protective Equipment |
| **RCP** | Representative Concentration Pathway |
| **RLs** | Relative Levels |
| **SRES** | Special Report on Emissions Scenarios |
| **SSPs** | Shared Socio-economic Pathways |
| **TCCS** | Transport Canberra & City Services |
| **WSUD** | Water Sensitive Urban Design |

# Glossary

| Term | Definition |
|---|---|
| Adaptation | Anticipating adverse effects and taking appropriate action to prevent or minimise the damage they can cause, as well as to harness any beneficial opportunities[1]. |
| Climate Change | Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. |
| Climate hazards | 'Hazard' is defined by the Intergovernmental Panel on Climate Change (IPCC) as: "The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources." |
| Climate projections | Scientifically derived estimations of how different variables (such as temperature, precipitation, wind, solar radiation, sea level rise) in our climate and weather will be affected by increases in greenhouse gasses in the Earth's atmosphere. |
| Climate resilience | Capacity of a system to survive, adapt, bounce back and grow no matter what kinds of climate-related chronic stresses and acute shocks they experience. |
| Climate variables | A physical, chemical or biological variable or a group of linked variables that critically contributes to the characterisation of Earth's climate. Changes in climate variables (such as temperature) can lead to changes in climate hazards (such as heatwaves). |
| Consequence | The consequence of a risk is based on the impact of the event happening |
| Extreme weather events | Refers to climate hazards such as bushfires, periods of poor air quality, extreme heat days and/or periods of hot weather, severe storms, heavy rainfall events, etc. |
| Likelihood | The likelihood of a risk is based on the chance that it will occur. |
| Mitigation | Actions taken globally, nationally and individually to limit changes caused in the global climate by human activities. Mitigation activities are designed to reduce greenhouse emissions and/or increase the amounts of greenhouse gases removed from the atmosphere by greenhouse sinks. |
| Physical risk | Physical risk is the risk of direct damage to ACT Government assets and services, supply chains, market impacts or liability due to failure to foresee losses from physical impacts of climate change. Physical risks can be:<br>• Acute risks –event driven (shocks)<br>• Chronic risks –longer-term shifts in climate patterns (stresses). |
| Representative Concentration Pathways (RCPs). | The IPCC developed four emission scenarios that explore a range of credible futures based on possible scenarios for future global greenhouse gas concentrations within the atmosphere. These are referred to as Representative Concentration Pathways (RCPs). The IPCC's Fifth Assessment Report (AR5) considered four pathways: RCP8.5, RCP6, RCP4.5 and RCP2.6. Each RCP reflects a different concentration of global GHG emissions reached by 2100, based on assumptions of different combinations of possible future economic, technological, demographic, policy, and institutional trajectories[2] |
| Resilience | The capacity of communities to resist, absorb, accommodate, recover, transform, and thrive in response to shocks and stresses, to realise positive economic, social, and environmental outcomes[3]. |
| Risk | A risk is a function of the likelihood that any hazard/shock and/or stress will cause harm under a given scenario and consequence or the extent to which the system, environment, economy, and society might be adversely affected under this scenario. |

[1] Available at: https://climatechange.environment.nsw.gov.au/Adapting-to-climate-change/Local-government/Adaptation-planning
[2] Representative Concentration Pathways (RCPs) Fact Sheet, Australian Government, Department of Environment
[3] Available at: https://www.infrastructureaustralia.gov.au/publications/pathway-infrastructure-resilience-0

| Term | Definition |
|---|---|
| Shocks | An acute natural or man-made event or phenomenon threatening major loss of life, damage to assets and a city's ability to function and provide basic services, particularly for poor or vulnerable populations. |
| Stresses | A chronic (ongoing or cyclical) natural or man-made event or phenomenon that renders the city less able to function and provide basic services, particularly for poor or vulnerable populations. Stresses can amplify shock events or exacerbate hazards. |

# Executive Summary

## Overview

The purpose of this report is to present the findings of a Climate and Natural Hazards Assessment (CNHA) completed as part of the proposal to extend the Canberra Light Rail (CLR) from its current terminus on Alinga Street to Commonwealth Park (referred to as Canberra Light Rail Stage 2A (CLRS2A) ('the Project')).

This report aims to align with relevant National and ACT Government policies, strategies and plans such as the *Australian Government's National Climate Resilience and Adaptation Strategy*[4] and the *ACT Climate Change Strategy 2019-2025*[5]. It also aligns with the criteria outlined in the ISC Rating Scheme v2.0.

This report assesses risks and vulnerability related to climate change relevant to the Project in accordance with current guidelines, utilises relevant climate change projections, and identifies and recommends specific adaption actions.

In addition to complying with the relevant policies, strategies and plans, this report identifies relevant climate effects and provides an assessment of the potential climate change risks to the Project. It further identifies appropriate risk management and adaptation measures to build the resilience of the Project to changing climate conditions. It is worth noting the scope of this CNHA covers physical climate risks and no consideration to transition climate risks has been given.

Physical risks are related to the risk of direct damage to the Project, supply chains, market impacts or liability due to failure to foresee losses from physical impacts of climate change. Physical risks can either considered as acute risks – event driven (shocks) or chronic risks – longer-term shifts in climate patterns (stresses).

Transitions climate related risks and opportunities are not discussed within this report however can be defined as risks associated towards the global shift towards a low carbon economy. These may include risks and opportunities associate with Market and Technology Shift, Policy and Legal Changes and Reputation.

## Data sources

In order to assess the risk to the Project posed by climate change, the current climate science and model projections have been investigated for the following parameters based on available data sources. Reflecting the requirements of the relevant National and ACT Government policies, strategies and plans, this CNHA has used two data sources for climate change projections:

- NARCliM developed by the Office of Environment and Heritage (OEH) (OEH, 2014) which provides projections at the 10 kilometre resolution.
- CSIRO and BOM Climate Futures (CSIRO, 2015) which supplements the information available from the NARCliM projections for a number of key climate variables.

Projections from the Fifth Assessment Report (AR5) are presented for emission scenarios or possible pathways, referred to as Representative Concentration Pathways (RCPs), each of which reflects a different concentration of global GHG emissions. While RCPs exist for low emissions (RCP 2.5) and medium emissions (RCP 4.5), the RCP reported here is for high emissions (RCP 8.5). The RCP 8.5 pathway, which arises from limited effort to reduce emissions and represents a failure to prevent warming by 2100, is similar to the highest Special Report on Emissions Scenario (SRES) and is used in this report. The RCP 8.5 pathway is also closest to the current emissions trajectory.

It is noted that following the development of climate projections outlined in this report the IPCC published their Sixth Assessment Report which introduced new global emissions pathways referred to as Shared Socio-economic Pathways (SSPs). With these new pathways, results of global climate

[4] Available: https://www.awe.gov.au/science-research/climate-change/adaptation/strategy/ncras-2021-25

[5] Available https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache

models are becoming available however the resolution of these models is very coarse, with no regionalisation of models thus AR5 data was utilised for the purpose of this assessment.

## Construction risks

Risks for construction resulting from a changing climate were not identified as part of the risk assessment process, in the understanding that construction would be complete within the next few years, and that changes in the climate over this period would not be too dissimilar to current conditions. As such, risks to construction were only assessed at the 2030 time horizon (and not 2070) as works are expected to be completed well in advance of 2030.

Due to previous events experienced in and around the Project, including observed trends, risks to construction from climate hazards could occur by way of physical damage, reduced capacity, and potential risks to human health and safety. Based on these past events and trends, risks to the construction process could include:

- Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts.
- Extreme heat (days over 35°C) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts.
- Bushfire smoke affecting visibility and air quality for construction workers.

Mitigation and adaptation measures to reduce the impacts of the identified construction climate risks for the Project have been provided.

## Operational risks

Based on the CNHA for the Project, the following risks were identified as presenting the highest risk in both the near term (2030) and long term (2070):

- Extreme rainfall and flooding
- Extreme heat
- Drought / mean rainfall changes
- Extreme storms
- Bushfire.

The assessment identified a total of 42 risks, both direct and indirect risks for the Project as presented below in Table 1. Note residual risk ratings were applied where not applied where the preliminary risk rating was low or very low for both timeframes.

**Table 1 Summary of identified risks**

| | 2030 – Preliminary | 2030 - Residual | % reduced | 2070 – Preliminary | 2070 - Residual | % reduced |
|---|---|---|---|---|---|---|
| Negligible | 0 | 0 | NA | 0 | 0 | NA |
| Very Low | 0 | 9 | NA | 0 | 0 | NA |
| Low | 11 | 21 | NA | 4 | 12 | NA |
| Medium | 23 | 8 | 91 | 12 | 26 | 83 |
| High | 7 | 0 | 100 | 23 | 0 | 100 |
| Very high | 1 | 0 | 100 | 3 | 0 | 100 |
| Significant | 0 | 0 | NA | 0 | 0 | NA |
| Total | **42** | **38** | **-** | **42** | **38** | **-** |

The consequences of these risks may include physical damage, increased discharge of water and the accelerated deterioration of assets.

In accordance with best practice and current design standards, operations and maintenance practices, risk management, and adaptation measures, a number of treatment options have been incorporated into the pre-concept and concept designs for the Project.

A residual risk assessment (post-application of adaptation measures) for the Project was undertaken. Based on the application of the adaptation measures, no residual 'very high' or 'high' risk ratings remain for the Project against 2030 and 2070 timeframes.

## Next steps

The climate risk and adaptation actions identified in this report have been tested and refined through feedback and discussion from team members across a range of disciplines and provide a baseline assessment to inform the design process. As the design is still currently progressing, there are opportunities to identify and explore additional treatment options to add value and support improved response to climate change. These could include:

- Exploring initiatives such as coordination / opportunities with other stakeholders for downstream augmentation to support better drainage outcomes as well as additional water capture options to improve response to flood risks and extreme rainfall.
- Communicating outcomes of Project investigations, such as sensitivity testing and shading constraints, to surrounding stakeholders to develop shared / collaborative responses.
- Exploring additional options to improve to response to extreme heat through actions such as additional shading along the corridor, materials selections for Project elements (e.g. permeable pavements) and reviewing key specifications (such as pavement design) to ensure they can accommodate future increases in temperature.

In order to apply these findings and support the requirements set out the relevant National and ACT Government policies, strategies and plans, the following next steps are recommended:

- Risk and adaptation review – the risk assessment and adaptation actions have been identified based on the current design for the Project and are a snapshot at this time in the Project development process. It is noted that the adaptation actions should be re-examined at future design milestones or phases to confirm inclusion and suitability as well as for feasibility of construction for the Project. Changes to the adaptation actions may reduce the ability to respond to the identified risks.

# 1.0 Introduction

## 1.1 Project overview

The Canberra Light Rail Stage 1 provided a new, approximately 12km, light rail route connecting the Gungahlin area in the north with Canberra's city centre. Recognising the need to further provide connections across Canberra, Major Projects Canberra (MPC) proposed to extend the light rail from its current terminus at Alinga Street to Commonwealth Park (referred to as Canberra Light Rail Stage 2A (CLRS2A) ('the Project')).

The Project is needed as part of a coordinated and holistic delivery of a series of major projects in Canberra City and surrounds, to realise the strategic planning and development for Canberra City presented in the Territory Plan, the Transport for Canberra Plan and the National Capital Plan (NCP). The Project also supports the ACT Government's vision for a compact and efficient city and reaching net zero by 2045. Furthermore, the Project is a specific directive identified as a key strategy for developing and delivering an efficient, compact and sustainable Canberra City within the Moving Canberra Plan, The Light Rail Network Plan and The ACT Planning Strategy.

MPC's projects align well with an extensive legislative and policy framework in the ACT, highlighting a commitment for providing climate resilient infrastructure and to delivering on the principles of ecologically sustainable development. MPC have a demonstrated commitment to achieving sustainable and resilient outcomes, as evidenced by their achieving a 'Leading' rating from the Infrastructure Sustainability Council (ISC) for Stage 1 Light Rail. MPC have registered the Project to pursue an Infrastructure Sustainability (IS) rating under the ISC Rating Scheme V1.2 .

## 1.2 Purpose of this report

Recent events, such as the 2019/2020 bushfires, maximum temperature records set in 2020 and a more recent 2021 extreme rainfall event, have demonstrated the vulnerability of critical infrastructure in and around Canberra. This technical report provides a *Climate and Natural Hazards Assessment* (CNHA) for the Project.

The assessment has been completed to understand and identify the potential effects and risks associated with climate change as well as the identifying treatment options and risk management measures to be incorporated throughout the design, construction and operation phases to build the resilience of the Project to changing climate conditions. It is worth noting the scope of this CNHA covers physical climate risks, while no consideration to transition climate risks has been given.

Physical risks are related to the risk of direct damage to the Project , supply chains, market impacts or liability due to failure to foresee losses from physical impacts of climate change. Physical risks can either considered as acute risks – event driven (shocks) or chronic risks – longer-term shifts in climate patterns (stresses).

Transitions climate related risks and opportunities are not discussed within this report however can be defined as risks associated towards the global shift towards a low carbon economy. These may include risks and opportunities associate with:

- *Market and Technology Shifts*: Relating to changes in demand for products due to policy shifts, stranding of assets due to market shifts.
- *Policy and Legal Changes*: Cost and / or revenue impacts resulting from policy changes. Including increased liability due to failure to foresee and mitigate losses from any transition risks.
- *Reputation*: Reputational damage resulting from an organisation's limited response to mitigation needs

## 1.3 Approach

Section 1 has provided an overview of the Project and presented the purpose of the CNHA. The remainder of the report is structured as follows:

- **Section 2** provides the Project description.

- **Section 3** highlights and summarises the relevant legislation and strategic context.
- **Section 4** details the methodology including risk assessment guidelines and stakeholder engagement.
- **Section 5** provides an overview of the existing environment including the local climate context and observed climate.
- **Section 6** provides the projected future conditions resulting from a changing climate for the region.
- **Section 7** presents the risks to construction of the project.
- **Section 8** presents the risks to operation of the project.
- **Section 9** concludes the report and provides the next steps.

# 2.0 Project description

Major Projects Canberra (MPC) proposes to extend the Canberra Light Rail (CLR) network from its current southern terminus at Alinga Street, Canberra City, to Woden (Light Rail City to Woden). Light Rail Stage 2 City to Woden is being progressed in two, self-contained stages for a faster project delivery: Stage 2A City to Commonwealth Park (the Project, the subject of this Assessment), and Stage 2B Commonwealth Park to Woden.

The Project is needed as part of a coordinated and holistic delivery of a series of major projects in Canberra City and surrounds, to realise the strategic planning and development for Canberra City presented in the Territory Plan, the Transport for Canberra Plan and the National Capital Plan (NCP). The Project also supports the ACT Government's vision for a compact and efficient city and reaching net zero by 2045. Furthermore, the Project is a specific directive identified as a key strategy for developing and delivering an efficient, compact and sustainable Canberra City within the Moving Canberra Plan, The Light Rail Network Plan and The ACT Planning Strategy.

The Project would involve extending the CLR network from the current southern terminus at Alinga Street to a proposed stop at Commonwealth Park. A full project description for the Project is provided in Chapter 3.0 of the Environmental Assessment.

The Project would include the following key elements:

- An extension of approximately 1.7 km of trackform, extending southbound via the western side of London Circuit before continuing on Commonwealth Avenue
- A new bridge across Parkes Way
- Three stops are proposed to be located at key points along the alignment to provide access to the light rail where there is expected to be high demand: Edinburgh Avenue Stop, City South Stop and Commonwealth Park Stop.
- One scissor crossover (crossover of railway tracks) to allow LRVs to reverse direction
- Utility, stormwater drainage and streetlighting adjustments, relocations and provisions
- Landscaping features sympathetic with Canberra's design as envisioned by the Griffins' along with requirements set out in other Territory and Australian Government policy
- 'Green tracks' running along Commonwealth Avenue and Northbourne Place that involve planting grass or shrubs between and besides the alignment
- Intersection layout, traffic signal phasing and road traffic speed changes along the alignment, including new intersections and modifications to existing intersections
- Pedestrian footpaths and crossing modifications
- Road widening and verge and kerb line changes.

The completed Project, including its key features and elements, is shown on **Figure 1**.

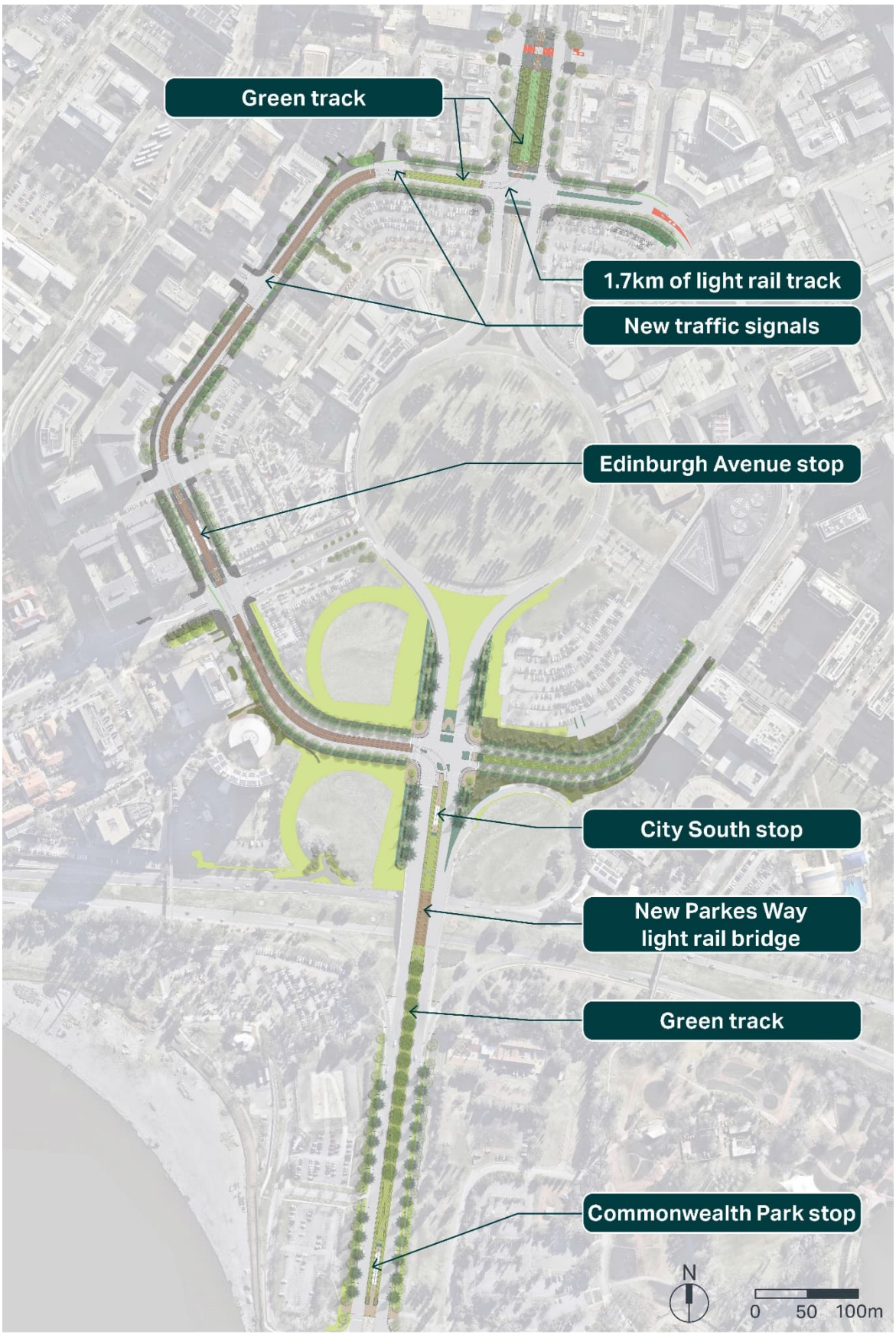



**Figure 1 The Project and its key features**

## 2.1 Construction

Construction activities associated with the Project would occur within a footprint referred to as the 'delivery phase area' (**Figure 2**). The operation of the Project would occur within a subset of the delivery phase area. The delivery phase area includes both Designated Land and Territory land. This Assessment addresses the Project in its entirety to allow for consideration of the Project as a whole.

