Appendix W

Climate change risk assessment framework

WestConnex

Appendix W Detailed risk assessment information

Risk assessment framework

Table W-1 and 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	Greater than 90% probability that the event is expected to occur	Event is expected to occur greater than once per year
High	Likely	The event will probably occur in most circumstances	51% to 90% probability that the event is expected to occur	Event is expected to occur once in 10 years
Medium	Moderate	The event should occur at some time	21% to 50% probability that the event is expected to occur	Event is expected to occur once in 50 years
Low	Unlikely	The event could occur at some time	10% to 20% probability that the event is expected to occur	Event is expected to occur once in 100 years
Negligible	Rare	The event might occur in exceptional circumstances	Less than 10% probability that the event is expected to occur	Event is expected to occur once in 1000 years

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

Table W2 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% of the overall construction cost	10% of the overall constructi on cost	Workers Compens ation Liability > $250,000 Death, permanen t loss of physical or mental amenity	Multiple Workers Compensat ion 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 improvemen t	Severe disruptio n	Severe community protests	Functional failure
High	Months	Months	15% of the overall construction cost	7% of the overall constructi on cost	Workers Compens ation Liability $10,001 – $250,000 Lost time >= 5 days	Workers Compensat ion 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 improvemen t	Disruptio n	Communit y Protests	Serious functional failure

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					
Medium	Months	Months	7.5% of the overall construction cost	(4% of the overall construction cost	Workers Compensation Liability $1,001 – $10,000 Lost time 1-4 days	Workers Compensation Liability $10,001- $250,000 Lost time >= 5 days	Environmental damage and/or EPA infringement notice			Daily complaints	Minor functional failure
Low	Months	Weeks	1% of the overall construction cost	1% of the overall construction cost	Workers Compensation Liability $251 – $1000 Lost time >= 1 day	Workers 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% of the overall construction cost	0.1% of the overall construction cost	Workers Compensation Liability $1 – $250 First aid treatment (no lost time)	Workers Compensation Liability $252 – $1000 Lost time >= 1 day	Minor repairable environmental damage Verbal community comment	km/hr		Negligible complaints	

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

Existing and historical climate

Existing climate

Figure W-1 shows the climate profile for the project region, indicated by weather monitoring data obtained from the Sydney Airport AMO BoM 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 nine kilometres from the eastern end of the project, and its setting within a similar physical environment (built-up, coastal and low elevation). Sydney Airport AMO BoM Monitoring Station was the most appropriate station compared to other nearby stations as it has the longest continuous dataset and is located closest to the project site. The BoM Monitoring Station at Canterbury Racecourse, located approximately four kilometres from the project site has been open only since 1995 and therefore does not have a sufficient period of data. The BoM Monitoring Station at Bankstown Airport, located approximately 10 kilometres south-west of the project site has climate data for the period 1968 to 2015.

Figure W-1 indicates that the wettest month on average in the project region is June, followed by February and March, and the driest 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 millimetres. Mean maximum daily temperatures range between 17°C and 18.3°C in winter, and 25.8°C and 26.4°C in summer.

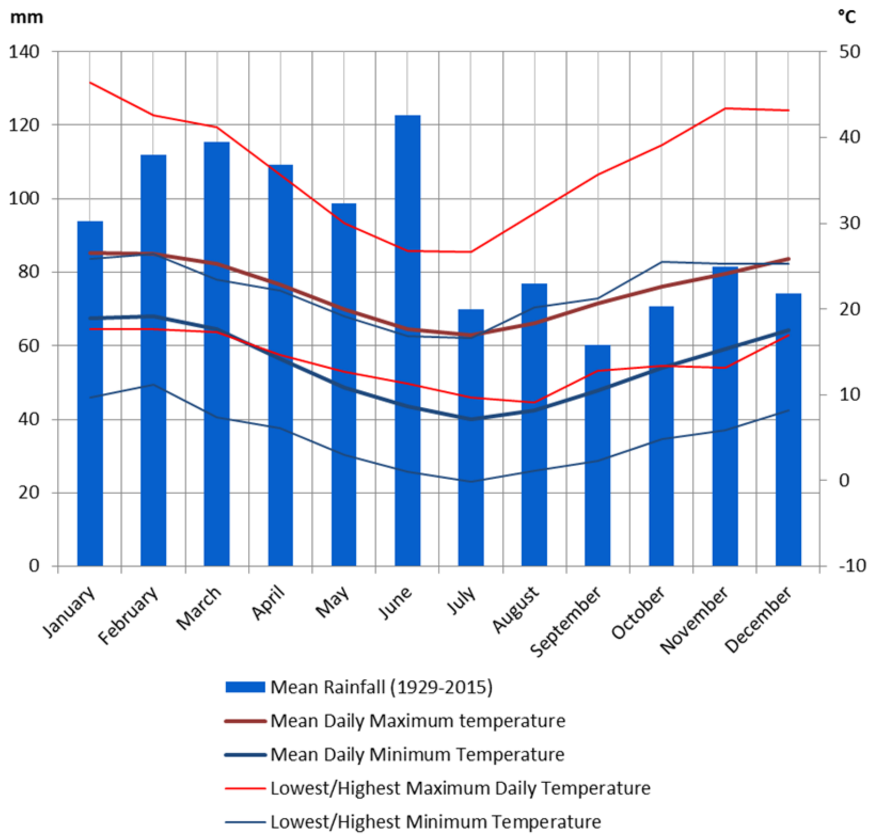

Figure W-1 Climate profile for Sydney (Source: Sydney Airport AMO BoM Monitoring Station)

