Chapter 12

Climate and Climate Change

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12. CLIMATE AND CLIMATE CHANGE

12.1 Introduction

This chapter describes the existing climatic conditions for the project site and surrounding region; and describes the extremes of climate and the risks they pose to management of the project.

This chapter also describes the predictions of climate change for the region surrounding the project and the potential impacts and risks of climate change to the project. Climate change adaptation strategies are proposed where significant risks are identified.

12.2 Climate

This section summarises the existing climate for the project site. Climate data for rainfall and temperature for the project site includes daily patched-point data, from 1889 to 2012, for a point located over the project area (latitude: -21.3000; longitude: 147.8500). Daily patched-point data was sourced from the DataDrill database (The Long Paddock, 2012) which accesses grids of data interpolated (using splining and kriging techniques) from point observations by the Bureau of Meteorology (BOM, 2012a). This same data was used in the water balance model presented in **Appendix 11**. Wind data for the project site was taken from the meteorology data set used in the air quality modelling component of the project as presented in the Air Quality Assessment report prepared by Noise Mapping Australia (NMA, 2013), provided as **Appendix 23**. Climate data for relative humidity includes data taken from local monitoring information available from Moranbah and Collinsville Bureau of Meteorology (BOM) weather monitoring stations (BOM, 2012a), also presented in **Appendix 23**. This data is deemed appropriate as the site is located between these two stations.

12.2.1 Regional Climate Patterns

The project site experiences a dry tropical climate characterised by hot humid summers. The project site can experience drought, floods, heatwaves and frosts. The project site falls within the summer dominant major seasonal rainfall zone, and therefore experiences marked wet summers and dry winters. Half the rainfall occurs between the months of December to February from thunderstorms and tropical lows associated with cyclones.

12.2.2 Temperature

Average monthly maximum and minimum temperatures are derived from DataDrill and are shown in **Figure 12-1**. December has the highest average monthly temperature (33.5 ^{o}C) and July has the lowest average minimum temperature (8.1 ^{o}C).

Seasonal average minimum and maximum daily temperatures for the project site are provided in **Table 12-1** and show the seasonal variation and the expected temperature range. These temperatures are typical of the tropical Queensland climate, with warmer summer months during December, January and February and cooler winter months in June, July and August.

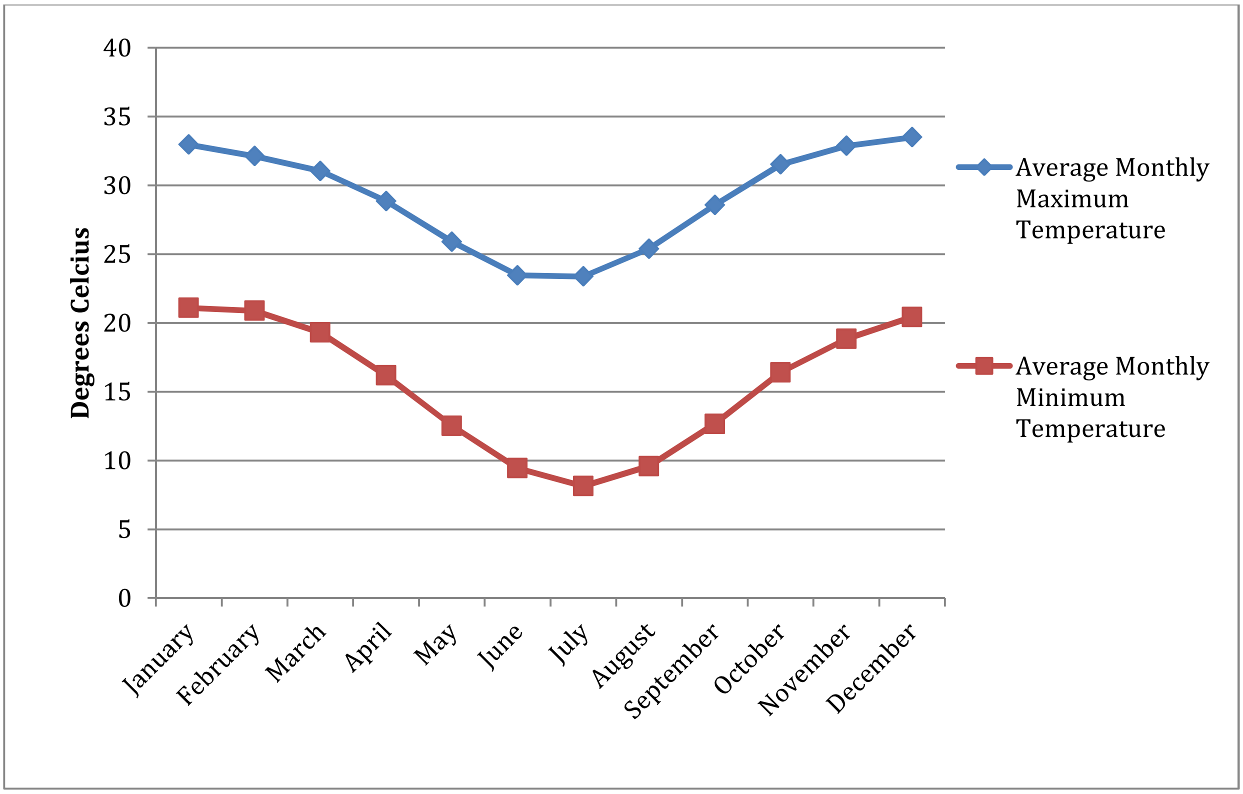


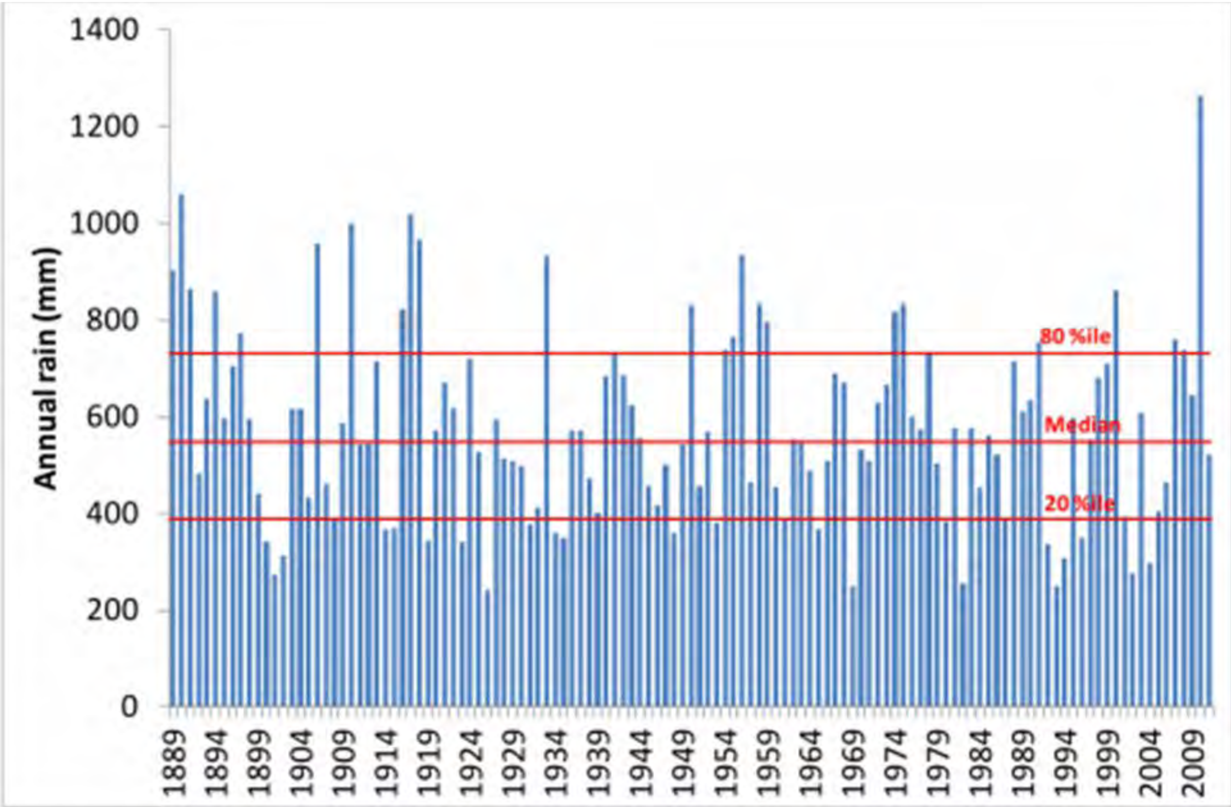
Figure 12-1 Average Monthly Maximum and Minimum Temperatures

Table 12-1 Seasonal Average Maximum and Minimum Temperatures

Season	Minimum Temperature (°C)	Maximum Temperature (°C)
Spring	11.7	27.3
Summer	20.8	32.9
Autumn	16.0	28.6
Winter	9.0	24.0

12.2.3 Rainfall

Rainfall at the project site is seasonal and extremely variable. Based on data from DataDrill, the annual rainfall ranges from around 200 mm to above 1,200 mm, with a median annual rainfall of approximately 550 mm across the 1989 to 2012 period for the project site, graphically shown in **Figure 12-2**. The December to March period accounts for 69% of the annual mean rainfall (**Figure 12-3**). The wettest month is February whilst the driest month is September.