Construction of the Project is anticipated to commence in 2024 with completion of construction planned in 2026. However, the duration of the construction would be dependent on final construction methodology and staging selected by the delivery contractor, as well as any efficiencies identified during the program. Following construction, a period of up to nine months would be required for testing and commissioning of the new light rail. Successful completion of the testing and commissioning programme would allow the Project Contractor to obtain accreditation from the Office of the National Rail Safety Regulator (ONRSR). Once complete, the system would be ready to be handed over for operation.

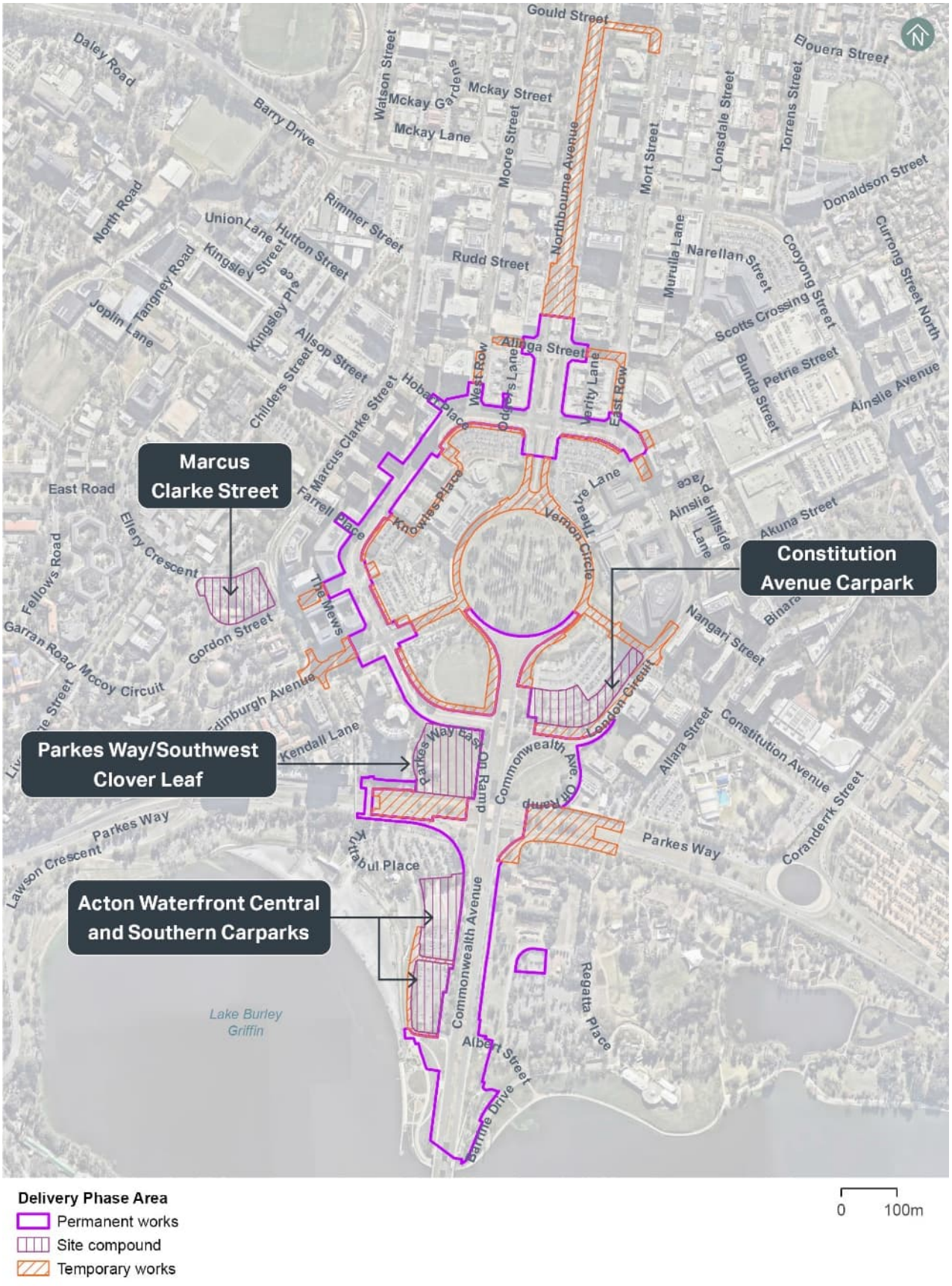



**Figure 2 Delivery phase area**

### 2.1.1 Site establishment and preparatory works

There would be four major compound sites, as shown on **Figure 2**. Several temporary construction compounds, stockpile sites and laydown areas would also be required as part of the Project. Upon completion of the works all established site compounds would be reinstated prior to handing back to the respective land owners.

There are utilities within the delivery phase area which are affected to various degrees by the Project. Most protection, decommissioning and removal of utilities would be completed early in the Project construction period, but may also be staged during the construction period depending on construction planning requirements.

Traffic management arrangements would include full and partial road closures and would introduce necessary traffic detours to direct the travelling public around work sites and construction access and egress points. Notification of these closures would be advertised in advance and sufficient time to deliver written notice would be required for the local businesses and residents. All temporary traffic management arrangements and diversionary routes would be agreed and approved by TCCS (RoadsACT) prior to implementation.

### 2.1.2 Construction strategy

The construction strategy of the Project has been divided by construction zones, major intersections and the Parkes Way Bridge.

**Table 2 Construction staging locations**

| Location | Description |
|---|---|
| Block closures | These are construction areas between major intersections. Block closures would be used to close off entire sections of the road network, typically between blocks to allow the Project contractor full access to the worksite and the best opportunity to complete the Project most efficiently. Stops would be constructed upon the occupation of the block section where it is located. Blocks include:<br>• Northbourne Avenue (between Alinga Street and London Circuit)<br>• London Circuit (between Northbourne Avenue and Petrie Plaza)<br>• London Circuit (between Northbourne Avenue and West Row)<br>• London Circuit (West Row to Knowles Place North)<br>• London Circuit (between Knowles Place North and Gordon Street)<br>• London Circuit (between Gordon Street and Edinburgh Avenue)<br>• London Circuit (between Edinburgh Avenue and Commonwealth Avenue)<br>• Commonwealth Avenue (between London Circuit and Parkes Way)<br>• Commonwealth Avenue (between Parkes Way and Lake Burley Griffin). |
| Major intersections | The major intersections include Northbourne Avenue and Alinga Street, Northbourne Avenue and London Circuit, London Circuit and Edinburgh Avenue, London Circuit and Gordon Street and Commonwealth Avenue and London Circuit.<br><br>For works within major intersections, wherever possible the construction of the intersection would be carried out during normal working hours, within the confines of a protected worksite. Closures, where required, are expected to be carried out over several weekends (typically from Friday 10pm to Monday 6am) for a maximum of 56 hours at a time, except during construction of track slab where a continuous 80 hours would be required to facilitate concrete curing and ensure adequate concrete strength is achieved prior to intersection reopening and eventual trafficking.<br><br>The Commonwealth Avenue and London Circuit intersection would not require full closure, and would be subject to a contraflow arrangement for several weeks. |

| Location | Description |
|---|---|
| Parkes Way bridge | A new bridge would be built between the two road bridges on Commonwealth Avenue over Parkes Way. In appearance, the gap would be infilled to create a single surface. The new rail bridge would be supported on 8 concrete piles (four piles for each bridge abutment) and concrete-walled abutments.<br>The construction of temporary roads allows for the continued movement of traffic during bridge construction activities, with the location of temporary roads selected by the contractor in line with the Roads ACT requirements. |

## 2.2 Operation

The Project would be an extension of the City to Gungahlin service and would therefore have the same frequency. It would take approximately six to nine minutes to travel between Alinga Street and Commonwealth Park.

A minimum of five LRVs would be required for the expansion of the CLR network. The new LRVs would be similar in appearance, size and performance to those that operate on the current CLR network. These LRVs and modifications to the stabling yard at the Mitchell Depot would be complete prior to the operation of this Project.

A wire free track is proposed for the Project alignment with LRVs operating using onboard battery power supply between the current Alinga Street southern terminus and the proposed Commonwealth Park terminus. Battery storage capacity for additional and existing LRVs has been proposed to minimise visual impact in landscape and visual sensitive zones, such as Commonwealth Avenue.

Two track forms, a permanent form of rail infrastructure that provides a surface for rail vehicles to move, are required for the Project. One trackform would operate northbound and the other southbound, with a crossover installed on Commonwealth Avenue to allow LRVs to change direction. Green track would also be included as part of the Project, in three locations: Northbourne Place, London Circuit between Northbourne Avenue and West Row, and Commonwealth Avenue between London Circuit and Albert Street. Non-potable water would be used for the irrigation of the Commonwealth Avenue green track.

## 2.3 Changes to the road network

The proposed light rail track would run within a median between opposing vehicular traffic flows for the entire length of the proposed alignment. The median would be between 80-150 mm high between intersections to minimise the possibility of road vehicles straying into the rail corridor. The median height would transition to be at grade just before each signalised intersection. This would facilitate vehicular and pedestrian movement across the track.

Road network changes required to accommodate the Project's median light rail alignment and associated stops are provided in Table 3

**Table 3 Lane configuration**

| Road | Proposed lane configuration |
|---|---|
| London Circuit | • The lane arrangement on London Circuit between Edinburgh Avenue and Commonwealth Avenue would remain unchanged<br>• Two 3.3m wide traffic lanes in each direction along London Circuit between Northbourne Avenue and West Row, including a dedicated westbound right turn lane to West Row<br>• A single 3.7m wide traffic lane in each direction along London Circuit between West Row and Edinburgh Avenue, except on the southbound approach to Gordon Street which would have a dedicated right turn lane.<br>• The posted speed limit along London Circuit would remain 40km/h except in the vicinity of the Edinburgh Avenue stop where the speed would be reduced to 20km/h because of the high pedestrian activity expected at the stop |

| Road | Proposed lane configuration |
|---|---|
| | • All on street parking and loading along London Circuit would be removed.<br>• Two new signalised intersections on London Circuit to facilitate right turns across the Project's alignment at West Row and University Avenue. The remaining unsignalised intersections along London Circuit would be converted to left-in/left-out out[6]. |
| Alinga Street | One lane in each direction on Alinga Street within the median on Northbourne Avenue. These lanes would be for buses only. |
| Commonwealth Avenue | No change |
| Northbourne Avenue | No change |

### 2.3.1 Active transport infrastructure

The Project includes walking and cycling facilities or upgrades that aim to improve pedestrian and cyclist safety, connectivity and amenity within the study area, and in particular along London Circuit West and Commonwealth Avenue. Active transport infrastructure includes dedicated and separate pedestrian and cycling paths.

# 3.0 Legislation and strategic context

## 3.1 National policy

The Australian Government's *National Climate Resilience and Adaptation Strategy*[7] provides a set of principles to guide effective adaptation and build the resilience of communities, the economy and the environment. The guiding principles include priorities for shared responsibility, climate change risks factored into decision making, a risk management approach based on the best available scientific data, assisting the vulnerable, collaboration with stakeholders and the need to revisit decisions and outcomes overtime.

While the Project is not specifically mentioned as part of this strategy, the preparation of this CNHA will support the effective implementation of adaptation and help further build the resilience of not only the Project, but also the broader Canberra region. This includes the use of the best available scientific data, support for vulnerable communities, a multi-disciplinary / stakeholder approach to design as well as learnings from previous infrastructure projects to improve on performance outcomes.

Furthermore, the Australian Government's *Direct Action Plan*[8] sets out how the 2030 emissions reduction target will be achieved. As part of the *Direct Action Plan*, a range of policies, programs and aims were identified to reduce Australia's Greenhouse Gas (GHG) emissions by creating positive incentives to adopt better technologies and practices to reduce emissions. The Australian Government has considered the 2030 target policy framework in detail in 2017-2018 and is confident in achieving the identified reduction targets through the implementation of the Renewable Energy Target[9], Minimum Energy Performance Standards[10] . No additional national policies or plans have been prepared since 2018. While the *Direct Action Plan* is largely aimed at climate mitigation, policies and program, if applied at the local level, can support adaptation to physical risks.

[6] Right turn out from Knowles Place south permitted by emergency vehicles under signals
[7] Available: https://www.environment.gov.au/climate-change/adaptation/publications/national-climate-resilience-and-adaptation-strategy
[8] Available: https://www.aph.gov.au/parliamentary_business/committees/senate/environment_and_communications/direct_action_plan/report/c05
[9] Available: http://www.cleanenergyregulator.gov.au/RET
[10] Available: https://www.energyrating.gov.au/suppliers/legislation#:~:text=Minimum%20Energy%20Performance%20Standards%20(MEPS)%20specify%20the%20minimum%20level%20of,in%20Australia%20and%20New%20Zealand.

In September 2022, The Australian Government passed the Climate Change Act (2022)[11]. The Bill legislates Australia's commitment to reducing greenhouse gas emissions by 43% by 2030 (2005 baseline) and to achieve net zero by 2050. Further to this, the Bill requires the Climate Change Authority to provide the minister advice on their annual climate change statement and advice at least once every five years future greenhouse gas emission reduction targets. Reviews of the operation of this legislation will be provided periodically.

## 3.2 Territory policy

### 3.2.1 Climate Change Risk Assessment for the ACT (2022)[12]

In 2021, AECOM was commissioned by the Chief Minister, Treasury and Economic Development Directorate (CMTEDD) to undertake a Whole-of-Government Climate Change Risk Assessment to identify and assess physical climate-related risks across the ACT and identify opportunities to improve resilience across the risks identified.

The assessment found the frameworks established for adaptation within the ACT provide the potential to deliver effective action in comparison to other jurisdictions within Australia. Further to this, the assessment identified the role of the ACT Government in enabling, facilitation and supporting the private sector though the development of resilient infrastructure including transportation.

Significant risks identified to the ACT included damage or disruption of infrastructure and assets as a result of extreme weather events, impacts to vulnerable members of the community, longer and more intense fire seasons. Risks of a similar nature were considered for the Project. Overall the assessment identified that mitigation actions against drought conditions are most progressed, followed by bushfire, extreme heat, flood and storms.

The assessment identified a strong need to improve the ACT's understanding of the future exposure of assets and services to climate hazards through the consideration of climate projections and hazard mapping in planning.

### 3.2.2 ACT Climate Change Strategy 2019-2025[13]

As part of Canberra's commitment to achieving net zero emissions by 2045, the ACT has outlined a series of five year interim targets to support emissions reductions. The 2019-2025 Strategy outlines this next stage of the ACT Government's response to climate change and identifies the necessary steps to meet both interim targets and set up longer-term aspirations to achieve the end goal of net zero. Actions have been developed in concert with both the community and a range of stakeholders and are focused on a number of climate adaptation and mitigation options, most notably building resilience to physical climate change impacts.

The Strategy has a particular focus on transport – the largest sources of emissions (generally accounting for more than 60% of total emissions) and specifically outlines several key priorities, several of which the Project helps support, as described in Table 4.

**Table 4 Project compliance with ACT Climate Change Strategy 2019-2025**

| Priority | Description | Project support of the priority |
|---|---|---|
| ACT Government Leadership | Consider climate change adaptation outcomes in all policies, budget decisions and capital works decisions | Treatment options identified in this report are intended to achieve climate change adaptation outcomes |
| ACT Government Leadership | Monitor climate change projections and ensure infrastructure and | This report references the latest climate change projections. These |

[11] Available at: https://www.legislation.gov.au/Details/C2022A00037#:~:text=This%20Act%20sets%20out%20Australia's%20greenhouse%20gas%20emissions%20reduction%20targets.&text=The%20Minister%20must%20prepare%20an%20annual%20climate%20change%20statement.&text=The%20Climate%20Change%20Authority%20is,an%20annual%20climate%20change%20statement.

[12] Available at: https://www.climatechoices.act.gov.au/__data/assets/pdf_file/0011/2071739/Climate-Change-Risk-Assessment-for-the-ACT-Summary.pdf

[13] Available: https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache

| Priority | Description | Project support of the priority |
|---|---|---|
| | services are resilient to climate change impacts | projections were utilised to identify potential impacts to the project |
| Transport | Supporting higher uptake of public transport by continuing to improve services to meet community travel needs | Treatment options identified in this report improve the climate response of the Project and encourage community travel through active transport and connections to existing public transport services, including light rail services |

This Strategy replaces the *Climate Change Strategy and Action Plan 2* (2012) and the 2016 *Climate Change Adaptation Strategy*. It is supported by the *Living Infrastructure Plan: Cooling the City* and has been developed in alignment with the *ACT Planning Strategy 2018*, *ACT Housing Strategy 2018* and the draft *Moving Canberra: Integrated Transport Strategy*.

Key other actions where the Project can support the aims and the 2025 target goals are highlighted in Table 5 below.

**Table 5 Project response to aims and target goals**

| Action | Project Response |
|---|---|
| *Action 1.5* – Work with the ACT Climate Change Council to encourage community participation in climate change initiatives | Community engagement activities are being encouraged to facilitate the opportunity to comment on the climate risk assessment and work to identify potential responses to climate change. |
| *Action 3.4* – Prioritise improving public transport services and supporting infrastructure, including buses, light rail stage two and connecting services | The subject of the Project is the extension of the light rail stage two. |
| *Action 3.9* - Prioritise walking and cycling and enhance active travel infrastructure to improve safety and connectivity of the active travel network. | The Project would include upgrades to the existing active transport in and south of the city centre. These upgrades aim to provide safer and improved active transport connections. |
| *Action 3.18* - Investigate options for dedicating a greater proportion of road space and public realm space to sustainable transport modes. | A key Project objective is to "provide Canberrans with an attractive, convenient, efficient and reliable integrated public transport system that facilitates choice, increases public transport patronage and reduces car dependency." Road space has been taken and property boundaries reduced to provide the active verges along the corridor and facilitate the light rail extension . |
| *Action 3.1.6* - Explore and implement new approaches to improving the productivity of key transport corridors through prioritisation of public transport and/or active travel. | The Project contributes to the productivity of key transport corridors and supports active travel by providing active transport infrastructure, including dedicated and separate pedestrian and cycling paths. These active transport corridors will connect with the existing network. |
| *Action 4.22* - Implement Canberra's Living Infrastructure Plan to work towards 30% urban canopy cover and 30% surface permeability, account for the value of living infrastructure and assess local needs for managing heat | The Project has included as part of its design a range of green infrastructure including the planting of mature canopy trees to provide shade, landscaping across the corridor to reduce the need for hardstand as well as the use of permeable pavement where possible to help improve response to heat and flooding. |
| *Action 5.5* - Ensure the social cost of carbon and climate change adaptation outcomes are considered in all ACT Government policies, budget | Climate change adaptation outcomes identified in this report have been considered in the design development of the Project and incorporated into the |

| Action | Project Response |
|---|---|
| decisions, capital works projects and procurements. | scope. |
| *Action 5.6* - Ensure all new Government capital works with a budget of more than $10 million either seek or are consistent with an independent sustainability rating such as an Infrastructure Sustainability rating from the Infrastructure Sustainability Council (ISC), or a Greenstar rating from the Green Building Council of Australia or equivalent, and review ratings at least every five years. | The Project is targeting a rating under the ISC Rating Scheme. As part of the rating scheme, two credits will be pursued that respond to climate change and natural hazards (the subject of this report). |

### 3.2.3 Canberra's Living Infrastructure Plan: Cooling the City[14]

The *Living Infrastructure Plan* details the ACT Government's strategic direction and commitment, through action, to maintain and improve living infrastructure across Canberra. This includes the understanding that urban areas generally contribute to the urban heat island effect – raising temperatures across urban areas both during the day and retaining heat during the night (up to 10$^{o}$C warmer than other parts of Canberra). Living infrastructure supports efforts to make cities 'climate-wise' by enhancing capacity to respond to climate change and extreme weather events – through retention of water in the landscape, using rainfall better, increasing access to shade, improving water penetration and facilitating recharge and improving access to and amenity of nature in urban areas.

