WestConnex

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New M5

Environmental Impact Statement

Climate change risk assessment framework

Appendix W

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Contents

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Glossary of terms and abbreviations

Term	Meaning
Adaptation	The process of adjustment to actual or expected climate and its effects. Adaptation can be autonomous or planned (CSIRO and BoM 2015a).
AR5	IPCC Fifth Assessment Report
BoM	Bureau of Meteorology
Bushfire	Bushfires in Australia occur as grass fires or forest fires.
Climate change	A change in the state of the climate that can be identified (eg by statistical tests) by changes in the mean and/or variability of its properties, and that persists for an extended period of time, typically decades or longer (CSIRO and BoM 2015a).
Climate projection	A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which in turn is based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised (CSIRO and BoM 2015a).
CO2	Carbon dioxide. A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass, of land use changes and of industrial processes (eg cement production). It is the principle anthropogenic greenhouse gas that affects the Earth's radiative balance (CSIRO and BoM 2015a).
CSIRO	Commonwealth Scientific and Industrial Research Organisation.
Emissions scenario	A plausible representation of the future development of emissions of substances that are potentially radiatively active (eg greenhouse gases, aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships (CSIRO and BoM 2015a).
ENSO	El Nino-Southern Oscillation. A fluctuation in global scale tropical and subtropical surface pressure, wind, sea surface temperature, and rainfall, and an exchange of air between the south-east Pacific subtropical high and the Indonesian equatorial low (CSIRO and BoM 2015a).
Extreme temperature	Definitions vary, however this Chapter refers to extreme temperature as hot days (days above 35˚C) and very hot days (days above 40˚C).
Extreme rainfall	There is no consistent global definition for extreme rainfall. It can be defined by either relative rainfall at a location (amount relative to averages), or absolute rainfall amounts (eg over 100 millimetres in a single day). In this Chapter, an extreme rainfall event is defined as the wettest day in 20 years.
FFDI	Forest fire danger index.
Fire weather	Weather conditions conducive to triggering and sustaining wild fires, usually based on a set of indicators and combinations of indicators including temperature, soil moisture, humidity, and wind. Fire weather does not include the presence or absence of fuel load (CSIRO and BoM 2015a).
Greenhouse gas	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary greenhouse gases in the Earth's atmosphere (CSIRO and BoM 2015a).
IOD	Indian Ocean Dipole. Large-scale mode of interannual variability of sea surface temperature in the Indian Ocean. This pattern manifests through a zonal gradient of tropical sea surface temperature, which in its positive phase in September to November shows cooling off Sumatra and warming off Somalia in the west, combined with anomalous easterlies along the equator (CSIRO and BoM 2015a).

Term	Meaning
IPCC	Intergovernmental Panel on Climate Change
Mean rainfall	The arithmetically averaged total amount of precipitation recorded during a calendar month or year (BoM 2007).
NARCliM	NSW/ACT Regional Climate Modelling
O/C	Overall construction cost
RCP	Representative concentration pathways. Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/cover (CSIRO and BoM 2015a).
WCL	Workers compensation liability

W1. Risk assessment framework

Table W-1 and **Table W-2** provide the likelihood and consequence criteria used for the climate change risk assessment. The criteria are from the Guidelines for Risk Management (RMS, 2014).

Table W-1 Likelihood criteria

Likelihood rating	Description		Probability parameters	
Extreme	Almost Certain	The event is expected to occur in most circumstances	>90% probability	>1 in one year
High	Likely	The event will probably occur in most circumstances	51% to 90% probability	1 in 10 years
Medium	Moderate	The event should occur at some time	21% to 50% probability	1 in 50 years
Low	Unlikely	The event could occur at some time	10% to 20%	1 in 100 years
Negligible	Rare	The event might occur in exceptional circumstances	<10% probability	1 in 1000 years

Source: Guidelines for Risk Management (Roads and Maritime 2014)

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Table W-2 Consequence criteria - impacts on the project objectives (Roads and Maritime Guidelines for Risk Management)

