Hexham Straight Widening

Climate Change Assessment

IA301100-HSW-EN-RPT-0016 | 04

07 October 2021

Transport for NSW

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Executive summary

Background

Transport for NSW (Transport) is proposing to widen a six kilometre section of the Pacific Highway (Maitland Road) from four lanes to six lanes, starting about 290 metres south of the intersection with the Newcastle Inner City Bypass at Sandgate, and extending through to about 760 metres north of Hexham Bridge, in Hexham, NSW (the proposal). The proposal would create two additional lanes, one in each direction and would include the replacement of the twin bridges at Ironbark Creek. The section of road is known as the 'Hexham Straight' and is located within the City of Newcastle local government area (LGA), with a small portion of the construction area on the eastern side of the Hunter River within the Port Stephens Council LGA.

Maitland Road is a critical link as part of the National Land Transport Network and is among the busiest transport corridors carrying some of the highest traffic volumes in the Hunter. The proposal is required to reduce congestion and improve safety along Maitland Road.

The proposal is subject to assessment under two planning pathways, a review of environmental factors (REF) under Part 5, Division 5.1 of the Environmental Planning and Assessment Act 1979 (EP&A Act) and an environmental impact statement (EIS) under Part 4 of the EP&A Act. The majority of the proposal (the REF area) is subject to approval under Division 5.1 of the EP&A Act that would be determined through a REF by Transport. However, a small part of the proposal (3.28 hectares) is within land mapped as 'Coastal Wetlands' under State Environmental Planning Policy (Coastal Management) 2018 (CM SEPP). As such, that part of the proposal (known as the EIS areas) is subject to approval under Part 4 of the EP&A Act and will be assessed within an EIS.

Purpose

The purpose of this report is to assess the potential impacts of climate change during constructing and operating the proposal. This assessment supports both the REF and EIS for the proposal.

Overview of climate change risk impacts

A climate change risk assessment identified risks relating to:

- Increased high temperature extremes and more frequent incidence and severity of heatwaves
- Increased length and severity of seasonal drought
- Increase in the frequency and intensity of extreme rainfall events
- Increased severity of fire weather conditions
- Increased rate of annual evaporation (along with more intense droughts and higher temperatures)
- Increased concentration of carbon dioxide in the atmosphere.

Of the above, one risk was identified as 'very high', two risks were identified as 'high', six risks were identified as 'medium' and seven risks were identified as 'low' prior to the implementation of environmental management measures.

Following the implementation of current design controls or proposed risk treatments, one risk was identified as 'very high', two risks were identified as 'high', five risks were identified as 'medium' and eight risks were identified as 'low'.

Management measures

Environmental management measures have been proposed to manage the impacts expected from climate change, including the consideration of a full range of temperature projections, as well as expected life of bridge components, when materials are specified during detailed design. Detailed design would also consider the potential impacts to structures, utilities and fauna connectivity structures in bushfire prone areas. *Hexham Straight Widening Flooding and Hydrology Assessment* results will be reviewed to determine what mitigations

need to be built into the design to provide sufficient resilience to extreme rainfall and sea level rise. Further, a material durability report will be prepared and actioned which will specifically review the potential impacts of climate change on concrete durability, including depth of cover over reinforcement.

Conclusion

The climate risk assessment identified risks associated with increased temperatures and the effect that these risks would have on material tolerances. The detailed design phase will be used to further assess design and material tolerance to climate change. Current design controls have sought to minimise flooding impacts and additional flooding modelling will be carried out during detailed design to address any design changes.

Contents

Attachments

Tables

Figures

Limitations

The sole purpose of this report and the associated services performed by Jacobs was to provide a preliminary assessment of climate change risk in accordance with the scope of services set out in the contract between Jacobs and Transport for NSW (the Client). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the public domain, the Client (if any) and from observations made during the site inspection. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the proposal and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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1. Introduction

1.1 Overview of the proposal

Transport for NSW (Transport) proposes to widen about six kilometres of the Pacific Highway (Maitland Road) from four lanes to six lanes, starting about 290 metres south of the intersection with the Newcastle Inner City Bypass at Sandgate, and extending through to about 760 metres north of Hexham Bridge, in Hexham, NSW (the proposal). The section of road is known as the 'Hexham Straight' and is located within the Newcastle local government area (LGA) with a small portion of the construction area within Port Stephens Council LGA (refer to **Figure 1.1**).

Maitland Road is a critical link from the Port of Newcastle to the National Land Transport Network and is among the busiest transport corridors carrying some of the highest traffic volumes in the Hunter. The proposal is required to reduce congestion and improve safety along Hexham Straight during peak travel times.

The proposal is subject to assessment under two planning pathways, a review of environmental factors (REF) under Part 5, Division 5.1 of *Environmental Planning and Assessment Act 1979* (EP&A Act) and an environmental impact statement (EIS) under Part 4 of the EP&A Act. The majority of the proposal is subject to assessment under Division 5.1 of the EP&A Act. However, a small part of the proposal (3.28 hectares) is within land mapped as 'Coastal Wetlands' under State Environmental Planning Policy (Coastal Management) 2018 (CM SEPP). As such, that part of the proposal (known as the EIS area) is subject to approval under Part 4 of the EP&A Act and considered within the EIS.

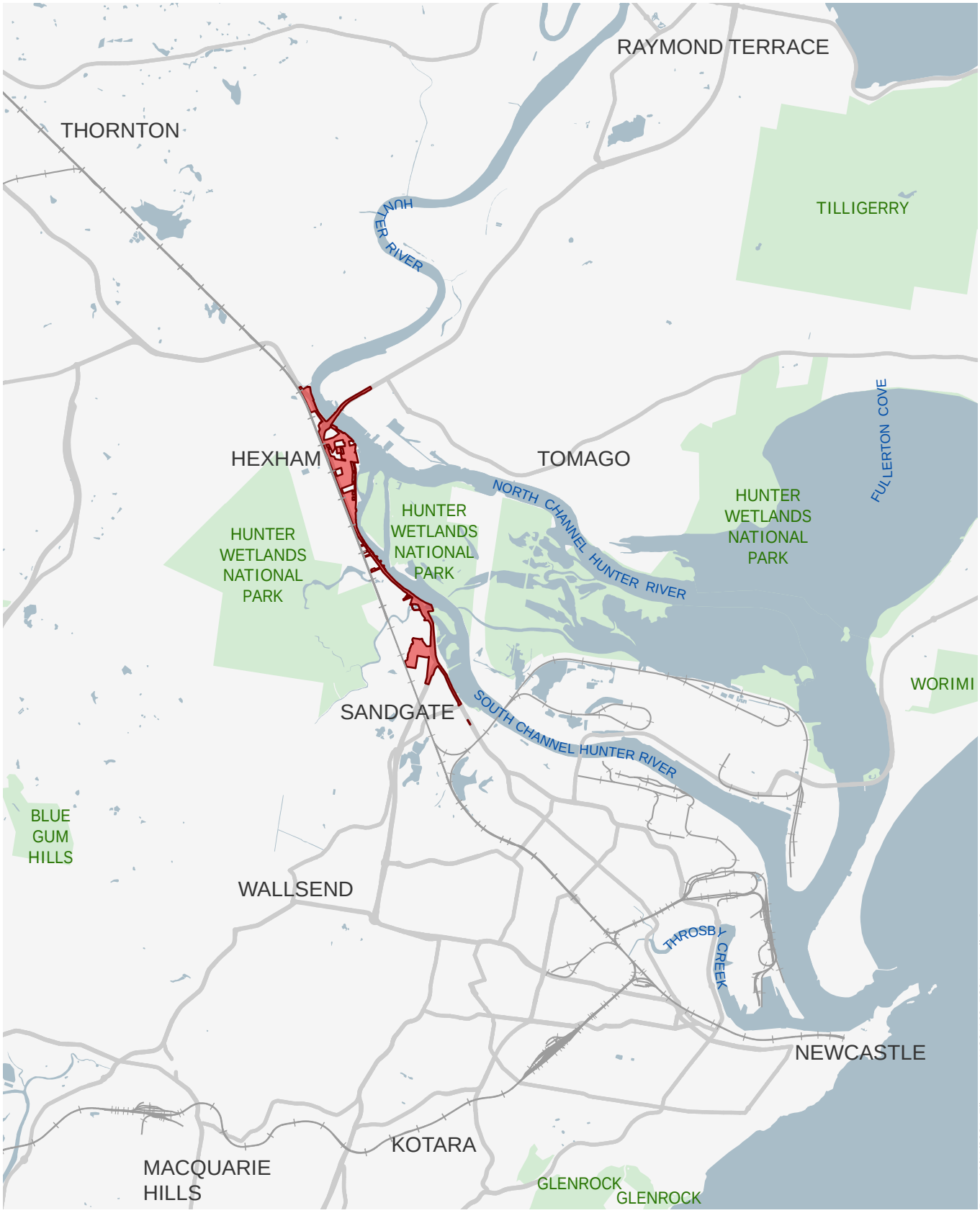
1.1.1 The proposal

The proposal consists of:

- Widening of Maitland Road for about six kilometres starting about 290 metres to the south of the intersection with the Newcastle Inner City Bypass (A37) at Sandgate and extending to about 760 metres north of Hexham Bridge at Hexham on Maitland Road. The highway would be widened from generally two lanes in each direction to three lanes in each direction
- Replacement of the bridge which spans Ironbark Creek with new twin bridges. The existing bridge and all piers would be demolished, and the outlet of a small drainage channel would be relocated about 10 metres to the east of its existing location
- Minor improvements to nine signalised intersections:
  - Newcastle Inner City Bypass and Maitland Road intersection
  - Old Maitland Road, Sandgate to the south of the Calvary St Joseph's Retirement Community at Sandgate and the Maitland Road intersection
  - Northbound U-turn facility and pedestrian facility opposite Calvary St Joseph's Retirement Community at Sandgate
  - Sparke Street and the Maitland Road intersection
  - Shamrock Street and the Maitland Road intersection
  - Old Maitland Road to the south of Hexham Bowling Club and the Maitland Road intersection
  - Old Maitland Road, Hexham to the north of Hexham Railway Station, rail maintenance access road, and the Maitland Road intersection
  - The southbound A1 Pacific Highway exit ramp off Hexham Bridge and the Maitland Road intersection
  - Southern access to the Oak Factory and Maitland Road intersection.

- Minor improvements to access roads, unsignalised intersections, entry and exit ramps connecting to the A1 Pacific Highway and the U-turn facility at the northern end of the proposal
- Closure of breaks in the existing median and direct access to two local side roads, one private access road and one U-turn facility
- Provision for a three metre wide shared use path northbound between the Oak Factory and the northern end of the proposal and a new section of off-road shared use path heading east along the NICB
- Widening of existing footpaths at intersection and bus stops
- Adjustments to property accesses and bus stops
- Provision of U-turn facilities on Sparke Street, Shamrock Street, and Old Maitland Road at Hexham
- Relocation of utilities including power, communications, water, gas and wastewater services
- Modifications and maintenance of existing drainage structures including pits, pipes, headwalls and culverts to suit the road widening and to maintain capacity
- Construction of retaining walls to minimise impacts on nearby properties
- Property acquisition, leases and adjustments
- Construction of hardstand for oversize and overmass (OSOM) vehicle parking at the southern and northern end of the proposal
- Intrusive investigation works such as geotechnical investigations
- Temporary construction facilities, including site compounds and stockpile sites at:
  - One area located in the industrial estate located on Old Maitland Road, Sandgate to the south of Calvary St Joseph's Retirement Community (Compound 1)
  - Two areas located in the industrial estate located to the east of Maitland Road and the west of Old Maitland Road, Hexham extending north from the northern boundary of the Hexham sports field to the area of road corridor underneath the entry ramps to the A1 Pacific Highway and Hexham Bridge (Compound 2)
  - Two areas located in the industrial estate located to the west of Maitland Road, Hexham near the Oak Factory (Compound 3)
  - One area located on vacant land to the east of the U-turn facility at the northern end of the proposal on Maitland Road, Hexham to the west of the main channel of the Hunter River (Compound 4).

An overview of the proposal is shown in **Figure 1.2**. Construction of the proposal would be staged and would take about 30 months to construct.



Legend

- Construction area
- National Park
- Waterway
- Railway
- Road

0 1 2 km

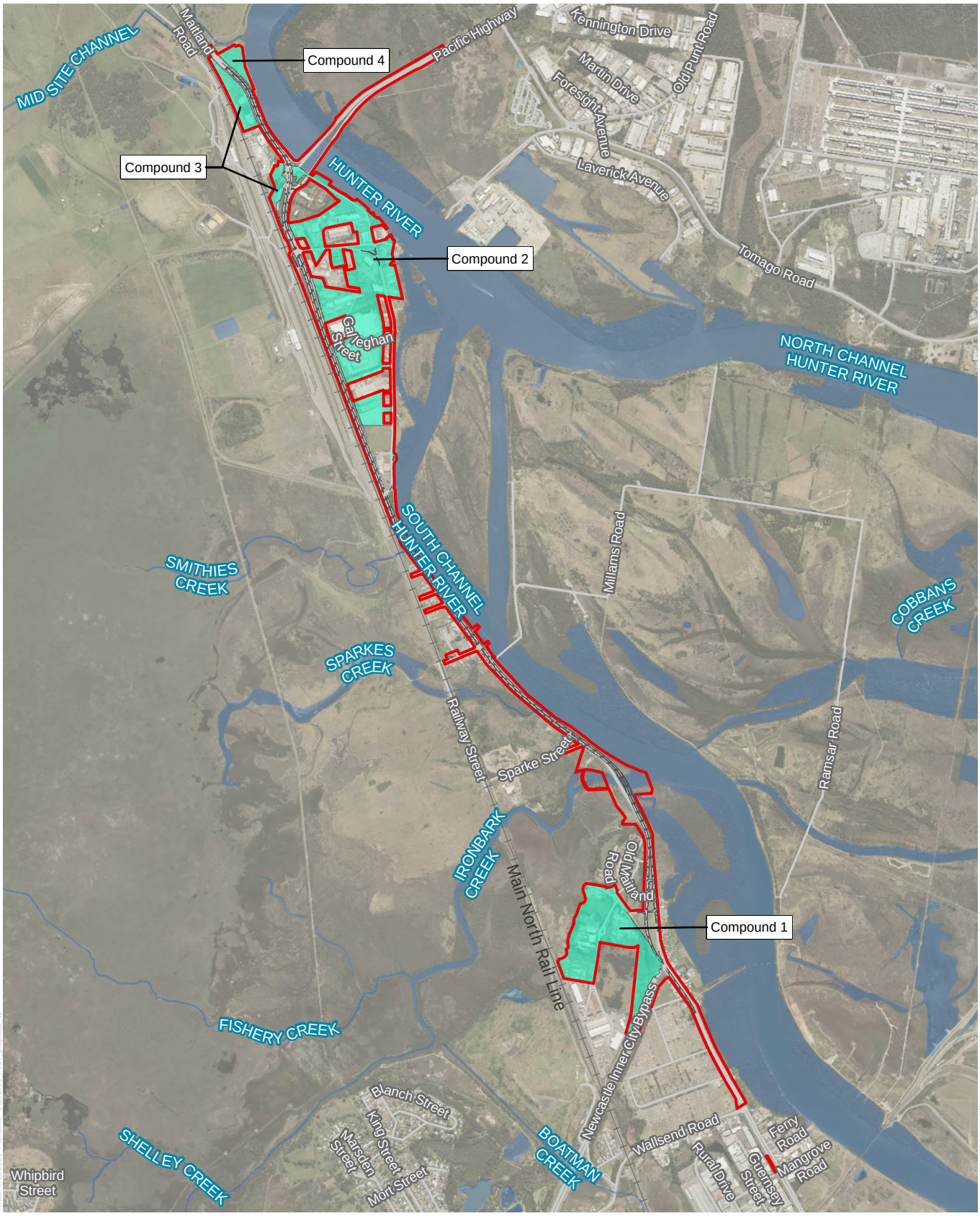
Scale 1:100,000 at A4

GDA94 MGA56

Data sources:
Jacobs 2020
Department Finance, Services and Innovation 2020

Figure 1.1 Proposal local area

Hexham Straight Widening



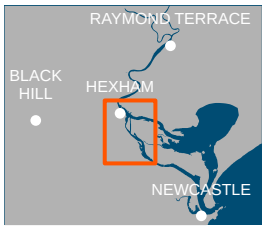
Legend

- The proposal
- Construction area
- Construction compound
- Waterway
- Road
- Railway

0 200 400 m

Scale 1:30,000 at A4

GDA94 MGA56



Data sources:
Jacobs 2020
Department Finance, Services and Innovation 2020

Figure 1.2 The proposal

1.1.2 The EIS area

The EIS area (refer to **Figure 1.3**) only assesses impacts of the proposal within land subject to the CM SEPP, which are mostly at the following three locations:

- Location 1 – a small area located to the south of Ironbark Creek on the eastern side of Maitland Road and to the west of a parcel of Crown land and a section of Hunter Wetlands National Park. The land mapped as coastal wetlands includes areas of remnant mangrove and saltmarsh vegetation and also crosses sections of an existing track that provides access to the south bank of Ironbark Creek and to the base of Ironbark Creek Bridge. The work required for the proposal in this area is comprised of some permanent works, being road pavement, earthworks (embankment), the construction of piers to support the new bridge over Ironbark Creek and the relocation of the unnamed drainage channel to the south-east of Ironbark Creek. In addition, access would be required to construct the proposal
- Location 2 – a small area located to the north of Ironbark Creek on the eastern side of Maitland Road. The land mapped as coastal wetlands includes areas of remnant mangrove, saltmarsh and freshwater wetland vegetation. The work required for the proposal in this area is comprised of some permanent works, being road pavement, earthworks (embankment) and construction of piers to support the new bridge over Ironbark Creek. In addition, access would be required to construct the proposal
- Location 3 – a small area located on the west bank of the south channel of Hunter River to the east of Maitland Road and to the northwest of Millams Road and the Ash Island Bridge. The land mapped as coastal wetlands includes areas of the road shoulder and remnant mangrove vegetation. The work required for the proposal in this area is comprised of the permanent road widening work to include a third lane in the eastbound direction, as well as a new road shoulder, batter and upgrades to drainage.