The Plan in particular seeks to increase the canopy coverage of the city from a current 21% coverage to 30% by 2045 through the use of trees, or tree canopy equivalent (e.g. green roofs, shrub beds, rain gardens, etc.) as well as a 30% commitment to permeable surfaces. The Plan further recognised the need to respond to climate change, particularly considering the criticality of living infrastructure and potential impacts resulting from longer periods of drought, higher temperatures and increased duration of heatwaves.

Key actions resulting from the Plan of relevance to the Project are highlighted in Table 6. Specific treatment options and design features that support each action can be found in the treatment options register in Appendix F.

**Table 6 Project response to key actions**

| Action | Project Response |
|---|---|
| *Action 2: Living Infrastructure Targets* - achieve 30% tree canopy cover (or equivalent) and 30% permeable surfaces in Canberra's urban footprint by 2045 | The Project has included as part of its design a range of green infrastructure including the planting of mature canopy trees to provide shade, landscaping across the corridor to reduce the need for hardstand as well as the use of pervious pavement where possible to help improve response to heat and flooding.<br><br>The Project will seek to utilise green track form solutions on Commonwealth Ave and adjacent the Melbourne Building. This will improve urban amenity, reduce the pressure on the existing drainage network and reduce urban heat island effects. |
| *Action 5*: *Climate-wise Landscape Guide* – prepare a guide for use by the community and built environment professionals to support effective landscape plans, and increase the opportunity for healthy, climate resilient and biodiverse gardens and public lands | The landscaping plan for the Project is incorporating elements from the climate-wise landscape guide to improve outcomes and response to extreme heat, drought, bushfire and changes to rainfall patterns (e.g. less frequency, higher volume). |

[14] Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1413770/Canberras-Living-Infrastructure-Plan.pdf

| Action | Project Response |
|---|---|
| *Action 10*: *City Cooling Program* – trial city cooling initiatives in high priority locations | The Project will include a high proportion of green infrastructure to help reduce the urban heat island effect along the corridor and improve response to heat challenges within the city centre.<br><br>Deciduous trees align the corridor, providing shade within the warmer months and allowing more light to infiltrate within the winter, providing more warmth and improving safety of the pedestrian environment. |
| *Action 13*: *Demonstration Projects* – showcase best practice climate-wise design through display houses and exhibition sites in Government projects | The drainage design incorporates climate change into design accounting for a 20% increase in rainfall intensity.<br><br>The design incorporates deciduous and drought resilient planting to provide shade and reduce heat impacts whilst maintaining aesthetic appeal.<br><br>The Project will feature transit stops that have utilised key design elements to reduce heat transfer (e.g. cool materials) as well as providing adequate protection from extreme storms, solar exposure and flooding. |
| *Action 14*: *Water Sensitive Urban Design* – support trials and demonstration projects to retrofit infrastructure to allow hydration of open spaces using stormwater. | The design of the Project includes Water Sensitive Urban Design (WSUD) features such as passive irrigation, raingardens, and structural soils where feasible to capture stormwater, minimise flood risks and allow for the hydration of open spaces. |

In addition, the Plan recognises that living infrastructure provides a range of other benefits including improved social (e.g. higher liveability and connections) and health (e.g. mental health) outcomes from being closer to nature.

### 3.2.4 The Territory Wide Risk Assessment (2017)[15]

The Territory Wide Risk Assessment 2017, is the second revision of the ACT's strategic level analysis of natural hazards and emergency risks faced by the ACT. The assessment links local and national disaster strategies to provide guidance to the ACT and considered how emergencies may impact the local community. The assessment was driven by the national agreement that States and Territories would review and update their State wide assessments. The document serves to guide decision making by the Government, businesses, community and individuals and enhance resilience and mitigation of risks.
The number of natural hazards and emergency risks was consolidated from previous assessments. 16 risks were identified during this assessment.

## 3.3 Infrastructure Sustainability Council requirements

The CNHA report is an assessment that aligns to the requirements for climate and natural hazard risks outlined in v1.2 of the ISC IS Rating Scheme for Cli-1 and Cli-2. In particular, this report highlights the consideration of direct and indirect risks in the context of past and observed climate as well as projected future changes. The report further validates and identifies risks and treatment options to respond to those high-priority and extreme rated risks. This report responds to the Cli-1 and Cli-2 criteria for achievement of Level 3, a summary of alignment is presented in Appendix **A**. To achieve a Level 3 rating, adaptation actions to treat at least 50% of all medium priority climate change risks must be identified and assessed and following treatment no high or extreme priority residual climate risks remain across both 2030 and 2070 timeframes.

[15] Available at: https://esa.act.gov.au/sites/default/files/wp-content/uploads/The-Territory-Wide-Risk-Assessment-2017_building-WEB.pdf

# 4.0 Methodology

## 4.1 Risk assessment guidelines

The CNHA provided in this report has been undertaken in line with the following relevant standards and guidelines:

- The climate change projections used in this assessment have been collated and informed by both the AdaptNSW NARCliM data and CSIRO Climate Futures data in accordance with AS 5334:2013 *Climate change adaptation for settlements and infrastructure.*
- The climate change risks have been assessed in line with the methods recommended in *Climate Change Impacts and Risk Management: A Guide for Business and Government* (Department of Environment and Heritage (DEH), 2006).
- The project-specific Risk Management approach, in accordance with Australian Standard (AS) / New Zealand Standard (NZS) ISO 31000:2018 *Risk Management – Principles and guidelines* (note the Likelihood and Consequence descriptors and Risk Matrix can be found in **Appendix B**).

## 4.2 Risk assessment methodology

The following key steps were undertaken to complete the climate and natural hazards assessment (CNHA) (DEH, 2006 and AS 5334:2013):

- Identification of key climate variables (such as temperature, rainfall, and extreme events) and the climate variability that differentiates regional climate zones.
- Development of potential climate change scenarios, based on the latest climate science, that broadly identify how each climate variable may change over the design life of the proposed works.
- Identification of broad climate-based risks that may impact on the proposed works.
- Completion of a high-level CNHA, with risk ratings evaluated using the project-specific Risk Management framework criteria and further refined through stakeholder consultation to evaluate and socialise the consequence and likelihood of each risk.
- Identification of treatment options to mitigate and respond to climate risks.

Figure 3 identifies how risks to the Project have been developed from an assessment of climate variables and projected changes in climate.

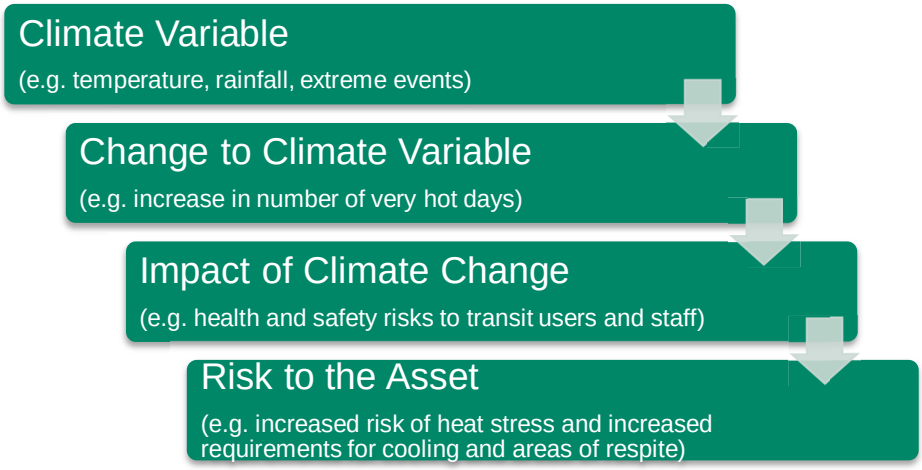



**Figure 3 Climate Change Risk Assessment Process (adapted from DEH, 2006)**

## 4.3 Stakeholder consultation

To review, evaluate and validate climate risks to the Project, a workshop was undertaken with key stakeholders on the 8 June 2021. In addition to the session facilitator, the workshop was attended by 31 key internal and external stakeholders (both in person and virtually) from:

- Major Projects Canberra
- Canberra Metro Operations (the operator of the Stage 1 alignment)
- Infrastructure Australia
- Cox Architecture
- Layer 2 Intelligence (Rail Network Integration)
- AECOM (Design and Sustainability and Resilience)
- Transport Canberra and City Services
- Environment, Planning and Sustainable Development Directorate.

These stakeholders contributed to the validation and further identification of climate risks, as well as undertaking a sensitivity test of the risk ratings attributed to each risk and efforts to prioritise risks for future action. Key risks areas identified during the stakeholder workshop included:

- The potential impacts due to extreme rainfall impacting on drainage infrastructure and surrounding areas resulting in nuisance flooding.
- The exacerbation of extreme heat impacts due to the highly urbanised nature of the Project footprint including safety risks to transport users from lack of shading as well as implications for electrical equipment,
- The consideration of drought and changes to rainfall impacting on landscaping, particularly in relation to the green infrastructure and ongoing maintenance.

Emergency Services were invited to attend, however did not attend the workshop.

Furthermore, discussion during the workshop included the identification of a range of opportunities for design elements and other responses to be incorporated to enhance the climate resilience of the Project through the implementation of treatment options.

Refer to **Appendix C** for a summary of workshop participants and a copy of the workshop materials. Workshop participants were consulted in the refinement and development of climate risks, risk ratings and treatment options for the Project. This includes considering climate change through sensitivity testing for flooding and rainfall, the use of additional shade and cooling materials to reduce heat impacts and climate-wise considerations for landscaping to be installed along the corridor to better account for heat, drought and changes in rainfall.

# 5.0 Existing environment

## 5.1 Overview

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2021) states with high confidence that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events, an increase in record hot days, a decrease in record cold days and increases in global GHG concentrations.

As highlighted in the *State of The Climate* (CSIRO and BoM, 2020) report, it is noted that Australia's climate has warmed on average by 1.44$^{o}$C (+/- 0.24$^{o}$C) since 1910. It is noted that the Paris Climate Change Accord (effective 4 November 2016) seeks to limit climate change to under 2$^{o}$C with a target of 1.5$^{o}$C.

Other key points of note from *State of The Climate 2020* include:

- There has been an increase in extreme fire weather, and in the length of the fire season, across large parts of the country since the 1950s, especially in southern Australia.
- In the southeast of Australia there has been a decline of around 12 per cent in April to October rainfall since the late 1990s.
- There has been a decrease in streamflow at the majority of streamflow gauges across southern Australia since 1975.

## 5.2 Climate variables

Climate variables fall into two categories: primary and secondary effects.

- **Primary effects** are those climate variables that are directly influenced or changed as a result of climate change. These include things such as air temperature, precipitation, wind and solar exposure.
- **Secondary effects** are those derived from primary effects, but still influenced by climate change. These include things such as bushfire weather and drought.

Selection of climate variables are based on the following factors:

- The location of the Project in an area subject to overland flooding.
- The location of the Project being surrounded by areas subject to increased bushfire risk (resulting in smoke impacts).
- The location of the Project within an urbanised area, contributing to higher ambient temperatures and greater durations of heatwaves.
- A growing trend of increased drought conditions, influencing water availability in the region.

The relevant climate variables applicable to the Project are listed below. It is noted that due to the inland location the Project, sea level rise was not considered.

- Mean ambient temperature, extreme heat days and heatwaves
- Solar exposure / radiation
- Average annual and extreme rainfall
- Bushfire weather
- Flooding and flash floods
- Drought / evapotranspiration
- Storm events.

## 5.3 Local climate context

The local climate surrounding the Project (being the broader region – not simply the urban area of the Canberra central business district) varies widely owing to the range of topographical conditions over a relatively small area. Areas to the north of Canberra are characterised by relatively dry and warm conditions, based on its lower altitudes and flatter land, while areas to the south experience colder temperatures, being higher in elevation.

The average annual temperature for the region is 16ºC with an average summer temperature range of 20-22ºC and average winter temperature range of 12-14ºC. Long term temperature measurements have shown an increase in annual temperatures from around 1950 to present, with an acceleration in the rate of increase over the past 20 years. Furthermore, the area experiences fewer than 10 days over 35ºC per year. It is worth noting however, that the three hottest days on record (across the months of December, January and February) have occurred since December 2019 – highlighting the increasing trend of hotter days and more frequent heatwaves [16]

Rainfall throughout the area is largely consistent across the seasons with limited variability, with an average of 100-300 mm per season, bringing an average annual total of approximately 800-1200 mm. The first decade of the 21st century however was characterised by lower than average rainfall (associated with the Millennium Drought)[17]. The BoM has officially declared Australia is currently experiencing a period of La Niña[18]. This has resulted in periods of extreme periods of rainfall and flooding, it is predicated that this period will end in early 2023[19] at which point the climate is predicted to return to a neutral El Niño period.

Bushfires are highly dependent on four criteria – available fuel, dry fuel loads, favourable weather conditions (e.g. high winds) and an ignition source. In NSW and the ACT, the Forest Fire Danger Index (FFDI) is the mechanism for measuring fire weather. FFDI combines the observed climate variables of temperature, humidity and wind speed. Long term FFDI estimates for Canberra show daily average FFDI of 7 (indicating low to moderate fire weather), while observations note that Canberra has on average, 1.1 severe fire weather days each year.

## 5.4 Observed climate

The past five years saw a range of extreme weather events affect the area in which the Project would be located, but also the broader surrounds of Canberra. A summary of recent climate events is presented in Table 7.

**Table 7 Summary of recent climate events**

| Climate Events | Date | Impacts |
|---|---|---|
| Extreme rainfall | December 2017 | Canberra Airport recorded 55mm of rain over an 8 hour period resulting in wide-spread flooding events[20] |
| Extreme rainfall | February 2018 | More rain fell in 6 hours than a typical month of February which resulted in the backflow of stormwater drainage across the city, disrupting services and flooding of residential areas resulting in damage[21] |
| Extreme storm | January 2019 | Damaging hail and uprooted trees resulted in numerous callouts to emergency services across Canberra including for accidents, power outages and other disruptions[22] |
| Bushfire | Summer 19/20 | Bushfires (both flames and smoke) resulted in a backlog of emergency callouts, heavy smoke across the city (including several days where air quality was the worst in the world) and requirements |

[16] Available: http://www.bom.gov.au/climate/averages/tables/cw_070351_All.shtml
[17] Available: https://www.environment.act.gov.au/__data/assets/pdf_file/0009/671274/ACTsnapshot_WEB.pdf
[18] Available: https://media.bom.gov.au/releases/914/bureau-of-meteorology-declares-la-nina-underway/
[19] Available: http://www.bom.gov.au/climate/enso/outlook/
[20] https://www.abc.net.au/news/2017-12-02/canberra-to-prepare-for-months-worth-of-rain/9219396
[21] https://knowledge.aidr.org.au/resources/2018-flood-act-australian-capital-territory-flash-flood/
[22] https://www.canberratimes.com.au/story/5997052/hail-strikes-trees-down-in-canberra-during-stormy-start-to-the-weekend/

| Climate Events | Date | Impacts |
|---|---|---|
| | | for residential evacuation (and in some cases, 'too late to leave warnings')[23], [24] - refer Figure 4 |
| Extreme heat | January 2020 | Highest ever temperature was recorded in Canberra (44°C) resulting in increased heat stress and disruptions across the city[25] as well as leading to drought conditions bordering on a 'worst-case scenario' as defined by Icon Water[26] |
| Extreme storm | January 2020 | Hailstones damaged numerous buildings and vehicles as well as lightning which resulted in injuries to multiple persons[27], [28] - refer Figure 5 |
| Extreme rainfall | March 2021 | 60mm of rain was recorded in an hour, resulting in the wide-spread closure of roads, inundation of buildings and further disruption around the city[29], [30] |
| Extreme storm | January 2022 | Severe thunderstorms and hail in northern Canberra resulted in trees falling on homes and roads, fallen powerlines, localised flooding, and water damage[31]. |
| Extreme Rainfall | October 2022 | Canberra experienced it's wettest October since 1939, with 166.2 mm of rainfall falling during the month. |

**Figure 4 Bushfire impacts - existing Canberra Light Rail Stage 1. Source: Getty Images, 2020.**

**Figure 5 CBD flooding. Source: Canberra Times, 2020.**

[23] https://www.smh.com.au/national/nsw/bushfire-burning-out-of-control-east-of-canberra-20191129-p53fir.html
[24] https://www.theguardian.com/australia-news/2020/jan/22/nsw-and-victoria-fires-soaring-temperatures-increase-bushfire-danger-once-again
[25] https://www.canberratimes.com.au/story/6611507/start-to-2020-brings-a-month-of-weather-chaos/#:~:text=degrees%20above%20average.-,The%20mean%20temperature%20at%20the%20Canberra%20Airport%20weather%20station%20was,of%20extreme%20heat%20in%20January.
[26] https://www.canberratimes.com.au/story/6586098/canberras-drought-close-to-worst-case-scenario/
[27] https://www.theguardian.com/australia-news/2020/jan/20/severe-thunderstorms-and-hail-to-batter-south-eastern-australia
[28] https://www.canberratimes.com.au/story/7036775/severe-thunderstorm-blows-through-canberra-causes-destruction/
[29] https://thenewdaily.com.au/news/2021/03/23/canberrra-queanbeyan-floods/
[30] https://www.willyweather.com.au/news/7472/canberra+hit+by+heavy+rain,+flash+flooding+inundates+homes.html
[31] https://canberraweekly.com.au/parts-of-canberra-smashed-by-large-hailstones/

## 5.5 Hazard mapping

To better understand the local climate and exposure of the Project, local hazard mapping was sourced to help identify risks. In particular, data was gathered for bushfire, flooding and urban heat. Additional mapping around flood hazards, erosion and heat is provided in **Appendix D**.

### 5.5.1 Bushfire

Figure 6 shows that while direct bushfire risk (from flames) is limited due to the urban nature of the area in which the Project is located, significant areas surrounding the corridor have high exposure, highlighting the potential impacts from smoke. Smoke risk can manifest as human health and safety concerns, potential disruption to electrical systems and increased maintenance requirements such as cleaning drains blocked with ash or debris.