Consequence rating	Time		Cost		Safety		Environment Delivery Operation	Traffic flow peak hour	Local traffic	Community attitude	Fit for purpose Defects Accidents Maintenance costs
	Development	Delivery	Development	Delivery	Delivery	Operation					
Extreme	Year	Months	$(25% overall construction cost)	$(10% overall construction cost)	Worker's Compensation Liability > $250,000 Death, permanent loss of physical or mental amenity	Multiple Worker's Compensation Liability > $250,000 Death, permanent loss of physical or mental amenity	Major environmental damage and/or delay due to legal finding in Land and Environment	No improvement	Severe disruption	Severe community protests	Functional failure
High	Months	Months	$(15% overall construction cost)	$(7% overall construction cost)	Worker's Compensation Liability $10,001 – $250,000 Lost time >= 5 days	Worker's Compensation Liability >$250,000 Death, permanent loss of physical or mental amenity	Serious environmental damage and/or delay due to public inquiry or EPA major notice	Marginal improvement	Disruption	Community protests	Serious functional failure
Medium	Months	Months	$(7.5% overall construction cost)	$(4% overall construction cost)	Worker's Compensation Liability $1,001 – $10,000 Lost time 1-4 days	Worker's Compensation Liability $10,001-$250,000 Lost time >= 5 days	Environmental damage and/or EPA infringement notice			Daily complaints	Minor functional failure

Consequence rating	Time: Development	Time: Delivery	Cost: Development	Cost: Delivery	Safety: Delivery	Safety: Operation	Environment Delivery Operation	Traffic flow peak hour	Local traffic	Community attitude	Fit for purpose Defects Accidents Maintenance costs
Low	Months	Weeks	$(1% overall construction cost)	$(1% overall construction cost)	Worker's Compensation Liability $251 – $1000 Lost time >= 1 day	Worker's Compensation Liability $1001 – $10,000 Lost time 1-4 days	Minor environmental damage and/or minor EPA infringement notices, written community complaints	km/hr		Complaints	
Negligible	Weeks	Nil	$(0.1% overall construction cost)	$(0.1% overall construction cost)	Worker's Compensation Liability $1 – $250 First aid treatment (no lost time)	Worker's Compensation Liability $252 – $1000 Lost time >= 1 day	Minor repairable environmental damage Verbal community comment	km/hr		Negligible complaints	

Source: Guidelines for Risk Management (Roads and Maritime 2014)

W2. Existing and historical climate

2.1 Existing climate

Figure W-1 shows the climate profile for the project region, indicated by weather monitoring data obtained from the Sydney Airport AMO Bureau of Meteorology Monitoring Station for the period 1939 to 2015 (1929 to 2015 for rainfall data). Climate data from the Sydney Airport monitoring station is representative of conditions across the project corridor, being located around three kilometres from the eastern end of the project, and its setting within a similar physical environment (built-up, coastal and low elevation).

Figure W-1 indicates that the wettest month in the project region is June, followed by February and March. The driest month is September. Generally, January through to June has more rainfall than the second half of the year, July to December. Historical rainfall records between 1929 and 2015 record an annual mean rainfall of 1085.3 mm. Mean maximum daily temperatures range between 17°C and 18.3°C in winter, and 25.8°C and 26.4°C in summer.