(Source: KBR, 2012)

Figure 12-2 Annual Rainfall

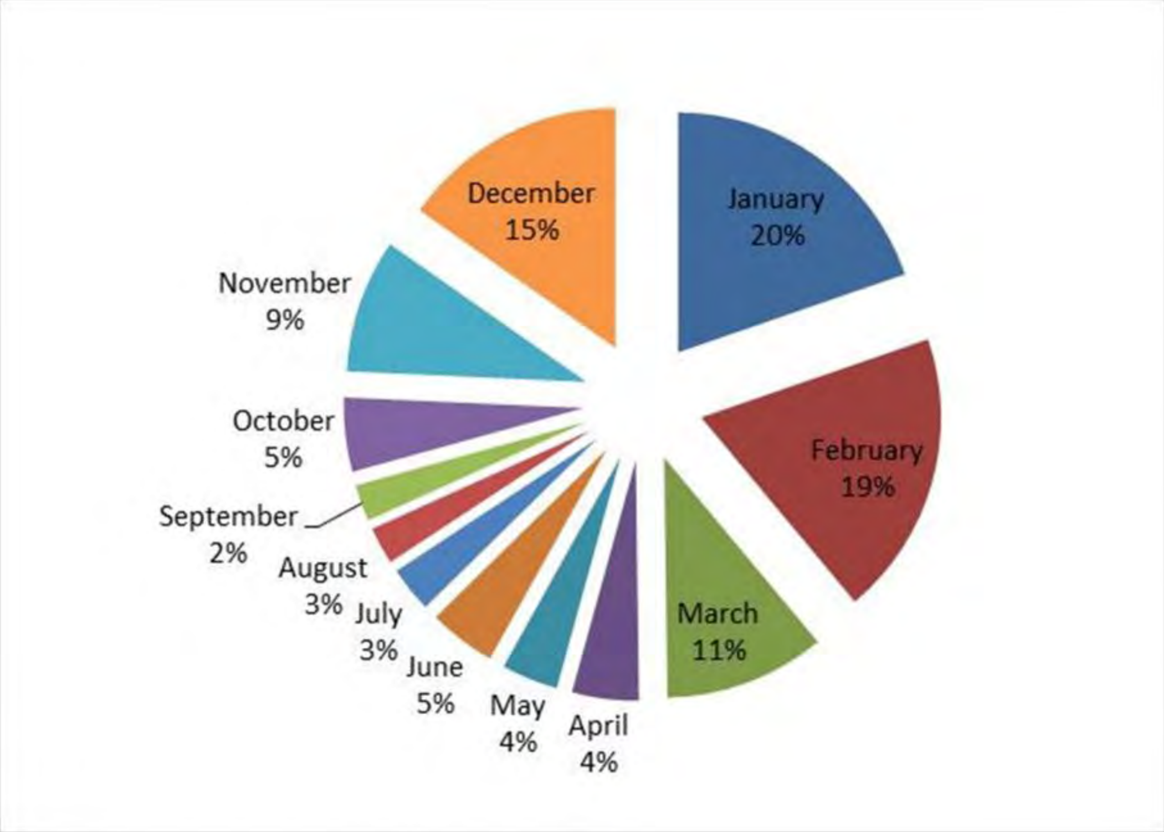


Figure 12-3 Monthly Average Rainfall Proportions for the Project Area

12.2.4 Humidity

Table 12-2 and **Table 12-3** provide Relative Humidity (RH) values based on long-term average measurements collected daily at 9 am and 3 pm from the Moranbah and Collinsville BOM weather monitoring stations, respectively. On average RH is higher in the morning for both weather monitoring stations. The highest monthly average RH readings were recorded in February at 9am (68%) and 3pm (45%) for Moranbah and June at 9am (64%) and February at 3pm (40%) for Collinsville.

As the project site is located between Collinsville and Moranbah it is expected to experience similar relative humidity levels.

Table 12-2 Monthly Average Relative Humidity at Moranbah for Years 1992 - 2010

Month	Average Relative Humidity (%)	
	9.00am	3.00pm
January	63	41
February	68	45
March	61	37
April	60	36
May	60	37

Month	Average Relative Humidity (%)	
	9.00am	3.00pm
June	64	41
July	60	36
August	57	32
September	54	30
October	53	31
November	55	33
December	58	36

(Source: NMA, 2013)

Table 12-3 Monthly Average Relative Humidity at Collinsville

Month	Average Relative Humidity (%)	
	9.00am*	3.00pm^
January	56	38
February	62	40
March	58	37
April	57	38
May	58	36
June	64	38
July	59	34
August	50	29
September	46	27
October	44	27
November	44	28
December	49	32

* data available from 1938 – 2010

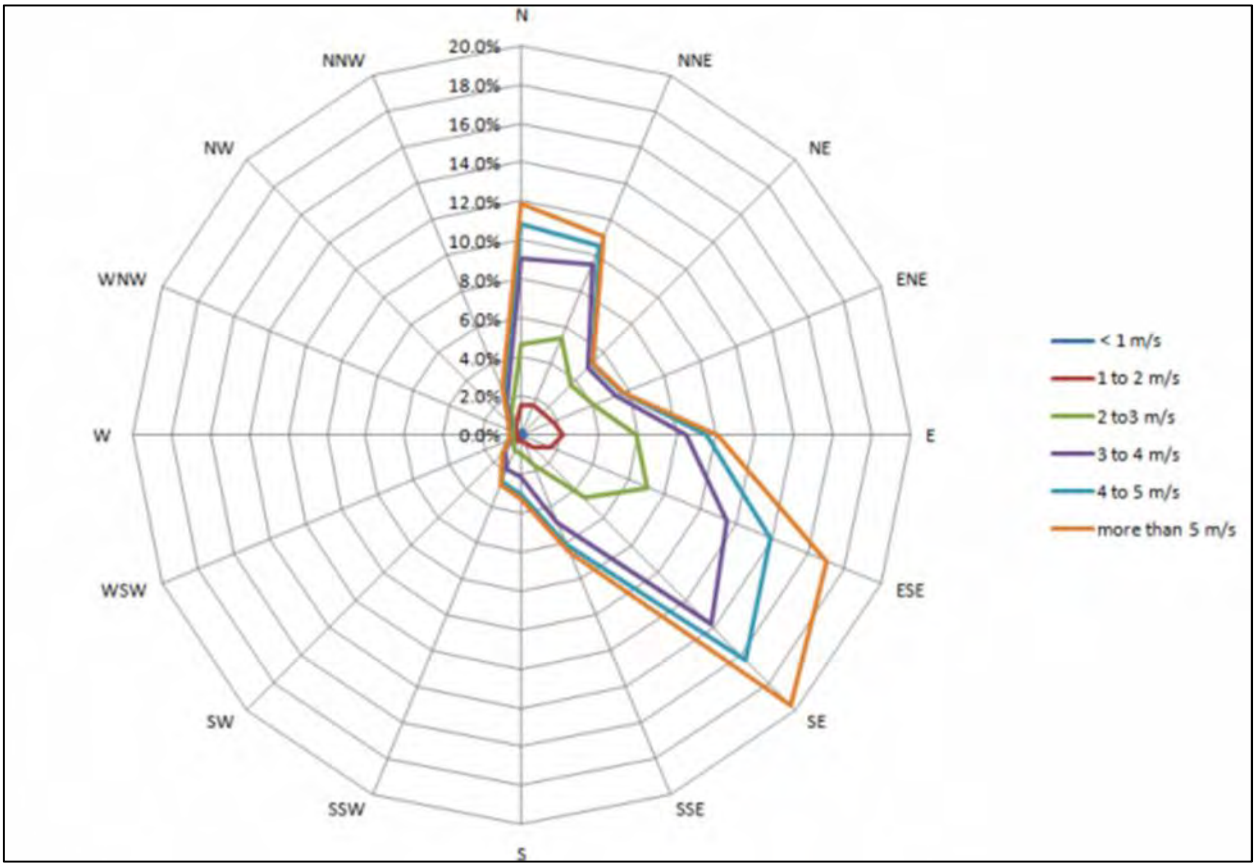
^ data available from 1962 – 2010

(Source: NMA, 2013)

12.2.5 Wind

The atmospheric dispersion model adopted for the air quality modelling component of the project (refer **Appendix 23**), CSIRO's The Air Pollution Model (TAPM), allowed for the development of the meteorology data set used in the modelling. TAPM is highly regarded in the scientific community as a suitable tool to develop meteorological data sets for sites without site-specific meteorological observations, such as the project site.

The TAPM meteorological file developed for the site covered the two year period 2004 and 2005. **Figure 12-4** shows the annual windrose for the site using the wind data obtained in the TAPM meteorological file. The figure shows the most common winds experienced for the site are either from the N to NNE, approximately 23% of the time or from the E to SE, approximately 47% of the time.



(Source: NMA, 2013)

Figure 12-4 Annual Windrose for Site (TAPM Years 2004 and 2005) Showing the Source Direction

12.3 Extremes of Climate

12.3.1 Temperature Extremes

The temperature data for the project area includes extreme values as low as -4.5 °C (July 22, 1946) to as high as 44.0 °C (January 6, 1994). The months of November to March have all experienced days over 40 °C. The months of April to September have all experienced days less than 2 °C. Temperatures exceed 39°C on 1% of December and January days. Temperatures fall below 1 °C on 1% of June and July days.

12.3.2 Droughts

Periodic drought is part of the Australian weather pattern. Major Australian droughts have included 1963 to 1968, 1972 to 1973, 1982 to 1983 and 1991 to 1995 (BOM 2012b).

As at 30 June 2012, there were no local government areas drought declared under the State processes or Individually Droughted Property (IDP) declarations in Queensland (Department of Science, Information Technology, Innovation and the Arts, 2012).

12.3.3 Floods

The project is located within the Rosella Creek and Upper Suttor River sub-catchments of the Bowen River catchment and Suttor River catchment respectively. These catchments constitute part of the headwaters of the Burdekin Basin. Kangaroo Creek drains the northern section of the proposed open cut operations, subsequently flowing into Rosella Creek, which drains into the Bowen River. The southern portion of the Project area is drained by the Suttor River and Suttor Creek. The Suttor River subsequently collects into the Burdekin Falls Dam downstream of its confluence with the Belyando River.

Two Bureau of Meteorology (BOM) streamflow gauging stations are located in proximity to the project. These are:

- Suttor River at Eaglefield (120304A) – Located approximately 20 km downstream from where the Suttor River intersects the project boundary. The records for this gauge extend from August 1967 to the present day (data extracted 12 October 2012).
- Kangaroo Creek at Byerwen (120218A) – Located just upstream of Kangaroo Creek and Wilson Creek Junction. This gauge was operational over the period 1980 to 1989, although there is a very high proportion of missing data.

A plot of gauged streamflow rates measured at the Suttor River and Kangaroo Creek stations over the corresponding monitoring period are provided in **Figure 12-5** and **Figure 12-6** respectively.