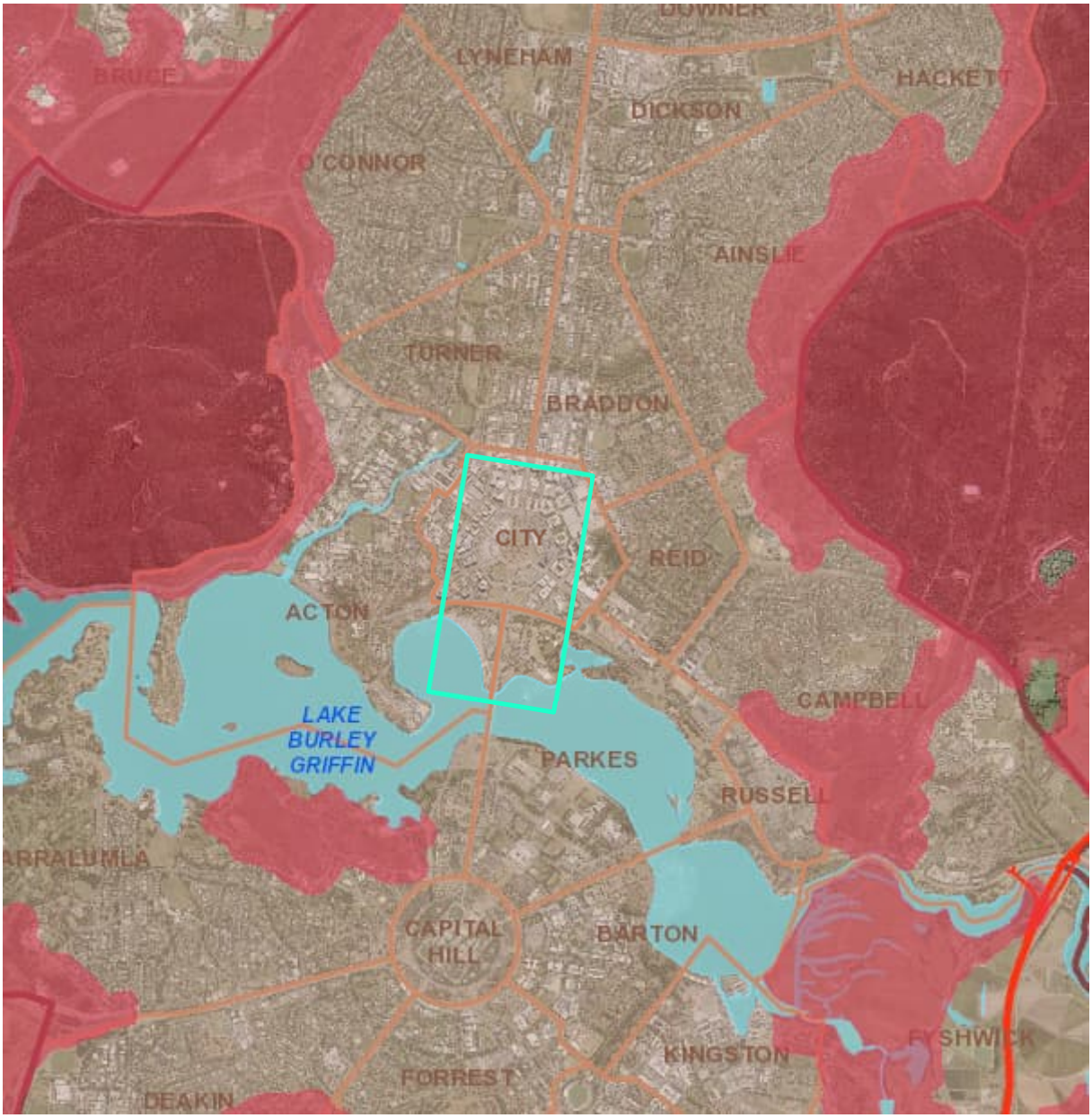



**Figure 6 Bushfire Prone Areas. Source: ACTmapi, 2022[32]. Approximate Project area shown in teal.**

[32] https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=bushfire

### 5.5.2 Flooding

Figure 7 shows the relationship of the one in 100 year flood event to the Project. It is noted however that the areas subject to inundation within these maps do not account for any potential future increases due to rainfall, overland flow or construction of additional infrastructure. While the Project is located outside of the one in 100 year flood event, it is noted that flood events may result in a backflow of drainage infrastructure, resulting in potential impacts such as nuisance flooding and inundation of the corridor resulting in disruption to traffic movements.

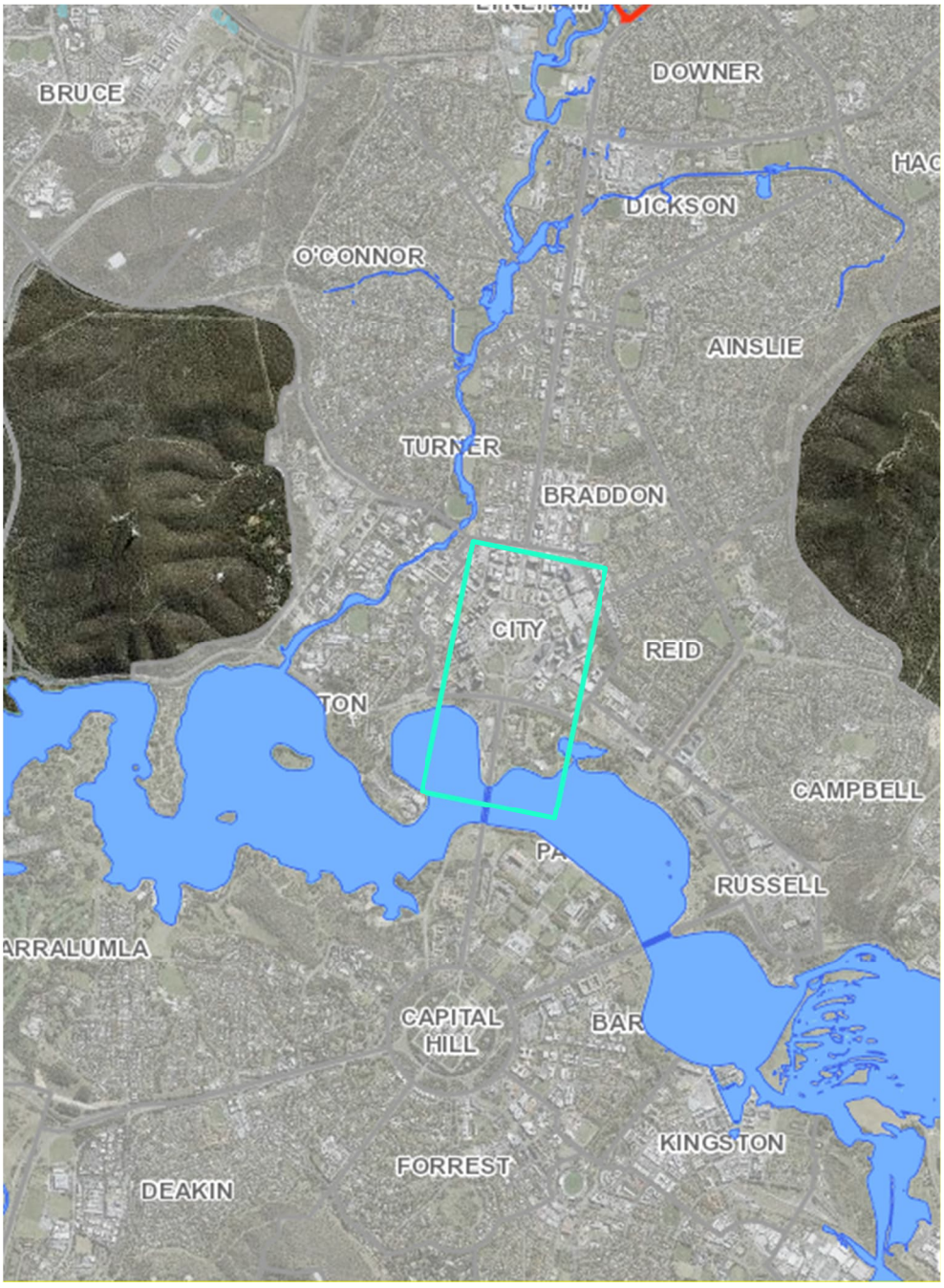



**Figure 7 1% Annual Exceedance Policy (AEP) Flood Model Extent. Source: ACTmapi, 2022[33]. Approximate Project area shown in teal.**

[33] https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=bushfire

### 5.5.3 Urban Heat

Figure 8 shows the relative heat distribution across the ACT region, in particular the maximum temperatures experienced during the day, minimum temperatures at night and the relative difference in day and night temperatures over a summer period. While the Project is generally located within areas of lower maximum temperature (Plate (a)), due to the urban nature of the surrounds, it experiences a higher average night-time temperature (Plate (b)). The smaller range between maximum and minimum across the Project highlights how components (e.g. pavements), active transport users and other project elements (e.g. landscaping) are subject to higher ongoing temperatures and do not experience the night-time reprieve when compared to the surrounds. This can result in difficulties as electrical equipment operates at higher temperatures for longer periods (higher risk of failure) and materials (such as pavements) degrade quicker due to heat exposure.

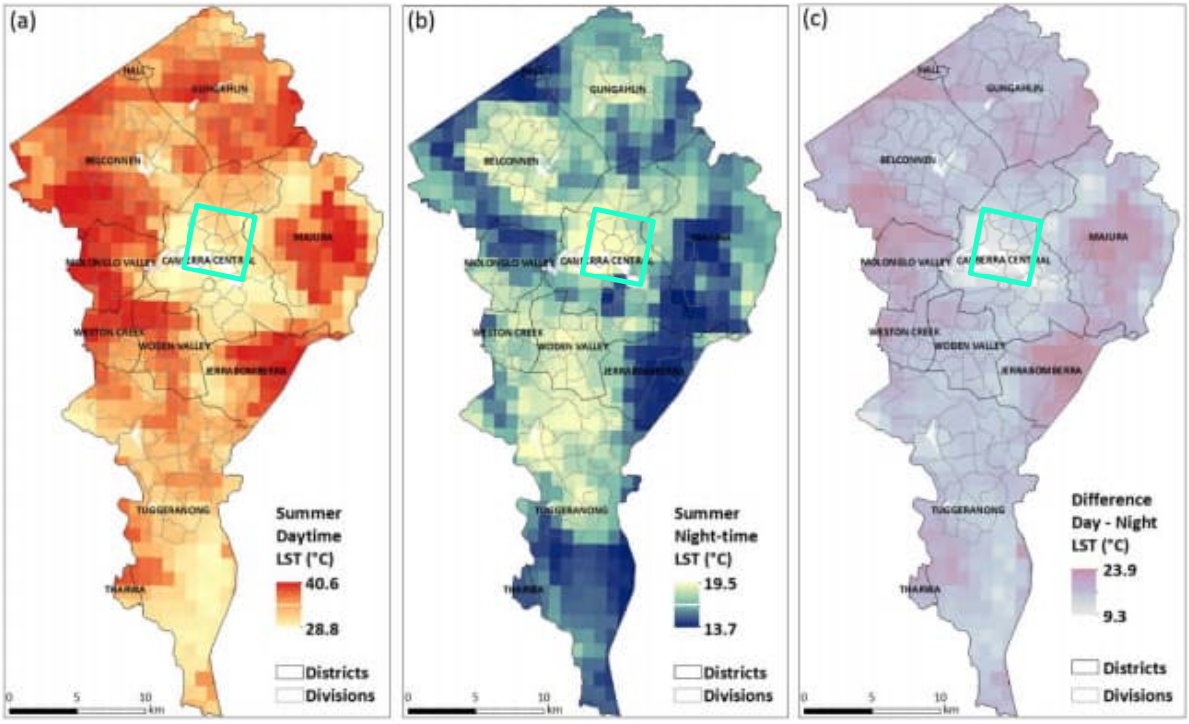



**Figure 8 Land Surface Temperatures. Source: ACT Government, 2017[34]. Approximate Project area shown in teal.**

[34] Available: https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1170968/CSIRO-Mapping-Surface-Urban-Heat-In-Canberra.pdf

# 6.0 Projected future conditions

The climate of Canberra, as is the case with global climate trends, is naturally variable; however, it is expected that climate change will lead to shifts beyond this natural variability. An assessment of the risk of climate change requires an understanding of the current climate using historical data for comparison with future climate scenarios.

Future climate scenarios are typically prepared using data from Global Climate Models. Climate change model projections, generated by Global Climate Models, are tools used for understanding how the climate will respond to changes in greenhouse gas (GHG) emission levels.

Data projections for future climate scenarios were obtained from two data sources, NARCliM data, and CSIRO data. This allows for the comparison of data, which provides a better understanding of predicted future climate and can help assist in the identification of risks to the Project. Understanding the range of future climate scenarios and associated risk can also help inform the appetite for various treatment options and mitigation undertaken for the project.

NARCliM data presents regional downscaled climate projections for 12 regions within NSW and the ACT – the most appliable being the Australian Capital Territory Climate Change Snapshot (OEH and ACT Government, 2014).

The Murray Basin Cluster Report (CSIRO, 2015) provides the best approximation of future climate projection conditions for Canberra. These two reports have been used to inform this assessment with preference being given to the NARCliM data, while the CSIRO data was used as a basis of scenario comparison to understand potential differences in future impacts.

## 6.1 Time horizons

It is important to choose several time horizons for climate projections to understand how a changing climate may impact on various design elements, understanding that different assets and elements of the Project have varying design lives.

As the design lives for various components of the Project range from approximately:

- 10-20 years (e.g. pavements, electrical equipment).
- 50 years (e.g. drainage structures, tanks and inaccessible pipe systems).
- 100 years (e.g. culverts and concrete pits).

As a result, the time periods selected for the assessment are 2030 and 2070. Climate projections for these time scales represent averages over a 20 year period, being:

- Projections for 2030 represent the 20 year period between 2020-2039 (*near future*, as defined by AdaptNSW).
- Projections for 2070 represent the 20 year period between 2060-2079 (*far future*, as defined by AdaptNSW).

In addition, projections for 2030 were identified as appropriate to account for potential impacts during construction as well as early years of the roadway operations, while projections for 2070 are relevant for the longer, on-going operation and maintenance requirements. Climate projections have been provided for 2090 to provide an understanding of the longer-term potential changes due to climate change for the longer lived elements such as drainage infrastructure. These are provided in Appendix E.

Greenhouse gas emission scenarios estimate the quantity of GHG that may be released into the atmosphere in the future, based on a range of possible future economic, business, social and environmental pathways.

The GHG emission scenario used to inform this CNHA was based on the SRES (IPCC, 2000) A2 scenario, representing a high emissions pathway driven by economic growth, which is projected to result in a global warming of approximately 3.4ºC by 2100. The SRES A2 scenario was used as a review of current global emissions trajectory suggest we are tracking along the higher end of the A2 scenario.

The Climate Futures data used in this CNHA were for the RCP 8.5, which most closely corresponds to the SRES A2 data, given current trajectory. The RCP 8.5 pathway arises from little effort to reduce emissions and is most closely aligned with how global emissions are tracking (CSIRO, 2015).

## 6.2 Climate change projections

The most recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report – Sixth Assessment Report (AR6) (AR6, 2021) states with high confidence, that Australia is currently experiencing impacts from climate change, including the greater frequency and intensity of extreme weather events. As noted in *State of The Climate 2020*, Australia is likely to experience a range of ongoing changes into the future including:

- Continued increases in air temperatures, more heat extremes and fewer cold extremes.
- Continued decrease in cool season rainfall across many regions of southern and eastern Australia, likely leading to more time in drought, yet more intense, short duration heavy rainfall events.
- A consequential increase in the number of dangerous fire weather days and a longer fire season for southern and eastern Australia.

It is noted that following the development of climate projections outlined in this report the IPCC published their Sixth Assessment Report which introduced new global emissions pathways referred to as Shared Socio-economic Pathways (SSPs). With these new pathways, results of global climate models are becoming available however the resolution of these models is very coarse, with no regionalisation of models (i.e. at a resolution suitable for site-specific analysis) produced to date. Until this regionalisation occurs, it is prudent to prioritise the use of higher resolution climate data produced by the CSIRO and the Bureau of Meteorology (BoM) using the RCP projections for the purpose of this report.

A summary of the current climate science available based on AR5 for the Australian Capital Territory (OEH, 2014) is provided in Table 8. Detailed quantitative climate projections (including for the Murray Basin Cluster Report) are provided in Appendix E for reference. The Murray Basin Cluster Report is also based on AR 5 projections.

**Table 8 Climate projections**

| Climate variable | Baseline | 2030 | 2070 | Summary |
|---|---|---|---|---|
| **Mean temperature (ºC)** | 20 to 22ºC (Summer)<br>6 to 8ºC (Winter) | +0.7ºC<br>(0.50 to 0.81ºC) | +2.0ºC<br>(1.56 to 2.34ºC) | Changes in temperature often occur at the extremes, for instance increasing the duration of drought, extending bushfire seasons and resulting in heat waves that last longer and are more intense.<br>There is a high level of confidence across all models showing an increase in temperature for both the 2030 and 2070 timeframes across all temperature variables (average, maximum and minimum). The greatest change in temperature for the region is projected for the spring months. |
| **Average maximum temperature change (ºC)** | 26-28ºC (Summer) | +0.7ºC<br>(0.58 to 0.95ºC) | +2.0ºC<br>(1.82 to 2.48ºC) | |
| **Average minimum temperature change (ºC)** | 2-4ºC (Winter) | +0.6ºC<br>(0.40 to 0.74ºC) | +2.0ºC<br>(1.38 to 2.33ºC) | |
| **Extreme heat (days above 35ºC) for Canberra** | <10 days per year | +1 to 5 days | +10 to 20 days | While Canberra currently only experiences around 10 days per year where temperatures are higher than 35ºC, it is expected to experience more hot days in the future. The greatest increase is expected around the Canberra area for the far future.<br>Equipment, plant and individuals are sensitive to extreme temperature, with days over 35ºC having the potential to adversely impact on both infrastructure and people (such as active transport users).<br>Figure 9 shows the projected increase of days above 35ºC by 2070. |
| **Bushfire weather days (FFDI[35] > 50)** | 1.1 days per year | +0.1 days<br>(-0.13 to 0.36 days) | +0.3 days<br>(-0.04 to +0.78 days) | The FFDI – Forest Fire Danger Index combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50. Severe fire weather days (FFDI > 50) are projected to increase, particularly during summer (peak fire risk) and spring (peak prescribed burning season) months across the region for both the 2030 and 2070 timeframes.<br>As shown previously in Figure 6, there is a low direct bushfire risk to the Project, however areas surrounding are bushfire prone and highlight a range of indirect risks (e.g. smoke inhalation for active transport users or potential power supply interruption with transmission lines disrupting Project lighting). |
| **Mean annual rainfall change (%)** | 400 to 800 mm per year | -2.8%<br>-11% to +8% | -0.4%<br>-9% to 13% | Mean annual rainfall varies considerably from year to year and this variability is reflected in global models. While overall rainfall is expected to remain much the same through 2030, seasonal falls are likely to change, with an increased forecast for autumn, while spring will likely see decreases in rainfall totals.<br>By 2070, annual rainfall is projected to increase, however seasonal projections span both drying and wetting scenarios, highlighting the need for appropriate consideration during Project planning.<br>Changes to rainfall can correspond to drought conditions, which in turn may impact the Project through increased risk of erosion / soil cracking and / or loss of landscaping / green infrastructure. |
| **Extreme rainfall - flooding** | N/A | Extreme rainfall events to increase in intensity and severity. | | While projections for extreme rainfall (NARCliM) are not yet available, in a warming climate, extreme rainfall events are expected to increase in intensity due to a warmer atmosphere being able to hold more moisture.<br>According to the CSIRO and BoM (CSIRO 2015), the period from 2010 to present has seen widespread, individual very-heavy rainfall events, particularly during the warmer months.<br>In 2017, an event where the 24 hour rainfall total exceeded the 99th percentile – this event resulting in wide-spread flash flooding across the city. |
| **Drought** | N/A | Time spent in drought conditions to increase | | Global models suggest a similar uncertainty for drought as it does mean rainfall change. The models do strongly indicate however, that there will be an increase in the proportion of time spent in drought. Variability in mean rainfall and the occurrence of storms will largely drive time spent in drought across the Central Slopes.<br>As ground conditions become further subjected to drought, there is an increased risk of infrastructure movement as a result of soil cracking. |

[35] FFDI – Forest Fire Danger Index: The FFDI combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50.