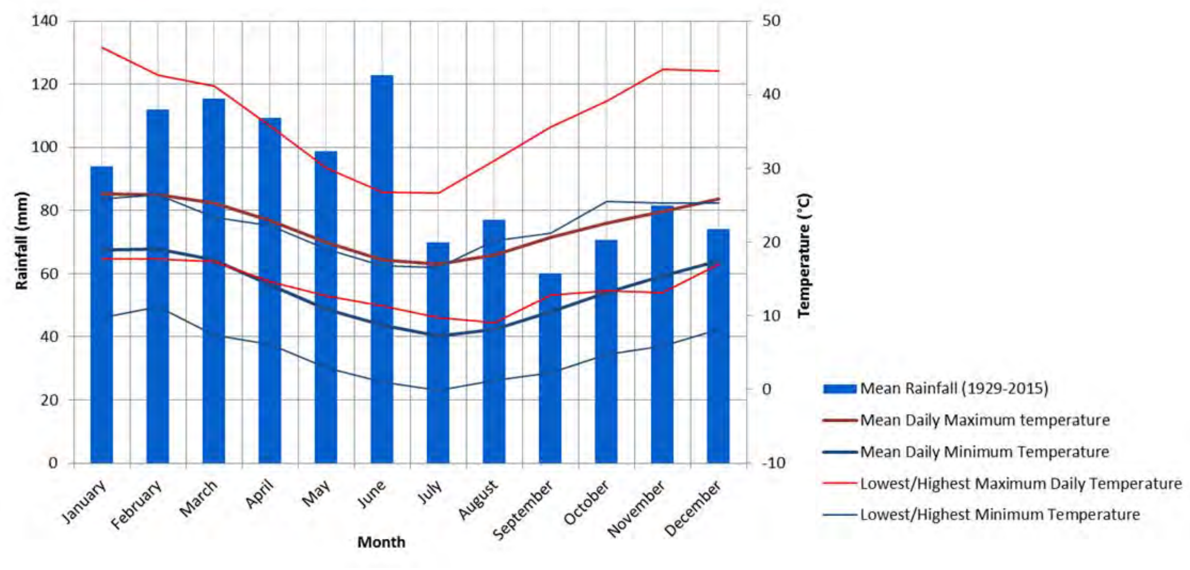

Figure W-1 Climate profile for Sydney (Source: Sydney Airport AMO BoM Monitoring Station)

2.2 Historical trends

2.2.1 Mean surface temperature

Surface air temperatures have been increasing along the east coast of Australia since national records began in 1910, and in particular, since 1960 (CSIRO and BoM, 2015). Mean surface temperature along the east coast of Australia has increased by about 0.8˚C since 1910 (CSIRO and BoM, 2015).

2.2.2 Extreme heat

Historical observations show that mean temperature changes in Australia have been accompanied by large increases in extreme temperatures (CSIRO and BoM, 2015). There has been a recent significant increase in the frequency of high-temperature extremes, and heatwave events, and a decrease in the frequency of low temperature extremes (CSIRO and BoM, 2015). The number of very warm months has increased five-fold in the past 15 years, and the frequency of very cool months has declined by around a third (CSIRO and BoM, 2015).

2.2.3 Mean annual rainfall

Rainfall in Australia is highly variable, spatially and temporally, and is influenced by a number of key local processes such as the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). As a result of the high rainfall variability in Australia, attributing observed rainfall changes to climate change is difficult. Observations indicate declines in average rainfall by 10-20 per cent in south-eastern Australia over cooler months (April to September) with some areas experiencing declines through the whole century (CSIRO and BoM, 2015). Although there remains uncertainty regarding the cause, this decline has been linked to changes in the frequency and impact of ENSO and IOD that are influenced by increasing greenhouse gases and reductions in ozone (CSIRO and BoM, 2015).

2.2.4 Extreme rainfall

In Australia, extreme rainfall is driven by ENSO, east coast low pressure systems, tropical cyclones, monsoon troughs, severe thunderstorms, cut-off lows and mid-latitude fronts (CSIRO and BoM, 2011; King et al. 2013). Historical rainfall observations show that the percentage of Australia's area receiving a greater than the 90th percentile of annual rainfall from heavy rainfall events has been increasing since the 1970s (CSIRO and BoM, 2015). However there is large regional variability, with the east coast region experiencing a significant decrease in extreme rain events (CSIRO and BoM, 2015).