There is potential to indirectly impact other areas mapped as Coastal Wetlands from the proposal and where this occurs the impacts have been assessed within this report. The EIS area would be constructed and operated together with the REF area, which has been assessed in the REF prepared by Transport.

1.1.3 The REF area

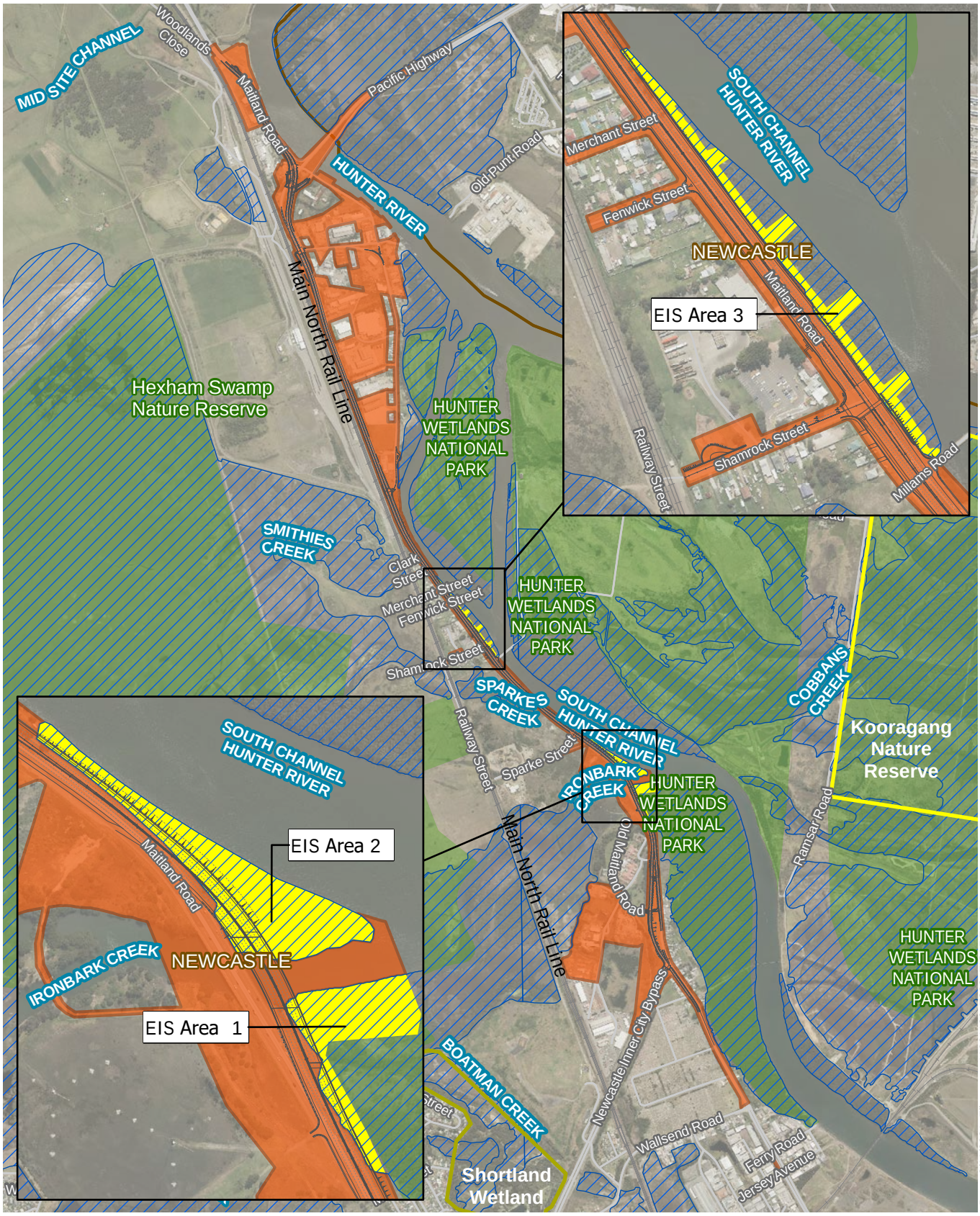
The REF area (refer to **Figure 1.3**) assesses all other aspects of the proposal included in **Section 1.1.1** that are outside the footprint of the EIS area described in **Section 1.1.2** and shown in **Figure 1.3**.

1.1.4 Relationship of the REF and EIS

Detailed discussion of the planning approval framework and consent requirements is provided in the REF and the EIS. In summary, development consent under Part 4 is usually not required for development for the purposes of a road being undertaken by Transport as a public authority. Rather, this development is ordinarily assessed as an 'activity' under Part 5 of the EP&A Act.

However, on those parts of the land which are identified as coastal wetland under the CM SEPP, the development is classified as designated development and requires consent from the City of Newcastle under Part 4 of the EP&A Act. The part of the proposal located within the Coastal Wetlands is therefore assessed under Part 4 of the EP&A Act. An EIS is required to assess the impacts of any works located within the Coastal Wetlands or any impacts on a Coastal Wetland.

A separate REF has been prepared for the assessment of the REF area in accordance with Part 5 of the EP&A Act. This document would be determined by Transport. The EIS area would be constructed and operated together with the REF area. Together, the EIS and the REF assess the potential environmental impacts of the proposal and it is intended that these documents be read in conjunction with each other.



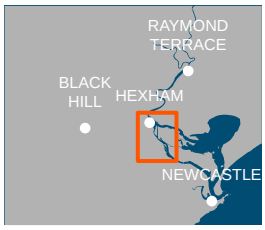
Legend

- The proposal
- EIS area
- REF area
- Railway
- Road
- LGA
- Coastal Wetlands
- Kooragang Nature Reserve
- Shortland Wetland
- National Park

0 400 800 m

Scale 1:30,000 at A4

GDA94 MGA56



Data sources:
Jacobs 2020
Department Finance, Services and Innovation 2020

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Figure 1.3 EIS area and REF area

1.1.5 Location

The proposal is located about 10 kilometres north of the City of Newcastle in the suburbs of Sandgate and Hexham. To the east and in some locations next to the proposal is the Hunter River and the South Channel of the Hunter River and the proposal crosses Ironbark Creek. The major freight rail line into the Port of Newcastle uses the Main North Rail Line and this is located west of the proposal and in some locations immediately next to the proposal. The Hunter Wetlands National Park is located both to the east and west of the proposal and the area to the west is also known as Hexham Swamp Nature Reserve. Much of the low-lying national park estate as well as some other low-lying swamp areas including the larger back barrier Hexham Swamp areas are identified as wetlands under the CM SEPP. These low-lying areas connect to two areas of Ramsar listed wetlands identified as the Hunter Estuary Wetlands that includes Kooragang Nature Reserve about one kilometre to the east and Shortland Wetlands (including Hunter Wetlands Centre Australia) about 800 metres to the west of the proposal.

The land use along the proposal is characterised by a mix of transport corridors (road and rail), environmental areas including wetlands and waterways, recreational areas both public and private, residential areas and light and heavy industrial areas. The main features of the proposal area and its surrounds include:

- Sandgate Cemetery
- Calvary St Joseph's Retirement Community
- Hexham Bowling Club
- Hexham Park and Cricket Grounds
- Hexham Railway Station
- Residential properties which are located on both sides of Maitland Road to the south of the Calvary St Joseph's Retirement Community, to the west of the proposal along Shamrock Street, Fenwick Street, Merchant Street and Clark Street and along Old Maitland Road behind the industrial estate at Hexham
- Industrial and commercial properties which are located to the north of the Newcastle Inner City Bypass, off Sparke Road at Sandgate and at the northern end of the proposal to the east and north of the Hexham Railway Station.

1.2 Purpose of the report

The purpose of this report is to assess the potential impacts to climate change from constructing and operating the proposal. The report:

- Describes the existing environment with respect to climate
- Assesses the impacts of climate change on operation of the proposal
- Recommends measures to mitigate and manage the impacts identified.

The methodology for the assessment is described in **Section 3**.

1.3 Terms and definitions

The following terms are used in this report:

- Proposal – the widening of a six kilometre section of Maitland Road from four lanes to six lanes, starting about 290 metres south of the intersection with the Newcastle Inner City Bypass at Sandgate, and extending through to about 760 metres north of Hexham Bridge, in Hexham, NSW Construction area – the area to be directly impacted by the proposal. This comprises the future construction footprint of the proposed bridge over Ironbark Creek and the upgrade of Maitland Road, including all roadside cut and fill, construction compound areas and parking areas for oversize and overmass vehicles, refer further to **Section 1.1.1**
- Study area – the construction area and additional areas that are likely to be affected by the proposal, either directly or indirectly

- EIS area – the areas of the proposal to be assessed under the EIS that are within land subject to the CM SEPP as defined in **Section 1.1.2**
- REF area – the areas of the proposal to be assessed by the REF and this covers all other aspects of the proposal included in **Section 1.1.1** that are outside the footprint of the EIS area described in **Section 1.1.2**
- Proposal local area - the area within 10 kilometres of the proposal.

2. Policy framework

2.1 NSW Policy and Guidelines

2.1.1 NSW Climate Change Policy Framework

The Commonwealth Government has committed to reduce emissions to 26-28 per cent on 2005 levels by 2030 (see **Section 2.3.1**). In response, the NSW government has developed the *NSW Climate Change Policy Framework* (Office of Environment and heritage (OEH, 2016) which sets the objective of achieving net-zero emissions by 2050. It intends to achieve this through a combination of policy development, leading by example and advocacy. Energy generation and transport emissions form a significant part of the NSW emissions inventory, and as such the proposal would be assessed in the context of state and national emissions to determine its contribution.

The *NSW Climate Change Policy Framework* also aims to "maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate and current and emerging international and national policy settings and actions to address climate change" (OEH, 2016)

Within this framework, the NSW Government recognises its role with respect to development of appropriate policy, improving its own operations and advocacy with respect to climate change adaptation. It notes the following key policy directions:

- Reduce risks and damage to public and private assets in NSW arising from climate change – climate change will lead to more extreme weather, heatwaves and sea level rise, which increase the risk of direct impacts on public and private assets and services. The government will manage the impact of climate change on its assets and services by embedding climate change considerations into asset and risk management. The government will also reduce barriers that will prevent effective private sector adaptation by providing information and a supportive regulatory framework for adaptation measures at the local level
- Reduce climate change impacts on health and wellbeing – the government will enable communities and individuals to be better prepared and more resilient to climate change impacts by anticipating increased demand for services, such as health and emergency services. The government will also identify ways to support communities that are more vulnerable to the health impacts of climate change
- Manage impacts on natural resources, ecosystems and communities – the government will provide long-term and coordinated efforts to increase the resilience of primary industries and rural communities as climate change impacts water availability and water quality. The government will also manage the environment impacts of climate change, such as the impacts on habitats, weeds and air pollution.

The *NSW Climate Policy Framework* will be delivered through the Climate Change Fund Strategic Plan+, as well as through action plans and policies adopted by other government agencies. Two key features of the NSW Climate Policy Framework include identifying options to manage climate risks to transport infrastructure, as well as addressing key emissions sources across the NSW transport network.

2.1.2 NSW Transport Future Strategy 2056

The *NSW Transport Future Strategy 2056* (Transport for NSW, 2020) is an update to the previous *NSW Long Term Transport Master Plan* (Transport for NSW, 2012). It incorporates the Regional NSW Services and Infrastructure Plan and Greater Sydney Service and Infrastructure Plan together with several supporting plans to provide a 40-year vision, direction and outcomes for transport and traffic in NSW. Of relevance to greenhouse gas management, the strategy includes:

- Reducing emissions through the uptake of public transport over private vehicles
- Investing in technology to reduce emissions from public transport
- Improving the climate resilience of the public transport network.

2.1.3 Environmental Sustainability Strategy 2019-2023

Transport's *Environmental Sustainability Strategy 2019-23* (Roads and Maritime Services, 2019) is an update and continuation of the previous 2015-19 strategy. It incorporates nine focus areas for sustainability objectives from the previous strategy and adds a tenth focus area of Corporate Sustainability. These areas focus on priority environmental issues for the strategy, namely:

- Climate change resilience
- Air quality
- Energy and carbon management
- Sustainable procurement
- Resource use and waste management
- Pollution control
- Biodiversity
- Heritage – Aboriginal and non-Aboriginal
- Liveable communities
- Corporate Sustainability.

Regarding Climate Change Risk, Transport's *Environmental Sustainability Strategy 2019-2023* has the following Climate Change Resilience Targets and Key Initiatives. These targets are used as guidance for the Climate Change Risk Assessment used in this document:

- Targets
  - CC1 - Assess climate change risks for all potentially affected projects and programs.
  - CC2 - Address all identified climate change risks ranked as high or above during project planning
- Key Initiatives
  - Reviewing climate change impacts and risks during the planning phase of potentially affected projects with a level of detail commensurate to the size of the project and the potential risk
  - Designing infrastructure for the predicted future climate or designing for cost-effective adaptation in the future
  - Consulting and partnering with key stakeholders to reduce vehicle carbon emissions and supporting new technologies to reduce road transport carbon emissions
  - Minimising the carbon impacts associated with vegetation clearance by reducing project footprints where possible
  - Maintaining our capacity to respond to significant events on our roads or waterways through emergency management plans to ensure our agency responds appropriately when required
  - Working within government agencies to identify interdependencies across transport, water, energy, and telecommunications infrastructure during significant weather events
  - Monitoring developments in climate modelling and ensure our approach is updated as new information is available
  - Ensuring our specifications for delivery, maintenance and operation of infrastructure consider suitable climate and weather-related constraints which include current best practice climate change predictions.

2.1.4 Technical Guide for Climate Change Adaptation for the State Road Network

This Technical Guide (RMS, in draft) outlines the approach to carrying out a climate change risk assessment, including identification of potential impacts to road projects in NSW. This Technical Guide has been used to inform this assessment.

Transport's Climate Risk Assessment Guideline was developed to provide contractors and stakeholders with support on how to complete Climate Risk Assessments in line with Transport's latest Sustainable Design Guidelines (SDG) requirements.

2.2 National Policy and Guidelines

2.2.1 National Climate Resilience Adaption Strategy

The Commonwealth Government's approach to climate change adaptation is documented in its *National Climate Resilience and Adaptation Strategy* (DoE, 2015). The scope of this strategy is to, "Highlight resilience-building by governments, businesses and communities in Australia and our region; guide effective climate change adaptation with a set of principles; and establish priority areas for future consultation and action".