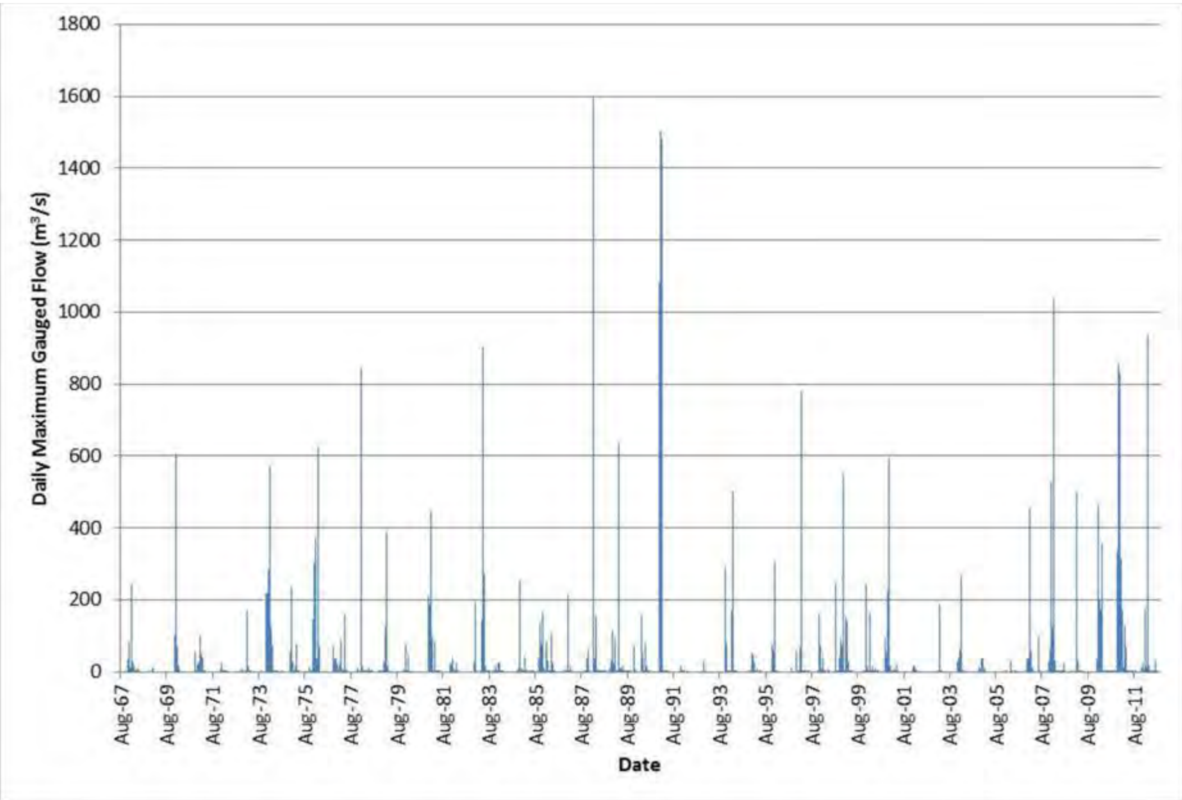


Figure 12-5 ***Gauged Streamflow Records at*** **Suttor River -** ***Station No.*** **120304A**

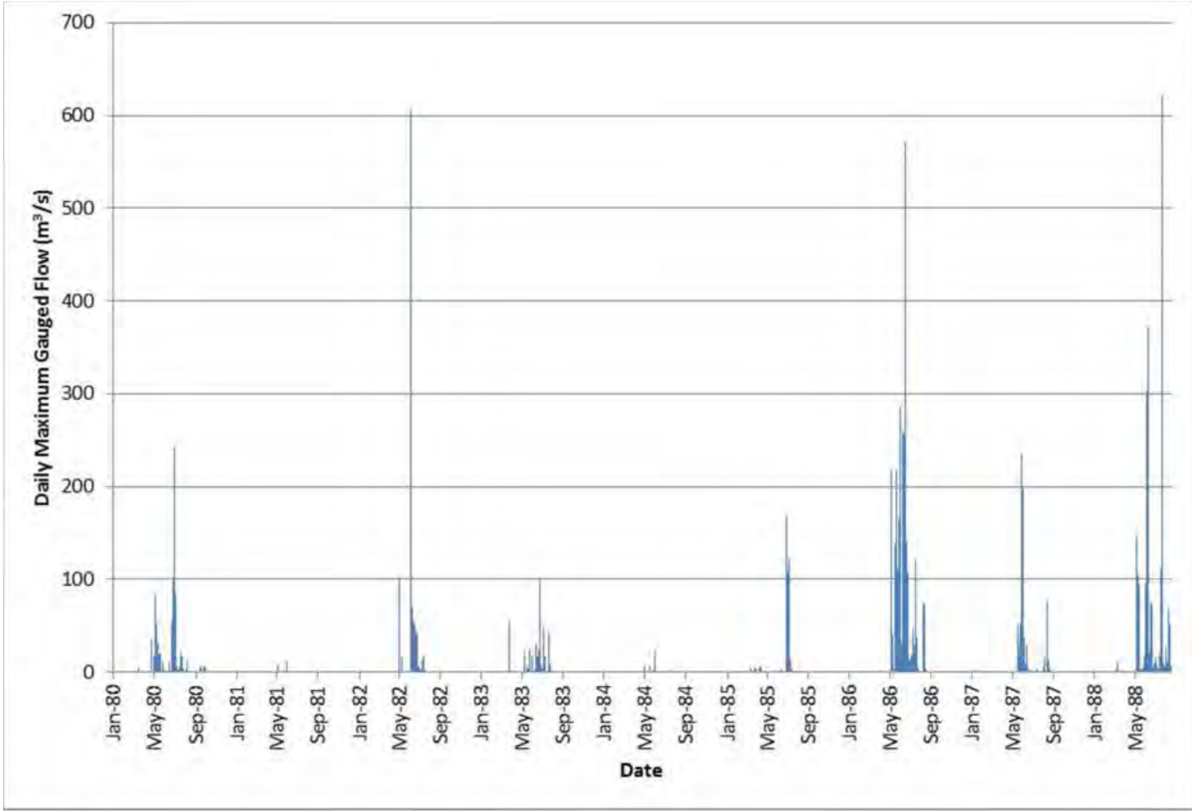


Figure 12-6 Gauged Streamflow Records at Kangaroo Creek - Station No. 120218A

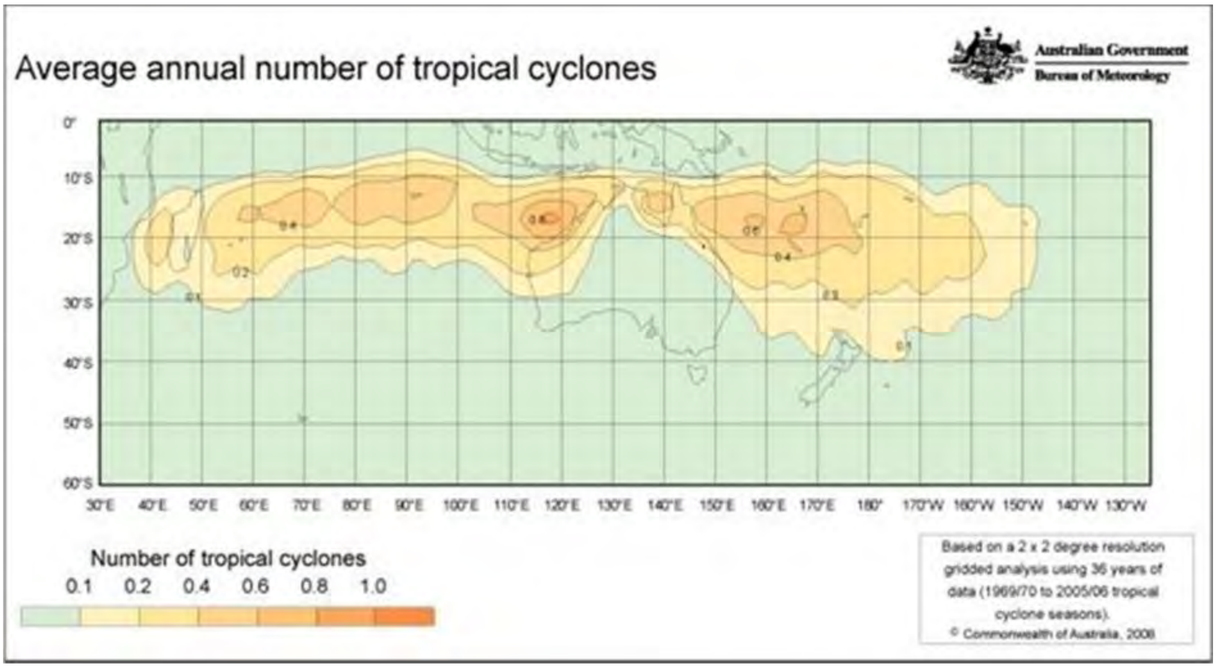
The data for Suttor River at Eaglefield station confirms that the highest flow rates typically occur in summer months. The greatest flow rate at the site was recorded on 3 March 1988, being 1,597 m^3/s, corresponding to a gauge height of 12.87 m. Based on a gauge datum of RL 249m, this height equates to a peak flood level of RL 262 m.

Data for Kangaroo Creek is only available during the operation period of the station from 1980 to 1989. A high proportion of data is also missing for this period. Data available indicates flow rates vary, although appear to peak during summer months.

12.3.4 Extreme Winds and Tropical Cyclones

Figure 12-7 shows the average number of tropical cyclones through the Australian region and surrounding waters for a 36 year period from the 1969/70 to 2005/06 tropical cyclone season. Tropical cyclones are low pressure systems that form over warm tropical waters and have well defined wind circulations of at least gale force strength (sustained winds of 63 km/h or greater with gusts in excess of 90 km/h).

The project location, indicated by the red dot, is in the zone with an average annual number of tropical cyclones of 0.1 to 0.2.



(Source: BOM, 2011)

Figure 12-7 Average Annual Number of Tropical Cyclones

12.3.5 Bushfire Risk

The project is located within the boundaries of the former Nebo and Bowen Shires (now part of the Isaac Regional Council and Whitsunday Regional Council). The Nebo and Bowen Planning Schemes identify bushfire hazard areas as low, medium or high. The project is predominantly located in areas of medium bushfire hazard with some areas of low bushfire hazard.

It may be expected that bushfire risk increases under a combination of increased temperatures, higher winds and lower rainfall. An increased risk of bushfires for the project may have the following impacts:

- increased probability of damage to project infrastructure
- increased probability of injury or fatality to workers and the public from bushfire starting off site or on site
- increased risk of rehabilitation failure due to bushfires destroying areas subject to rehabilitation.

The hazard and risk assessment has identified a number of mining activities that may present a high risk to people and property from causing bush fires. The proponent will develop and implement Fire Management Plans to reduce the risk of causing bushfires, which will include working closely with regional and local fire service providers.

The project will result in vegetation clearance in mine work areas which is likely to reduce the risk of bushfires in and around the mine site.

12.3.6 Risk Assessment of Extremes of Climate

A risk assessment of how extremes of climate may affect management of the project is provided below in **Table 12-4**, which identifies the potential impact to mine site activities from extremes in climate, assigns a risk ranking to the impact, describes controls currently in place to manage the risk and describes future controls that will be implemented to manage risks. The risk assessment is based on comparable EIS studies for coal mines in the region in similar climatic locations. The risk assessment matrix used to evaluate risks is provided in **Figure 12-8**.

The risk assessment matrix:

- considers the likelihood of impact from an extreme in climate across five scales ranging from rare to almost certain
- considers the environmental consequence of an impact from an extreme in climate across five scales ranging from minimal environmental harm to extreme environmental harm causing irreversible damage
- assigns a risk ranking of low, medium, high or extreme based on the combination the likelihood and consequence of an impact from an extreme in climate.

The assessment focuses on impacts to the project from extreme climatic events that have the potential to result in environmental harm. The risk assessment does not consider operational or financial consequences associated with an impact caused extremes of climate such as stoppage of production.

Risks to the public and the community from potential impacts caused by the project resulting from extreme climatic events are assessed in **Chapter 32**.