2.2.5 Fire weather

In most Australian states, forest fire weather risk is quantified using the McArthur Forest Fire Danger Index (FFDI) (Luke & McArthur, 1978). FFDI is calculated using observed and modelled data on air temperature, relative humidity and wind speed in combination with an estimate of fuel levels. The FFDI incorporates fuel state through the 'drought factor' which depends on daily rainfall and time since the last rain, with an aim to account for long-term and short-term rainfall and its impact on fuel moisture.

FFDI values are classified into one of six fire danger ratings, ranging from low to catastrophic. These categories and their associated FFDI values are shown in **Table W-3**.

Table W-3 Forest fire danger index rating categories

Fire danger rating category	Forest fire danger index (FFDI)
Catastrophic	100 +
Extreme	75 -99
Severe	50 - 74
Very high	25 – 49
High	12 – 24
Low to Moderate	0 - 11

Due to the strong relationship between bushfire risk and the weather, climate change will have a significant impact on future fire weather (CSIRO and BOM, 2015). Past observations show an increase in annual cumulative FFDI over the period 1973 to 2010, across Australia (CSIRO and BoM, 2015). The trend is particularly evident in south-eastern Australia, where the fire season has extended further into spring and autumn (CSIRO and BoM, 2015). Across Australia, there has also been an increase in higher FFDI values indicating that extreme fire weather days have become more frequent over time (CSIRO and BoM, 2015).

2.2.6 Sea level

The sea level at any point in time is the consequence of the mean sea level, the state of the tides, wave set-up, responses to air pressure and local and remote near-shore winds, and may sometimes be affected by additional flows of water from on-shore (DCC, 2009a).

Over the period of 1966 to 2009, relative sea level has risen around Australia at an average rate of 1.6 mm per year, when the influence of ENSO on sea level is removed (CSIRO and BoM, 2015).

Extreme sea levels are caused by a combination of factors including storm surges, wind, waves and astronomical tides. Along the NSW coastline, the majority of storm surges are caused by east coast low weather patterns (CSIRO and BOM, 2015). Rising sea levels exacerbate extreme sea levels.

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W3. Screening

Table W-4 provides the risk screening matrix developed for the project. On one axis are the key project elements; the other axis presents the key climate variables relevant to the project. Where there is a relationship between a climate variable and a project element, this has been indicated in the matrix with an '✓'. Identified relationships form the basis of the development of risk scenarios in the following section, noting that one relationship might result in multiple risks and multiple relationships may combine to result in a single risk.

Table W-4 Risk screening matrix

		Project components													
		Tunnel drainage	Bridges over Alexandra Canal	St Peters interchange bridges	Surface drainage	Water treatment facilities	Cuttings, embankments and retaining walls	Pavement and base layers	Ancillary infrastructure (signs, traffic signals, buildings, etc)	Power supply	Tunnel ventilation (including ventilation outlet)	Alexandria Landfill leachate treatment system	Alexandria Landfill gas capture system	Landscaping	New M5 road users
Climate variable	Extreme rainfall	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓
	Mean rainfall	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓
	Extreme temperature	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓
	Mean surface temperature					✓						✓		✓	
	Mean annual wind speed		✓	✓					✓		✓				
	Atmospheric carbon dioxide (CO2)	✓	✓	✓	✓		✓		✓					✓	
	Bushfire weather										✓				✓
	Sea level rise		✓		✓	✓	✓		✓	✓		✓	✓	✓	
	Extreme sea level		✓		✓		✓		✓	✓		✓	✓	✓	

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W4. Detailed Risk Assessment

Table W-5 provides the risk scenarios identified for the project, along with their likelihood and consequence ratings and subsequent risk levels. The risks have been identified under the 2090 High emissions (RCP8.5) scenario.