## 6.3 Projected future mapping

### 6.3.1 Bushfire

As highlighted above, the FFDI is based on a range of factors that sum to a numerical value. The value indicates the relative severity of fire conditions – being low to moderate, high, very high, severe, extreme and catastrophic. When FFDI values exceed 50, it is likely that total fire bans will be put in place to limit the potential for a bushfire.

The ACT is projected to experience an increase in both average and severe FFDI, both into the near future and far future – highlighting the increase potential for both indirect and direct bushfire risks to the project. Changes are projected to be higher in summer and spring (including a lengthening of the traditional 'bushfire season'), while autumn is projected to have a slightly lower occurrence of high FFDI days. This is largely related to the projected increase in rainfall for autumn.

### 6.3.2 Mean temperature, heatwaves and extreme heat days

According to projections provided by NARCliM, all temperature variables (minimum, average and maximum) are expected to increase across the ACT. By 2030, temperatures are projected to increase by 0.7°C and 2°C by 2070. It is noted that spring will experience the greatest rise in temperatures across the year – highlighting the growing risk to human health.

As shown below in Figure 9, the change in number of projected days above 35°C is anticipated to be the highest for the Canberra region and surrounds (approximately 10-20 additional days per year), when compared to the rest of the ACT. As noted above, this is likely to be further exacerbated by the urban heat island effect, placing additional pressure onto electrical systems, pavements and landscaping.

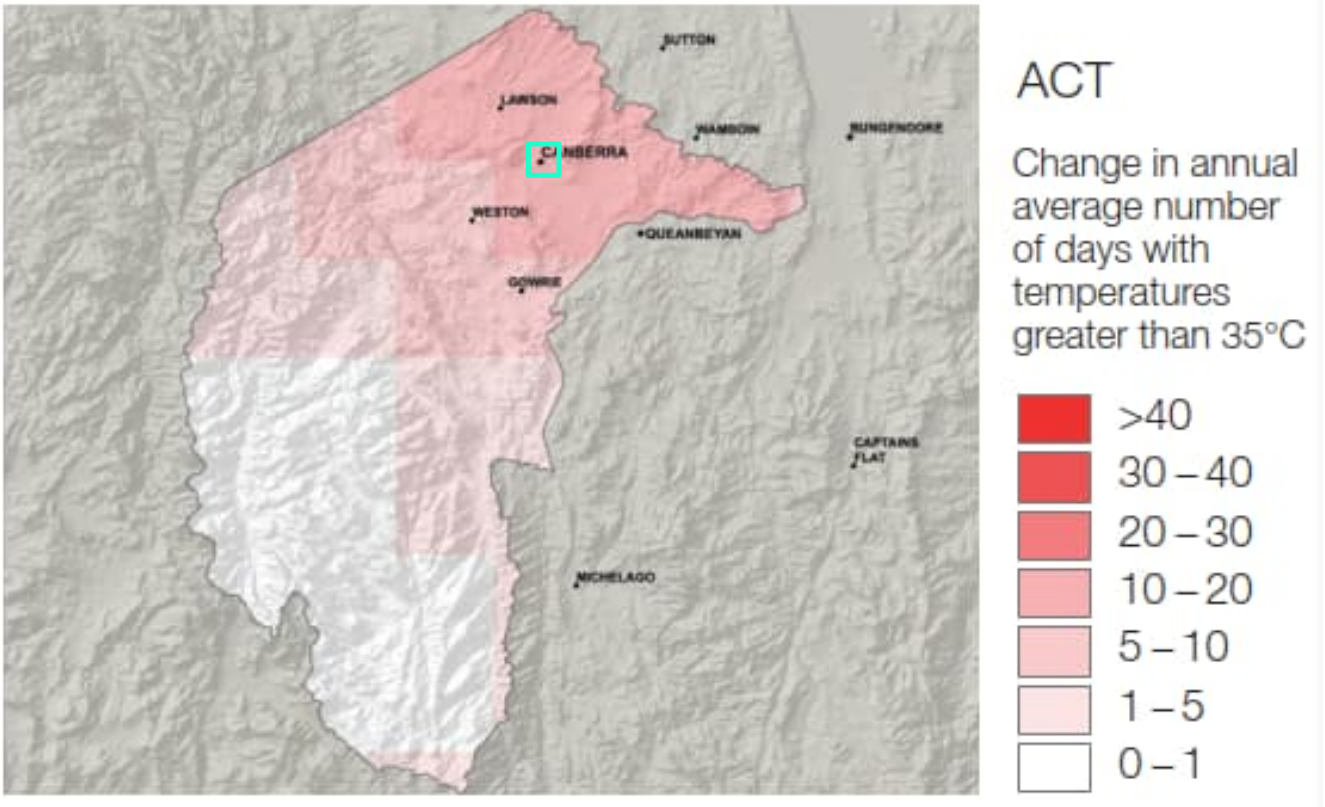



**Figure 9 Future changes in days per year above 35°C. Source: AdaptNSW. Approximate location of the Project highlighted in teal.**

### 6.3.3 Mean rainfall, drought and extreme rainfall

Changes to mean rainfall are projected to remain highly variable into both the near future and far future. Changes in rainfall have the ability to exacerbate extreme events resulting in severe drought or more frequent flood events – both of which result in secondary impacts such as challenges for water quality and soil erosion. It is noted that rainfall in winter and spring is projected to decrease, while increases are projected for autumn.

As highlighted below in Figure 10 and Figure 11, changes in rainfall are projected to be highly variable into the future, with an anticipated decrease in rainfall by 2030, but increase in rainfall for Canberra by 2070. It is further projected that year on year changes will remain highly variable as well, highlighting the need to consider both drying (e.g. drought) and wetting (e.g. floods) scenarios.

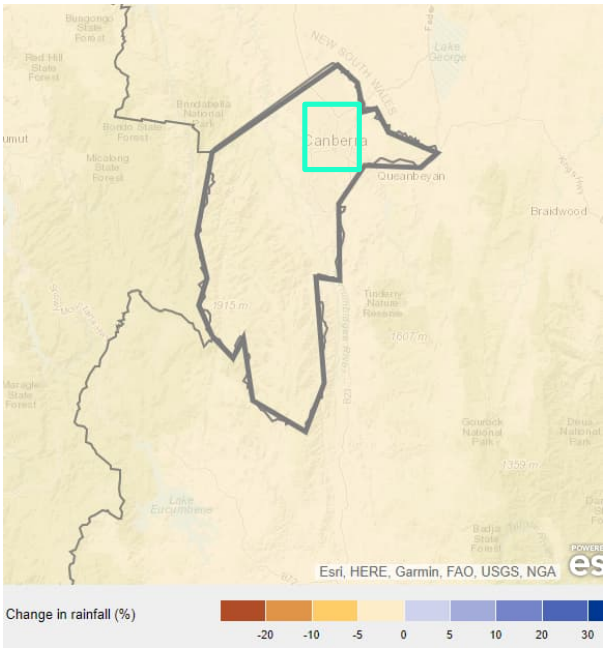



**Figure 10 Future changes in rainfall (percentage change) - 2030. Source: AdaptNSW. Approximate footprint highlighted in teal.**

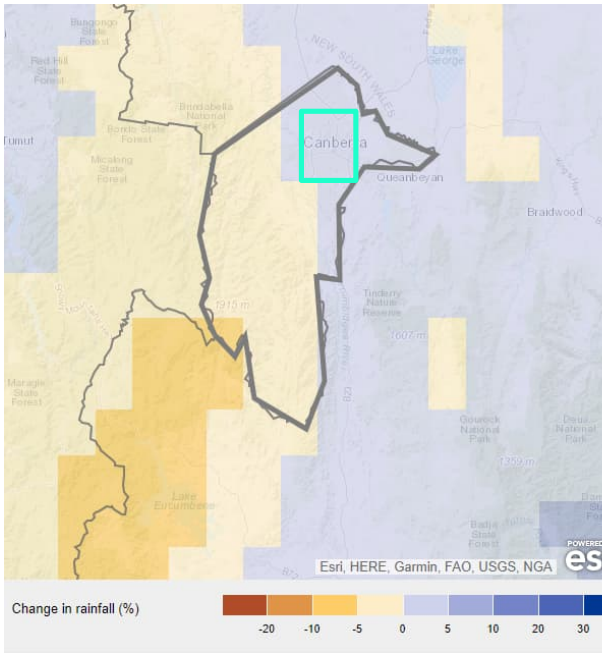



**Figure 11 Future changes in rainfall (percentage change) - 2070. Source: AdaptNSW. Approximate footprint highlighted in teal.**

# 7.0 Construction risks

A risk assessment was conducted utilising the likelihood and consequence criteria presented in **Appendix B**. The criteria was based on the definitions set out in Proponent's Guide to Environmental Impact Statements (published by ACTPLA). The risk rating is a function of the likelihood and consequence ratings as set out in the matrix presented in Table 9.

**Table 9 Risk Matrix**

| Likelihood | Consequence | | | | | |
|---|---|---|---|---|---|---|
| | Positive | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost certain | Beneficial | Medium | High | Very High | Significant | Significant |
| Likely | Beneficial | Low | Medium | High | Very High | Significant |
| Possible | Beneficial | Very Low | Low | Medium | High | Very High |
| Unlikely | Beneficial | Negligible | Very Low | Low | Medium | High |
| Remote | Beneficial | Negligible | Negligible | Very Low | Low | Medium |

## 7.1 Assessment of potential impacts

Risks to the Project as a result of climate events by way of delays in construction schedule, supplies and potential risks to human health and safety are likely, based on observed events and projected trends.

The climate risk assessment identified a total of three (3) climate change risk statements relating to construction of the Project. Based on the rating of risk statements, there would be (2) high or very high risk and no (0) extreme risks at 2030. It is noted that risks to construction were only assessed at the 2030 time horizon (and not 2070) as works are expected to be completed well in advance of 2030. Table 10 summarises the climate change risks to construction.

**Table 10 Climate Change Risks to Construction**

| Risk ID | Risk Statement | 2030 | | |
|---|---|---|---|---|
| | | Likelihood | Consequence | Risk Rating[36] |
| CR1 | Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts. | Likely | Moderate | High |
| CR2 | Extreme heat (days over 35°C) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts. | Likely | Moderate | High |
| CR3 | Bushfire smoke affecting visibility and air quality for construction workers. | Possible | Moderate | Medium |

## 7.2 Management and mitigation measures

Table 11 outlines the associated mitigation and adaptation measure to reduce the impacts of the identified priority construction climate risks for the Project. Identified measures include a combined

[36] Risk rating definitions can be found in Appendix B

approach that addresses the avoidance of risk where possible as well as management / operational procedure changes for risks that may be unavoidable.

**Table 11 Management and Mitigation Measures**

| Ref | Mitigation Measure | Timing | Reference |
|---|---|---|---|
| C1 | Treatments and mitigation measures identified in this climate change technical report would be incorporated into the detailed design and delivery of the Project. | Prior to and during construction | Appendix F |
| C2 | Construction-related climate change risks (e.g., heatwaves or increased frequency and severity of extreme rainfall events) would be considered during the development of environmental management measures as part of the CEMP and other management plans, as relevant. | During construction | |
| C3 | To reduce Scope 3 emissions where feasible:<br>• Select materials with lower embodied energy values and for high embodied energy materials (such as concrete, steel and asphalt) reduce or substitute quantities<br>• Select local materials or Australian materials over imported materials to minimise transport emissions.<br>• Minimise construction waste. | Detailed design and during construction | |

## 7.3 Residual impacts

The final step in completing the assessment outlined within this technical report is understanding the level of residual climate risk relative to the Project once the adaptation actions (management and mitigation measures) identified have been applied. In accordance with v.1.2 of the ISC IS Rating Scheme Cli-1 and Cli-2 criteria, treatment options for all very high and high-priority risks have been identified with appropriate measures implemented.

A residual risk assessment for the proposal was undertaken to apply the relevant adaptation measures identified in the above section for all 'high' and 'extreme' risks and shown in Table 12.

In addition, adaptation actions have been identified to treat all 'medium' risks. Based on the application of the adaptation measures, no residual 'extreme' or 'high' risk ratings remain for the Project. It is anticipated that as the Project develops, this register will continue to be incorporated into ongoing monitoring and evaluation documentation for the Project, and used to track compliance and progress against the adaptation measures to assist in reducing the risk exposure of the Project.

**Table 12 Residual Risk Table**

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | |
|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating |
| Direct risks | | | | | | | |
| CR-1 | Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts. | High (Likely / Moderate) | *N/A* | • Emergency response plans for construction staff will be prepared as part of Construction Environmental Management Plans to account for extreme events including extreme storms and rainfall. This includes coordination with emergency responders, training and evacuation procedures.<br>• Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events. | Likely | Minor | Medium |
| CR-2 | Extreme heat (days over 35$^{o}$C) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts | High (Likely / Moderate) | *N/A* | • Contingency to be built into the construction schedule to account for delays and disruptions due to extreme heat events.<br>• Health and safety plans will include extreme heat response measures including:<br>- Decreased temperature thresholds for tools down.<br>- Heat-specific PPE for construction staff.<br>- Split shifts to avoid hotter parts of the day<br>- Include areas of respite for construction staff<br>- Ensure availability of water and cooling<br>- Avoid heat generating activities during the hotter parts of the day. | Possible | Moderate | Medium |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CR-3 | Bushfire smoke affecting visibility and air quality for construction workers | Medium (Possible / Moderate) | *N/A* | • Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events.<br>• Health and safety plans will include extreme air quality response measures. | Possible | Minor | Low |

# 8.0 Operational risks

## 8.1 Assessment of potential impacts

Using previous observed events and projected trends, risks to the Project associated infrastructure and human health and safety concerns are likely to occur. The consequences of these risks may include physical damage, increased discharge of water and the accelerated deterioration of assets. The increased frequency of extreme events including rainfall, heatwaves and bushfires are already impacting on infrastructure. Recent events both in and around Canberra have highlighted the susceptibility of infrastructure to these extreme events.

The climate risk assessment identified a total of 42 climate change risk statements relating to operation and maintenance of the Project, both direct and indirect. In the context of climate change impacts, direct risk comprise climate hazards (direct impacts of rainfall extremes such as exceeding infrastructure drainage capacity), while indirect climate-related impacts are secondary to the direct risk (roadways becoming inundated due to failure of drainage infrastructure).

Based on the rating of risk statements, there would be seven (7) high , one (1) very high risks and no (0) extreme risks at 2030, increasing to twenty-five (22) high and four (4) very high risks and no (0) extreme risk at 2070. Table 13 provides a summary of the operational risk assessment, while Table 14 details the risk statements and risk ratings

Risks have been grouped by the following climate variables:

- Extreme rainfall and flooding – 13 risks
- Extreme heat – 13 risks
- Drought / mean rainfall changes – 2 risks
- Extreme storms – 6 risks
- Bushfire – 8 risks.

**Table 13 Summary of Operational Risk Assessment**

| Risk Rating | 2030 | 2070 |
|---|---|---|
| Negligible | 0 | 0 |
| Very Low | 0 | 0 |
| Low | 11 | 2 |
| Medium | 23 | 14 |
| High | 7 | 23 |
| Very High | 1 | 3 |
| Significant (Extreme) | 0 | 0 |
| **Total** | **42** | **42** |

**Table 14 Climate Change Risks to Operation (2030 and 2070)**

| | | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| **Risk IS** | **Risk Statement** | **Likelihood** | **Consequence** | **Risk rating** | **Likelihood** | **Consequence** | **Risk rating** |
| **Increased intensity of extreme rainfall & flash flooding events leading to:** | | | | | | | |
| **Direct risks** | | | | | | | |
| R1 | Exceeding the capacity of drainage infrastructure due to blockage from debris such as mulch leading to inundation and nuisance flooding of the track or station infrastructure | Almost Certain | Minor | High | Almost Certain | Minor | High |
| R2 | Exceeding the capacity of drainage infrastructure due to high volumes of water leading to inundation of track or station infrastructure | Possible | Moderate | Medium | Likely | Moderate | High |
| R3 | Scour of key infrastructure (e.g. embankments, cuttings, drainage inlets / outlets) and subsequent maintenance, repairs and service disruptions | Unlikely | Moderate | Low | Unlikely | Moderate | Low |
| R4 | Health and safety risks for station staff, maintenance workers and passengers during periods of extreme rainfall | Possible | Moderate | Medium | Likely | Moderate | High |
| R5 | Disruption to standard evacuation procedures during an extreme rainfall event for people with mobility challenges or other disabilities (e.g. blind, deaf) | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| R6 | Faults and failures for rail-critical electrical and communications (e.g. heavy rainfall can affect radio signal propagation), leading to service and maintenance disruptions, and safety impacts | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R7 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) affecting water quality treatment levels | Likely | Minor | Medium | Almost Certain | Minor | High |
| R8 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) mobilising pollutant load impacts on operations | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| R9 | An increase in volume of runoff from catchment areas, increasing loads for project drainage | Almost certain | Moderate | Very High | Almost certain | Moderate | Very High |
| R10 | An increased water table, resulting in increased loading on structures (e.g. underground pits, retaining walls) | Unlikely | Moderate | Low | Unlikely | Moderate | Low |

| | | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| **Risk IS** | **Risk Statement** | **Likelihood** | **Consequence** | **Risk rating** | **Likelihood** | **Consequence** | **Risk rating** |
| **Indirect risks** | | | | | | | |
| R11 | Damage to the local electricity network resulting in loss of power to project infrastructure and subsequent service delays | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R12 | Inundation of the surrounding road and rail network (e.g. Stage 1) resulting in reduced access to rail corridor and stations (e.g. emergency services, maintenance workers) | Possible | Moderate | Medium | Likely | Moderate | High |
| R13 | Exceeding the capacity of network drainage infrastructure (due to either blockage from debris such as mulch or volume of water) leading to inundation of surrounding roads or buildings | Possible | Major | High | Likely | Major | Very High |
| **Increased intensity of extreme storm (including lightning) and wind events resulting in:** | | | | | | | |
| **Direct risks** | | | | | | | |
| R14 | Damage to rail-critical communications (e.g. traffic signals) and other electrical systems due to high winds, lightning, debris, fallen branches / trees, etc. resulting in service disruptions and increased operational costs | Possible | Moderate | Medium | Likely | Moderate | High |
| R15 | Damage to light rail bridges, track and other connections (e.g. cycleway, pedestrian, road) resulting in service delay, limited access to stations and potential safety impacts (e.g. transit users and workers) | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| R16 | Damage to the LRVs from lightning strikes or debris, resulting in service delays or increased costs for repairs | Unlikely | Moderate | Low | Unlikely | Moderate | Low |
| R17 | Health and safety risks for station staff, maintenance workers and transit users during extreme storm and wind events (e.g. risk of slips, trips and falls; risk of being stuck by hail/debris; risks posed by damaged infrastructure such as station furniture / roofing) | Likely | Moderate | High | Likely | Moderate | High |
| R18 | Disruption to standard evacuation procedures during a storm event for people with mobility challenges or other disabilities (e.g. blind, deaf) | Possible | Minor | Low | Likely | Minor | Medium |
| **Indirect risks** | | | | | | | |
| R19 | Damage to the surrounding road and rail network due to debris, fallen branches, etc. resulting in reduced access to rail corridor and stations | Possible | Moderate | Medium | Likely | Moderate | High |

| | | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| **Risk IS** | **Risk Statement** | **Likelihood** | **Consequence** | **Risk rating** | **Likelihood** | **Consequence** | **Risk rating** |
| **Increased intensity and duration of extreme heat events and increased average temperatures resulting in:** | | | | | | | |
| **Direct risks** | | | | | | | |
| R20 | Extreme heat resulting in track buckling, and subsequent reduced operating speeds and service disruptions (e.g. potential derailment) | Unlikely | Major | Medium | Possible | Major | High |
| R21 | Reduced efficiency and/or heat related damage resulting in failure of project electrical infrastructure (e.g. signalling, telecommunications as well as the LRVs) and subsequent disruption to service, increased maintenance costs and safety risk | Likely | Minor | Medium | Almost Certain | Minor | High |
| R22 | Health and safety risks for station staff, maintenance workers and transit users during periods of extreme heat (e.g. heat stress, dehydration, hospitalisation) | Likely | Moderate | High | Likely | Moderate | High |
| R23 | Safety risks for station staff, maintenance works and transit users due to street furniture and other materials becoming too hot to be touched, resulting in potential injuries | Likely | Minor | Medium | Almost Certain | Minor | High |
| R24 | Increased transit user discomfort (e.g. due to lack of shading, LRV HVAC not operating properly) resulting in increased customer complaints | Almost Certain | Minor | High | Almost Certain | Minor | High |
| R25 | Adverse impacts to plant species (e.g. wilting of plants), resulting in increased landscaping costs and exacerbate erosional issues | Likely | Moderate | High | Almost Certain | Moderate | Very High |
| R26 | Increased damage and accelerated degradation of materials and equipment (e.g. concrete, furniture, electrical equipment and paved areas, batteries) requiring increased maintenance or costs to replace | Likely | Minor | Medium | Almost Certain | Minor | High |
| R27 | Increased risk of chemical, fuel or other flammable liquid (e.g. battery, maintenance materials) combusting due to high heat damaging infrastructure / LRVs or safety risks to staff and transit users | Unlikely | Major | Medium | Possible | Major | High |
| R28 | Increased expansion movement within key infrastructure joints / sealants resulting in failure, early replacement and increased maintenance and operational costs | Possible | Minor | Low | Likely | Minor | Medium |
| R29 | Deterioration of the polymers on the track, resulting in increased maintenance and operational costs | Possible | Minor | Low | Likely | Minor | Medium |

| | | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| **Risk IS** | **Risk Statement** | **Likelihood** | **Consequence** | **Risk rating** | **Likelihood** | **Consequence** | **Risk rating** |
| R30 | Extreme heat resulting in deterioration of the green track resulting in a lack of aesthetic appeal | Possible | Moderate | Medium | Likely | Moderate | High |
| **Indirect risks** | | | | | | | |
| R31 | Disruption to the local electricity network (blackout/brownout due to heat and/or increased demand for electricity) resulting in loss of power to project infrastructure and subsequent service delays | Likely | Moderate | High | Almost Certain | Moderate | Very High |
| R32 | An increased power load to bring LRVs to a comfortable temperature on start-up, potentially damaging electrical infrastructure (or resulting in reduced operating efficiency) | Likely | Minor | Medium | Almost Certain | Minor | High |
| **Changes to average annual rainfall and increased duration and intensity of drought resulting in:** | | | | | | | |
| **Direct risks** | | | | | | | |
| R33 | Soil subsidence, movement and cracking as a result of increased variability of soil wetting/drying. This may reduce the integrity of station foundations, rail track and bridge piles potentially resulting in structural failure over the long-term | Unlikely | Major | Medium | Unlikely | Major | Medium |
| R34 | Decreased availability of water during periods of drought negatively impacting on landscaped areas (particularly the green track) | Likely | Minor | Medium | Almost Certain | Minor | High |
| **Increased frequency and intensity of bushfire and dust events resulting in:** | | | | | | | |
| **Direct risks** | | | | | | | |
| R35 | Damage to LRV HVAC units due to bushfire smoke or dust necessitating more frequent maintenance and repairs | Likely | Minor | Medium | Almost Certain | Minor | High |
| R36 | Reduced visibility from smoke, resulting in a reduction in travel speeds / cancellation of service | Possible | Moderate | Medium | Likely | Moderate | High |
| R37 | Health and safety risks for station staff, maintenance workers and transit users due to smoke or dust inhalation | Likely | Moderate | High | Likely | Moderate | High |
| R38 | Damage to trackside infrastructure (e.g. signals, telecommunications, stations) from fire, ash, embers or smoke requiring increased operational / maintenance costs and resulting in service delays | Unlikely | Moderate | Low | Possible | Moderate | Medium |

| | | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| **Risk IS** | **Risk Statement** | **Likelihood** | **Consequence** | **Risk rating** | **Likelihood** | **Consequence** | **Risk rating** |
| **Indirect risks** | | | | | | | |
| R39 | Damage to power supply infrastructure or need to cut supply, leading to power interruptions with increased frequency and duration – limiting the ability of the LRVs to operate | Possible | Moderate | Medium | Likely | Moderate | High |
| R40 | Closure of the surrounding road network, impacting emergency access or rescue as well as maintenance needs | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R41 | Disruption of maintenance staff for those needing to defend their homes in lieu of attending work | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R42 | Pedestrians, cyclists and other individuals using the light rail corridor as an evacuation route and/or running across at non-safe locations (e.g. mid-block) during a bushfire, increasing the risk of LRV strikes | Unlikely | Moderate | Low | Unlikely | Moderate | Low |

## 8.2 Management and mitigation measures

Table 15 outlines the planned management and mitigation measures to reduce the impacts of the identified operational climate risks for the Project. Identified measures include a combined approach that addresses the avoidance of risk where possible, designing out risk where practicable, as well as management / operational procedure changes for risks that may be unavoidable.

It is noted that for the purpose of the risk assessment, there are a range of actions / treatment options that have been identified as already having been integrated into the design or part of the planning process. These actions have not been included in the following table, but have been used to inform the residual risk assessment (identified as 'current actions') and are provided in the full list of treatment options in Appendix F.

The identification of these adaptation measures has resulted from discussions with design leads and technical specialists, review of design information (including drawings and flooding reports) and documentation of existing operating practices.

**Table 15 Management and Mitigation Measures**

| Ref | Mitigation Measure | Timing | Reference |
|---|---|---|---|
| O1 | Development and implementation of a **Carbon and Energy Management Plan** to support the reduction of ongoing emissions associated with maintenance activities. | During operation | |
| O2 | Carbon offsets would be retired at the completion of construction to account for emissions associated with the construction of the Project to achieve a zero net carbon footprint for all Scope 1 and 2 emissions. | Post construction | ACT Climate Change Strategy 2019-2025 |

## 8.3 Residual impacts

The final step in completing the assessment outlined within this technical report is understanding the level of residual climate risk relative to the Project once the adaptation actions (management and mitigation measures) identified have been applied. Treatment options for all extreme and high-priority risks have been identified with appropriate measures implemented.

A residual risk assessment for the proposal was undertaken to apply the relevant adaptation measures identified in the above section for all 'very high and 'high' risks'. All 'very high' and 'high' and at least 50 percent of 'medium' priority risks were mitigated across both 2030 and 2070 timeframes. A summary is provided in Table 16 with detail provided in Table 17.

**Table 16 Summary of residual risks**

| | 2030 – Preliminary | 2030 - Residual | % reduced | 2070 – Preliminary | 2070 - Residual | % reduced |
|---|---|---|---|---|---|---|
| Negligible | 0 | 0 | NA | 0 | 0 | NA |
| Very Low | 0 | 9 | NA | 0 | 0 | NA |
| Low | 11 | 21 | NA | 4 | 12 | NA |
| Medium | 23 | 8 | 91 | 12 | 26 | 83 |
| High | 7 | 0 | 100 | 23 | 0 | 100 |
| Very high | 1 | 0 | 100 | 3 | 0 | 100 |
| Significant | 0 | 0 | NA | 0 | 0 | NA |
| Total | **42** | **38** | **-** | **42** | **38** | **-** |

Adaptation actions identified contributed towards treating all 'medium' risks, resulting in a number of those 'medium' risks having their corresponding residual risks revised to 'low'. Based on the application of the adaptation measures, no residual 'very high' or 'high' risk ratings remain. As part of the residual

risk assessment, individual, specific adaptation measures have been applied to multiple risks to help reduce the potential risks to the Project. It is anticipated that as the Project develops, this register will continue to be used to track compliance and progress against the adaptation measures to assist in reducing the risk exposure of the proposal.

**Table 17 Residual Risk Assessment**

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| **Increased intensity of extreme rainfall & flash flooding events leading to:** | | | | | | | | | | |
| **Direct risks** | | | | | | | | | | |
| R1 | Exceeding the capacity of drainage infrastructure due to blockage from debris such as mulch leading to inundation and nuisance flooding of the track, station infrastructure | High (Almost Certain / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities<br><br>Gutters are sized by hydraulic engineers to quickly and effectively drain water out of station roofs in heavy rain fall situations<br><br>Curb levels have been set higher than bed levels to reduce the potential of mulch escaping and blocking drains<br><br>Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br><br>Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Likely | Minor | Medium | Likely | Minor | Medium |
| R2 | Exceeding the capacity of drainage infrastructure due to high volumes of water leading to inundation of track and station infrastructure | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br><br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities<br><br>Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater; rainwater harvesting from structure roofs and hardstand runoff<br><br>Gutters are sized by hydraulic engineers to quickly and effectively drain water out of station roofs in heavy rain fall situations<br><br>Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br><br>Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R4 | Health and safety risks for station staff, maintenance workers and passengers during periods of extreme rainfall | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Gutters are sized by hydraulic engineers to quickly and effectively drain water out of station roofs in heavy rain fall situations<br><br>Canopies provided at transit stations for over half the station length, with full canopies provided for termini stops. Canopy structure is | Unlikely | Moderate | Low | Possible | Moderate | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | modular in design and can be extended to accommodate increasing population.<br><br>Emergency response plans for transit staff and transit users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes.<br><br>Stop platforms are open on sides and wide access walkways are provided for easy passenger flow/evacuation | | | | | | |
| R5 | Disruption to standard evacuation procedures during an extreme rainfall event for people with mobility challenges or other disabilities (e.g. blind, deaf) | Low (Unlikely / Moderate) | Medium (Possible / Moderate) | Emergency response plans for transit staff and transit users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. Emergency response plans to consider options for evacuation of people with mobility challenges or other disabilities. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Unlikely | Minor | Very Low | Possible | Minor | Low |
| R6 | Faults and failures for rail-critical electrical and communications (e.g. heavy rainfall can affect radio signal propagation), leading to service and maintenance disruptions, and safety impacts | Medium (Possible / Moderate) | Medium (Possible / Moderate) | **Planned Action**<br>Emergency power generation as backup that is decoupled from the grid has been designed including on-board batteries | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R7 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) affecting water quality treatment levels | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br><br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities<br><br>Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater; rainwater harvesting from structure roofs and hardstand runoff<br><br>Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Possible | Minor | Low | Likely | Minor | Medium |
| R8 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) mobilising pollutant load impacts on operations | Low (Unlikely/ Moderate) | Medium (Possible / Moderate) | Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br><br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities<br><br>Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater; rainwater harvesting from structure roofs and hardstand runoff | Unlikely | Minor | Very Low | Possible | Minor | Low |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | | | | | | |
| R9 | An increase in volume of runoff from catchment areas, increasing loads for project drainage | Very High (Almost Certain / Moderate) | Very High (Almost Certain / Moderate) | **Current Actions**<br>Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br><br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities<br><br>Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater; rainwater harvesting from structure roofs and hardstand runoff<br><br>Gutters are sized by hydraulic engineers to quickly and effectively drain water out of station roofs in heavy rain fall situations<br><br>Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Possible | Moderate | Medium | Possible | Moderate | Medium |
| **Indirect risks** | | | | | | | | | | |
| R11 | Damage to the local electricity network resulting in loss of power to project infrastructure and subsequent service delays | Medium (Possible / Moderate) | Medium (Possible / Moderate) | **Current Actions**<br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br>**Planned Action**<br>Emergency power generation as backup that is decoupled from the grid has been designed including on-board batteries | Possible | Minor | Low | Possible | Minor | Low |
| R12 | Inundation of the surrounding road and rail network (e.g. Stage 1) resulting in reduced access to rail corridor and stations (e.g. emergency services, maintenance workers) | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>All new pits and pipes within the project area have been sized to allow for the 20% increase in rainfall intensities.<br><br>A flood study has been undertaken to assess impact of the proposed LRS2A works on the existing downstream/upstream drainage network and upgrades required to cater for increased peak flows due to climate change.<br><br>**Planned Action**<br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes<br><br>Design pavements and base layers to accommodate impacts caused by variability in rainfall (e.g. wetting and drying) and increases in temperature | Possible | Minor | Low | Likely | Minor | Medium |
| R13 | Exceeding the capacity of network drainage infrastructure (due to either blockage from | Medium | High | **Current Actions** | Possible | Minor | Low | Likely | Minor | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | debris such as mulch or volume of water) leading to inundation of surrounding roads or buildings | (Possible / Moderate) | (Likely / Moderate) | Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br><br>All new pits and pipes within the project area to be sized to allow for the 20% increase in rainfall intensities<br><br>Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater; rainwater harvesting from structure roofs and hardstand runoff<br><br>Gutters are sized by hydraulic engineers to quickly and effectively drain water out of station roofs in heavy rain fall situations<br><br>Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br><br>Incorporate and model 100% permeable surfaces into the public realm through the use of pavements, green infrastructure and other mechanisms<br><br>Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | | | | | | |
| **Increased intensity of extreme storm (including lightning) and wind events resulting in:** | | | | | | | | | | |
| **Direct risks** | | | | | | | | | | |
| R14 | Damage to rail-critical communications (e.g. traffic signals) and other electrical systems due to high winds, lightning, debris, fallen branches / trees, etc. resulting in service disruptions and increased operational costs | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br><br>Spare capacity has been provided in the combined services route to facilitate future system upgrades (e.g. with more robust components or cabling as needed)<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Building materials (e.g. street furniture) and Wind loading for key built elements<br><br>Asset management plans will be developed for the termini stops to account for both seasonal variation and in response to climate variables (e.g. inspection after a storm event, regular maintenance – dry limb removal)<br><br>**Planned Action**<br>Emergency power generation as backup that is decoupled from the grid has been designed including on-board batteries | Possible | Minor | Low | Likely | Minor | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| R15 | Damage to light rail bridges, track and other connections (e.g. cycleway, pedestrian, road) resulting in service delay, limited access to stations and potential safety impacts (e.g. transit users and workers) | Low (Unlikely/ Moderate) | Medium (Possible/ Moderate) | Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Building materials (e.g. street furniture) and Wind loading for key built elements<br><br>Asset management plans will be developed for the termini stops to account for both seasonal variation and in response to climate variables (e.g. inspection after a storm event, regular maintenance – dry limb removal) | Unlikely | Minor | Very Low | Possible | Minor | Low |
| R17 | Health and safety risks for station staff, maintenance workers and transit users during extreme storm and wind events (e.g. risk of slips, trips and falls; risk of being stuck by hail/debris; risks posed by damaged infrastructure such as station furniture / roofing) | High (Likely / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Roof canopies and glazed weather protection screens at stops provide protection from wind<br><br>The materials used for the stop designs are robust and building elements such as roof canopies, balustrades and weather protection screens are designed for appropriate wind loads<br><br>Emergency response plans for transit staff and transit users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes.<br><br>Asset management plans will be developed for the termini stops to account for both seasonal variation and in response to climate variables (e.g. inspection after a storm event, regular maintenance – dry limb removal)<br><br>Stop platforms are open on sides and wide access walkways are provided for easy passenger flow/evacuation | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R18 | Disruption to standard evacuation procedures during a storm event for people with mobility challenges or other disabilities (e.g. blind, deaf) | Low (Unlikely/ Moderate) | Medium (Possible/ Moderate) | Emergency response plans for transit staff and transit users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. Emergency response plans to consider options for evacuation of people with mobility challenges or other disabilities. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Unlikely | Minor | Very Low | Possible | Minor | Low |
| **Indirect risks** | | | | | | | | | | |
| R19 | Damage to the surrounding road and rail network due to debris, fallen branches, etc. resulting in reduced access to rail corridor and stations | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Possible | Minor | Low | Likely | Minor | Medium |
| **Increased intensity and duration of extreme heat events and increased average temperatures resulting in:** | | | | | | | | | | |
| R20 | Extreme heat resulting in track buckling, and subsequent reduced operating speeds and service disruptions (e.g. potential derailment) | Medium (Unlikely / Minor) | High (Possible / Major) | Materials (e.g. facades, station furniture, electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy. | Unlikely | Minor | Very Low | Possible | Minor | Low |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Compliant rail fastening systems used to accommodate impacts caused by changes in temperature (e.g. buckling). Where possible, rails to be encapsulated in polymer to mitigate extreme changes in rail temperature<br><br>The track slab has been designed for durability with consideration to future heat extremes (hot and cold) with air shade temperature ranges from -5ºC to 45ºC (in accordance with AS 5100.2)<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including: Rail fastening systems/track stressing conditions.<br><br>**Planned Action**<br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes.<br><br>Allow for +/- 5o C variation to bridge code design thermal range | | | | | | |
| R21 | Reduced efficiency and/or heat related damage resulting in failure of project electrical infrastructure (e.g. signalling, telecommunications as well as the LRVs) and subsequent disruption to service, increased maintenance costs and safety risk | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Materials (e.g. facades, station furniture) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br><br>Traffic signal control houses will be placed under tree coverage or similar shaded areas to prevent overheating during the summer. The gauge of the proposed stainless steel sheet cladding, location and provision of ventilation (e.g. double-skinned) in the integrated services cabinets is sufficient to prevent oil-canning in extreme temperatures<br><br>Integrated service cabinets ventilation will be designed for day 1 loads plus additional capacity to account for up to 20% additional heat load.<br><br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br><br>Spare capacity has been provided in the combined services route to facilitate future system upgrades (e.g. with more robust components or cabling as needed)<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including: Electrical equipment<br><br>**Planned**<br>Traffic signal control houses will be double skinned cabinets | Possible | Insignificant | Very Low | Likely | Insignificant | Low |
| R22 | Health and safety risks for station staff, maintenance workers and transit users during | High | High | **Current Actions** | Possible | Moderate | Medium | Possible | Moderate | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | periods of extreme heat (e.g. heat stress, dehydration, hospitalisation) | (Likely / Moderate) | (Likely / Moderate) | Materials (e.g. facades, station furniture) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy.<br><br>Air conditioning units for LRVs and have been designed with appropriate capacity and to operate in high temperatures<br><br>Canopies provided at transit stations for over half the station length, with full canopies provided for termini stops<br><br>Health and safety plans should include extreme heat response (e.g. staffing plans, tools down, etc.) and PPE for transit staff<br><br>Street tree planting will reduce ambient temperatures by as much as 4 degrees Celsius. Canopy cover will be maximised along the alignment to shade workers and the community. | | | | | | |
| R23 | Safety risks for station staff, maintenance works and transit users due to street furniture and other materials becoming too hot to be touched, resulting in potential injuries | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Materials (e.g. facades, station furniture, electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br><br>Canopies provided at transit stations for over half the station length, with full canopies provided for termini stops<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Building materials (e.g. street furniture)<br><br>Street tree planting will reduce ambient temperatures by as much as 4 degrees Celsius. Canopy cover will be maximised along the alignment to shade workers and the community.<br>**Planned Action**<br>Health and safety plans should include extreme heat response and PPE for transit staff. | Possible | Minor | Low | Likely | Minor | Medium |
| R24 | Increased transit user discomfort (e.g. due to lack of shading, LRV HVAC not operating properly) resulting in increased customer complaints | High (Almost Certain / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Materials (e.g. facades, station furniture, electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br><br>Tinting has been applied to LRVs to reduce solar exposure<br>Air conditioning units for LRVs and have been designed with appropriate capacity and to operate in high temperatures<br><br>Canopies provided at transit stations for over half the station length, with full canopies provided for termini stops | Likely | Minor | Medium | Likely | Minor | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Approximately 100 trees are proposed at back of transit stations and along the corridor (to achieve a 30% canopy cover target), where space allows, to provide shade and protect transit users from solar exposure.<br><br>**Planned Action**<br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes.<br><br>Explore opportunities to provide additional shade (e.g. sails, awnings, public art as shade, etc.) or misting solutions for customer comfort where canopies or mature trees are not suitable to provide respite. | | | | | | |
| R25 | Adverse impacts to plant species (e.g. wilting of plants), resulting in increased landscaping costs and exacerbate erosional issues | High (Likely / Moderate) | Very High (Almost Certain / Moderate) | **Current Actions**<br>Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the AMU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation.<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Planting schedules<br><br>**Planned Action**<br>Asset management plans should be developed for the landscaping to account for both seasonal variation and in response to climate variables (e.g. frequency of inspection / maintenance).<br><br>Irrigation systems would be designed to only deliver water via subsurface systems to reduce water loss. Soil moisture to be measured to ensure efficient and effective irrigation. | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| R26 | Increased damage and accelerated degradation of materials and equipment (e.g. concrete, furniture, electrical equipment and paved areas, batteries) requiring increased maintenance or costs to replace | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Materials (e.g. facades, station furniture) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br><br>The gauge of the proposed stainless steel sheet cladding, location and provision of ventilation (e.g. double-skinned) in the integrated services cabinets is sufficient to prevent oil-canning in extreme temperatures<br><br>Integrated service cabinets ventilation will be designed for day 1 loads plus additional capacity to account for up to 20% additional heat load. The track slab has been designed for durability with consideration to future heat extremes (hot and cold) with air shade temperature ranges from -5oC to 45oC (in accordance with AS 5100.2) | Possible | Minor | Low | Likely | Minor | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Electrical equipment | | | | | | |
| R27 | Increased risk of chemical, fuel or other flammable liquid (e.g. battery, maintenance materials) combusting due to high heat damaging infrastructure / LRVs or safety risks to staff and transit users | Medium (Unlikely / Major) | High (Possible / Major) | **Current Actions**<br>Materials (e.g. facades, station furniture) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br><br>**Planned Action**<br>Health and safety plans should include extreme heat response (e.g. chemical sheets, storage instructions, etc.) and PPE for transit staff<br><br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Rare | Major | Low | Unlikely | Major | Medium |
| R28 | Increased expansion movement within key infrastructure joints / sealants resulting in failure, early replacement and increased maintenance and operational costs | Low (Possible /Minor) | Medium (Likely / Minor) | Materials (e.g. facades, station furniture, electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy.<br><br>Compliant rail fastening systems used to accommodate impacts caused by changes in temperature (e.g. buckling). Where possible, rails to be encapsulated in polymer to mitigate extreme changes in rail temperature<br><br>The track slab has been designed for durability with consideration to future heat extremes (hot and cold) with air shade temperature ranges from -5$^{o}$C to 45$^{o}$C (in accordance with AS 5100.2)<br><br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including: Rail fastening systems/track stressing conditions | Unlikely | Minor | Very Low | Possible | Minor | Low |
| R29 | Deterioration of the polymers on the track, resulting in increased maintenance and operational costs | Low (Possible /Minor) | Medium (Likely / Minor) | Materials (e.g. facades, station furniture, electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy.<br><br>Compliant rail fastening systems used to accommodate impacts caused by changes in temperature (e.g. buckling). Where possible, rails to be encapsulated in polymer to mitigate extreme changes in rail temperature<br><br>The track slab has been designed for durability with consideration to future heat extremes (hot and cold) with air shade temperature ranges from -5$^{o}$C to 45$^{o}$C (in accordance with AS 5100.2) | Unlikely | Minor | Very Low | Possible | Minor | Low |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including: Rail fastening systems/track stressing conditions | | | | | | |
| **Indirect risks** | | | | | | | | | | |
| R31 | Disruption to the local electricity network (blackout/brownout due to heat and/or increased demand for electricity) resulting in loss of power to project infrastructure and subsequent service delays | High (Likely / Moderate) | Very High (Almost Certain / Moderate) | **Current Actions**<br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br><br>**Planned Action**<br>Emergency power generation as backup that is decoupled from the grid has been designed including on-board batteries<br>Investigate battery specifications to ensure they can accommodate the impacts of extreme heat during both operation and storage | Possible | Minor | Low | Likely | Minor | Medium |
| R32 | An increased power load to bring LRVs to a comfortable temperature on start-up, potentially damaging electrical infrastructure (or resulting in reduced operating efficiency) | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br><br>Air conditioning units for LRVs and have been designed with appropriate capacity and to operate in high temperatures | Possible | Minor | Low | Likely | Minor | Medium |
| R33 | Soil subsidence, movement and cracking as a result of increased variability of soil wetting/drying. This may reduce the integrity of station foundations, rail track and bridge piles potentially resulting in structural failure over the long-term | Medium (Unlikely / Major) | Medium (Unlikely / Major) | The track form has been designed to resist and control shrinkage effects through selection of pavement type, joint detailing and design of crack controlling steel reinforcement in accordance with AS 5100.5<br><br>Inspections will be conducted to monitor the development of cracks in infrastructure or surrounding land. | Unlikely | Major | Medium | Unlikely | Major | Medium |
| **Changes to average annual rainfall and increased duration and intensity of drought resulting in:** | | | | | | | | | | |
| **Direct risks** | | | | | | | | | | |
| R34 | Decreased availability of water during periods of drought negatively impacting on landscaped areas (particularly the green track) | Moderate (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation | Possible | Minor | Low | Likely | Minor | Medium |
| **Increased frequency and intensity of bushfire and dust events resulting in:** | | | | | | | | | | |
| **Direct risks** | | | | | | | | | | |
| R35 | Damage to LRV HVAC units due to bushfire smoke or dust necessitating more frequent maintenance and repairs | Medium (Likely / Minor) | High (Almost Certain / Minor) | **Current Actions**<br>Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>• Air conditioning standards (including filters)<br>• Maintain landscaped areas to minimise potential bushfire origin point and fuel loads<br><br>Inspection of infrastructure after bushfire events to be undertaken to determine damage and appropriate maintenance or repair requirements<br><br>LRVs have been designed according to EN 45545 for fire behaviour materials and components including those that have low propagation properties and those that limit the emissions of smoke and gasses | Possible | Minor | Low | Likely | Minor | Medium |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| R36 | Reduced visibility from smoke, resulting in a reduction in travel speeds / cancellation of service | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Coordinate with operators of connecting transport prior to, and during bushfire events<br>Maintain landscaped areas to minimise potential bushfire origin point and fuel loads<br><br>**Planned Action**<br>A Bushfire Management Plan will be prepared which highlights preventative measures to respond to bushfire events as well as ongoing incident and emergency responses to active bushfires during operation of the project. This includes evacuation procedures, site safe havens and emergency notification protocols for both stations and the LRVs | Possible | Minor | Low | Likely | Minor | Medium |
| R37 | Health and safety risks for station staff, maintenance workers and transit users due to smoke or dust inhalation | High (Likely / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Coordinate with operators of connecting transport prior to, and during bushfire events<br><br>Maintain landscaped areas to minimise potential bushfire origin point and fuel loads<br><br>**Planned Action**<br>A Bushfire Management Plan will be prepared which highlights preventative measures to respond to bushfire events as well as ongoing incident and emergency responses to active bushfires during operation of the project. This includes evacuation procedures, site safe havens and emergency notification protocols for both stations and the LRVs | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R38 | Damage to trackside infrastructure (e.g. signals, telecommunications, stations) from fire, ash, embers or smoke requiring increased operational / maintenance costs and resulting in service delays | Low (Unlikely/ Moderate) | Medium (Possible/ Moderate) | **Planned Action**<br>A Bushfire Management Plan will be prepared which highlights preventative measures to respond to bushfire events as well as ongoing incident and emergency responses to active bushfires during operation of the project. This includes evacuation procedures, site safe havens and emergency notification protocols for both stations and the LRVs | Unlikely | Minor | Very Low | Possible | Minor | Low |
| **Indirect risks** | | | | | | | | | | |
| R39 | Damage to power supply infrastructure or need to cut supply, leading to power interruptions with increased frequency and duration – limiting the ability of the LRVs to operate | Medium (Possible / Moderate) | High (Likely / Moderate) | **Current Actions**<br>Coordinate with operators of connecting transport prior to, and during bushfire events<br><br>N-1 redundancy in place, so that LRVs can continue operating during isolated disruptions and blackouts<br>**Planned Action**<br>Emergency power generation as backup that is decoupled from the grid has been designed including on-board batteries | Possible | Minor | Low | Likely | Minor | Medium |
| R40 | Closure of the surrounding road network, impacting emergency access or rescue as well as maintenance needs | Medium (Possible / Moderate) | Medium (Possible / Moderate) | **Current Actions**<br>Coordinate with operators of connecting transport prior to, and during bushfire events<br><br>**Planned Action**<br>Emergency response plans for transit staff and transit users will be prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with | Possible | Minor | Low | Possible | Minor | Low |