Historical trends

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 2015b). Mean surface temperature along the east coast of Australia has increased by about 0.8˚C since 1910 (CSIRO and BoM 2015b).

Extreme temperature

Historical observations show that mean temperature changes in Australia have been accompanied by large increases in extreme temperatures (CSIRO and BoM 2015b). 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 2015b). 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 2015b).

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 Nino-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). As a result of the high rainfall variability in Australia, it is difficult to attribute observed rainfall changes to climate change. Observations indicate declines in average rainfall of 10 to 20 percent in south-eastern Australia over cooler months (April to September), with some areas experiencing declines through the whole century (CSIRO and BoM 2015b). Although there remains uncertainty regarding the cause, this decline has been linked to changes in the frequency and impact of ENSO and IOD, which are influenced by increasing greenhouse gases and reductions in ozone (CSIRO and BoM 2015b).

Extreme rainfall

In Australia, extreme rainfall is driven by ENSO, east coast lows, 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 that receives more than 90 per cent of its annual rainfall from heavy rainfall events has been increasing since the 1970s (CSIRO and BoM 2015b). However, there is large regional variability, with the east coast region experiencing a significant decrease in extreme rainfall events (CSIRO and BoM 2015b).

Screening

Table W-3 provides the risk screening matrix developed for the project. The key project elements are shown on the top axis, and the left axis presents the key climate variables relevant to the project. Where there is a direct or indirect 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 that multiple relationships may combine to result in a single risk.

Table W-3 Risk screening matrix

Climate variable		Tunnel drainage	Tunnel infrastructure	All bridges	Bridges over watercourses (only)	Surface drainage	Cuttings, embankments and retaining walls	Pavement and base layers	Ancillary infrastructure (signs, traffic signals, buildings etc)	Tunnel ventilation system (including ventilation outlet)	Power supply	Water treatment facilities	Landscaping	M4 East road users
	Extreme rainfall	✓			✓	✓	✓		✓		✓	✓	✓	✓
	Extreme temperature	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
	Mean surface temperature											✓	✓	
	Wind speed			✓					✓	✓				
	Mean rainfall	✓			✓	✓	✓		✓		✓	✓	✓	✓
	Atmospheric carbon dioxide (CO_2)	✓	✓	✓		✓	✓		✓	✓			✓	
	Bushfire weather									✓				✓
	Sea level rise					✓								

Detailed risk assessment

Table W-4 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-4 Detailed risk assessment

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 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 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 • 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 damages • Bridge failure or damages would result in reduced safety for bridge users and 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 to 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 due to increased runoff, leading to localised flooding of surface roads, cycle and pedestrian paths, landscaped areas, and within the tunnel.	Medium	• Extreme rainfall is projected to increase by between 10% and 30% by 2090 • Increases in extreme rainfall have not yet been considered in surface drainage system design • There is substantial uncertainty in extreme rainfall projections.	Medium	• Localised flooding could adversely affect the safety of road users and operational personnel • 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 significant adverse impacts to the road network level of service.	Medium
Increase in the intensity and frequency of extreme rainfall and exacerbated risk of failure of water treatment facilities due to water inflow exceeding the capacity of treatment facilities.	Medium	• Extreme rainfall is projected to increase by between 10% and 30% by 2090 • The level of redundancy in the capacity of the water treatment facilities is uncertain. This would be determined during detailed design. • There is substantial uncertainty in extreme rainfall projections.	Medium	• If the design of the water treatment facilities does not include contingency measures for excess water inflow (such as a water treatment facility bypass, increased sedimentation basin capacity etc), this could result in reduced performance of the drainage systems and lead to localised flooding. • Failure of the water treatment facilities could result in the release of untreated water.	Medium