Table W-5 Detailed risk assessment

Risk scenario	Likelihood	Consequence	Risk level
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated localised flood risks at Campbell Road and Gardeners Road bridge crossings over Alexandra Canal.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Alexandra Canal is tidal and thus influenced by sea level rise. Sea level is projected to rise by up to 0.88 metres by 2090. A height of 0.89 metres is the projected minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise.	Medium: • Localised flooding could adversely affect the safety of road users, and New M5 operational personnel. The risk of significant loss and damages remains low due to low water levels associated with localised flooding. • Localised flooding could lead to temporary road closure which could in turn have some adverse impacts on the road network level of service.	Medium
Increase in atmospheric CO_2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of bridge structures due to corrosion and thermal expansion of steel reinforcement in concrete and thermal expansion of steel, protective cladding, and coatings on bridges.	Low: • Atmospheric CO_2 is projected to continue to increase. • The number of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090. • The proposed bridges have a long design life, over a period which projected climate trends are likely to be experienced. • Accelerated deterioration rates due to increasing CO_2 and heat extremes are expected to be minor compared to baseline deterioration rates.	High: • Accelerated deterioration of bridges could result in bridge failure or damage. • Bridge deterioration or damages would result in reduced safety for bridge users and New M5 operational personnel. • Bridge failure or damages could result in substantial costs for rectification works. • Bridge failure or damages may result in increased road/lane closures and adverse impacts on road network level of service during rectification works.	Medium

Risk scenario	Likelihood	Consequence	Risk level
Increase in the intensity and frequency of extreme rainfall adversely affects performance of surface drainage system at western surface works due to increased runoff, leading to localised flooding of surface roads, and potential flooding of ancillary infrastructure, substations, landscaped areas and within the project tunnels.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Increase in extreme rainfall not considered in surface drainage design.	Medium: • Localised flooding could adversely affect the safety of road users, and New M5 operational personnel. The risk of significant loss and damages remains low due to low water levels associated with localised flooding. • Localised flooding could lead to damage to substations and power outages. • Localised flooding could lead to damage and functional failure of ancillary infrastructure. • Localised flooding could lead to temporary road closure which could in turn have some adverse impacts on the road network level of service.	Medium
Increase in the intensity and frequency of extreme rainfall combined with sea level rise (and increased extreme sea levels during storm surges) adversely affects performance of surface drainage system at St Peters interchange and local road upgrades due to inundation, leading to localised flooding of surface roads, ancillary infrastructure, substations, landscaped areas and within the tunnel.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Alexandra Canal (adjacent to the St Peters interchange and local road upgrades) is tidal and thus influenced by sea level rise. • Sea levels are projected to rise by up to 0.88 metres by 2090. A height of 0.89 metres is the projected minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise. • The area around the St Peters interchange and local road upgrades is presently prone to flooding.	Medium: • Localised flooding could adversely affect the safety of road users, and New M5 operational personnel. The risk of significant loss and damages remains low due to low water levels associated with localised flooding. • Localised flooding could lead to damage to substations and power outages. • Localised flooding could lead to damage and functional failure of ancillary infrastructure. • Localised flooding could lead to temporary road closure which could in turn have some adverse impacts to the road network level of service.	Medium

Risk scenario	Likelihood	Consequence	Risk level
Sea level rise causes reduced performance or failure of water treatment system due to increased water levels at the location of the submerged discharge infrastructure in Cooks River and deterioration from saline intrusion.	Medium: • Sea level is projected to rise by up to 0.88 metres by 2090.	Medium • Reduced performance of water treatment system may result in the requirement for retrofitting works to the water treatment discharge infrastructure.	Medium
Increased frequency and intensity of bushfire events due to increased bushfire weather adversely affects performance of tunnel ventilation system as a result of smoke pollution.	Low: • The annual number of days with severe fire danger is projected to increase by 130 per cent by 2090, however the probability that a bushfire will cause smoke pollution that is heavy enough to reduce the performance of tunnel is low.	High: • Reduced in tunnel air quality could have adverse impacts to the health and safety of tunnel users and New M5 operational personnel.	Medium
Decrease in mean rainfall combined with an increase in mean surface temperature and the frequency and intensity of extreme heat events, leads to exacerbated risk of dust storms adversely impacting the performance of tunnel ventilation system.	Low • Mean rainfall is projected to decrease by at least 15 per cent by 2090. • Mean surface temperature is projected to increase by up to 4.7˚C by 2090. • The number of days above 35˚C and 40˚C are projected to increase by an average of 11.0 days and 2.0 days per year respectively, by 2090.	High • Reduced in tunnel air quality could have adverse impacts to the health of tunnel users and New M5 operational personnel.	Medium