| Risk ID | Risk | 2030 Preliminary Risk Rating | 2070 Preliminary Risk Rating | Adaptation actions | Likelihood | Consequence | 2030 Residual Risk Rating | Likelihood | Consequence | 2070 Residual Risk Rating |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | | | | | | |
| R41 | Disruption of maintenance staff for those needing to defend their homes in lieu of attending work | Medium (Possible / Moderate) | Medium (Possible / Moderate) | **Planned Actions**<br>Emergency response plans for transit staff will be prepared to account for extreme events including bushfires | Possible | Minor | Low | Possible | Minor | Low |

# 9.0 Conclusion

As this CNHA has confirmed, extreme rainfall, flooding and extreme heat are expected to pose the greatest risk to the Project in both the near future and far future. Risks associated with these events include:

- The potential impacts due to extreme rainfall impacting on drainage infrastructure and surrounding areas resulting in nuisance flooding.
- Reduced access to the Project and surrounding areas impacting on emergency response during extreme events (e.g. storms, bushfire).
- The consideration of drought, extreme heat and changes to rainfall impacting on landscaping, particularly in relation to green infrastructure and ongoing maintenance.

The findings of this assessment have confirmed that as a result of the application of treatment options for priority risks, for the 2030 time period, of the twenty three (23) medium risks and eight (8) high and very high risks, the residual risk rating has resulted in a downgrading to thirty (30) low or very low risks, eight (8) medium risks and no (0) high risks.

The findings of this assessment have confirmed that as a result of the application of treatment options for priority risk, for the 2070 time period, of the twelve (12) medium risks and twenty six (26) high and very high risks, the residual risk rating has resulted in a downgrading to twelve (12) low risks, twenty six (26) medium risks and no (0) high risks.

The findings of this assessment have resulted in the application of treatment options for priority risks. No residual significant, very high or high risks remain. The assessment mitigated all very high and high risks, and 91% and 83% of medium risks across the 2030 and 2070 timeframes respectively. This meets the ISC requirement of no very high of high risks remaining and the mitigation of at least 50% of medium risks.

| | 2030 – Preliminary | 2030 - Residual | % reduced | 2070 – Preliminary | 2070 - Residual | % reduced |
|---|---|---|---|---|---|---|
| Very Low | 0 | 9 | NA | 0 | 0 | NA |
| Low | 11 | 21 | NA | 4 | 12 | NA |
| Medium | 23 | 8 | 91 | 12 | 26 | 83 |
| High | 7 | 0 | 100 | 23 | 0 | 100 |
| Very high | 1 | 0 | 100 | 3 | 0 | 100 |
| Significant | 0 | 0 | NA | 0 | 0 | NA |
| Total | 42 | 38 | - | 42 | 38 | - |

It is recognised that while there is uncertainty regarding the extent to which the climate will change beyond 2030, the adaptation actions identified within this assessment will result in the lowering of residual risks across a range of future scenarios (both emissions pathways and future time frames).

## 9.1 Next steps

As noted above, the climate risk and adaptation actions identified in this report have been tested and refined through feedback and discussion from team members across a range of disciplines and provide a baseline assessment to inform the design process. As the design is still currently progressing, there are opportunities to identify and explore additional treatment options to add value and support improved response to climate change. This could include:

- Exploring initiatives such as coordination / opportunities with other stakeholders for downstream augmentation to support better drainage outcomes as well as additional water capture options to improve response to flood risks and extreme rainfall.
- Communicating outcomes of Project investigations, such as sensitivity testing and shading constraints, to surrounding stakeholders to develop shared / collaborative responses.

- Exploring additional options to improve to response to extreme heat through actions such as additional shading along the corridor, materials selections for Project elements (e.g. pervious pavements) and reviewing key specifications (such as pavement design) to ensure they can accommodate future increases in temperature.

In order to apply these findings and support the requirements set out the in the policies and strategies discussed in Section 3.0, the following next steps are recommended:

- **Risk and adaptation review –** the risk assessment and adaptation actions have been identified based on the current design for the Project and are a snapshot at this time in the Project development process. It is noted that the adaptation actions should be re-examined at future design milestones or phases to confirm inclusion and suitability as well as for feasibility of construction for the Project. Changes to the adaptation actions may reduce the ability to respond to the identified risks.

# 10.0 References

ACT Government, 2017. ACTmapi. [Online] Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1170968/CSIROMapping-Surface-Urban-Heat-In-Canberra.pdf [Accessed 2021].

ACT Government, 2019. ACT Climate Change Strategy 2019-2025, Canberra: s.n. ACT Government, 2019. Australian Capital Territory Climate Change Snapshot, Canberra: s.n. ACT Government, 2021. ACTmapi. [Online] Available at: https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=flood [Accessed 2022].

ACT Government, 2021. ACTmapi. [Online] Available at: https://app.actmapi.act.gov.au/actmapi/index.html?viewer=bushfire [Accessed 2021]. ACT Government, 2021. Current Erosion Hazard. [Online] Available at: https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=shl

Australian Associated Press, 2019. Australia fires: massive fire near Canberra airport prompts warning to residents. s.l.:The Guardian.

Australian Institute for Disaster Resilience, 2018. Australian Capital Territory flash flooding, 2018.

Australian Government, Climate Change Act 2022

Australian Government: National Climate Resilience and Adaptation Strategy 2021 – 2025

Australian Government: National Recovery and Resilience Agency.

Australian Government Clean Energy Regulator, Renewable Energy Target

BoM, 2021. Climate statistics for Australian locations. [Online] Available at: http://www.bom.gov.au/climate/averages/tables/cw_070351_All.shtml

BoM, 2022, Australian Capital Territory in October 2022: Very wet; cooler than average days and warmer than average nights, [Online] Available at: http://www.bom.gov.au/climate/current/month/act/summary.shtml#:~:text=Total%20rainfall%20for%20Canberra%20Airport,all%20years%20of%2061.7%20mm.

Brown, A., 2020. January 2020 one of Canberra's hottest months on record. s.l.:The Canberra Times.

Brown, A. & Bungard, M., 2019. Bushfire burning out of control east of Canberra. s.l.:Sydney Morning Herald.

CSIRO and BoM, 2020. State of The Climate , Canberra: Commonwealth of Australia.

CSIRO, 2015. CSIRO and BOM Climate Futures.

CSIRO, 2015. Murray Basin Cluster Report: Climate Change in Australia, Projections for Australia's NRM Regions

DAWE, 2015. National Climate Resilience and Adaptation Strategy, Canberra: Australian Government.

Department of Climate Change, Energy, the Environment and Water, Legislative Framework

EPSDD, 2019. Keeping our city cool. [Online] Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1413770/CanberrasLiving-Infrastructure-Plan.pdf

Government, A., 2017. Mapping Surface Urban Heat in Canberra. [Online] Available at: https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1170968/CSIROMapping-Surface-Urban-Heat-In-Canberra.pdf [Accessed 2022].

Guardian staff and Australian Associated Press, 2020. Huge hail batters Canberra as severe thunderstorms hit south-eastern Australia. s.l.:The Guardian.

Healy, J., 2021. Canberra hit by heavy rain, flash flooding inundates homes. s.l.:Willy Weather.

Infrastructure Australia 2021, A Pathway to Infrastructure Resilience [Online] Available at: https://www.infrastructureaustralia.gov.au/publications/pathway-infrastructure-resilience-0 [Accessed 5 August 2022]

Kanapathippillai, J. & Lewis, K., 2020. Canberra storm: severe thunderstorm makes its way through the capital. s.l.:The Canberra Times.

Lievre, L., 2020. Icon Water says the Canberra drought is close to the 'worst-case scenario'. Canberra: The Canberra Times.

Lindell, J. & Dingwall, D., 2019. Hail strikes, trees down in Canberra during stormy start to the weekend. s.l.:The Canberra Times.

Mannheim, M., 2020. Canberrra and Queanbeyan residents brace for flooding as dams spill amid heavy rainfall. s.l.:The New Daily.

Newstime Media 2022, Parts of Canberra smashed by large hailstones, [Online], Available at: https://canberraweekly.com.au/parts-of-canberra-smashed-by-large-hailstones/

OEH, 2015. NARCliM. s.l.:NSW Government.

Parliament of Australia 2013 , Chapter 5 – Direct Action Plan

Riotact 2022, Canberra's October rain record washed away by recent downpour, [Online], Available at: https://the-riotact.com/canberras-october-rain-record-washed-away-by-recent-downpour/607815

Sibthorpe, C. & Evans, J., 2017. Canberra weather: Emergency services to work throughout the night in response to heavy rain. Canberra: ABC News.

# Appendix A

# Infrastructure Sustainability rating scheme

# Appendix A Infrastructure Sustainability rating scheme

The Infrastructure Sustainability Council (ISC) Infrastructure Sustainability (IS) rating scheme is Australia's only comprehensive rating scheme for evaluating sustainability for infrastructure. The Project is seeking to achieve 'Leading' Design and As-Built IS ratings. As part of this process, alignment with the Cli-1 (Climate Change Risk Assessment) and Cli-2 (Adaptation measures) credits are required. This report seeks to align with the IS criteria and additional guidance where relevant to the scope of the assessment.

Table 18 outlines specific requirements as part of Cli-1 and Cli-2 credits to demonstrate achievement of the required target levels and where these are addressed in this report.