The strategy specifically highlights damage to roads and infrastructure that may result from the projected increased frequency and intensity of flooding and heatwave events is a major risk for Australia. The strategy also calls for the collaboration of state and federal governments to revise the Australian Transport Assessment and Planning Guidelines to include guidance on climate change adaption measures to address risks. The strategy also promotes the development of new technologies to also address the risks posed by climate change.

2.3 International policies

2.3.1 Paris Climate Conference COP21

Following the 2015 Paris Climate Conference, known as COP21, international agreements were made for signatories to:

- Keep global warming well below 2.0 degrees Celsius, with an aspirational goal of 1.5 degrees Celsius
- Submit revised emission reduction targets every five years (from 2018), with the first being effective from 2020, and goals set to 2050
- Define a pathway to improve transparency and disclosure of emissions
- Make provisions for financing the commitments beyond 2020.

In response to this challenge, Australia has committed to reduce emissions to 26-28 per cent on 2005 levels by 2030. Greenhouse gas emissions from new developments and projects such as this proposal need to be understood to better position Australia to meet these commitments.

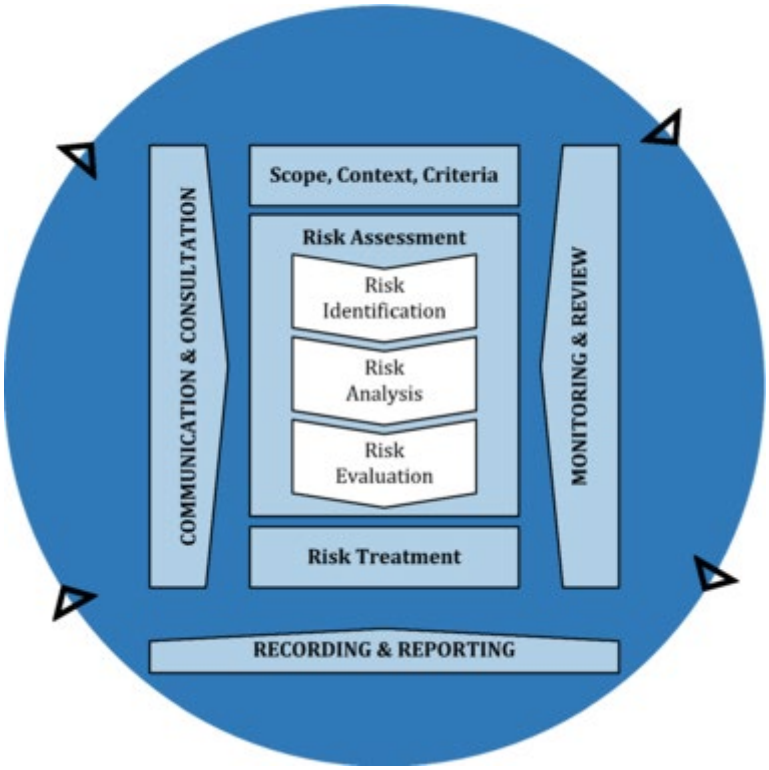
3. Methodology for the assessment

3.1 Methodology

3.1.1 Climate Change Risk

The methodology for conducting this climate change risk assessment is based on the *Australian Standard AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk-based approach*. The risk assessment is intended to form part of a risk management process which involves communication and consultation with the design team, relevant stakeholders such as transport departments as well as regular monitoring and review of the risk assessment plan as shown in **Figure 3.1**.

The standard follows the *International Standard ISO 31000:2018, Risk management – Principles and guidelines* (adopted in Australian and New Zealand as AS/NZS ISO 31000:2018), which provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and responses into their existing management and decision-making processes.



Source: Reproduced from AS/NZS ISO 31000

Figure 3.1 Risk Management Process

3.1.2 Risk Evaluation and Approach

Risks to the operation and maintenance of the proposal that might be influenced by climate change have been identified. The hazard-receptor pathway model has been applied to identify and describe risks. This model is outlined below:

- **Hazard** – climate or climate-influenced attributes with potential to influence the proposal's operation and maintenance. Example of hazards specific to the proposal can be found in **Table 5.1**

- **Receptor** – the component of the proposal's operation and/or maintenance impacted by the hazard. This may also include users of the proposal and affected elements of the surrounding environment. Key components of the proposal at risk can be found in **Table 5.2**

- **Risk rating** – utilising the likelihood (Table A.1) and consequence (Table A.2) rating system outlined in **Attachment A**, an assessment of the way hazards influence the proposal receptors was carried out and a risk rating awarded (Table A.3). The completed assessment is provided in **Attachment B**.

Within the risk assessment process, the risk resulting from the projected change in climate is assessed, whether this is a newly identified or elevated existing risk. For example, some risks are already present (flooding) but the frequency and intensification of these are projected to change. Other risks (such as migration of pests and weeds) may not be expected to happen in the absence of a changing climate.

3.1.3 Proposed risk treatment

Development of risk treatment options have commenced for some of the higher climate change risks, including consideration of the full range of temperature projections in detailed design. A material durability report specifically aimed at climate change impacts will be developed in the detailed design. The modelling completed for the *Hexham Straight Widening Flooding and Hydrology Assessment* (Jacobs, 2021) would also be reviewed to determine what resilience to climate change needs to be built into the design to address increased rainfall and sea level rise. These treatment options would, where necessary, build on existing design controls, and be developed further as the design progresses from concept design to detailed design, at which point detailed modelling and decisions surrounding design components would be further developed and/or incorporated.

4. Existing environment

4.1 Historical climate for the study area

This section describes the study area's historical climate, based on meteorological observations from BoM station 061078 located at the Royal Australian Air Force Base (RAAF) Williamtown (operating from 1942 until present). RAAF Williamtown is located approximately 14 kilometres northeast of the proposal and has a substantial level of historical climate data available (i.e. greater than 20 years). Rainfall observations are available for the years 1958-2020 and temperature observations are available for the years 1951-2020. No meteorological readings were available for 1942 and the period between 1946 and 1950. There were also no rainfall records for the period between 1953 and 1960, and the record between 2010 and 2015 contains some gaps.

Within the historical climate projections shown in this section, records are shown for the full range of those available, as well as the climate change reference period. The climate change reference period is 1976-2015 and is the period on which the projections are overlaid to determine future climate. The projections were originally developed to be based on a 1986-2005 period, however, as eastern Australia has seen significant temperature extremes in the period 2005-2015, Jacobs has expanded the baseline period to include these hotter periods, and retain an element of conservancy in the assessment.

4.1.1 Annual rainfall

4.1.1.1 Annual rainfall

Annual rainfall for the Southern Hunter over the full period of record is 1,120 millimetres. Average rainfall during the climate change projection reference period is shown in **Figure 4.1** and is equivalent to the long-term average at 1,122 millimetres. Annual rainfall has ranged between 541 and 1,739 millimetres over that period

Annual rainfall in the Southern Hunter has trended downwards over the period of record, however the high level of year to year variability in rainfall means that this trend is not statistically significant.

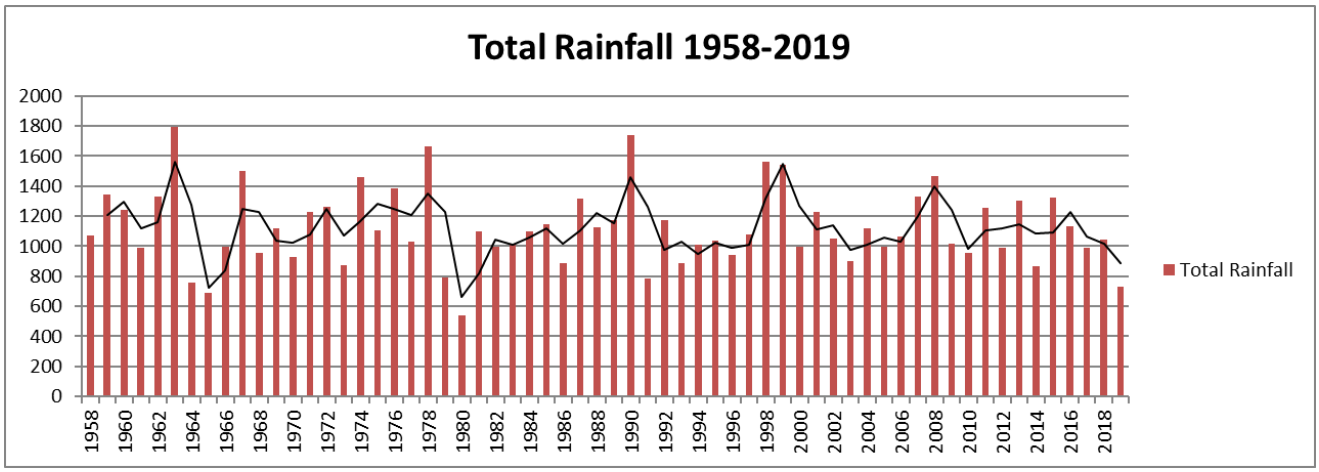


Figure 4.1 Annual rainfall for Williamtown (RAAF)

Source: BoM station 061078. Graph plots total annual rainfall and the five-year moving average of annual rainfall. The latter highlights the influence of multi-year climate cycles, such as ENSO.

4.1.1.2 Monthly rainfall

Average monthly rainfall ranges between 61 millimetres in September and 130 millimetres in June (**Figure 4.2**). Average monthly rainfall during late winter and early spring (particularly July to September) is considerably

lower than the average for autumn, where rainfall almost doubles. The pattern in extreme monthly rainfalls indicates that the potential for very wet months is highest during January to June.

The Southern Hunter's pattern of monthly rainfall during the climate change projection reference period follows that of the long-term average reasonably closely. Average monthly rainfall over this period ranged between 59 millimetres in August and 125 millimetres in March.

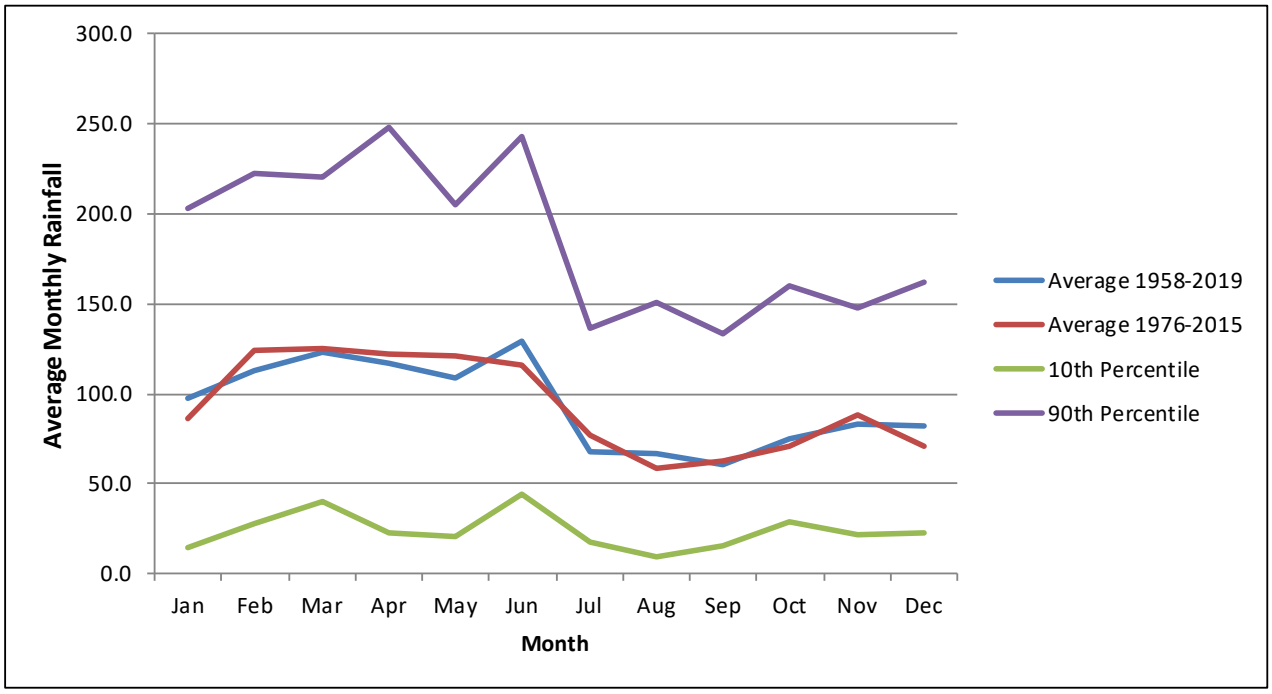


Figure 4.2 Average and extreme monthly rainfall totals for the Southern Hunter

Source: BoM station 061078. Graph shows average monthly rainfall for RAAF Williamtown, as well as the 10th and 90th percentile of monthly rainfall totals for each month. The latter are provided as an indication of rainfall variability. They are the monthly rainfall totals which are exceeded in 10 and 90 per cent of months, respectively.

4.1.1.3 Daily rainfall

Maximum recorded daily rainfalls are shown in **Figure 4.3**. Maximum recorded daily rainfall totals are typically greater during summer-autumn than at other times of year, which reflects that the warmer air is able to hold more water. The climate change projection reference period includes the highest daily rainfall total for the Southern Hunter for every month apart from January and May.

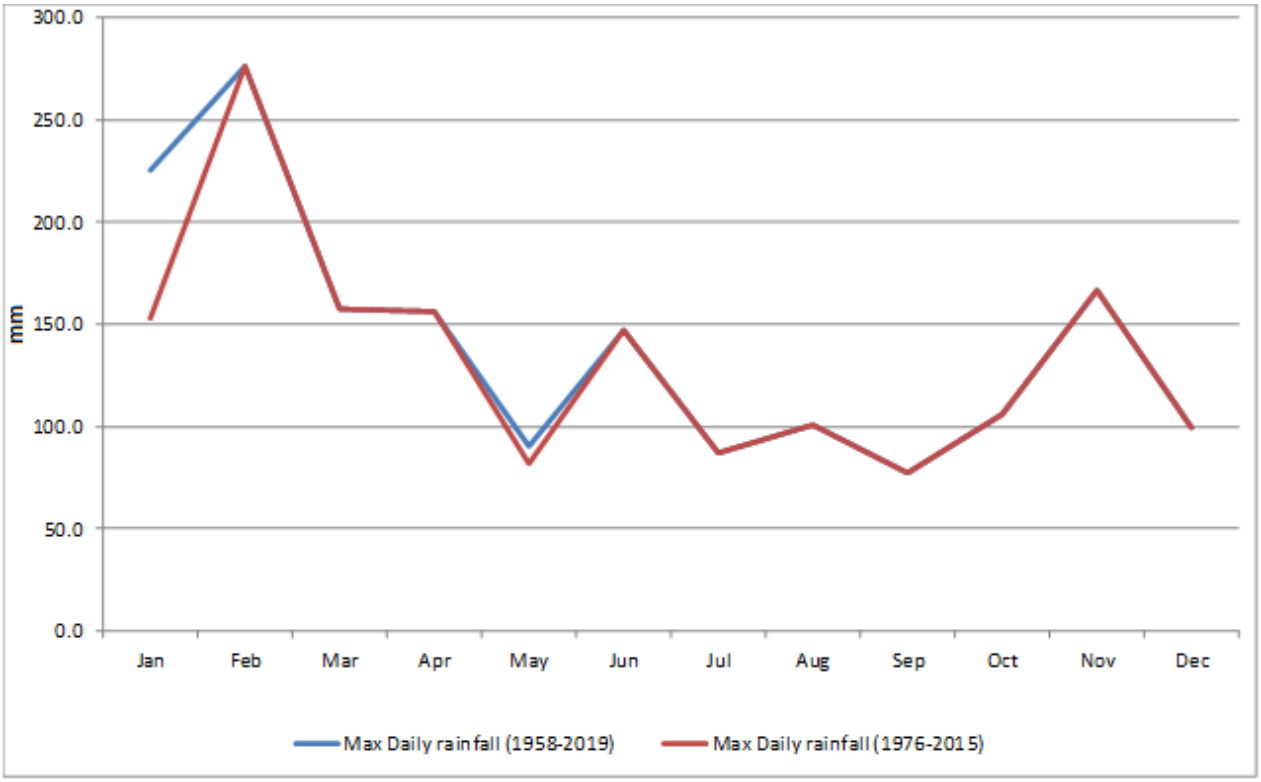


Figure 4.3 Highest recorded daily rainfall totals for the Southern Hunter

4.1.2 Temperature

4.1.2.1 Annual temperature

Table 4.1 shows the maximum, average and minimum annual temperatures for the Southern Hunter. There are consistent trends for increased maximum temperatures since about 2000. This trend is most obvious for maximum and minimum recorded temperatures. Average temperatures over the climate change projection reference period are 0.1 degrees Celsius to 0.2 degrees Celsius warmer than over the entire period of record.