			Consequence (the Effect of the Hazard)				
Type of Loss ↓			**1 (Insignificant)**	**2 (Minor)**	**3 (Moderate)**	**4 (Major)**	**5 (Catastrophic)**
Environmental Impact (E) = Harm to the Environment			- Minimal environmental harm	- Material environmental harm - Remediable in the short term	- Serious environmental harm - Remediable within Life of Mine	- Major environmental harm - Remediable post Life of Mine	- Extreme environmental harm - Irreversible damage
A (Almost Certain)	The unwanted event has occurred frequently: occurs one or more times per year and is likely to re-occur within 1 year.	> 90% chance	medium	high	high	extreme	extreme
B (Likely)	The unwanted event has occurred but is not frequent: occurrs less than once per year and is likely to re-occurr within 5 years.	50-90% chance	medium	medium	high	high	extreme
C (Possible)	The unwanted event has happened in the business in the past 10 years or could happen within the next 10 years.	30-50% chance	low	medium	high	high	high
D Unlikely	The unwanted event has happened in the business in the past 20 years or could happen within the next 20 years.	10-30% chance	low	low	medium	medium	high
E (Rare)	The unwanted event has never been known to occur in the business and it is highly unlikely that it will occur within less than the next 20 years.	<10% chance	low	low	medium	medium	medium

(Source: QCoal, 2012)

Figure 12-8 Risk Assessment Matrix for Extremes of Climate

Table 12-4 Risk Assessment of Extremes of Climate

Extreme Climate Scenario	Impact	Current Controls	Environmental Consequence	Likelihood	Risk Ranking	Risk Score (CxL)	Future Controls
Drought	Reduction or cessation of mine water supply	none	insignificant	rare	low	1	Mine water management system to consider water supply security
Drought	Effective revegetation during rehabilitation is compromised	none	minor	possible	medium	4	Development of an appropriate rehabilitation strategy including drought contingencies
Drought	Releases from water storage facilities due to structural integrity being compromised	none	moderate	rare	medium	3	Water storage facilities will be designed with consideration of climatic variance and will be monitored and repairs made where required
Extreme Rainfall Events	Release of potentially hazardous wastes to waterways	Water management and water balance studies, hydrology studies and studies characterising waste and rejects	moderate	unlikely	medium	6	Dams designed to meet required engineering and Department of Environment and Heritage Protection standards
Extreme Rainfall Events	Overflow from mine pits	Hydrology and water balance studies	moderate	rare	medium	3	Hydrology studies show open pit not a risk of riverine flooding Mine water management system, Rehabilitation Management Plan

Extreme Climate Scenario	Impact	Current Controls	Environmental Consequence	Likelihood	Risk Ranking	Risk Score (CxL)	Future Controls
Extreme Rainfall Events	Damage to access and haul roads and other civil infrastructure works	none	insignificant	possible	low	3	Roads and other civil infrastructure will be designed to include suitable drainage Ongoing maintenance and repairs as required
Cyclones	Damages to infrastructure resulting in release of contaminants	none	moderate	rare	medium	2	Infrastructure will be designed for severe weather events
Cyclones	Rehabilitation success is compromised due to cyclone damage	none	minor	rare	low	2	Repair damage and restart rehabilitation works
Bushfire	Destruction of mine infrastructure with potential release of contaminants.	Review bushfire risk zones in Council planning schemes Management of vegetation	minor	possible	medium	6	Bushfire MP and Emergency Response Plan (ERP)
Bushfire	Rehabilitation failure due to bushfires destroying areas subject to rehabilitation	none	moderate	unlikely	medium	6	Rehabilitation Management Plan, Bushfire MP and Emergency Response Plan (ERP)

(Source: Adapted and amended from QCoal, 2012)

The risk ranking for impacts from extremes was assessed as low to medium for all potential impacts. Detailed engineering will consider the risk of extreme climatic events in the design of infrastructure and management plans will be developed to guide the actions required by project staff in the event of an extreme climatic event

12.4 Climate Change

12.4.1 Climate Change Data and Scenarios

The CSIRO produced a Technical Report in 2007 on Climate Change in Australia (CSIRO, 2007). Information on climate change in the area of the project has been obtained from this Technical Report. The CSIRO report considers various emissions scenarios as a basis for prediction of climate change impacts. Scenario A1B assumes a world of rapid economic growth with global population stabilising mid-century and a balance between fossil-intensive and non-fossil-intensive energy sources. Emissions scenario B1 has the least global warming for 2050 and beyond and emissions scenario A1FI has the greatest warming. Emissions scenario A1B is a mid range global warming scenario.

Figures used in this section were obtained from the CSIRO Report and information available on the CSIRO website1. In accordance with the report and website information, in the figures in this section showing climate change scenarios:

- scenario B1 is referred to as the low emissions scenario
- scenario A1B is referred to as the medium emissions scenario
- scenario A1FI is referred to as the high emissions scenario.

Climate change predictions for each future year and each emissions scenario are considered for the 10^{th}, 50^{th} and 90^{th} percentile, using multiple climate change models. The 50^{th} percentile is used as the 'best estimate' of the projected change. The 10^{th} and 90^{th} percentile are given as a guide to the uncertainty range.

Climate change predictions are made for 2030, 2050 and 2070. The predictions for 2030 and 2050 provide the best indication of the future climate for the project as 2030 occurs midway through operations and 2050 towards the end of operations.

12.4.2 Temperature Changes

The following temperature change predictions were obtained from the CSIRO report:

- The best estimate of annual warming over Australia by 2030 is around 1.0°C, with warming of around 0.7-0.9°C in coastal areas and 1-1.2°C inland.
- The midrange A1B case has a global warming of 0.9°C by 2030.
- For most of Australia, and in each season and the annual case by 2030, the range in warming allowing for uncertainty in climate response is about 0.6°C to 1.5°C for the A1B emission scenario.
- By 2050, annual warming over Australia ranges from around 0.8 to 1.8°C (best estimate 1.2°C) for the B1 scenario and 1.5 to 2.8°C (best estimate 2.2°C) for the A1FI scenario.
- By 2070, the best estimate for annual warming over inland Australia ranges from around 1.8°C for the B1 scenario to around 3.4°C for the A1FI scenario.
- By 2070 the annual warming for Australia is around 1.0 to 2.5°C for the B1 scenario, and around 2.2 to 5.0°C for the A1FI scenario.

[1] http://www.climatechangeinaustralia.gov.au/qldtemp1.php

- Associated with the warming is a projected strong increase in frequency of hot days and warm nights.

Figure 12-9 shows the annual average change in temperature expected in Queensland for the 10th, 50th and 90th percentiles across low, medium and high emissions scenarios. The location of the project is indicated by the red dot. The figure shows that the predicted variation in temperature change by 2030, at the project location, for the 50th percentile across low, medium and high emissions scenarios, is an increase of 1%.

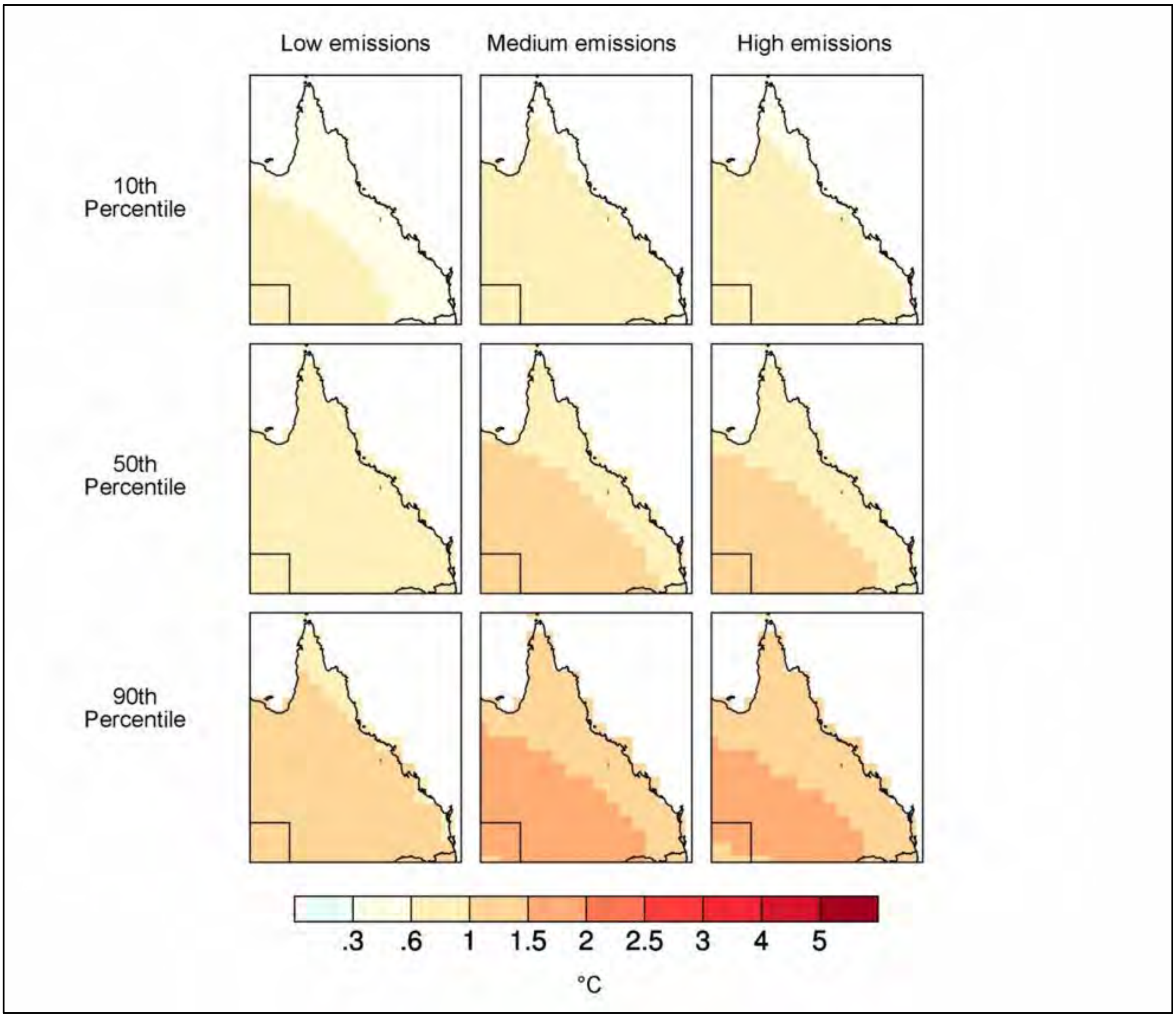


Figure 12-9 Changes in Annual Average Temperature in Queensland in 2030

Figure 12-10 shows the annual average change in temperature expected in Queensland for the 10th, 50th and 90th percentile across low, medium and high emissions scenarios. From the figure it can be seen that the predicted variation in temperature change by 2050, at the project location, for the 50th percentile ranges from an increase of:

- 1.5°C for the low emissions scenario
- 2.0°C for the medium emissions scenario
- 2.0°C for the high emissions scenario.