Risk scenario	Likelihood	Consequence	Risk level
Increase in frequency and intensity of extreme heat events causes higher temperatures within the tunnel.	Low • The number of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090. • Temperatures within the tunnel would be influenced by external surface temperatures as outside air would be drawn into the tunnel through the portals with the in-coming movement of vehicles and through mechanical ventilation fans. Higher temperatures are likely to be experienced within the tunnel as external surface temperatures increase, particularly on extreme temperature days. • Although temperatures within the tunnel are likely to be influenced by external surface temperatures, the tunnel is anticipated to maintain a cooler environment compared with external surface temperatures	High • High tunnel temperatures could have adverse impacts to the health of tunnel users and New M5 operational personnel.	Medium
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated risk of flooding of Alexandria Landfill Leachate Treatment System.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • The area around St Peters interchange, where the Alexandria Landfill Treatment System is located, is presently prone to flooding. • Alexandra Canal (adjacent to the Alexandria Landfill) is tidal and thus influenced by sea level rise. • Sea levels are projected to rise by up to 0.88 metres by 2090. A height of 0.89 metres is the projected minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise.	Medium: • Flooding of the landfill leachate treatment plant could lead to flooding of leachate ponds and release of leachate into waterways. Flooding could also result in failure of other components of the treatment system.	Medium

Risk scenario	Likelihood	Consequence	Risk level
Sea level rise causes failure of the underground cut-off wall at Alexandria Landfill due to raised water table.	Medium: • Sea levels are projected to rise by up to 0.88 metres by 2090. • Alexandra Canal (adjacent to Alexandria Landfill) is tidal and thus influenced by sea level rise.	Medium: • Failure of the cut-off wall could lead to contamination of the Botany Sands Aquifer due to leachate flow from the landfill. • Failure of the cut-off wall could lead to increased leachate volumes due to increased groundwater inflow.	Medium
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated risk of flooding of Alexandria Landfill gas capture system.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • The area of Alexandria Landfill is presently prone to flooding. • Alexandra Canal adjacent to Alexandria Landfill is tidal and thus influenced by sea level rise. • Sea level is projected to rise by up to 0.88 metres by 2090. A height of 0.89 metres is the projected minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise.	Medium: • Flooding of the Alexandria Landfill could result in reduce performance of the landfill gas capture system.	Medium
Increase in the intensity and frequency of extreme rainfall leads to exacerbated risk of road incidents.	Low: • Road incidents as result of extreme rainfall events already occur across the road network. The contribution of the projected changes in extreme rainfall to the risk of road incidents is expected to be minor.	High: • A road incident could lead to injury or fatality of road user/s • A road incident could lead to temporary road closure which could in turn have significant adverse impacts to the road network level of service.	Medium
Increase in frequency and intensity of extreme heat events increases the risk of heat stress conditions for operational personnel.	Low: • Measures to manage heat stress are considered in the project Work Health and Safety Management Plan.	High: • Heat stress could have adverse impacts to the health of operational personnel.	Medium