Table 4.1 Maximum, average and minimum temperatures (degrees Celsius) for the Southern Hunter.

Temperature measurement	1951-2019	1976-2015
Maximum recorded maximum temperature	45.5	44.8
Average maximum temperature	23.2	23.4
Average temperature	17.8	17.9
Average minimum temperature	12.4	12.4
Minimum recorded minimum temperature	-3.9	-3.4

Source: BoM stations 61078. Table includes a comparison of the full period of record and the 1976-2015 climate change projection reference period. T_{max} – maximum temperature; T_{min} – minimum temperature.

There are consistent trends for increased maximum temperatures since about 2000 as shown in **Figure 4.4.** This trend is most obvious for maximum and minimum recorded temperatures.

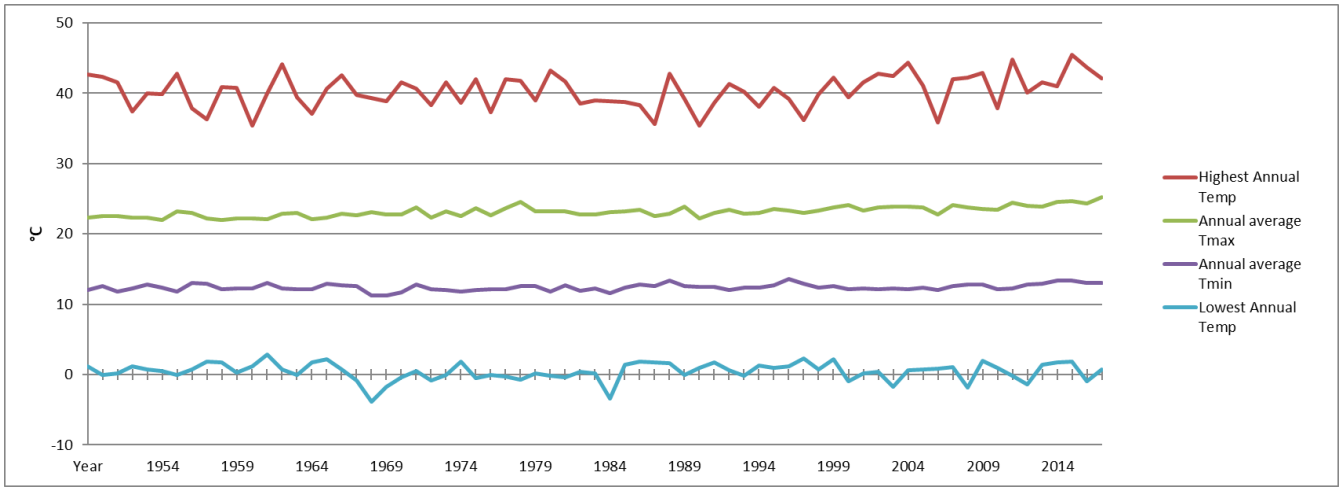


Figure 4.4 Temperature records for RAAF Williamtown, Southern Hunter

Source: BoM station 061078. Data presented for highest and lowest temperatures recorded each year and average T_{max} (daily maximum temperature) and T_{min} (daily minimum temperature) for each year of record, 1951-2019.

4.1.2.2 Monthly temperatures

Figure 4.5 shows the maximum, average and minimum monthly temperatures for the Southern Hunter. Monthly average and average maximum temperatures for the climate change projection reference period are typically higher than those for the full period of record. Average monthly minimum temperatures are generally the same.

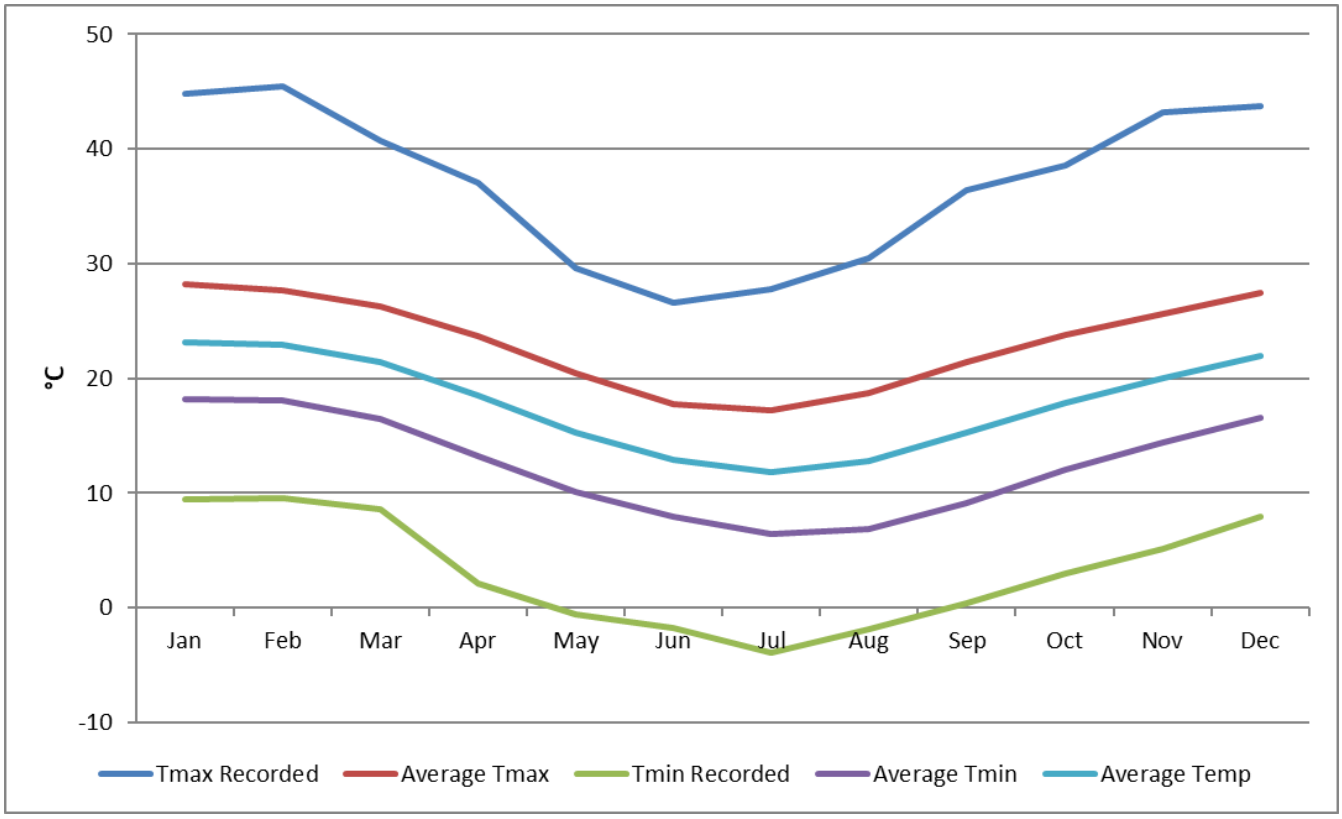
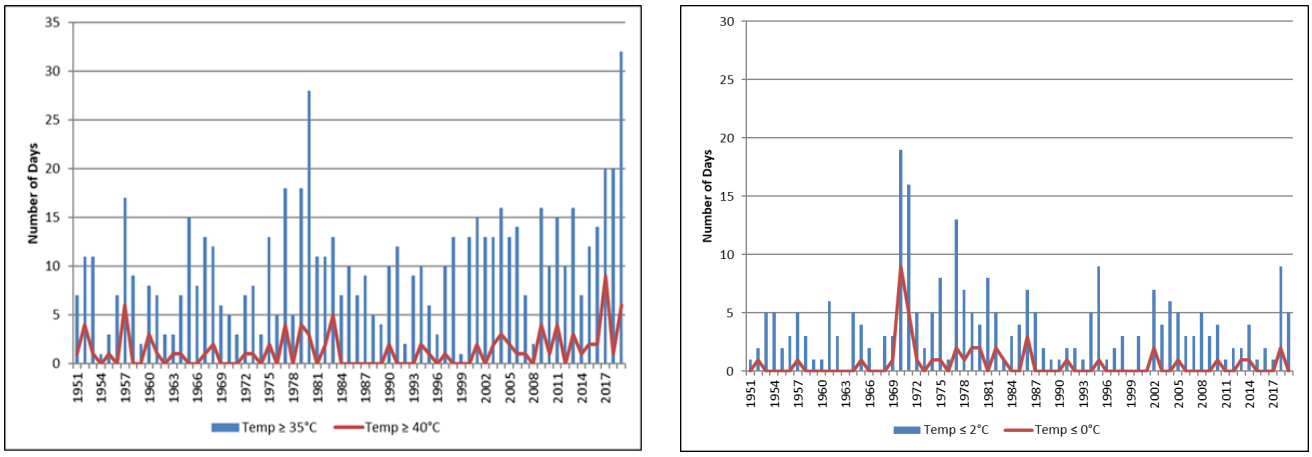


Figure 4.5 Monthly temperature profile for the Southern Hunter

Source: BoM station 061078. Figure plots maximum and minimum temperatures recorded in each month (T_{max}/T_{min} recorded), monthly average temperature and average monthly maximum and minimum temperature (T_{max}/T_{min}).

4.1.2.3 Daily temperature extremes

As shown in **Figure 4.5,** days in which maximum temperatures exceed 35 degrees Celsius are reasonably common in the Southern Hunter, while days during which minimum temperatures are two degrees Celsius or less are less common as shown in **Figure 4.6**.



a) **Incidence of days with maximum temperatures of 35 degrees Celsius or 40 degrees Celsius or more.**

b) **Incidence of days with minimum temperatures of 0 degrees Celsius or 2 degrees Celsius or less.**

Figure 4.6 Incidence of days for Southern Hunter with extreme low or high temperatures

Source: BoM station 061078.

4.1.2.4 Heatwaves

Nairn and Fawcett (2013) developed a heatwave concept that is applicable at any location and which acknowledges that perceptions of heat loading reflect local experiences. Excess heat may therefore occur at a much lower temperature at a cool climate location than in one with a warmer climate. Nairn and Fawcett (2013) calculated an Excess Heat Factor (EHF) which accounts for two main forms of thermal stress: that arising when the long-term thermal resilience of a system is overcome (i.e. when the weather is unusually hot for that location) and that which occurs when a heatwave event is unusual in relation to antecedent heat exposure (which helps to condition people to heat). A heatwave day is identified by positive EHF values. A severe heatwave is considered to be one in which EHF exceeds the 85th percentile (EHF_{85}) of positive values.

The annual frequency of heatwave and severe heatwave days during the period of record for the Southern Hunter is plotted in **Figure 4.7**. Over the period of record there has been an annual average of 23.8 heatwave days and 2.2 severe heatwave days. The average incidence of heatwave days and severe heatwave days during the climate change projection reference period was 24.8 days per year and 1.9 days per year respectively.

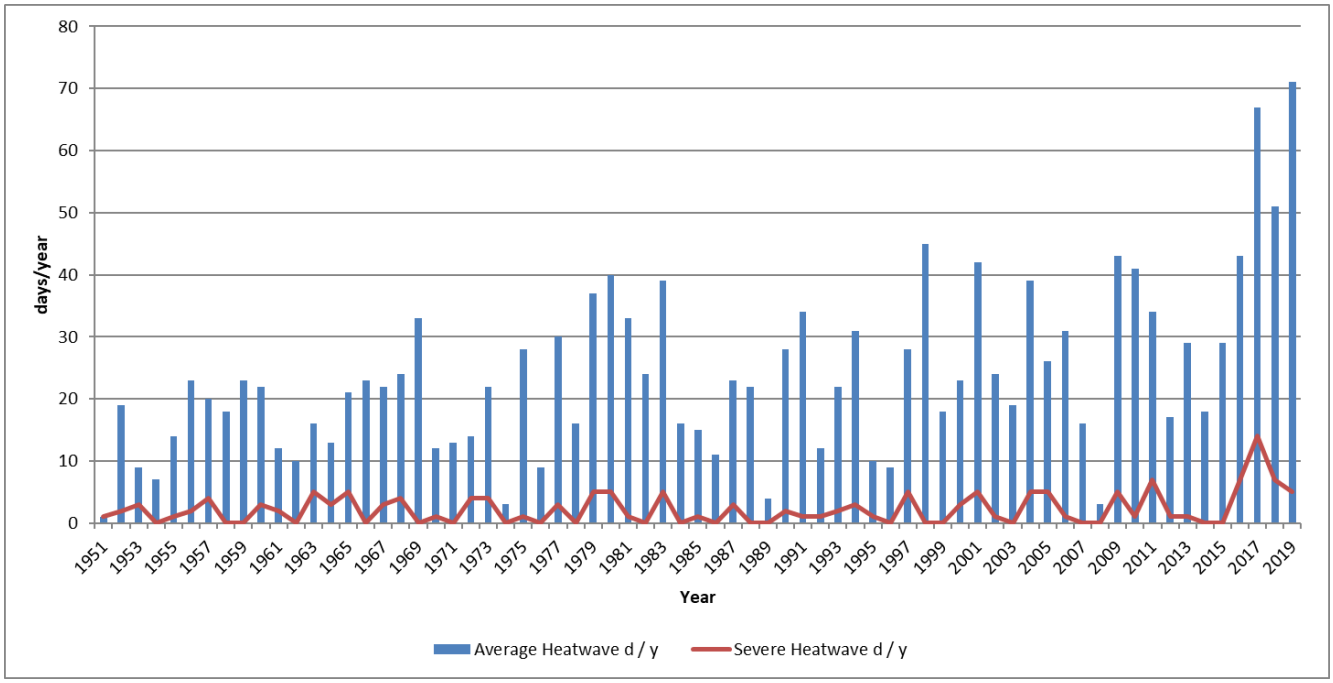


Figure 4.7 Annual incidence of heatwave (EHF>0) and severe heatwave days (EHF>EHF$_{85}$) for the Southern Hunter.

Source of underpinning data: BoM station 061078.

4.1.3 Wind

Wind speeds in the Southern Hunter typically increase through the day (**Figure 4.8**). Maximum recorded wind gusts in the Southern Hunter range between 98 kilometres per hour in February and 137 kilometres per hour in August and December.

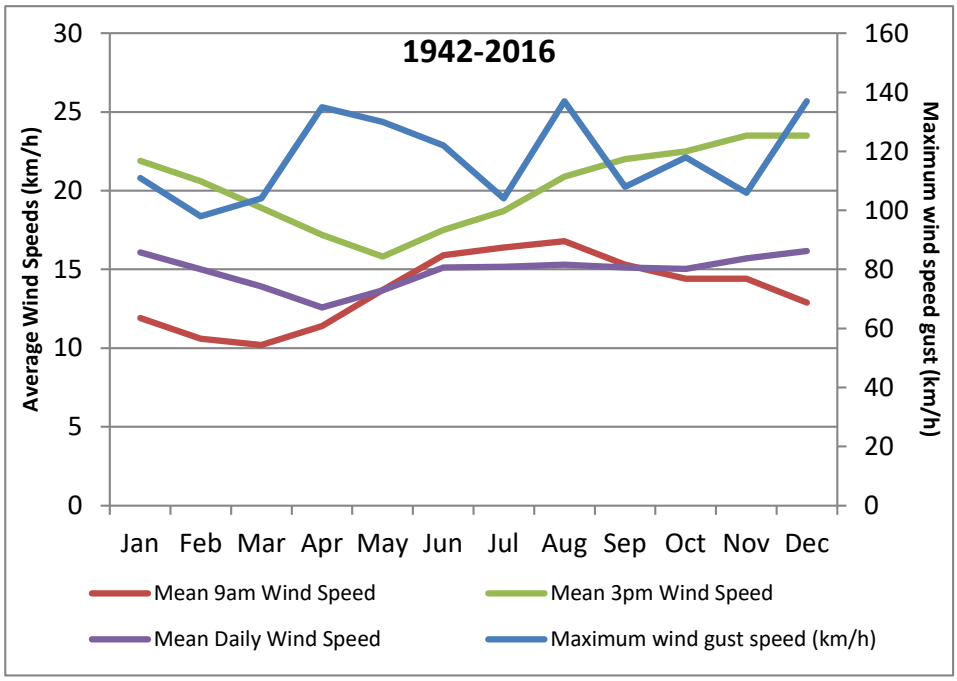


Figure 4.8 Monthly patterns in wind speed for the Southern Hunter

Source: BoM station 061078. Graph presents average daily wind speed (from 24 h wind run measurements), average 9 am and 3 pm wind speeds and maximum recorded wind gust for each month.