**Table 18 ISC Cli-1 and Cli-2 requirements**

| ISC requirement | Section addressed |
|---|---|
| **Cli-1** | |
| DL1.1 A readily available climate change projection, representing the range of variables which are produced from an appropriate climate change scenario, is identified and adopted for the asset region over the forecast useful life of the asset. | The asset life cycle is presented in **Section 6.1**.<br><br>A range of climate variables assessed are listed in **Section 5.2.** Readily available (and the most appropriately down scaled) natural hazard data and climate change projections over the forecasted useful life of the asset are provided in **Section 6.2** and **Table 6.1.**<br><br>A summary of the observed climate is proved in **Section 5.4, Table 5.1.** |
| DL1.2 Direct climate change risks to the asset over the forecast useful life are identified and assessed. | Direct risks to the asset are provided in **Section 7.3, Table 7.3** for construction risks and **Section 8.1, Table 8.2** for operational risks. |
| DL2.1 The climate change risk assessment also considered indirect climate change risks over the forecast useful life of the asset | Indirect risks to the asset are provided in **Section 8.1, Table 8.2** for operational risks. No indirect risks were accessed for construction. |
| DL 2.2 A multi-disciplinary team participated in identifying climate change risks and issues. | The methodology and outcomes of stakeholder engagement are provided in **Section 4.3**, with a copy of the workshop materials and activities (used to identify and assess direct risks and treatment options) provided in **Appendix C**. |
| DL3.1 Modelling is undertaken to characterise the likely impacts of the projected climate change for all High and Extreme priority climate change risks. | High risks were dominant in extreme rainfall and flooding hazards. Flood modelling was conducted by the design team and is discussed in the FSP report. The extend of flooding from the outputs of the modelling was considered during the risk assessment. |
| DL3.2 A comprehensive set of affected external stakeholders participated in identifying climate change risks and issues. | The methodology and outcomes of stakeholder engagement are provided in **Section 4.3**, with a copy of the workshop materials and activities (used to identify and assess direct risks and treatment options) provided in **Appendix C**. |
| **Cli-2** | |
| DL1.1 Adaptation options to treat all extreme and high priority climate change risks are identified, assessed and appropriate measures implemented. | Adaptation actions to treat extreme and high priority climate risks during construction are presented in **Section 7.3, Table 7.3**.<br>Adaptation actions to treat extreme and high priority climate risks during operation are presented in **Section 8.3, Table 8.5**. |
| DL1.2 After treatment there are no extreme priority residual climate change risks. | A residual risk assessment for construction risks is provided in **Section 7.3, Table 7.3**.<br>A residual risk assessment for operational risks is provided in **Section 8.3, Table 8.5**.<br><br>A summary of extreme residual risks is presented in **Table 8.4**. |

| ISC requirement | Section addressed |
|---|---|
| DL2.1 Adaptation options to treat 25-50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented. | A residual risk assessment for construction risks is provided in **Section 7.3, Table 7.3**.<br>A residual risk assessment for operational risks is provided in **Section 8.3, Table 8.5**.<br>A summary of treated medium priority climate change risks is presented in **Table 8.4.** 87 % of medium risks were mitigated as presented in **Section 9.0.** |
| DL3.1 The optimal scale and timing of options is addressed (which may be triggered by when a specific climate threshold is likely to be achieved). | The optimal scale and timing for the implementation of adaptation actions is presented in **Appendix F.** |
| DL3.1 Adaptation options to treat at least 50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented. | residual risk assessment for construction risks is provided in **Section 7.3, Table 7.3**.<br>A residual risk assessment for operational risks is provided in **Section 8.3, Table 8.5**.<br>A summary of treated medium priority climate change risks is presented in **Table 8.4.** 87 % of medium risks were mitigated as presented in **Section 9.0.** |

# Appendix B

## Risk Descriptors

# Appendix B Risk Descriptors

**Table 19 Quantitative likelihood descriptors**

| Item | Likelihood | Description |
|---|---|---|
| 1 | Remote | Extremely rare / unprecedented |
| 2 | Unlikely | Not expected to occur in most circumstances |
| 3 | Possible | Could occur |
| 4 | Likely | Probably would occur |
| 5 | Almost Certain | Expected to occur |

**Table 20 Consequence descriptors**

| Descriptor | Environment | Economic | Social |
|---|---|---|---|
| Insignificant | No environmental damage. | Minimal losses. | No noticeable change experienced by people in the locality. |
| Minor | Minor instances of environmental damage that could be reversed. | Several thousand dollars lost revenue or remediation costs. | Mild deterioration, for a reasonably short time, for a small number of people who are generally adaptable and not vulnerable |
| Moderate | Isolated but significant instances of environmental damage that might be reversed with intense efforts. | Half million dollars lost revenue or remediation costs. | Noticeable deterioration to something that people value highly, either lasting for an extensive time, or affecting a group of people. |
| Major | Severe loss of environmental amenities and a danger of continuing. | One million dollars lost revenue or remediation costs. | Substantial deterioration to something that people value highly, either lasting for an indefinite time, or affecting many people in a widespread area. |
| Catastrophic | Major widespread loss of environmental amenity and progressive irrecoverable environmental damage. | Several million dollars in lost revenue or remediation costs. | Substantial change experienced in community wellbeing, livelihood, amenity, infrastructure, services, health, and/or heritage values; permanent displacement or addition of at least 20% of a community. |

**Table 21 Risk matrix**

| Likelihood | Consequence | | | | | |
|---|---|---|---|---|---|---|
| | Positive | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost certain | Beneficial | Medium | High | Very High | Significant | Significant |
| Likely | Beneficial | Low | Medium | High | Very High | Significant |
| Possible | Beneficial | Very Low | Low | Medium | High | Very High |
| Unlikely | Beneficial | Negligible | Very Low | Low | Medium | High |
| Remote | Beneficial | Negligible | Negligible | Very Low | Low | Medium |

# Appendix C

## Workshop Summary and Attendees

# Appendix C Workshop Summary and Attendees

This information has been redacted for the purposes of public exhibition.

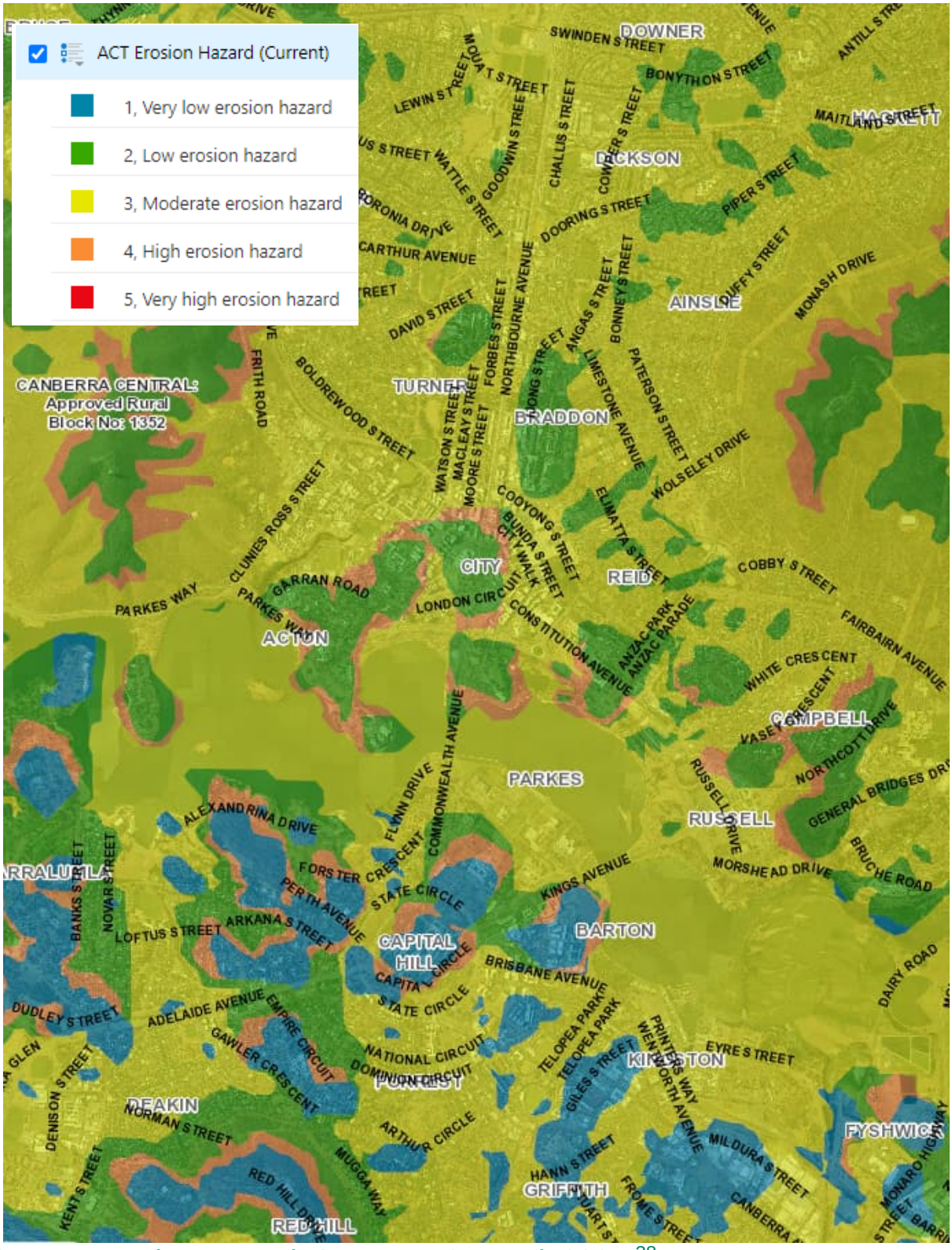
# Appendix D

## Climate Mapping

# Appendix D Climate Mapping

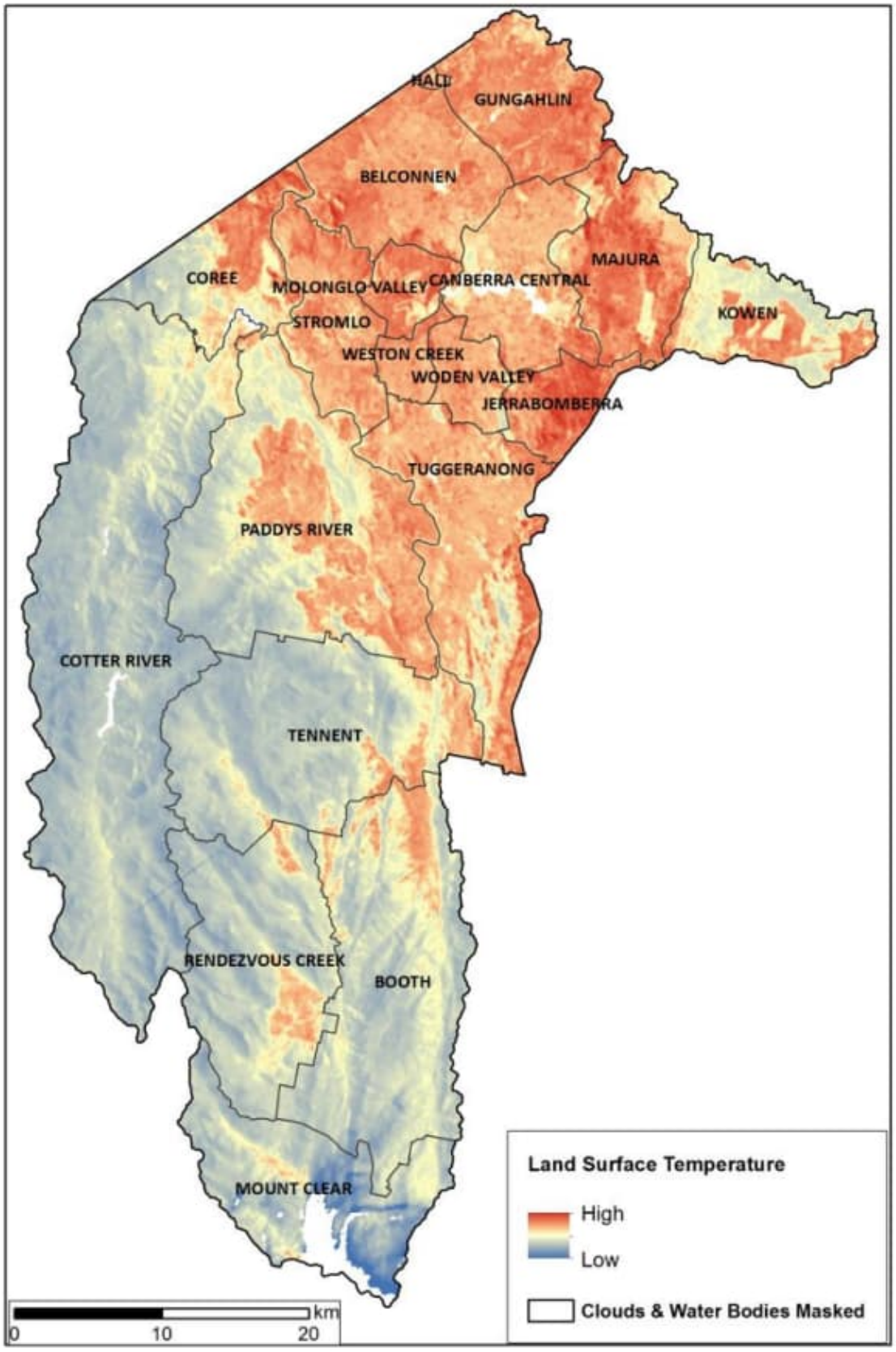

Flood Hazard Category. Source: ACTmapi, 2021.[37]

[37] https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=flood




Current Erosion Hazard. Source: ACTmapi, 2021.[38]

[38] https://app.actmapi.act.gov.au/actmapi2/index.html?viewer=shl


HALL
GUNGAHLIN
BELCONNEN
MAJURA
COREE
MOLONGLO VALLEY
CANBERRA CENTRAL
KOWEN
STROMLO
WESTON CREEK
WODEN VALLEY
JERRABOMBERRA
TUGGERANONG
PADDYS RIVER
COTTER RIVER
TENNENT
RENDEZVOUS CREEK
BOOTH
MOUNT CLEAR
Land Surface Temperature
High
Low
Clouds & Water Bodies Masked
km
0
10
20

Urban Heat Island Mapping. Source: ACT Government, 2017.[39]

[39] https://www.environment.act.gov.au/__data/assets/pdf_file/0005/1170968/CSIRO-Mapping-Surface-Urban-Heat-In-Canberra.pdf

# Appendix E

## Climate Projections

# Appendix E Climate Projections

## Murray Basin Cluster Report - Climate Future[1]

| Climate Variable | Baseline | 2030[2] | 2090[3] |
|---|---|---|---|
| Mean temperature change (°C) | Average 20-22°C | +0.9°C<br>(0.7 to 1.3°C) | +3.8°C<br>(2.7 to 4.5°C) |
| Average daily maximum temperature | 33 to 36°C (January) | +1.4°C<br>(0.8 to 1.4°C) | +5.0°C<br>(2.9 to 5°C) |
| Average daily minimum temperature | 0 to 3°C (July) | +1.2°C<br>(0.7 to 1.2°C) | +4.2°C<br>(2.8 to 4.2°C) |
| Extreme heat (days above 35°C) – for Canberra | 7.1 days per year | +12 days<br>(9.4 to 11 days) | +29 days<br>(22 to 39 days) |
| Very extreme heat (days above 40°C) – for Canberra | 0.3 days per year | +1.4 days<br>(0.7 to 3.1 days) | +4.8 days<br>(2.3 to 7.5 days) |
| Bushfire weather days (FFDI[4] > 50) – for Canberra | 1.4 days per year | +0.5 days | +2.9 days |
| Mean annual rainfall change (%) | 400 to 600 mm per year | -1%<br>-11% to +5% | -5%<br>-27% to +9% |
| Extreme rainfall - flooding | Extreme rainfall events to increase in intensity and severity. | | |
| Drought | Time spent in drought conditions to increase | | |
| Evapotranspiration (%) | N/A | +3.1%<br>(+1.9% to 5.1%) | +12%<br>(+7.6% to 18.1%) |
| Solar radiation (%) | N/A | +1%<br>(-0.4% to 2%) | +2.2%<br>(0% to 4.9%) |
| Wind speed (%) | N/A | +0.1%<br>(-2.6% to 2.4%) | -0.6%<br>(-5% to 2.6%) |

1 – RCP8.5 represents a high emissions pathway, with global carbon dioxide concentrations reaching around 940 ppm by the end of the 21st century.

2 – Climate change projections represent the average for the 20 year period between 2020-2039

3 – Climate change projections represent the average for the 20 year period between 2080-2099

4 – The FFDI combines observation of temperature humidity and wind speed. Fire weather is classified as severe when the PPDI is above 50.

# Appendix F

## Treatment Options

# Appendix F Treatment Options

| Related Risk ID /Climate Variable | Adaptation Action | Optimal Timing (Current/ Planned/Potential) | Trigger Point |
|---|---|---|---|
| Extreme Rainfall & Flooding | Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater). | Current | Review of flooding and hydrology assessments |
| Extreme Rainfall & Flooding | All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities. | Current | Detailed design review |
| Extreme Rainfall & Flooding | Water Sensitive Urban Design –bio-retention tree pits to collect and clean stormwater. | Current | Detailed design review |
| Extreme Rainfall & Flooding | Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials | Current | Detailed design review |
| Extreme Rainfall & Flooding | Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Current | Detailed design review |
| Extreme Rainfall & Flooding | Maximise the use of permeable surfaces into the public realm or verge areas through the use of pavements, green infrastructure and other mechanisms. | Current | Detailed design review |
| Extreme Rainfall & Flooding | Provide protection from future flooding through consideration of flood levels were identified in the flood study (including climate change) when deciding RLs across alignment (e.g. design for PMF/ minimum 1/100yr ARI+ 10%). | Current | PSP |
| Extreme Rainfall & Flooding/ Extreme heat | Design pavements and base layers to accommodate impacts caused by variability in rainfall (e.g. wetting and drying) and increases in temperature. | Current | N/A |
| Drought / extreme heat | Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation. | Current | Review of planting schedules and landscaping plans. As temperatures increase, review current guidance documentation and review planting schedule, landscaping plans and schedules. |

| Related Risk ID /Climate Variable | Adaptation Action | Optimal Timing (Current/ Planned/Potential) | Trigger Point |
|---|---|---|---|
| Extreme Heat | Materials will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow/ prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy. | Planned | Detailed design and procurement Track form materials to be selected in detailed design. |
| Extreme Heat | Traffic signal control houses will be placed under tree coverage or similar shaded areas to prevent overheating during the summer. | Current | Detailed design review |
| Extreme Heat | Integrated service cabinets ventilation will be designed for day 1 loads plus additional capacity to account for up to 20% additional heat load. | Current | Detailed design review |
| Extreme Heat | The gauge of the proposed stainless steel sheet cladding, location and provision of ventilation (e.g. double-skinned) in the integrated services cabinets is sufficient to prevent oil-canning in extreme temperatures | Planned | N/A |
| Extreme Heat | Health and safety plans should include extreme heat response (e.g. staffing plans, tools down, etc.) and PPE for transit staff | Planned | N/A |
| Extreme Heat | Canopies provided at transit stations for over half the station length, with full canopies provided for termini stops. Canopy structure is modular in design and can be extended to accommodate increasing population. | Current/planned | As population numbers increase. Canopy structure to be increased to provide shading to members of the community utilising the light rail service |
| Bushfire | Inspection of infrastructure after bushfire events to be undertaken to determine damage and appropriate maintenance or repair requirements. | Current | Post event |
| Bushfire | Spare capacity has been provided in the combined services route to facilitate future system upgrades (e.g. with more robust components or cabling as needed) | Current | PSP |
| General | Asset management plans should developed for the termini stops and landscaping to account for both seasonal variation and in response to climate variables (e.g. inspection after a bushfire or storm event, regular maintenance – dry limb removal). | Planned | N/A |
| General | Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including: - Planting schedules - Wind loading for key built elements | Current | Design and specifications review |