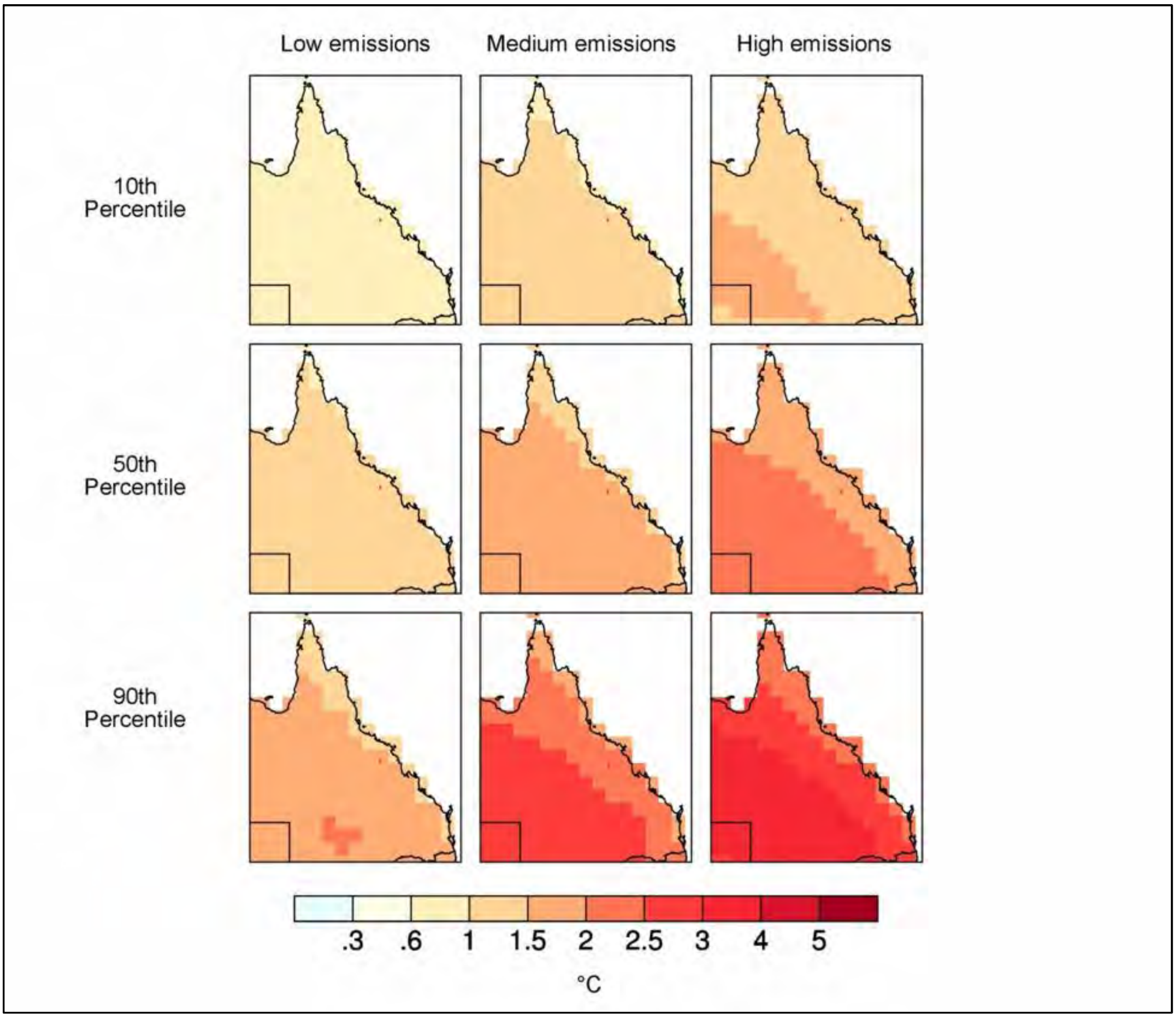


Figure 12-10 Changes in Annual Average Temperature in Queensland in 2050

12.4.3 Rainfall Changes

Unlike changes in radiation and temperature, precipitation changes are not directly influenced by increased concentration of greenhouse gases. However, a warmer atmosphere can hold more water vapour, and hence produce heavier precipitation. Also, changing the temperature patterns across the planet means that the wind patterns (the circulation) will change the rain patterns.

Regional precipitation variations can be quite sensitive to small differences in the circulation and other processes. Different climate models may therefore simulate different rainfall changes. The CSIRO states that it will not be possible to make definitive statements on the direction of precipitation change in many cases.

The following rainfall change predictions for Queensland were obtained from the CSIRO report:

- Best estimates of annual precipitation change by 2030 represent little change in far north and decreases of 2% to 5% elsewhere. Decreases of around 5% prevail in winter and spring, particularly in the south-west where they reach 10%.

- The range of precipitation change in 2030 allowing for model to model differences is large. Annually averaged, the 10th to 90th percentile range is around -10% to +5% in northern areas and -10% to little change in southern areas.
- By 2050, under the B1 scenario, the range of annual precipitation change is -15% to +7.5% in central, eastern and northern areas, with a best estimate of little change in the far north grading southwards to a decrease of 5%. The range of change in southern areas is from a 15% decrease to little change, with best estimate of around a 5% decrease.
- By 2050, under the A1FI scenario changes in precipitation are larger. The range of annual precipitation change is -20% to +10% in central, eastern and northern areas, with a best estimate of little change in the far north grading to around a 7.5% decrease elsewhere. The range of change in southern areas is from a 20% decrease to little change, with best estimate of around a 7.5% decrease.
- In 2070, precipitation changes under the B1 scenario are comparable to those seen for 2050 under the A1FI scenario. Those under the A1FI scenario are substantially larger. The range of annual precipitation change is -30% to +20% in central, eastern and northern areas, with a best estimate of little change in the far north grading to around a 10% decrease in the south-west. The range of change in southern areas is from a 30% decrease to a 5% increase, with best estimate of around a 10% decrease.
- An increase in daily precipitation intensity (rain per rain-day) and the number of dry days is likely.

Figure 12-11 shows the percentage change in annual rainfall expected in Queensland for the 10th, 50th and 90th percentile across low, medium and high emissions scenarios by 2030. The project location is shown as the red dot. From the figure it can be seen that the predicted variation in rainfall change by 2030, at the project location, across low, medium and high emissions scenarios is a:

- decrease of 10 to 20% for the 10th percentile
- decrease of 2 to 5% for the 50th percentile
- increase of 2 to 10% for the 90th percentile

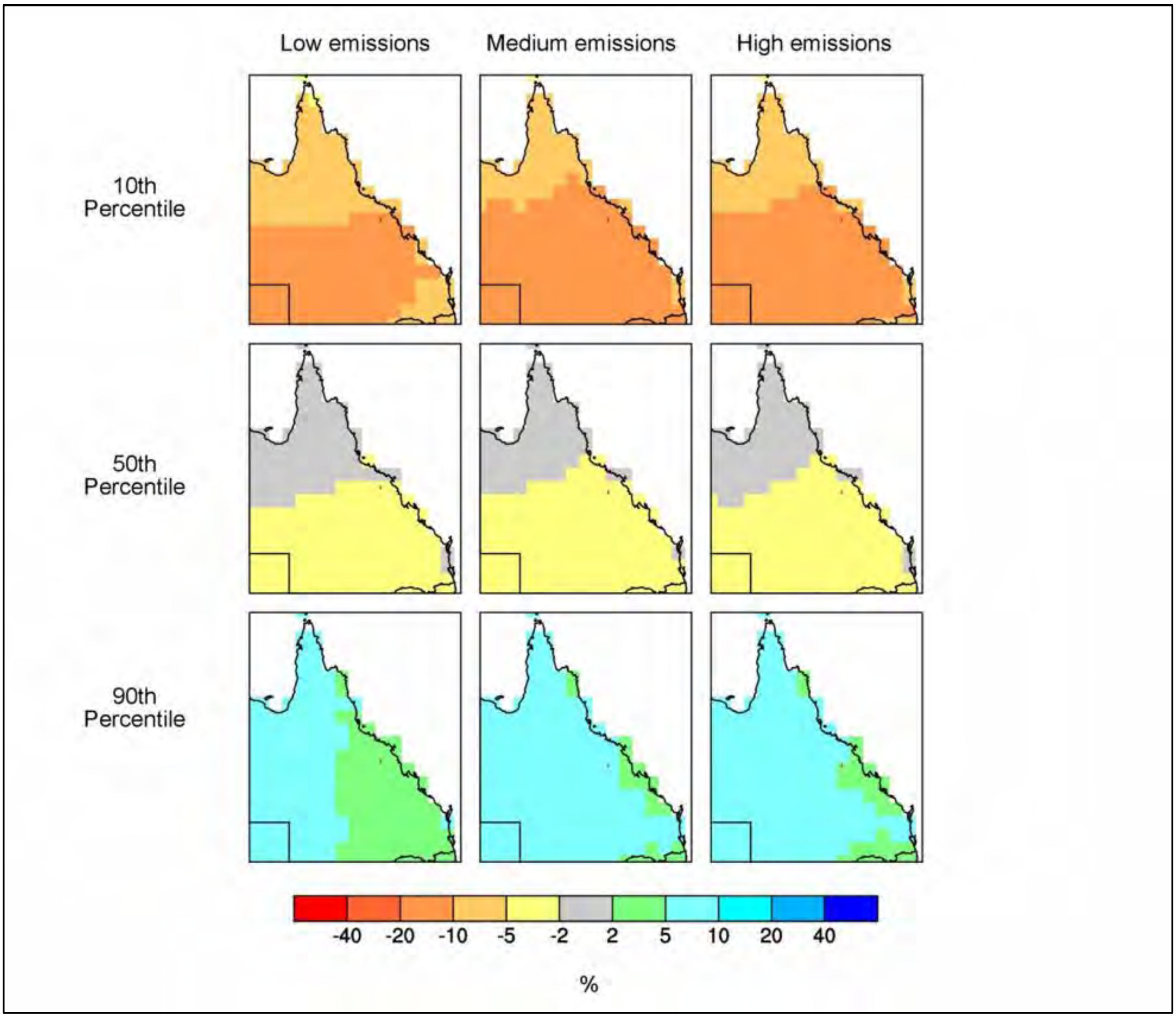


Figure 12-11 Percentage Changes in Annual Average Rainfall in Queensland in 2030

Figure 12-12 shows the percentage change in annual rainfall expected in Queensland for the 10th, 50th and 90th percentile across low, medium and high emissions scenarios by 2050. The project location is shown as the red dot. From the figure it can be seen that the predicted variation in rainfall change by 2050, at the project location, across low, medium and high emissions scenarios is a:

- decrease of 10 to 40% for the 10th percentile
- decrease of 2 to 10% for the 50th percentile
- increase of 5 to 20% for the 90th percentile.