4.2 Climate change projections

4.2.1 Climate change

Carbon dioxide (CO_2) is a vital gas for photosynthesis and global climate regulation. Since CO_2 and other "greenhouse gases" trap long wave radiation, changes in their concentrations in the atmosphere would influence the Earth's radiation balance and contribute to the warming of both the atmosphere and the Earth's surface. This phenomenon is known as the greenhouse effect.

4.2.2 Overview

Climate change projections are derived using general circulation models (often referred to as global climate models or GCMs), which simulate the ocean, atmospheric and land surface processes which influence climate. The models are run under historical conditions and with scenarios representing long-term trajectories for greenhouse gas emissions or their effect on radiative forcing.

The GCMs selected as most able to model Australian East Coast climate were used to develop climate change projections to 2090. It is anticipated that the three scenarios included in this analysis represent a plausible range in projections for the course of the 21st century. They capture the central tendency for changes in rainfall and temperature for a lower radiative forcing scenario for 2030, 2050 and 2090. While some models project the lower emissions scenario would result in wetter conditions, this is not reflective of the broader group of more reliable models.

The IPCC's Fifth Assessment Report (AR5) (IPCC, 2013) provides a synthesis of climate change modelling carried out by leading international climate research organisations. Radiative concentration pathways (RCP) were identified under AR5, one of which (RCP8.5) is used throughout this report as it reflects the highest of the emissions scenarios considered in AR5. They follow the projections for this scenario through time from 2030 to 2090.

The reliability of climate change projections varies between climate variables. In general, global projections are more certain than regional projections and temperature projections are more certain than those for rainfall. Changes in average conditions are also more certain than changes in extremes.

For this assessment, the Climate Futures Tool (CFT) from CSIRO and BoM has been used to develop projections.

4.2.3 Rainfall

4.2.3.1 Annual rainfall

Projected changes in rainfall for the Southern Hunter are shown in **Table 4.2**. The average rainfall is projected to become less in 2030 and the climate is projected to become drier in 2050 and 2090. Maximum annual rainfall is projected increase very slightly between the baseline and 2090, while minimum annual rainfall is projected to decline by 2090.

Table 4.2 Annual rainfall projections for the Southern Hunter for 2030, 2050 and 2090, RCP8.5

	1976-2015	2030 (2021-2040)	2050 (2041-2060)	2090 (2081-2100)
Maximum (mm)	1,739	1,739	1,723	1,784
Mean (mm)	1,122	1,063	1,053	1,028
Minimum (mm)	541	492	479	448

Based on BoM station 061078 and climate change factors from the Climate Futures Tool (www.climatechangeinaustralia.gov.au).

4.2.3.2 Monthly rainfall

Figure 4.9 and **Figure 4.10** show projected changes in average and extreme monthly rainfall respectively. Seasonal patterns in rainfall are not projected to change much to 2030, although winter rainfall is projected to be slightly less.

4.2.3.3 Daily rainfall

With climate change, extreme monthly rainfall values are generally projected to increase (**Figure** 4.10) in summer in 2090. Design of the proposal has considered very low frequency rainfall events, with average recurrence intervals (ARI) in excess of 1000 years. Atmospheric warming may increase the frequency of the current 1000-year ARI event, as well as increase the rainfall total during the projected 1000-year daily rainfall event with 2050 or 2090 climate.

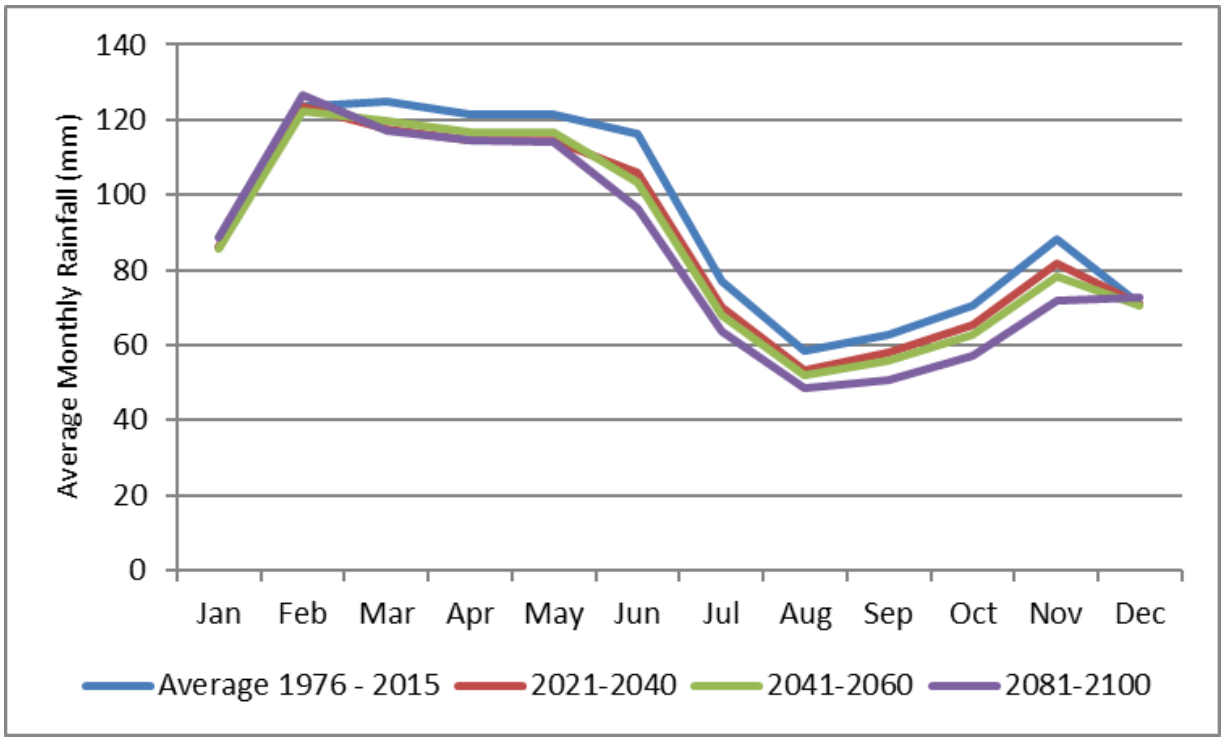


Figure 4.9 Variation in average monthly rainfall (millimetres)

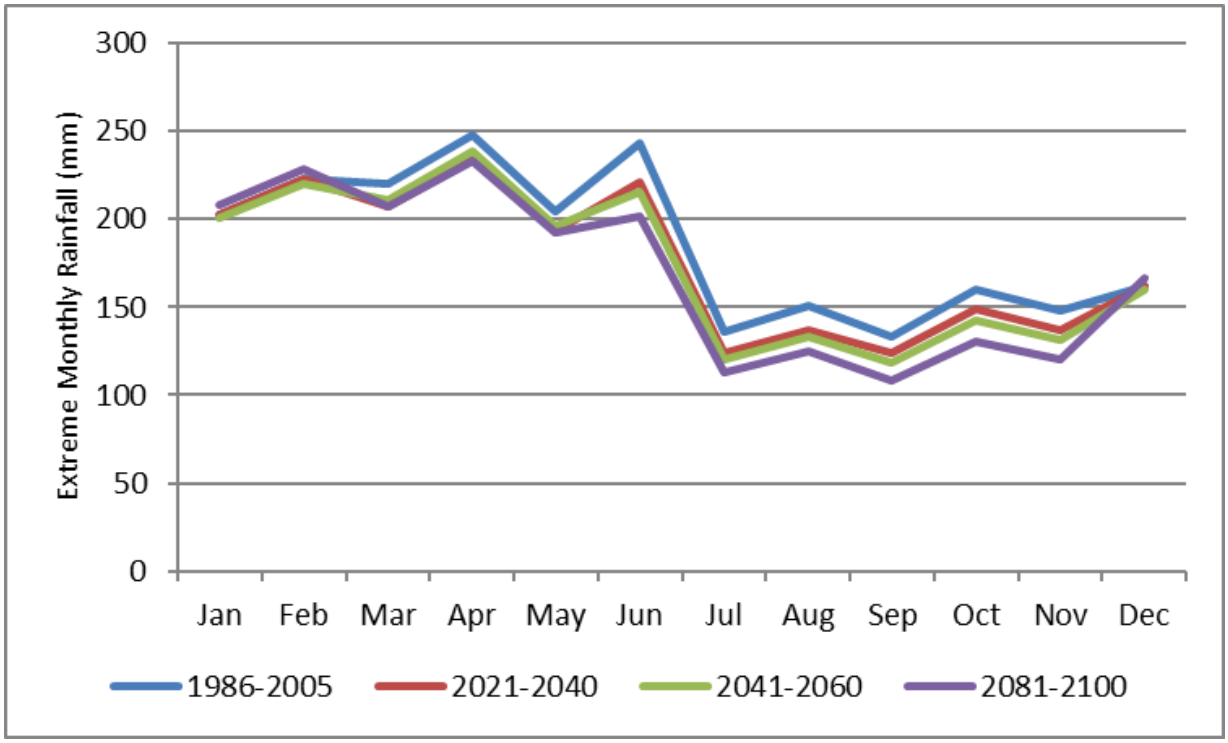


Figure 4.10 Variation in maximum monthly rainfall (millimetres)

4.2.4 Temperature

4.2.4.1 Annual temperature

Projected temperatures in the Southern Hunter are shown in **Table 4.3**. Average and extreme maximum and minimum temperatures are projected to increase 3.8 degrees Celsius and 3.9 degrees Celsius, respectively, under the 'RCP8.5' scenario (which represents a 'business as usual' scenario where no efforts are made to address climate change). The highest projected temperature exceeds the highest recorded temperature for this meteorological station in the projections for 2030 onwards.

The historical trend for reduced incidence of extreme cold conditions is projected to continue (albeit with more recent slight increase in the number of these days). The number of days with freezing minimum temperatures is projected to reduce, with temperatures being less severe.

Table 4.3 Maximum, average and minimum temperatures (degrees Celsius) for the Southern Hunter in response to projected climate change.

Parameter	1951-2019	1976-2015	2030 RCP8.5	2050 RCP 8.5	2090 RCP8.5
Maximum T_{max}	45.5	44.8	46.1	46.9	48.9
Average T_{max}	23.2	23.4	24.6	25.4	27.3
Average temperature	17.8	17.9	19.0	19.8	21.8
Average T_{min}	12.4	12.4	13.5	14.3	16.3
Minimum T_{min}	-3.9	-3.4	-2.4	-1.6	0.4

Base data from BoM stations 061078. Table includes a comparison of the full period of record, the 1976-2015 climate change projection reference period and RCP8.5 climate change scenarios for 2030 (2021-2040), 2050 (2041-2060) and 2090 (2081-2100). T_{max} – maximum temperature; T_{min} – minimum temperature

4.2.4.2 Monthly temperatures

Climate change is projected to increase average and extreme temperatures for the Southern Hunter throughout the year (**Figure 4.11**). Temperatures through the cooler months of winter are projected to increase to a lesser extent than those during other times of year. The range in average temperatures is projected to increase from 11.9-23.4 degrees Celsius during the climate change reference period to 15.8 to 27.2 degrees Celsius in 2090.

Days with maximum temperatures above 40 degrees Celsius are projected to increase from November to February, to September to April.

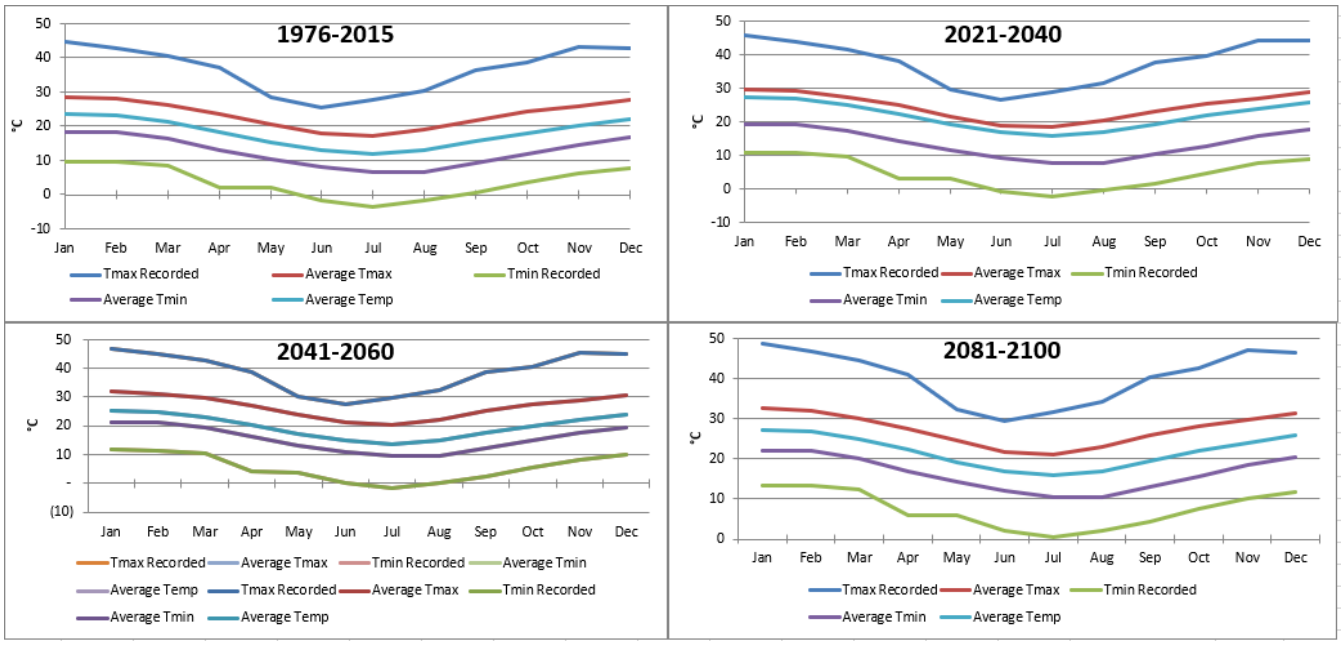


Figure 4.11 Monthly temperature profiles for the Southern Hunter (climate change reference period and 2030, 2050 and 2090 RCP8.5 climate change scenarios)

Base data from: BoM 061078. Figures plot maximum and minimum temperatures recorded in each month (T_{max}/T_{min} recorded), monthly average temperature and average monthly maximum and minimum temperature (T_{max}/T_{min}).

4.2.4.3 Daily temperature extremes

Days in which maximum temperatures reach high temperature benchmarks (35/40/45 degrees Celsius) in the Southern Hunter are projected to increase in frequency (**Table 4.4**). The frequency of days with temperatures exceeding 35 degrees Celsius is projected to more than triple relative to the climate change projection reference period by 2090. Days with temperatures exceeding 40 degrees Celsius are projected to experience a fivefold increase in frequency. Temperatures exceeding 45 degrees Celsius have only been recorded in the last few years. Such days are projected to be experienced almost once every two years by 2090.

Days with extreme minimum temperatures are projected to decline in frequency over the course of this century under the RCP8.5 scenario. Freezing days occur at a rate of approximately 0.5 days per year over the reference period and are projected to decline to zero by 2090. Days of frost are also projected to decline to zero days per year from 3.6 days per year by 2090.

Table 4.4 Frequency of extreme high and low temperatures (degrees Celsius) for the Southern Hunter in response to projected climate change, RCP8.5 scenario

Temperature	1951-2019	1976-2015	2030 RCP8.5	2050 RCP8.5	2090 RCP8.5
Days/y ≥45 degrees Celsius	<0.1	0	0.1	0.1	0.6
Days/y ≥40 degrees Celsius	1.4	1.3	2.5	3.6	6.6
Days/y ≥35 degrees Celsius	10.1	10.5	15.2	19.3	31.4
Days/y ≤2 degrees Celsius	3.9	3.6	1.4	0.7	0
Days/y ≤0 degrees Celsius	0.6	0.5	0.1	0.1	0

Base data from: BoM stations 61078.