Risk scenario	Likelihood		Consequence		Risk level
Increase in frequency and intensity of extreme heat events causes power outages due to spikes in energy demand across the grid for cooling systems.	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 • Back-up power supply is designed to last at least one hour.	Medium	• Power outage could result in traffic delays or reduced safety for road users and operational personnel due to functional failure of powered infrastructure.	Medium
Increase in the intensity and frequency of extreme rainfall and exacerbated risk of flooding of tunnels, and exacerbated risk of failure of tunnel dewatering and water treatment facilities due to power outage and/or water inflow exceeding the capacity of treatment facilities.	Low	• Extreme rainfall is projected to increase by between 10% and 30% by 2090 • The level of redundancy in the capacity of the water treatment facilities is uncertain. This would be determined during detailed design. • There is substantial uncertainty in extreme rainfall projections. • Back-up power supply is designed to last at least one hour.	High	• If the design of the water treatment facilities does not include contingency measures for excess water inflow (such as a water treatment facility bypass, increased sedimentation basin capacity etc), this could result in reduced performance of the drainage systems and lead to localised flooding. • Failure of the water treatment facilities could result in the release of untreated water. • Flooding of the tunnels could lead to temporary road closure which could in turn have adverse impacts to the road network level of service.	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

Risk scenario	Likelihood		Consequence		Risk level
Increase in frequency and intensity of extreme heat events reduces performance of tunnel ventilation.	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.	High	• High tunnel temperatures could have adverse impacts to the health of tunnel users and operational personnel.	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
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% 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 of tunnel users and 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 • The tunnel is anticipated to maintain a cooler environment compared with surface temperatures.	High	• Reduced in tunnel air quality could have adverse impacts to the health of tunnel users and operational personnel.	Medium

Risk scenario	Likelihood		Consequence		Risk level
Stormwater pipes which drain into Canada Bay become gradually inundated from sea level rise, and deteriorated from saline intrusion, reducing the performance of the drainage network.	Medium	• Sea level is projected to increase by 0.44 m to 0.88 m by 2090, resulting in rising levels of Canada Bay.	Medium	• Inundation of drainage pipes would reduce the performance of the drainage system and potentially result in localised flooding • Substantial modification works would be required to rectify the drainage system. This would result in significant costs, and likely disrupt network level of service during construction.	Medium
Increase in atmospheric CO_2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of 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 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 • 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 reduced safety due to hazardous structures or road collapse in sections of road underlain by drainage systems • Damages to the surface drainage system could result in significant costs for the replacement of drainage assets • Damages to the surface drainage system could increase localised flood risk as a result of functional failure .	Low

Risk scenario	Likelihood		Consequence		Risk level
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% and 30% by 2090 • Increases in extreme rainfall have not yet been considered in the tunnel drainage system design • Decrease in mean rainfall may change the likelihood of flooding during dry periods due to impacts on infiltration and groundwater recharge rates • The relationship between rainfall and groundwater in the context of the project is uncertain. It is expected that the event could occur at some time.	Medium	• Localised flooding could adversely affect the safety of tunnel users and operational personnel • 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 significant adverse impacts to the road network level of service.	Low
Increase in the intensity and frequency of extreme rainfall and exacerbated localised flood risks at Saleyards Creek bridge crossing and on ramp at Powells Creek.	Low	• Extreme rainfall is projected to increase by between 10% and 30% by 2090 • The existing bridge over Saleyards Creek is designed for a historical 1 in 100 year flood event.	Medium	• Exacerbated localised flooding could adversely affect the safety of road users and operational personnel • Localised flooding could lead to temporary road closure which could in turn have significant adverse impacts to the road network level of service.	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 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 numbers of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2 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.	Negligible
Changes in wind speed adversely affect performance of tunnel ventilation system.	Negligible	• Wind speed is not projected to increase by more than 1% by 2090.	Low	• The impacts of wind on the performance of tunnel ventilation system would be negligible.	Negligible
Changes in wind speed adversely affect structural stability of bridges.	Negligible	• Wind speed is not projected to increase by more than 1% by 2090 • There is a large degree of redundancy 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
Changes in wind speed adversely affects structural stability of ancillary infrastructure	Negligible	• Wind speed is not projected to increase by more than 1% by 2090 • There is a large degree of redundancy built into the design of infrastructure for structural stability and safety.	Low	• Structural instability of ancillary infrastructure could result in traffic delays or reduced safety for road users and operational personnel due to physical damage or functional failure.	Negligible

Risk scenario	Likelihood		Consequence		Risk level
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% and 30% by 2090 • 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) • There are minor isolated areas of cutting/embankments.	Low	• Subsidence or a landslide would 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 atmospheric CO_2 leads and the frequency and intensity of extreme heat events leads to accelerated deterioration of tunnel infrastructure and tunnel drainage system due corrosion of steel and reinforced concrete structures.	Low	• Atmospherically CO_2 is projected to continue to increase • The tunnel infrastructure and 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 CO_2 are expected to be minor compared to baseline deterioration rates • The tunnel is anticipated to maintain a cooler environment compared with 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
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
Increase in frequency and intensity of extreme heat events leads to accelerated deterioration of road pavement.	Low	• The numbers of days above 35˚C and 40˚C are projected to increase by an average of 11 days and 2 days per year respectively • The design life of road pavement is short • Road resealing would occur at intervals too short for impacts to occur.	Low	• Accelerated deterioration of road pavement could result in increased costs • The thermal tolerance of road pavement is relatively high.	Negligible
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 and wetlands 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.	Negligible