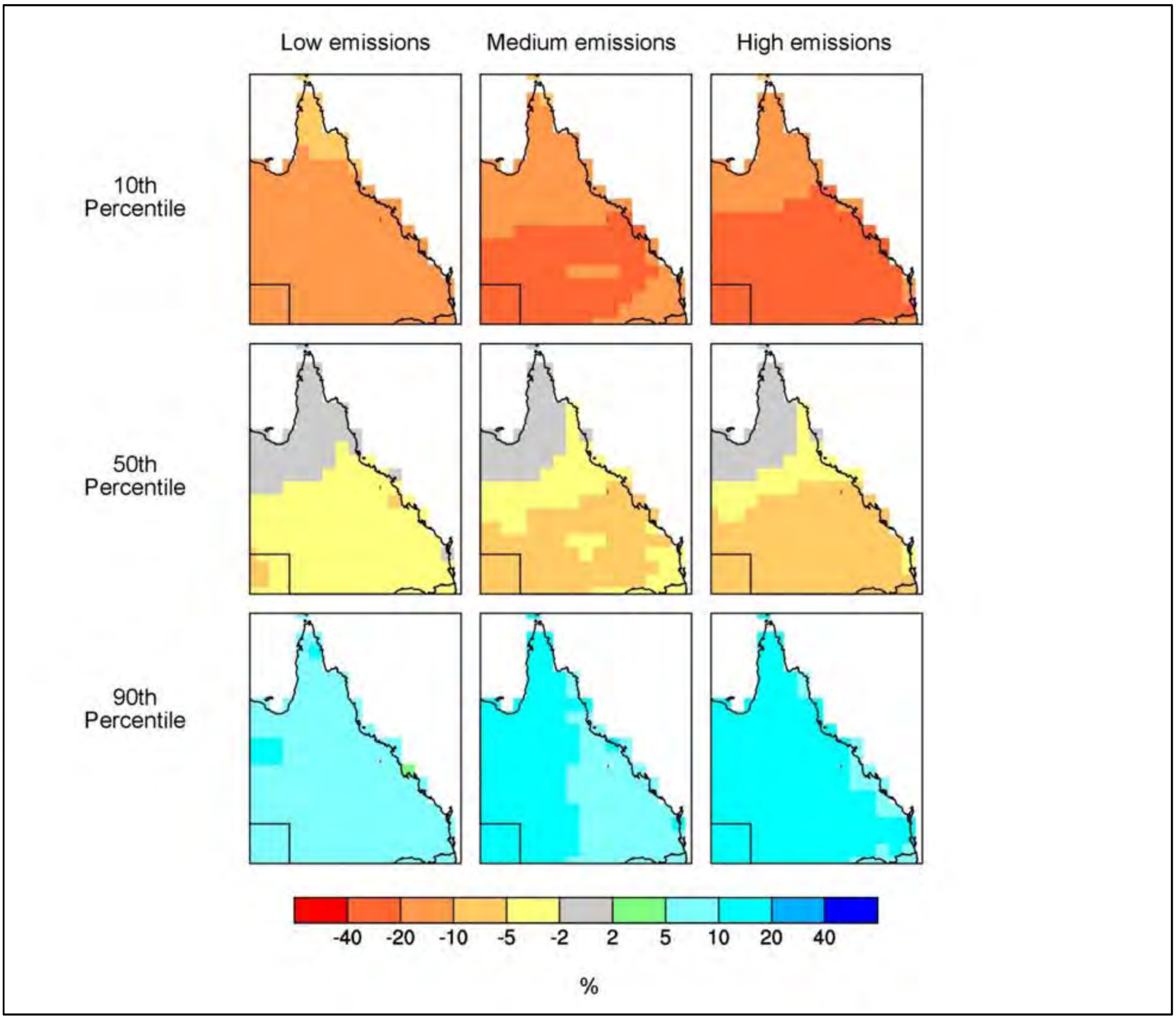


Figure 12-12 Percentage Changes in Annual Average Rainfall in Queensland in 2050

12.4.4 Changes in Drought Patterns

The project is located in an area that has been subject to drought periods.

The following drought predictions were obtained from the CSIRO Technical report:

- Model simulations show up to 20% more drought months over most of Australia by 2030, with up to 40% more droughts by 2070 in eastern Australia.

12.4.5 Wind Speed Changes

The following wind predictions were obtained from the CSIRO Technical Report:

- Model to model uncertainty in average wind speed change is high, but there is a tendency for increases in most coastal areas in 2030 (range of -2% to +7.5% with a best estimate 2-5%).

Figure 12-13 shows the percentage change in annual wind speeds expected in Queensland for the 10th, 50th and 90th percentile across low, medium and high emissions scenarios. **Figure 12-13** shows that the predicted variation in wind speeds by 2030, at the project location, for the 50th percentile across low, medium and high emissions scenarios, is -2 to +2%.

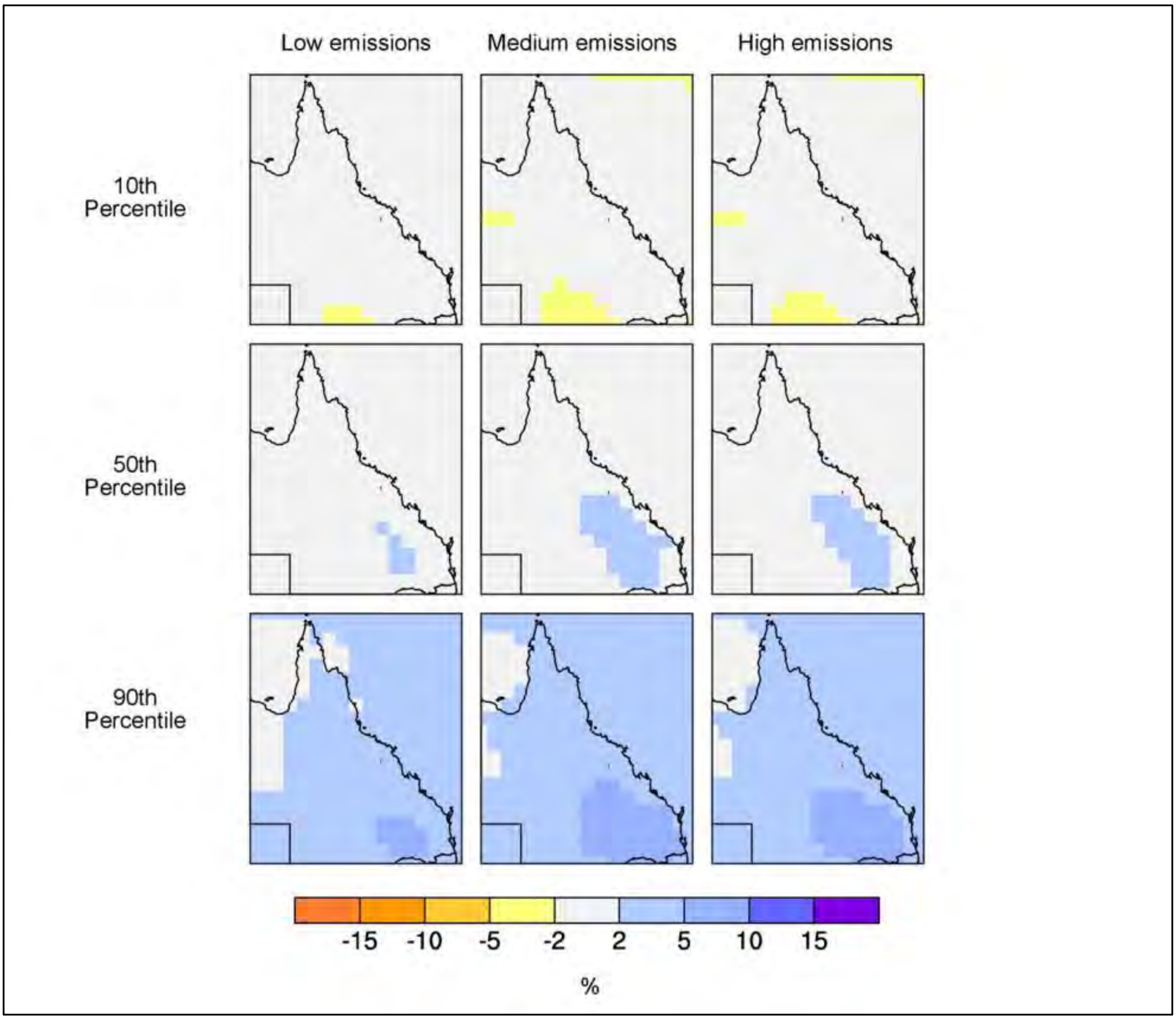


Figure 12-13 Percentage Changes in Annual Average Wind Speeds in Queensland in 2030

Figure 12-14 shows the percentage change in annual wind speeds expected in Queensland for the 10th, 50th and 90th percentile across low, medium and high emissions scenarios. From the figure it can be seen that the predicted variation in annual average wind speeds by 2050, at the project location, for the 50th percentile across low, medium and high emissions scenarios, is an increase of 5%.