4.2.4.4 Heatwaves

The frequency of days with an (EHF greater than zero (resulting in a heatwave event) is projected to increase more than fourfold between the climate change reference period and 2090 (**Table 4.5**), with the frequency of such days increasing from 25 occurrences per year to 117 occurrences per year. Severe heatwave days (denoted as EHF>EHF_{85}, the 85th percentile value of EHF) are projected to increase in frequency by a similar order.

Table 4.5 Change in incidence and duration of heatwaves in the Southern Hunter in response to projected climate change, RCP8.5 scenario

Heatwave incidence	1951-2019	1976-2015	2030 RCP8.5	2050 RCP 8.5	2090 RCP8.5
Days/y EHF>0	24	25	46	66	117
Days/y EHF>EHF_{85}	2	2	4	6	13.9

Base data from: BoM stations 061078. Analysis approach based on Nairn and Fawcett (2013). EHF (excess heat factor) >0 denotes a heatwave event. EHF>EHF_{85} (85th percentile value of EHF) denotes an extreme heatwave.

4.2.4.5 Wind

Climate change is anticipated to have only marginal impact on average and extreme wind events (**Figure 4.12**). Average wind speed is projected to decline by up to five per cent in all seasons, except winter in 2050 and summer in 2090 under the RCP8.5 scenario, when small increases in wind speed are projected.

The severity of the 1 in 20-year wind gust is projected to decline slightly in summer and autumn throughout the projection period and in winter in 2030 and spring in 2090, under the RCP8.5 scenario.

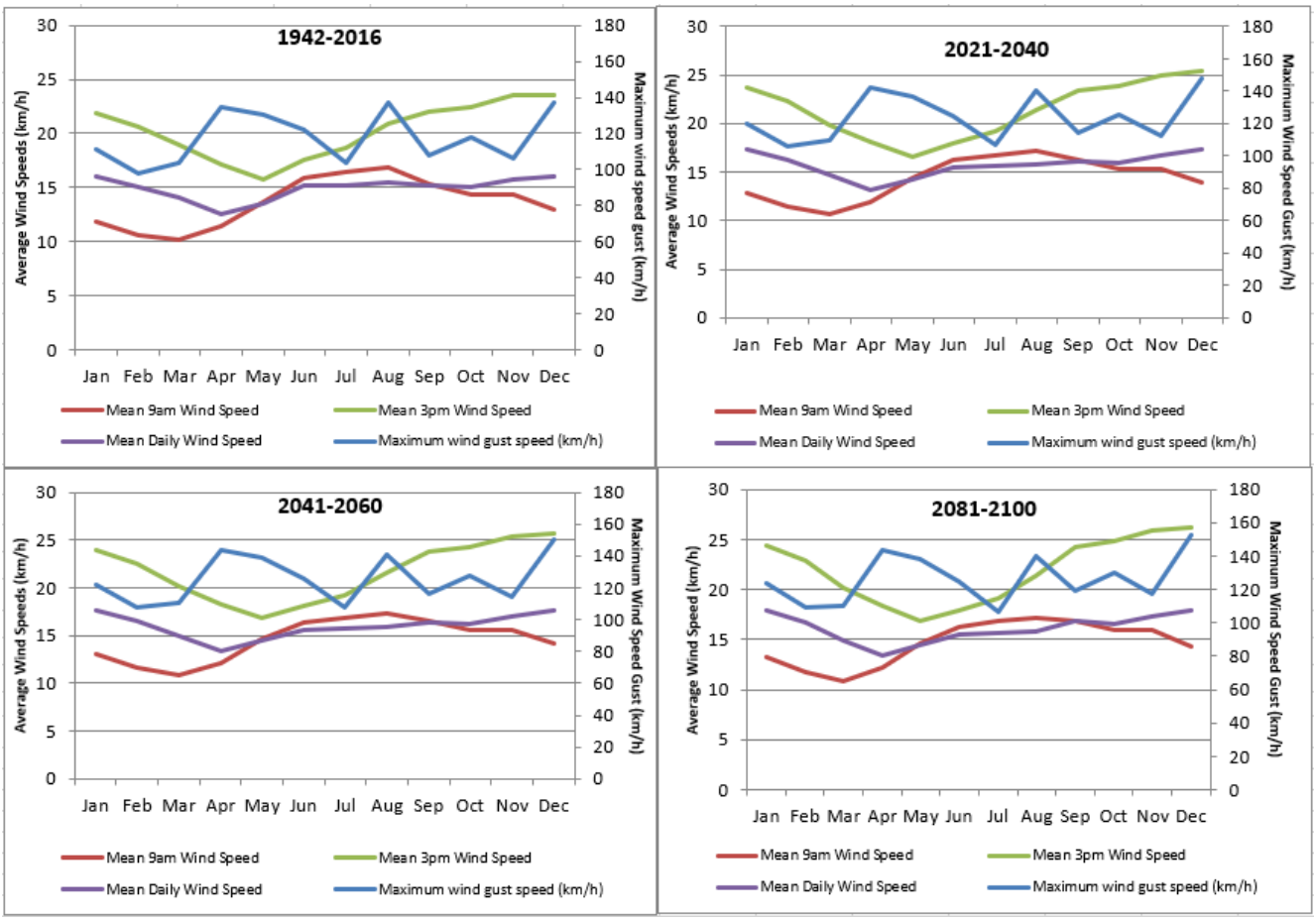


Figure 4.12 Projected changes in average wind speed for Southern Hunter, RCP8.5 scenario.

Base data from: BoM stations 061078. Projections based on change from full length of record (1942-2019) rather than the climate change reference period (1976-2015).

4.2.5 Sea Level Rise

Oceans are projected to continue to warm, with heat penetrating to the deep ocean, particularly in the Southern Ocean. Warming of the ocean and melting of continental ice sheets will contribute to further rises in sea levels. Sea level rise will likely be in the range 0.45-0.82 metres for RCP8.5 for 2081-2100 (compared with 1986-2005). The projected rise by 2100 is 0.52-0.98 metres for RCP8.5. Sea level rise is not expected to be uniformly distributed across the globe.

4.2.6 Discussion

The Southern Hunter has a highly variable climate. Annual and season rainfall and temperatures vary over a wide range. The area is periodically subject to extreme weather and climatic events which may disrupt the community, threaten health and safety and damage infrastructure and the environment. The Southern Hunter's climate is also changing, with signs evident in records of temperature. Those and other changes are projected to continue as increasing atmospheric concentrations of greenhouse gases drive warming and other changes in the climate system.

Over the course of the 21st century, the Southern Hunter's climate is expected to become:

- Warmer: with increased average and extreme high temperatures, but fewer extreme cold temperatures
- Drier: rainfall is projected to decline. Reduced annual rainfall and increased evaporation is anticipated to result in drier soil conditions, less run-off in water supply catchments and reduced average river flows and groundwater recharge

- More susceptible to coastal flooding and coastal erosion due to higher sea levels
- Subject to more extreme weather conditions: hydrological cycles are projected to intensify with atmospheric warming, leading to more intense rainfall events. Heatwaves would become more frequent, intense and prolonged. While extreme weather conditions may become more extreme, they may become less frequent.

Projected changes in climate over the course of the 21st century may be disruptive to the operations of the proposal and users of the Southern Hunter road network, increase operation and maintenance costs and shorten its operating life. While climate change projections are uncertain, the opportunity exists to assess its implications for the proposal and to incorporate appropriate, proportional measures to help ensure its resilience under the climate it would experience over its operating life.

5. Impact assessment

5.1 Construction impacts

Planning for construction of the proposal will have to consider the current climate, including more recent extremes of rainfall and bushfires which have been experienced. However, the climate change assessment is focused on longer term shifts in the climate based on projections for the middle and end of the 22nd century and as such does not assess potential construction impacts.

5.2 Operational impacts

5.2.1 Overview

Climate change is anticipated to have direct (climate event impact on the asset) and indirect impacts (such as impacts elsewhere affecting how the asset is used) on the proposal. The types of impacts are relatively well understood, however their severity and extent are uncertain. As such, risks need to be identified and assessed and strategies to treat them developed.

The combined direct and indirect impacts of climate change may contribute to one or more of the following categories of effect:

- Accelerated infrastructure deterioration and increased maintenance requirement
- Safety incidents (such as vehicle accidents)
- Increased frequency and/or duration of road closures
- Adverse road user experience due to climate (not as a result of service disruption)
- Infrastructure impact (total loss, partial damage / loss of function as a result of a severe weather event).

This is anticipated to have implications for capital and/or operational expenditure. In catastrophic situations, such as infrastructure failure related to extreme climate events, impacts may include major road accidents or loss of life (although with appropriate risk controls such event are extremely unlikely).

5.2.2 Identification of hazards

Hazards relevant to the proposal (**Table 5.1**) may include climate phenomena such as flooding and heatwaves. Hazards may occur in isolation or in combination with one another. The confluence of natural events, such as extreme rainfall combined with severe wind, may intensify projected impacts. The influence of climate change on such events is not well understood.

Table 5.1 Proposal hazards resulting from projected climate change

Hazard	Description and impact
Temperature and the incidence of heatwave	Increased average temperature and more frequent heatwave events may affect the structural integrity of the road surface, bridges and supporting infrastructure (i.e. electronic signals). It may also lead to higher operational and maintenance costs through enhanced deterioration of infrastructure or disruption of services such as closures and delays.
Severity of seasonal drought	Climate change is likely to influence the severity and duration of drought. These changes may affect the geotechnical stability of the land, hence undermining the structural integrity of road infrastructure. Drought may also alter the natural physical surroundings along the proposal. This is a potential issue for vegetation cover, especially when used for erosion protection.

Hazard	Description and impact
Rainfall amount and frequency	Decreased rainfall depth and frequency may result in changes to water table levels, which would affect groundwater flows. Drying of drainage channels may result in loss of vegetation cover, which in periods of severe rainfall are eroded more easily.
Severe rainfall events resulting in floods	Excessive rainfall can lead to flash or prolonged flooding (both from excessive stormwater and river flooding). The potential implications include infrastructure damage and/or failure and operational delays. Greater levels of surface water flow during extreme events may cause dangerous driving conditions and instability of embankments and retaining walls along the proposal.
Sea Level Rise	Sea Level Rise will increase the base level under riverine and stormwater flooding, and inundate areas not previously susceptible to flood.
Frequency and intensity of bushfire	Higher temperatures and changes to rainfall patterns suggest an increase in the frequency of extreme fire weather, which if fires occur, may make their behaviour more difficult to manage. Given its semi-rural location, the proposal may be directly affected by bushfire, and indirectly, the local air quality may be affected by smoke and dust, along with reduced visibility for drivers.
Rate of annual evaporation	Increased annual evaporation would have an impact on soil wetting and drying cycles, river flooding and fire. Drier climate (warmer, less rain, less humidity and increased evaporation) is associated with reduced road pavement deterioration).
Carbon dioxide concentration in the atmosphere	An increase in concentration of carbon dioxide combined appropriate temperatures and humidity levels would lead to increased depth of carbonation of concrete, which in turn can increase the likelihood of carbonation induced reinforcement deterioration (CSIRO, 2010). For the proposal this may involve enhanced deterioration of the reinforced concrete elements and shortening of its operational life.

5.2.3 Identification of receptors

Proposal components (receptors) that may be affected by the hazards described above are displayed in **Table 5.2**.

Table 5.2 Potential impact receptors

Receptor	Receptor components
Road infrastructure	▪ Roadway and footpaths ▪ Embankments, retaining walls and noise walls. ▪ Ancillary infrastructure – signals, power ▪ Signage ▪ Lighting ▪ Drainage and culverts.
Bridges	▪ Ramps ▪ Piers and Footings ▪ Bridge Deck and Railings ▪ Drainage.
Maintenance staff	▪ Maintenance workers.
Electrical supply	▪ Supply points ▪ Transformers ▪ Back –up generation.

5.2.4 Identified operational risks

Risk analysis and evaluation was carried out through desktop assessment, and in liaison with other specialist studies (such as hydrology). The risk assessment involved the following steps:

- Identify the hazard and receptor
- Assess the potential exposure
- Identify existing controls and their effectiveness
- Identify the consequence rating corresponding to the maximum credible impact across the consequence categories (may be more than one), given the existing controls and their effectiveness
- Identify the likelihood of occurrence of those consequences at that level, considering business as usual controls and their effectiveness
- Determine the level of risk based on the intersection of the consequence and likelihood rating
- Determine any action (e.g. risk treatment) and escalation based on the level of risk
- Recommend next steps for detailed design to carry out prior to reconsideration of the level of consequence and likelihood (and therefore residual risk).

Prior to the implementation of environmental management, one risk was identified as 'very high', two risks were identified as 'high', six risks were identified as 'medium' and seven risks were identified as 'low'. Medium and above risks are presented in **Table 5.3**. For low risks, no risk treatment is proposed at this stage, although where practicable, environmental management measures will be identified for these risks during future design stages.

Following the implementation of current design controls or proposed risk treatments, one risk was identified as 'very high' two risks were identified as 'high', five risks were identified as 'medium' and eight risks were identified as 'low'.

The full results of the risk assessment are presented in **Attachment B**.

Table 5.3 Inherent risks identified as 'Medium' or higher

ID	Cause, trigger or issue	Risk, hazard or opportunity	Potential consequences	Inherent (original) risk rating	Current control / Proposed risk treatment	Residual risk
3	Increased high temperature extremes and more frequent incidence and severity of heatwaves.	Maintenance activities have to be postponed due to extreme heat.	Delay in maintenance activities causes a backlog in work.	Medium	No additional control. WHS planning to take adaptive management approach.	Low
5	Increased high temperature extremes and more frequent incidence and severity of heatwaves.	Revegetated areas are unable to survive in higher temperatures and during extreme heatwaves.	Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance.	Medium	**Current Control:** Work practices (Work Health and Safety Planning) for extreme heat days to avoid excessive heat (and provide cooling). **Proposed Risk Treatment:** Detailed design to consider drought tolerance of species selected for revegetation as part of the landscaping plans. Choosing species that require little or no irrigation will also have potable water reduction benefits.	Medium
7	Increased high temperature extremes and more frequent incidence and severity of heatwaves.	Revegetated areas are unable to survive in drought conditions.	Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance.	Medium	**Current Control:** Ongoing Asset Management Program. **Proposed Risk Treatment:** Ensure revegetation plan considers climate change projections in specification of species (both in and outside the floodplain). Consider how vegetation will contribute to or support the structural integrity of soils in a changing climate. Detailed design will also include a requirement to ensure that new plant / tree species selection (and location of trees) caters for	Medium

ID	Cause, trigger or issue	Risk, hazard or opportunity	Potential consequences	Inherent (original) risk rating	Current control / Proposed risk treatment	Residual risk
					potential impacts if burnt (e.g. falling onto the roadway).	
8	Increase in the frequency and intensity of severe rainfall events coupled with Sea Level Rise.	Increased flooding (extent and depth) covers and damages areas previously modelled/designed to be immune from flooding.	Flooding damage to road and road infrastructure (including electrical infrastructure) which could temporarily close the road and severely delay traffic. Impact would require clean up and repair depending on level of damage. Impact could extend to neighbouring properties due to inability of flood waters to pass through the alignment.	High	**Current Control:** Detailed design to review climate change scenarios presented in the *Hexham Straight Widening Flooding and Hydrology Assessment* (Jacobs, 2021) and confirm whether any changes are appropriate to deliver short- or long-term flood protection.	High
9	Increase in the frequency and intensity of severe rainfall events coupled with Sea Level Rise.	Increased flooding (extent and depth) overwhelms areas previously modelled / designed to be immune from flooding	Flooding/standing water causes accidents for motor vehicles and cyclists resulting in safety incidents for road users.	Very High	**Current Control:** Detailed design to review climate change scenarios presented in the *Hexham Straight Widening Flooding and Hydrology Assessment* (Jacobs, 2021) and confirm whether any changes are appropriate to deliver short- or long-term flood protection,	Very High