Risk scenario	Likelihood	Consequence	Risk level
Increase in atmospheric CO_2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of the surface drainage system due to thermal expansion and corrosion of steel and reinforced concrete structures.	Low: • Atmospheric CO_2 is projected to continue to increase. • The number of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090. • The surface drainage system has a long design life, over a period which the projected climate trends are likely to be experienced. • Accelerated deterioration rates due to increasing CO_2 and heat extremes are expected to be minor compared to baseline deterioration rates.	Medium: • Accelerated deterioration of the concrete and steel components of the surface drainage system could result in increased maintenance costs and reduced safety due to hazardous structures or road collapse in sections of road underlain by drainage systems. • Damages to the surface drainage system could increase localised flood risk as a result of functional failure. • Increased maintenance may result in increased road/lane closures and adverse impacts to road network level of service.	Low
Increase in the intensity and frequency of extreme rainfall adversely affects performance of tunnel drainage system due to increased groundwater infiltration, leading to reduced capacity of drainage sump and pumping system and subsequent localised tunnel flooding.	Low: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Decrease in mean rainfall and increase in evaporation (due to increased mean surface temperature) may change the likelihood of flooding during dry periods due to impacts on infiltration and groundwater recharge rates. • It is expected that the event could occur at some time.	Medium: • Localised flooding could adversely affect the safety of tunnel users, and New M5 operational personnel. The risk of significant loss and damages remains low due to low water levels associated with localised flooding. • Localised flooding could lead to damage to substations and power outages. • Localised flooding could lead to damage and functional failure of ancillary infrastructure. • Localised flooding could lead temporary tunnel closure which could in turn have some adverse impacts to the road network level of service.	Low

Risk scenario	Likelihood	Consequence	Risk level
Increase in atmospheric CO_2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of concrete retaining walls due to thermal expansion and corrosion of steel and reinforced concrete structures.	Low: • Atmospheric CO_2 is projected to continue to increase. • The number of days of 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090. • Accelerated deterioration rates due to increasing CO_2 and heat extremes are expected to be minor compared to baseline deterioration rates.	Low: • Accelerated deterioration of concrete retaining walls could result in increased maintenance costs.	Low
Increase in frequency and intensity of extreme heat events causes power outages due to spikes in energy demand across the grid for cooling systems.	Low: • The number of days above 35˚C and 40˚C are projected to increase by an average of 11.0 days and 2.0 days per year respectively, by 2090. • The power supply system design comprises two redundant high voltage power supplies. In the event of failure of both supplies, an uninterruptable power system would provide 90 minutes of power to the operation and maintenance control systems, and 30 minutes of power to essential loads (such as tunnel ventilation).	Medium • Power outage could result in traffic delays or reduced safety for road users and New M5 operational personnel due to functional failure of powered infrastructure.	Low
Increase in frequency and intensity of extreme heat events leads to reduced efficiency of power generation and transmission, resulting in increased electricity consumption.	Medium: • The numbers of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090.	Low • Increased electricity consumption would result in increased operational costs.	Low

Risk scenario	Likelihood	Consequence	Risk level
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated risk of flooding of landscaped areas.	Medium: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Sea level is projected to rise by up to 0.88 metres by 2090. A height of 0.89 metres is the projected minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise.	Low: • Landscaped areas damaged from flooding may result in reduced visual amenity, as well as reduced habitat value and ecosystem function. This could adversely impact flora and fauna. • Damaged landscaped areas may result in increased costs for rehabilitation and maintenance.	Low
Increase in frequency and intensity of extreme heat events leads to reduced efficiency and function of vehicles utilising the tunnel, increasing the number of vehicles overheating and breaking down.	Low: • The number of days above 35˚C and 40˚C are projected to increase by an average of 11.0 days and 2.0 days per year respectively, by 2090 • The tunnel is anticipated to maintain a cooler environment compared with surface temperatures and the likelihood of heat stress impacts on vehicles is low.	Low • The tunnel design includes breakdown bays and provision of a shoulder on the left and the right side of the road which could be used to provide temporary accommodation for broken down vehicles and access for emergency vehicles.	Negligible
Changes in wind speed adversely affect structural stability of bridges.	Negligible: • Wind speed is not projected to increase more than one per cent by 2090. • A large degree of redundancy is built into the design of bridges for structural stability and safety.	Low: • Changes in wind speed are unlikely to result in structural damage to bridges, however it may cause minor structural stress.	Negligible