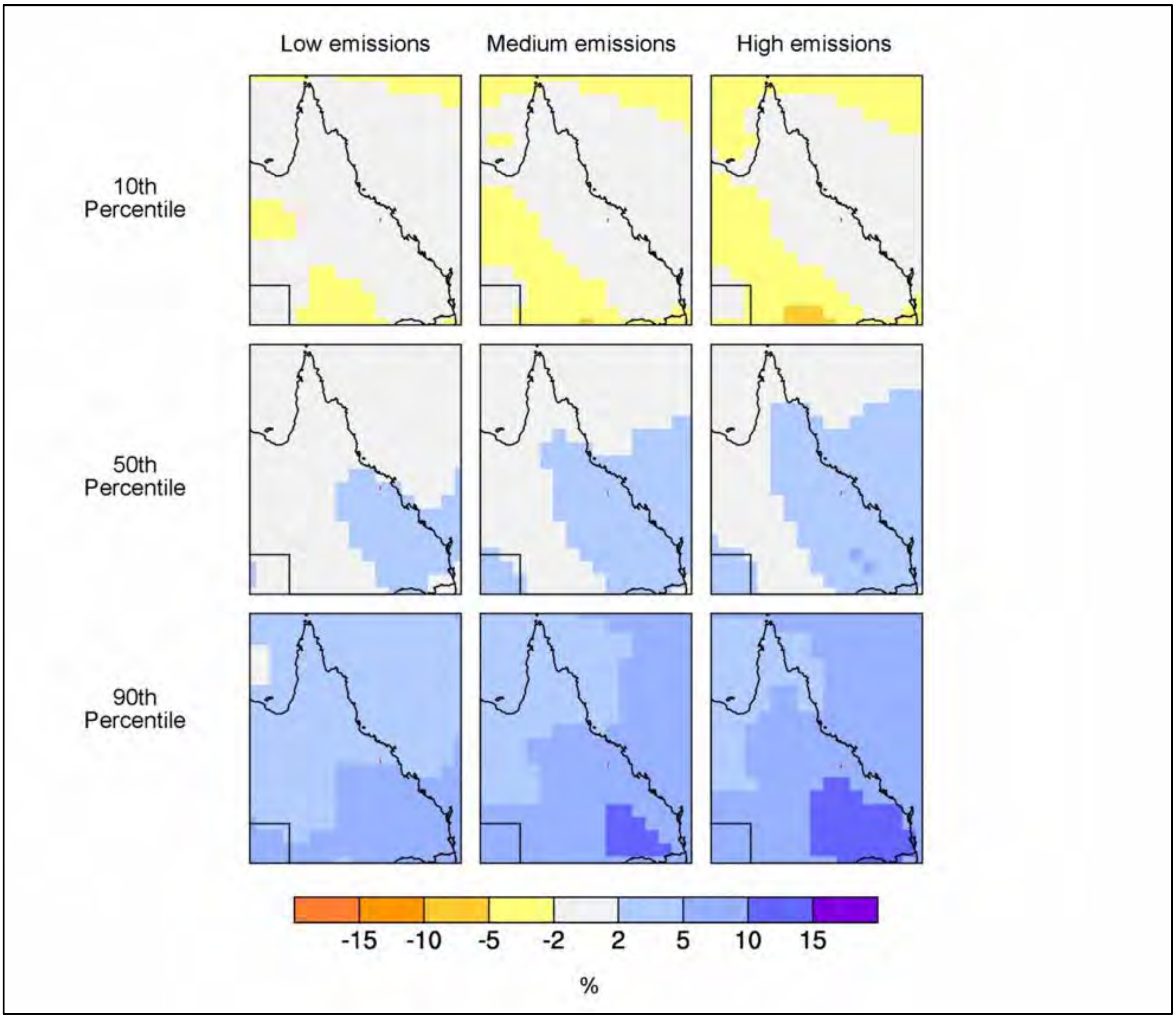


Figure 12-14 Percentage Changes in Annual Average Wind Speeds in Queensland in 2050

12.4.6 Changes in Storm and Cyclone Patterns

The following storm and cyclone predictions were obtained from the CSIRO Report:

- Australian region studies indicate a likely increase in the proportion of the tropical cyclones in the more intense categories, but a possible decrease in the total number of cyclones.
- Studies have found a marked increase (22% to 140%) in the severe Category 3-5 storms.
- Studies found a change in the latitudinal extent of tropical cyclones, with more storms forming closer to both the equator and the poles; a poleward extension of tropical cyclone tracks; and a poleward shift of over 2 degrees of latitude in the tropical cyclone genesis region. A poleward shift of 0.7 degrees of latitude (around 70 km) in the average tropical cyclone genesis region on both coastlines and a shift of almost 3 degrees latitude in the average decay location for east Australian cyclones were found for the year 2070.

Figure 12-15 shows the simulated change in annual average tropical cyclone occurrence in the Australian region for 40-year time slices centred on 2030 and 2070. Blue regions indicate a decrease in tropical cyclone occurrence and red regions indicate an increase in occurrence. The project location is outside of the range of any simulated change in annual average tropical cyclone occurrence.

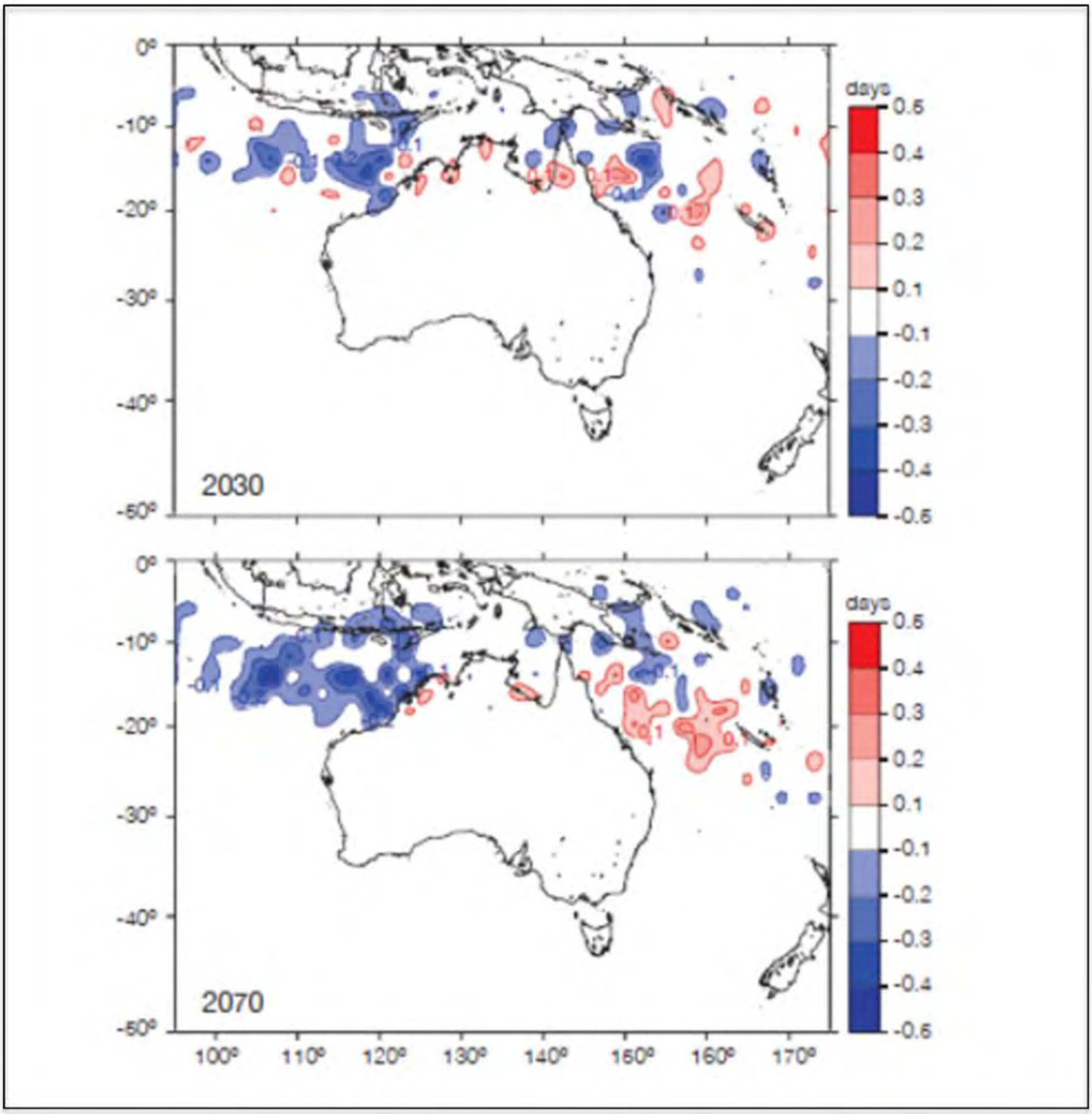


Figure 12-15 Change in Annual Average Tropical Cyclones

12.4.7 Sea Level Change

As the project is not located near the coast line and is at approximately 300 m above sea level, changes in sea level will not directly affect the project. However, coal export facilities at Abbot Point could be affected by future rises in sea level. Future sea level changes were assessed under a separate process for Abbot Point Coal Terminal Stage 3 Expansion Project.

12.5 Impact of Climate Change on the Project

12.5.1 Temperature Change

The potential variation in temperature in the vicinity of the project is described in **Section 12.4.2**. All scenarios for temperature change show an expected increase in temperature.

An increase in temperature may affect the project, in excess of current expected temperature fluctuations, in the following ways:

- Equipment, machinery, roads and other civil works (e.g. dams) may be subjected to greater heat stress resulting in shorter life spans than the original designed life or failure.
- Workers may experience longer and more frequent periods of heat stress leading to a higher rate of incidents.
- Rehabilitation success may be compromised if vegetation types that would typically be selected for rehabilitation struggle to cope with an increase in temperature.

12.5.2 Rainfall Change

The variation in rainfall change in the vicinity of the project is described in **Section 12.4.3**. The scenarios for rainfall change indicate that, by 2050, rainfall change will decrease by up to 10% across the low, medium and high emissions scenarios in the 50th percentile.

A decrease in rainfall may affect the project, in excess of current expected rainfall events, in the following ways:

- Rehabilitation success may be compromised if vegetation types that would typically be selected for rehabilitation struggle to cope with a decrease in rainfall.
- Increase in water demand.

Based on the 50th percentile low, medium and high emissions scenarios there is no prediction of rainfall increases. However should there be an increase in rainfall, as predicted for the 90th percentile, in excess of current expected rainfall events, the project may be affected in the following ways:

- Water storage facilities and rejects storage facilities may be at risk of overtopping more frequently than would be the case using a design basis calculated on historical rainfall records.
- Roads and other civil infrastructure works such as bunds and diversion drains may be at risk of more frequent damage.
- The open pit and / or final void may receive rainfall and runoff in excess of volumes expected based on current rainfall patterns.
- Rehabilitation success may be improved with greater water availability.

Chapter 16 – Hydrology and Hydraulics describes flooding of the project area. Flood modelling for the Suttor River and statewide floodplain modelling demonstrate that the only project activities that will reached by a 1,000 Year annual recurrence interval (ARI) or probable maximum flood (PMF) event are sections of the West Pit complex waste rock dump, the out of pit waste rock dumps associated South Pit 1 and South Pit 2 and the south western corner of South Pit 1. There are no scenarios where the regional PMF flood event reaches the final voids of South Pit 1, West Pit 3, East Pit 2 or North Pit. Any change in rainfall attributable to climate change is likely to be within the existing natural variability in rainfall, which has been demonstrated through modelling of extreme rainfall events to have minor impact on the project.

12.5.3 Changes in Drought Patterns

An increase in the frequency and duration of droughts may affect the project, in excess of current expected drought events, in the following ways:

- Increased water demand.
- Water supply to the mine may cease or may be restricted due to competing demands on regional water supplies.
- Structural integrity of water storage facilities may be compromised.
- Rehabilitation success may be compromised if vegetation is subjected to increased drought stress.

12.5.4 Wind Speed Changes

A small percentage increase in average annual wind speeds may impact the project, in excess of current expected wind events, in the following ways:

- Without appropriate mitigation dust generation may increase and disperse more widely.

12.5.5 Changes in Storm and Cyclone Patterns

Based on data available, it is not expected that the frequency and intensity of storms and cyclones will change significantly in the area of the project.