ID	Cause, trigger or issue	Risk, hazard or opportunity	Potential consequences	Inherent (original) risk rating	Current control / Proposed risk treatment	Residual risk
10	Increase in the frequency and intensity of severe rainfall events coupled with Sea Level Rise.	Culverts and drainage channels are overwhelmed causing increased flooding on the up-flow side of the culverts, and increased scour at the outflows.	Increased road closures, and increased maintenance / rectification costs. Diverted water may lead to increased flooding at existing properties.	High	**Current Control:** Detailed design to review climate change scenarios presented in *Hexham Straight Widening Flooding and Hydrology Assessment* (Jacobs, 2021) and confirm whether any changes are appropriate to deliver short- or long-term flood protection,	High
11	More severe fire weather and elevated fire weather conditions.		Road users suffer reduced visibility due to smoke effects resulting in accidents. Roads may be closed until smoke clears and debris is removed.	Medium	**Current Control:** Bushfire Risk Management Plan. Variable messaging signs (permanent or temporary) provide hazard warning to motorists.	Medium
13	Sea Level Rise.	Sea Level Rise affects structure and /or stability of Ironbark Creek Bridge.	Bridge design or structure is compromised by elevated sea water levels in Ironbark Creek, South Channel Hunter River or the Hunter River resulting in accelerated degradation or performance below specification.	Low	**Current Control**: Levels to be reviewed at detailed design to ensure no reduction in likely asset life.	Low

ID	Cause, trigger or issue	Risk, hazard or opportunity	Potential consequences	Inherent (original) risk rating	Current control / Proposed risk treatment	Residual risk
14	Sea Level Rise	Exacerbated by the proposal. Sea Level Rise affects protected ecosystems alongside the Ironbark Creek, South Channel Hunter River and Hunter River.	Wetlands between Maitland Road and the Hunter River become permanently inundated resulting in total or partial loss of the ecosystem.	Medium	**Current Control:** Detailed design to confirm that the project does not influence likely inundation of wetlands and revisit risk rating.	Medium
15	Sea Level Rise	Sea Level Rise results in overtopping of road or ancillary infrastructure resulting in damage to asset.	Very low-lying areas of the proposal become regularly inundated due to sea level rise. Requirement to repair and potentially adjustment needed to provide ongoing resilience.	Low	**Current Control**: Flood levels to be reviewed at detailed design to confirm tolerance of low-lying areas to flooding.	Low
16	Increased concentration of carbon dioxide in the atmosphere.	Carbonation occurs to a greater depth in concrete structures, allowing exposure and degradation of reinforcement. Retaining walls, piers and bridge deck elements are degraded quicker than anticipated, shortening their design life.	Shorter design life results in greater levels of inspection and maintenance needed, increasing asset operational costs.	Medium	**Current Control:** Australian Standards (AS5100) (2017 version) makes reference to consideration of climate change. Concrete design accounts for carbonation based on historical CO_2 levels in atmosphere. **Proposed Risk Treatment:** Review material durability / concrete classification for the Ironbark Creek Bridge(s) to ensure a suitable exposure classification is assigned to include future climate.	Low

6. Mitigation measures

Recommended safeguards and management measures to specifically manage potential climate change impacts which have been predicted as a result of the proposed works. These are summarised in **Table 6.1**. These measures should be incorporated into relevant Environmental Management Plans (EMPs) during construction and operations.

Table 6.1 Environmental management measures

Impact	Mitigation measure	Responsibility	Timing
Climate change risk	Detailed design should incorporate the full range of temperature projections, as well as expected life of bridge components, when materials are specified.	Transport/ Contractor	Detailed design
Climate change risk	▪ Ensure that revegetation and landscaping design: ▪ Considers climate change projections in the selection of species (both in and outside the floodplain) ▪ Considers how vegetation will contribute to or support the structural integrity of soils in a changing climate. ▪ Ensures any newly plant/tree species selection (and location of trees) to cater for potential impacts if burnt (e.g. falling onto the roadway)	Transport/ Contractor	Detailed design
Climate change risk	A material durability report (or report section) will be prepared and actioned which will specifically review the potential impacts of climate change on concrete durability, including depth of cover over reinforcement.	Transport/ Contractor	Detailed design
Flood risk / Sea Level Rise	The climate change scenarios presented in the *Hexham Straight Widening Flooding and Hydrology Assessment* will be reviewed to confirm whether any design changes are required to provide ongoing resilience to the asset, or to minimise any impact on the surrounding area.	Transport/ Contractor	Detailed design

7. Conclusion

The climate change risk and adaptation assessment has identified climate change projections for the region through which the proposal will traverse, and highlighted a range of potential risks to the proposal as a result. The highest risks include:

- Risks associated with an increased rainfall intensity (from storm events) and stormwater or riverine flooding, coupled with sea level rise
- Material durability risks relating to tolerances to extreme heat.

Environmental management measures have been proposed to address the risks which are analysed as 'medium' or above, the majority of which are to be closed out in detailed design.

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Acronyms

Acronym	Definition
Adaptation	Adjustment in natural or human systems that are taken in response to actual or expected climatic [and other] stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation is concerned with managing the unavoidable impacts of climate change (and variability) and considers what needs to be done differently – both more and better – to cope with the change.
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
BoM	Australian Bureau of Meteorology.
CCIA	Climate Change in Australia web site and technical report; see www.climatechangeinaustralia.gov.au.
CEMP	Construction Environment Management Plan.
CFT	Climate Futures Tool.
Climate	A statistical description of "average" weather in terms of the mean and variability of relevant quantities over time scales ranging from months to millennia. It is influenced by factors that operate at various time and spatial scales, including atmospheric energy balance, atmospheric composition and ocean and atmospheric circulation patterns.
Climate change	Refers to a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may occur because of internal changes within the climate system; interaction between its components; or because of changes in external forces either for natural reasons or because of human activities. It is generally not possible to clearly attribute causation between these causes. Projections of future climate change generally consider only the influence on climate of anthropogenic increases in greenhouse gases and other human-related factors.
Climate change factors	The percentage or absolute change in rainfall, temperature or other climate variable that results from climate change under a particular scenario. Climate change factors describe the change from averages during the 1986-2005 reference period.
CO_2	Carbon dioxide.
CO_2e	Carbon dioxide equivalent – an amalgamation of all greenhouse gases into a single indicator.
COP	Conference of the Parties, referring to the countries that have signed up to the 1992 United Nations Framework Convention on Climate Change.
DCCEE	Department of Climate Change and Energy Efficiency.
DPI	Department of Primary Industries.
EPA	Environment Protection Authority.
EHF	Excess heat factor.
GCM	General Circulation Model or Global Climate Model. Computer model that runs mathematical representations of the global climate system. They are used to project the influence of emissions or other global change scenarios on climate. Climate change projections are typically based on an ensemble or group of models rather than the results of an individual GCM.

Acronym	Definition
GHG	Greenhouse gas.
Heat wave	An event with at least two consecutive days of high temperature. High temperature may be based on maxima of 35 or 40 degrees Celsius or more or average temperatures (average of daily maximum and minimum temperature) of 32 degrees Celsius or more. Nairn and Fawcett (2013) developed a heatwave index (based on an excess heat factor) which reflects whether hot weather is unusual for the location and grossly different to the antecedent conditions.
IPCC	Intergovernmental Panel on Climate Change.
ISCA	Infrastructure Sustainability Council of Australia. It is proposed that the proposal be designed to achieve an overall excellence rating under ISCA's sustainability rating tool. This may require the proposal to satisfy one or both climate change criteria.
LEP	Local Environment Plan.
LGA	Local government area.
OEH	New South Wales Office for Environment and Heritage.
NSW	New South Wales.
PEI	Preliminary environmental investigation.
POEO Act	*Protection of the Environment and Operations Act 1997.*
RCP	Radiative concentration pathway. A future trajectory for radiative forcing, reflecting changes in atmospheric greenhouse gas concentrations. Four RCP scenarios are commonly presented, ranging from RCP2.6 to RCP8.5. The numeric factor represents the 2100 RF value of the scenario (or in the case of RCP2.6, the peak value).
REF	Review of environmental factors.
Resilience	The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.
SEPP	State Environmental Planning Policy.
Transport	Transport for New South Wales.
UNFCCC	United Nations Framework Convention on Climate Change.

Attachment A. Risk Framework

Table A.1 Risk Assessment – Likelihood Criteria

Rating / description	L6 Almost unprecedented	L5 Very unlikely	L4 Unlikely	L3 Likely	L2 Very likely	L1 Almost certain
Qualitative expectation	• Not expected to ever occur during time of activity or project • Very little or no real chance of this risk occurring • History shows that this risk hardly ever happens, if at all	• Not expected to occur during the time of activity or project • Only an unusual chance of this risk occurring • History shows that this risk rarely happens, usually under unusual circumstances	• More likely not to occur than occur during time of activity or project • Chance of this risk occurring but not very often • History shows that this risk does happen but not very frequently	• More likely to occur than not occur during time of activity or project • Chance of this risk occurring in the current period • History shows that the risk has occurred on a number of occasions	• Expected to occur occasionally during time of activity or project • Good chance of this risk occurring • History shows that the risk occurs unacceptably too often	• Expected to occur frequently during time of activity or project • Very strong chance of this risk occurring • History shows that it is something that occurs frequently
Quantitative frequency	• Risk event will occur at least once every 50 years • Less than 2% probability of risk/event occurring within the next 12 months	• Risk event will occur at least once every 25 years • Greater than 2% and up to 4% probability of risk/event occurring within the next 12 months	• Risk event will occur at least once every 10 years • Greater than 4% and up to 10% probability of risk/event occurring within the next 12 months	• Risk event will occur once every year • Greater than 10% and up to 50% probability of risk/event occurring within the next 12 months	• Risk event will occur between 2 times and 10 times per year • Greater than 50% and up to 80% probability of risk/event occurring within the next 12 months	• Risk event will occur more than 10 times every year • Greater than 80% probability of risk/event occurring within the next 12 months

Note: When assessing risks associated with new or altered assets, the term 'activity' in the table should be considered to represent the intended operational life of the asset.

Source: TfNSW Enterprise Risk Management Procedure issued July 2020

Table A.2 Risk Assessment Consequence Criteria

Rating / description	C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Major	C1 Catastrophic
Safety	• Incident and/or injury/illness to staff/customer/community, not requiring first aid or medical treatment • No lost time	• Injury or illness to staff/customer/ community, requiring first aid or medical treatment (non-hospitalisation) • No lost time post medical treatment • Single event	• Minor injuries or illnesses to staff/customer/community, requiring professional medical treatment (that is, doctor, nurse, and paramedic) or hospitalisation resulting in lost time • Injuries to customer/community requiring hospitalisation	• 1 to 10 serious injuries or illnesses to staff/customer/community, as defined under section 36 of the *Work Health and Safety Act 2011* (WHS Act) resulting in hospitalisation, lost time and/or potential permanent impairment • Multiple injuries to customer/community requiring hospitalisation • Single event and/or multiple locations • Coordinated emergency response required	• Single fatality and/or 10 to 20 serious injuries or illnesses to staff/customer/ community, as defined under section 36 of the WHS Act (resulting in hospitalisation, lost time and/or potential permanent impairment • Could impact safety across the network • Coordinated emergency response required	• Multiple fatalities and/or more than 20 serious injuries or illnesses to staff/customer/community, as defined under section 36 of the WHS Act resulting in hospitalisation, lost time and/or potential permanent impairment. (permanent disabilities/chronic diseases) • Transport unable to assure community and network safety • Coordinated emergency response required

Rating / description	C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Major	C1 Catastrophic
Everyday service delivery (customer satisfaction)	• Isolated written complaints • No impact to overall customer satisfaction index or customer ratings (core customer satisfactions drivers) • Typical levels of complaints per 100000 boardings benchmark	• Uninterrupted complaints at an increased volume for more than three months, resulting in a material increase in the rate of customer complaints for the transport mode or service (but less than 33% of the normal background level), increased ministerial and potentially ombudsman complaints • No impact to the overall customer satisfaction index • Relatively small reduction (<5%) in the satisfaction level on one of the core drivers of customer satisfaction for no more than a year	• Continuous complaints at an increased volume for more than a year, and/or an increase in the rate of customer complaints for the transport mode or service of >33% of the normal background level (per 100000 boardings), increased ministerial and ombudsman complaints and some media coverage • Reduction in the overall customer satisfaction index for one transport mode by no more than 2% • relatively small reduction (<5%) in the satisfaction level in two or three core drivers of customer satisfaction • Relatively small reduction (<5%) in the satisfaction level in two or three core drivers of customer satisfaction	• A substantial and sustained uplift in the rate of customer complaints (per 100000 boardings) with a backlog that can be cleared within 30 days, depending on resources. Repeat complaints associated with a failure to respond in a timely manner, increased ministerial and Ombudsman complaints, along with intensified media coverage *Note: Major changes in services tend to generate customer complaints such as NorthWest Bus Service changes in July 2019. In some instances this may present a risk while in others it may represent an adjustment period for customers.* • Reduction in the overall customer satisfaction index for any transport mode by no more than 2% and can be recovered within 12 months • Small reduction (<5%) in the satisfaction level for more than three core drivers of customer satisfaction or more than 5% on any one driver	• Increased customer complaints for up to six months, with normal background rates for the transport mode or service increasing by a factor of three or more, and a persistent backlog in responses – allowing for typical seasonal variation in complaints volume throughout the year • Backlog of complaints not readily cleared within 30 days, and repeat complaints associated with delayed responses to complaints • Increased ministerial and Ombudsman complaints, accompanied by persistently negative media coverage • The overall customer satisfaction index for one major transport mode only dropping by 3% or more and can be recovered within 12 months • Larger reduction (5% or more) in the satisfaction level for more than three core drivers of customer satisfaction or more than 10% on any one driver	• A prolonged increase in customer complaints for greater than six months, with normal background rates for the transport mode or service increasing by a factor of 10 or more, and a persistent backlog in responses - allowing for typical seasonal variation in complaints volume throughout the year • Substantial backlog of complaints • Ministerial and Ombudsman complaints • Persistent media and political scrutiny • A prolonged material reduction in overall customer satisfaction across the board (5% or more) for one or more major transport modes • A prolonged reduction (10% or more) in the satisfaction levels of the core drivers of customer satisfaction on more than one transport mode

Rating / description	C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Major	C1 Catastrophic
Everyday service delivery	• Antisocial behaviour on service or resulting in minor delays • Minor traffic incident resulting in minor delays • Passenger(s) unable to disembark due to technical asset failure for more than five minutes • Business as usual (BAU) service delays	• BAU cancelations of service due to various causes including asset failure • Partial or full closure of a line/route/run or incidents resulting in minor to moderate delays such as track failure • Access and operation compromised (for example, closed entry and exits) for >30 minutes	• Police operation on a transport asset (for example, threat, suspicious package, security incident, civil unrest) • Incident requiring investigation by statutory authorities (WorkSafe, EPA, ONRSR/OTSI, NSW Police Force)	• Police operation on a transport asset (for example, threat, suspicious package, security incident, civil unrest) resulting in a significant delay for a prolonged period of time and likely to attract significant media attention such as no services during peak periods • Incidents resulting in a significant detrimental impact to a transport mode or multiple transport modes for a prolonged period of time in excess of an hour, or likely to attract significant media attention such as derailment, overcrowding at stations, significant delays or no services during peak periods, injury to school children, multiple injuries, person overboard, fire on a service • Evacuation or unplanned closure, caused by flood, fire, smoke, or hazardous substance spill, and suspicious substance	• Serious injury or fatality to member of staff • Fatality on a service or asset/station/ interchange (not self-harm)	• Multiple injuries or fatality due to asset failure/derailment or significant ongoing threat
Financial sustainability	• Capital expenditure (capex), above P50 capital budget of <$10 million • Non-infrastructure capex of <$100K • Operating expenditure (opex) (including accounting adjustments) of <$1 million • Revenue (including fines, penalties, compensation and so on) <$100K	• Capex (above P50 capital budget) of $10 million to $25 million • Non-infrastructure capex of $100K to $1 million • Opex (including accounting adjustments) of $1 million to $10 million • Revenue (including fines, penalties, compensation and so on) of $100K to $1 million	• Capex (above P50 capital budget) of $25 million to $50 million • Non-infrastructure capex of $1 million to $5 million • Opex (including accounting adjustments) of $10 million to $25 million • Revenue (including fines, penalties, compensation and so on) of $1 million to $5 million	• Capex (above P50 capital budget) of $50 million to $150 million • Non-infrastructure capex of $5 million to $25 million • Opex (including accounting adjustments) of $25 million to $75 million • Revenue (including fines, penalties, compensation) of $5 million to $25 million	• Capex (above P50 capital budget) of $150 million to $250 million • Non-infrastructure capex of $25 million to $50 million • Opex (including accounting adjustments) of $75 million to $150 million • Revenue (including fines, penalties, compensation and so on) of $25 million to $50 million	• Capex (above P50 capital budget) of >$250 million • Non-infrastructure capex of >$50 million • Opex (including accounting adjustments) of >$150 million • Revenue (including fines, penalties, compensation and so on) of >$50 million