Risk scenario	Likelihood	Consequence	Risk level
Increase in the intensity and frequency of extreme rainfall and exacerbated risk of failure of water treatment system due to surface water and/ or groundwater inflow exceeding capacity of treatment facilities.	Low: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Decrease in mean rainfall and increase in evaporation (due to increased mean surface temperature) may reduce the likelihood of high inflows to the water treatment system during dry periods. • The design of the water treatment plant incorporates contingency for high inflows of water, whereby high inflows from the western section of the project (from the western surface works to the Cooks River) can overflow from the first holding tank into the deluge holding tank and then be discharged straight to the Cooks River.	Low: • The contingency for high flows incorporated into the design of the water treatment plant would mitigate flooding of the water treatment system and drainage system. However, there may be downstream water quality impacts when untreated water is discharged directly to Cooks River.	Negligible
Increase in atmospheric CO2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of tunnel drainage system due to corrosion of steel and reinforced concrete structures.	Low: • Atmospheric CO2 is projected to continue to increase. • The tunnel drainage system has a long design life, over a period which the projected climate trends are likely to be experienced. • Accelerated deterioration rates due to increasing CO2 are expected to be minor compared to baseline deterioration rates. • Although temperatures within the tunnel are likely to be influenced by external surface temperatures, the tunnel is anticipated to maintain a cooler environment compared with external surface temperatures	Low: • Accelerated deterioration of the concrete and steel components of the tunnel infrastructure and tunnel drainage system could result in increased operational costs and reduced safety due to hazardous structures or increased tunnel flood risk as a result of functional failure of drainage system.	Negligible

Risk scenario	Likelihood	Consequence	Risk level
Decrease in mean rainfall and increase in mean surface temperature and the intensity and frequency of extreme heat events adversely impacts landscaped areas.	Low: • Mean rainfall is projected to decrease by at least 15 per cent by 2090. • Mean surface temperature is projected to increase by up to 4.7˚C by 2090. • The number of days above 35˚C and 40˚C are projected to increase by an average of 11.0 days and 2.0 days per year respectively, by 2090.	Low: • Landscaped areas unable to adapt to changing climate may result in reduced visual amenity, as well as reduced habitat value and ecosystem function. • Deteriorated landscaped areas may result in increased costs for rehabilitation and maintenance.	Negligible
Changes in wind speed adversely affect performance of tunnel ventilation system.	Negligible: • Wind speed is not projected to increase more than one per cent by 2090.	Low: • The impacts of wind on the performance of tunnel ventilation system would be negligible.	Negligible
Increase in the intensity and frequency of extreme rainfall, leads to exacerbated risk of slope instability or landslips at surface works.	Low: • Extreme rainfall is projected to increase by between 10 per cent and 30 per cent by 2090. There is substantial uncertainty in extreme rainfall projections. • Risk of slope instability during extreme rainfall events may be exacerbated by a decrease in mean rainfall, and increase in evaporation (due to increase in mean temperature). • Cuttings and embankments are minimal.	Low: • Subsidence or a landslip could result in minor volumes of material movement and may cause minor damage to pavement, localised sedimentation of the roadway, and associated minor safety hazards to users of the roadway.	Negligible
Increase in frequency and intensity of extreme heat events leads to accelerated deterioration of road pavement.	Low: • The number of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2.0 days per year respectively, by 2090. • The design life of road pavement is short. • Road maintenance including resealing would occur at intervals too short for impacts to occur.	Low: • Accelerated deterioration of road pavement could result in increased maintenance costs. • The thermal tolerance of road pavement is relatively high.	Negligible

Risk scenario	Likelihood	Consequence	Risk level
Changes in wind speed adversely affects structural stability of ancillary infrastructure	Negligible: • Wind speed is not projected to increase more than one per cent by 2090. • There is a degree of redundancy built into the design of infrastructure.	Low: • Structural instability of ancillary infrastructure could result in traffic delays or reduced safety for road users and New M5 operational personnel due to physical damage or functional failure. • Increased maintenance may result in increased road/lane closures and adverse impacts to road network level of service. • Increased maintenance costs.	Negligible

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