Rating / description	C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Major	C1 Catastrophic
Reputation and integrity	• Single negative article in local media • Limited social media commentary • Goodwill, confidence and trust retained • Confined to the branch • Local council may want to discuss	• Series of negative articles in local media (district / electorate based adverse media) • Some social media commentary • Confidence remains - minor loss of goodwill • Confined to branch but requiring notification to division • Council requires written explanation • Recoverable with little effort or cost. Some continuing scrutiny/attention	• Extended local media coverage with some broader regional media coverage • Extended negative social media coverage • Confidence and trust of stakeholders dented (recoverable at modest cost within existing budget and resources) • Division formal response needed to State - government/regulator	• State media coverage, short term negative national media coverage • Widespread social media coverage • Confidence/trust impaired • Project/activity credibility under question • TfNSW and/or Minister's office requires update	• Sustained negative State media coverage • Regular 'talk-back' programs questioning credibility and capability • Confidence and trust are severely damaged • Widespread negative social media coverage • Regular updates demanded by the Minister • Stakeholders withdraw their support recoverable at considerable cost, time and staff effort	• Sustained, high profile media attention at national level • Material change in the public perception of the agency • Extensive negative social media coverage • Confidence and trust non-existing. Government forced to reverse decision • Stakeholders are actively campaigning against the organisation
People	• Little employee interest/impact • Confidence and trust of employees retained • Confined to small number of people <5 • No performance impairment • Little or no impact on workload, employee numbers, work/life balance • No cultural impact • No noticeable excess stress or excessive absenteeism of key staff during/after workload peaks • Union activity/correspondence without staff pickup	• Impacts employees at a specific location and/or of a specific discipline (for example, accountants) (<50) • Employees concerned as to their wellbeing and future • Employees frustrated but still willing to proactively contribute to meeting objectives • Isolated incidence of excess stress or excessive absenteeism of key staff during/after workload peaks • Unions are being called upon to take up employee cause • industrial relations tension is high	• Impacts large numbers of employees (<500) • Employee's wellbeing and future is at risk • Employees frustrated and are largely only 'doing what needs to be done' • Culture and morale dropping • People are actively looking to leave • Noticeable incidence of excess stress or excessive absenteeism of key staff during/after workload peaks • Pockets of staff support for union agitation	• Majority of employees potentially impacted (50%). • Employee morale is low • Employees not willing to proactively engage – lack of commitment • Key people are actively looking to leave • Widespread staff support for union agitation • Widespread incidence of excess stress or excessive absenteeism of key staff	• All employees potentially impacted • Employee morale is poor • Employees not willing to proactively engage • Key people are leaving, workforce turnover rates increase (loss of IP) • Unions action – work to rule, stop work, short time but significant action • Stress and other work related injuries/health issues increasing • High incidence of excessive absenteeism of staff	• Employee brand significantly impaired • All employees potentially impacted • No confidence and trust of employees • Transport wide dissatisfaction – bad, dysfunctional morale. • Performance significantly impaired – little or no immediate sign of improvement • High staff turnover – poor corporate culture • Doubling of workload, stress levels dangerously high • Long-term (months) of ongoing rolling industrial action which significantly impacts on service delivery

Rating / description	C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Major	C1 Catastrophic
Project delivery	• Insignificant delay (one to two days) • No reduction in functionality/scope • No discernible impact, benefit realisation may have a slight decrease but largely intact • No time delay with initiative or project but will incur a slight decrease in the benefits realised • <2 month project delay	• Insignificant delay (one to two days) • No reduction in functionality/scope • No discernible impact • Benefit realisation partially impaired but still adds value and economically sound • No public impacts • Two to three months project delay	• Minor delay (<1% to max of one week) • <1% reduction in functionality/scope • Benefit realisation partially impaired but still adds value and economically sound • No public impacts • Three to six months project delay	• Major delay (<10% to max of five months) • <10% reduction in functionality/scope • Cost/benefit analysis may not have supported the program to go ahead • Publicly announced portion/milestone missed or final completion date missed with demonstrable mitigating external circumstances • Six to nine months project delay	• Severe delay (<15% to max of 9 months) • <15% reduction in functionality/scope • Cost/benefit analysis would not justify program • Publicly announced portion/milestone missed or final completion date missed on critical path project • Nine to twelve months project delay	• Total blow out in time (>9 months or >15%). • >15% reduction in functionality/scope • Will probably require a major project in the foreseeable future to either rectify or complete the results of this project • Publicly announced portion/ milestone significantly missed or final completion date significantly missed on critical path project • >12 months project delay • Failure to realise benefits of the initiative
Regulations and compliance	• Low-level/technical non-compliance with legal and/or regulatory requirement or duty by individuals or TfNSW-not reportable • Minor noncompliance to a low impact contract clause – little or no interest by either party to pursue or rectify	• Noncompliance with whole or significant aspects of government policy not reportable but requiring internal activity to put in place • Formal investigation and/or formal notification to regulator • Minor breach of contract by either party rectified through local management discussion	• Noncompliance with key government policy - reportable and/or explanation required – need to put in place as soon as possible • Noncompliance – key obligation • Formal notification to regulator • Agency on notice • Breach of contract by either party rectified at branch level management discussion • Small fine and no disruption to services	• Technical noncompliance with a minor government policy - not reportable • Low level noncompliance • Technical nonconformance • Minor noncompliance to a low impact contract clause – little or no interest by either party to pursue or rectify • Substantial fine and no disruption to services	• Noncompliance with high profile, outward facing government policy or ministerial decree - immediately reportable to government body such as Treasury and action to put in place required immediately (high priority) • Continuous breach resulting in prohibition notices • Breach of significant, key aspects of contract by either party leading to lodgement (threat) to sue and recompense at severe financial levels • Cessation of contract may occur • Large fines as a result of noncompliance • Licence or accreditation restricted or conditional affecting ability to operate	• Noncompliance with high profile government policy or ministerial decree - immediately reportable to ministerial level requiring actions to put in place immediately (high priority) and progress to be reported to the minister on an agreed and appropriate schedule • Litigation and potentially imprisonment • Loss of operating licenses • Continued breach cannot be tolerated • Major contract breach by either party leading to significant litigation and financial costs • Total breakdown and cessation of contract • Criminal prosecution as a result of noncompliance
Environment	• No appreciable changes to environment	• Change from existing conditions that can be rectified immediately (<1 day) with available resources	• Short-term (<1 year) and/or well-contained environmental impact • Minor remedial actions probably required	• Short to medium term (between 1 year and <5 years) environmental impact • Considerable remedial actions probably required	• Medium-term (>5 years) environmental impact • Extensive remedial actions probably required	• Long-term (>10 years) large-scale environmental impact • Extensive and ongoing remedial actions probably required

Table A.3 Risk Matrix – Likelihood and Consequence

			Consequence					
	Description		Insignificant C6	Minor C5	Moderate C4	Major C3	Severe C2	Catastrophic C1
Likelihood	Almost certain	L1	D	C	B	A	A	A
	Very likely	L2	D	C	B	B	A	A
	Likely	L3	D	C	C	B	B	A
	Unlikely	L4	D	D	C	C	B	B
	Very unlikely	L5	D	D	D	C	C	B
	Almost unprecedented	L6	D	D	D	D	C	C

Attachment B. Risk Register

#	Hazard	Climate risk cause	Risk/hazard description	Consequence/impact	BAU risk controls	Life of asset	L/hood	Consequence: Safety	Customer Satisfaction	Everyday Service Delivery	Financial Sustainability	Reputation and Integrity	People	Project Delivery	Regulations and Compliance	Environment	Max consequence (min number)	Inherent Risk	Planned/proposed additional risk controls	L/hood	Consequence: Safety	Customer Satisfaction	Everyday Service Delivery	Financial Sustainability	Reputation and Integrity	People	Project Delivery	Regulations and Compliance	Environment	Max consequence (min number)	Residual Risk
1	ExTmp	Increased high temperatures extremes and more frequent incidence and severity of heatwaves.	Road surface cracks or becomes degraded due to inability to cope with extreme heat.	Partial road closures, increased maintenance requirements, potential for car accidents.	Regular replacement of wearing course (10-15 years).	10-20	4	5	5		6						5	L	No additional control	4	5	5		6						5	L
2	ExTmp	Increased high temperatures extremes and more frequent incidence and severity of heatwaves.	Bridge infrastructure components are unsuited to future climate extremes. Example is bridge deck expansion joints are inadequately sized or unable to cope with greater maximum temperatures.	Additional wear on infrastructure causing damage or increased maintenance requirement.	Regular replacement of expansion joints (4 years)	>50	3				6						6	L	No additional control	3				6						6	L
3	ExTmp	Increased high temperatures extremes and more frequent incidence and severity of heatwaves.	Maintenance activities have to be postponed due to extreme heat.	Delay in maintenance activities causes a backlog in work.	Work practices (Work Health and Safety Planning) for extreme heat days to avoid excessive heat (and provide cooling).	≤10	3				6		4				4	M	No additional control. WHS planning to take adaptive management approach.	3				6		4				4	M
4	ExTmp	Increased high temperatures extremes and more frequent incidence and severity of heatwaves.	Transformers / back up generation and substations used for traffic control systems are unable to cope with periods of extreme heat and fail.	Failure of electronic monitoring and communication systems along the roadway provides less control for staff, and increases risk of traffic jams. Increased maintenance requirement and need to replace equipment more frequently. Potential additional costs associated with providing cooling for electronic equipment.	Standard cooling for electronic equipment based on historical climate.	20-50	4	6	5		6		5				5	L	Consider a wider range of temperatures when specifying electronic equipment noting that temperature extremes have been experienced in recent years.	5	6	5		6		5				5	L
5	ExTmp	Increased high temperatures extremes and more frequent incidence and severity of heatwaves.	Revegetated areas are unable to survive in higher temperatures and during extreme heatwaves.	Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance.	Ongoing asset maintenance program	>50	4		5			6				4	4	M	Detailed design to consider drought tolerance of species selected for revegetation. Choosing species that require little or no irrigation will also have potable water reduction benefits.	4		5			6				4	4	M
6	Drt	Increased length and severity of seasonal drought.	Embankments, retaining walls and noise walls become destabilised due to cracking in soil surrounding foundations as it dries out.	Increased maintenance / repair requirements. Potential closure of road during maintenance / repair.	Standard tolerances for such installations as per Australian Standards	>50	6		5		6						5	L	No additional control	6		5		6						5	L
7	Drt	Increased length and severity of seasonal drought.	Revegetated areas are unable to survive in drought conditions.	Reduction of visual amenity results in complaints. Reduction in vegetation cover results in instability to embankments and drainage channels requiring increased maintenance.	Ongoing asset maintenance program	>50	4		5		6	6				4	4	M	Detailed design to consider drought tolerance of species selected for revegetation. Choosing species that require little or no irrigation will also have potable water reduction benefits.	4		5		6	6				4	4	M
8	Comb	Increase in the frequency and intensity of severe rainfall events with Sea Level Rise	Increased flooding (extent and depth) covers and damages areas previously modelled / designed to be immune from flooding.	Flooding damage to road and road infrastructure (including electrical infrastructure) which could temporarily close the road and severely delay traffic. Impact would require clean up and repair depending on level of damage. Impact could extend to neighbouring properties due to inability of flood waters to pass through the alignment.	Detailed design to review climate change scenarios presented in Flooding and Hydrology paper and confirm whether any changes are appropriate to deliver short- or long-term flood protection,	>50	2		3	3	5	3				3	3	H		2		3	3	5	3				3	3	H
9	Comb	Increase in the frequency and intensity of severe rainfall events with Sea Level Rise	Increased flooding (extent and depth) overwhelms areas previously modelled / designed to be immune from flooding.	Flooding / standing water causes accidents for road users resulting in safety incidents	Detailed design to review climate change scenarios presented in Flooding and Hydrology paper and confirm whether any changes are appropriate to deliver short- or long-term flood protection,	>50	2	2	3	3		3					2	VH		2	2	3	3		3					2	VH
10	Swfld	Increase in the frequency and intensity of severe rainfall events.	Drainage channels and culverts are too small as storms are more severe as a result of climate change. Exits of culverts suffer increased scour.	Culverts and drainage channels are overwhelmed causing increased flooding on the up flow side of the culverts, and increased scour at the outflows. This results in increased road closures, and increased maintenance / rectification costs. Diverted water may lead to increased flooding at existing properties.	Detailed design to review climate change scenarios presented in Flooding and Hydrology paper and confirm whether any changes are appropriate to deliver short- or long-term flood protection,	>50	2		5		6	3				4	3	H		2		5		6	3				4	3	H
11	BF	More severe fire weather and elevated fire weather conditions.	Increased local bushfires cause decreased visibility due to smoke effects	Road users suffer reduced visibility due to smoke effects resulting in accidents.	Bushfire risk management plan.	>50	2	5	6								5	M	Consider variable messaging signs (permanent or temporary) to provide hazard warning to motorists.	3	5	6								5	M
12	BF	More severe fire weather and elevated fire weather conditions.	Increased local bushfires cause damage to structures such as retaining walls and bridges.	Bushfires in the proximity of the proposal cause direct damage to structures, utilities and fauna connectivity measures, resulting in road closures while repairs / damage assessment is carried out.	Bushfire risk management plan. Standard asset protection zones around buildings	>50	5		5		5					4	4	L	No additional control	5		5		5					4	4	L
13	SLR	Sea Level Rise	Sea Level Rise affects structure / stability of Ironbark Creek Bridge	Bridge design or structure is compromised by elevated sea water levels in Ironbark Creek / Hunter River resulting in accelerated degradation or performance below specification.	Levels to be reviewed at detailed design to ensure no reduction in likely asset life.	>50	4				6						6	L		4				6						6	L
14	SLR	Sea Level Rise	Exacerbated by the project; Sea Level Rise affects protected ecosystems alongside the Hunter River	Wetlands between Maitland Road and the Hunter River become permanently inundated resulting in total or partial loss of the ecosystem.	Detailed design to confirm that the project does not influence likely inundation of wetlands and revisit risk rating.	>50	6									2	2	M		6									2	2	M
15	SLR	Sea Level Rise	Sea Level Rise results in overtopping of road or ancillary infrastructure resulting in damage to asset	Very low-lying areas of the proposal become regularly inundated due to sea level rise requiring repair and adjustment to provide ongoing resilience.	Flood levels to be reviewed at detailed design to confirm tolerance of low-lying areas to flooding.	>50	3				6						6	L		3				6						6	L

								Consequence													Consequence								
#	Hazard	Climate risk cause	Risk/hazard description	Consequence/impact	BAU risk controls	Life of asset	L/hood	Safety	Customer Satisfaction	Everyday Service Delivery	Financial Sustainability	Reputation and Integrity	People	Project Delivery	Regulations and Compliance	Environment	Max consequence (min number)	Inherent Risk	Planned/proposed additional risk controls	L/hood	Safety	Customer Satisfaction	Everyday Service Delivery	Financial Sustainability	Reputation and Integrity	People	Project Delivery	Regulations and Compliance	Environment	Max consequence (min number)	Residual Risk
16	CO2	Increased concentration of carbon dioxide in the atmosphere.	Carbonation occurs to a greater depth in concrete structures, allowing exposure and degradation of reinforcement. Retaining walls, piers and bridge deck elements are degraded quicker than anticipated shortening their design life.	Shorter design life results in greater levels of inspection and maintenance needed, increase asset operational costs.	Australian Standards (AS5100) which (2017 version) makes reference to consideration of climate change. Concrete design accounts for carbonation based on historical CO2 levels in atmosphere.	>50	4				5				4		4	M	Review material durability / concrete classification for the Ironbark Creek Bridge(s) to ensure a suitable exposure classification is assigned to include future climate.	5				5				4		4	L