However, should there be an increase in the frequency and intensity of storms and cyclones this may impact the project, in excess of current expected storm and cyclone events, in the following ways:

- Increased frequency of damage to project infrastructure.
- Increased frequency of disruption to operations, including transport of product coal and supply of combustibles, materials and equipment.
- Water storage facilities and rejects storage facilities may be at risk of overtopping more frequently than would be the case using a design basis calculated on historical rainfall records.
- The open pit and / or final void may receive rainfall and runoff in excess of volumes expected based on current rainfall patterns.
- Rehabilitation success may be compromised through the loss of vegetation used in rehabilitation and increased erosion.

Chapter 16 – Hydrology and Hydraulics describes flooding of the project area under various extreme rainfall events (i.e. 1,000 Year ARI or PMF events). Any change in rainfall attributable to changes in storm and cyclone patterns is likely to be within the existing natural variability, which has been demonstrated through modelling of extreme rainfall events to have minor impact on the project.

12.6 Adaptation Strategies and Mitigation Measures for Climate Change Impacts

12.6.1 Temperature Change

Section 12.5.1 describes the potential impacts of temperature change on the project. **Table 12-5** presents these impacts from temperature change, provides adaptation strategies and mitigation measures for impacts and assesses the residual risk.

Table 12-5 Impacts of Temperature Change and Mitigation Measures

Impact (as described in Section 12.5.1)	Mitigation Measures and Adaptations Strategies	Residual Risk
Equipment, machinery, roads and other civil works (e.g. dams) may be subjected to greater heat stress	Equipment, machinery, roads and other civil works will be designed to the specification required to withstand heat stress caused by an increase in average ambient temperatures. For example; adequate allowance will be made for predicted thermal movements in concrete and the selection of bitumen grades will consider increases in temperature. It should be recognised that the project area is already subject to wide variations and extremes in temperature and that design of equipment, machinery, roads and other civil works is likely to include specifications for temperature ranges that encompass expected increases in average ambient temperatures.	Low
Increased heat stress for workers	The proponent will establish heat and fatigue management procedures, including provision of shade structures, water coolers, scheduled rest breaks. Due to the existing extreme temperatures that may be experienced these procedures will be implemented as a part of normal activities.	Low
Rehabilitation success may be compromised	The expected increase in average annual temperatures in the first 20 years of project life is not expected to compromise the success of progressive rehabilitation. Other climatic factors, which currently exist, such as drought periods or intense rainfall are likely to have more influence on rehabilitation success. Increased average ambient temperature may have more influence on final rehabilitation depending on actual temperature increases. The proponent will monitor changes in the climate over the life of the project and update rehabilitation strategies based on specialist advise (e.g. from ecologists, soil scientists and meteorologists) to maximise the probability of progressive and final rehabilitation success.	Low to medium as project life extends

12.6.2 Rainfall Change

Section 12.5.2 describes the potential impacts of rainfall change on the project. **Table 12-6** presents these impacts from rainfall change, provides adaptation strategies and mitigation measures for impacts and assesses the residual risk.

Table 12-6 Impacts of Rainfall Change and Mitigation Measures

Impact (as described in Section 12.5.2)	Mitigation Measures and Adaptations Strategies	Residual Risk
Decrease in Rainfall		
Rehabilitation success may be compromised	A decrease in average annual rainfall in the first 20 years of project life is not expected to compromise the success of progressive rehabilitation. Other climatic factors, which currently exist, such as drought periods or intense rainfall are likely to have more influence on rehabilitation success. A decrease in average rainfall may have more influence on final rehabilitation depending on actual rainfall decreases. The proponent will monitor changes in the climate over the life of the project and update rehabilitation strategies based on specialist advise (e.g. from ecologists and soil scientists) to maximise the probability of progressive and final rehabilitation success.	Low to medium as project life extends
Increase in water demand	The site water management system and site water balance will consider existing extremes in climate such as drought periods. Current mine water planning will consider water supply during periods of drought and the adequacy of off-site water supplies to provide uninterrupted supply of water. This will include consideration of the volume, duration and intended use of water stored in Gorge Weir (the primary option for water supply) over periods of drought and contingency plans should this supply of water cease. It is expected that current planning for periods of drought will provide adequate margin to encompass potential decreases in average rainfall. CHPP design and use of water at the mine site will be optimised to minimise water use. This may include investing in less water intensive equipment and processes.	Low
Increase in Rainfall		
Increased probability of dams overtopping	Dams, including the co-disposal dams, will be designed in accordance with relevant regulator's dam guidelines. Dams will be designed to hold rainfall events at a certain annual recurrence interval (ARI) rainfall event (e.g. 1:100 years). The calculation of the design storage is based on historical rainfall records. In the project area, historical rainfall records are highly variable with periods of extreme rainfall, well in excess of average rainfall. Only the 90th percentile rainfall forecasts predict an increase in rainfall. The 10th and 50th percentile forecasts predict a decrease in rainfall. It is expected that dam design using historical rainfall records to determine a design storage allowance will provide adequate margin to encompass any potential increase in average rainfall.	Low

Impact (as described in Section 12.5.2)	Mitigation Measures and Adaptations Strategies	Residual Risk
Increased damage to roads and other civil infrastructure works	Roads and other civil infrastructure works will be designed to include drainage suitable to maintain integrity during existing weather conditions. This is expected to be adequate to maintain integrity for any future increase in average annual rainfall. Roads and other civil infrastructure works will be regularly inspect and maintained, especially following periods of intense rainfall.	Low
Increased inflow to the open pit and / or final void	The catchment of the open pit would generally be limited to the pit footprint and immediate surrounds. The flooding impact assessment concludes that flood protection measures can be designed to protect pit and final void from flood events. Therefore it is not expected that any increase in average annual rainfall will result in inflow of water to the pit in excess of that expected under existing variable weather conditions. The site water management and water balance considers management of water captured in the pit.	Low
Rehabilitation success may be improved	Rainfall has the potential to benefit rehabilitation success.	Low

12.6.3 Changes in Drought Patterns

Section 12.5.3 describes the potential impacts of change in drought patterns on the project. **Table 12-7** presents these impacts from drought changes, provides adaptation strategies and mitigation measures for impacts and assesses the residual risk.

Table 12-7 Impacts of Change in Drought Patterns and Mitigation Measures

Impact (as described in Section 12.5.3)	Mitigation Measures and Adaptations Strategies	Residual Risk
Increase in water demand Water supply to the mine may cease or be restricted	The site water management system and site water balance will consider existing extremes in climate such as drought periods. Current mine water planning will consider water supply during periods of drought and the adequacy of external water supplies to provide uninterrupted supply of water. This will include consideration of the volume, duration and intended use of water stored in Gorge Weir (the primary option for water supply) over periods of drought and contingency plans should this supply of water cease. It is expected that current planning for periods of drought will provide adequate margin to encompass potential increases in the frequency or duration of droughts. During the detailed design phase of the project, predictions of increased frequency and duration of droughts will be considered in assessing ongoing security of water supply and contingency plans developed to cater for such events. Should water supply to mine cease, then the mine may have to	Medium

Impact (as described in Section 12.5.3)	Mitigation Measures and Adaptations Strategies	Residual Risk
	discontinue operations until water supplies are re-established. The CHPP design and use of water at the mine site will be optimised to minimise water use. This may include investing in less water intensive equipment and processes.	
Structural integrity of water storage facilities may be compromised	The structural integrity of water storage facilities engineered using earthen embankments may be compromised by prolonged dry periods. These facilities will be designed and constructed appropriately, monitored on a regular basis and repairs made where required.	Low
Rehabilitation success may be compromised	The expected increase in frequency and duration of may compromise the success of progressive rehabilitation and final rehabilitation depending on the timing and length of drought events. Existing climatic factors, such as prolonged drought periods or intense rainfall, are already a factor in rehabilitation success. The proponent will monitor changes in the climate over the life of the project and update rehabilitation strategies based on specialist advise (e.g. from ecologists, soil scientists and meteorologists) to maximise the probability of progressive and final rehabilitation success.	Low to medium as project life extends

12.6.4 Wind Speed Changes

An increase in average annual wind speeds may increase dust from the site. The predicted change in average wind speeds is minor and it is expected that mitigation measures planned to minimise dust emissions under existing variations in wind speed will be adequate to mitigate dust emissions caused by a minor increase in average wind speeds. The residual risk is assessed as low.

12.6.5 Changes in Storm and Cyclone Patterns

Section 12.5.5 describes the potential impacts of changes in storm and cyclone patterns on the project. It is not expected that the frequency and intensity of storms and cyclones will change significantly in the area of the project. **Table 12-8** presents the potential impacts from changes in storm and cyclone patterns, provides adaptation strategies and mitigation measures for impacts and assesses the residual risk.

Table 12-8 Impacts of Changes in Storm and Cyclone Patterns and Mitigation Measures

Impact (as described in Section 12.5.5)	Mitigation Measures and Adaptations Strategies	Residual Risk
Increased frequency of damage to project infrastructure	Buildings and other structures will be designed to applicable the Building Codes Australia (BCA) standards and wind strength ratings. As it is not expected that the frequency and intensity of storms and cyclones will change significantly in the area of the project, current design standards are considered adequate for design. Project infrastructure will be inspected and repaired following	Low

Impact (as described in Section 12.5.5)	Mitigation Measures and Adaptations Strategies	Residual Risk
	extreme weather events.	
Increased frequency of disruption to operations	It is not expected that operations will be disrupted at a greater frequency due to changes in cyclones and storm patterns than would be expected under current weather extremes. The proponent will develop emergency management plans for extreme weather events.	Low
Increase inflow to the open pit and / or final void	The catchment of the open pit would generally be limited to the pit footprint and immediate surrounds. The flooding impact assessment concludes that flood protection measures can be designed to protect pit and final void from flood events. Therefore it is not expected that any increase in average annual rainfall will result in inflow of water to the pit in excess of that expected under existing variable weather conditions. The site water management and water balance considers management of water captured in the pit.	Low
Rehabilitation success may be compromised	Storm and cyclones may affect rehabilitation success. However, as it is not expected that the frequency and intensity of storms and cyclones will change significantly, then rehabilitation success will not change relative to current expected extreme weather events. The proponent will monitor changes in the climate over the life of the project and update rehabilitation strategies based on specialist advise (e.g. from ecologists, soil scientists and meteorologists) to maximise the probability of progressive and final rehabilitation success.	Low
Increased probability of dams overtopping	Dams, including the co-disposal dams, will be designed in accordance with the Department of Environment and Heritage Protection guidelines. Dams will be designed to hold rainfall events at a certain annual recurrence interval (ARI) rainfall event (e.g. 1:100 years). The calculation of the design storage is based on historical rainfall records. In the project area, historical rainfall records are highly variable with periods of extreme rainfall, well in excess of average rainfall. Only the 90th percentile rainfall forecasts predict an increase in rainfall. The 10th and 50th percentile forecasts predict a decrease in rainfall. It is expected that dam design using historical rainfall records to determine a design storage allowance will provide adequate margin to encompass any potential increase in average rainfall.	Low

12.7 Commitments on Managing Climate Change

The proponent will work cooperatively with government, other industries and sectors to understand potential changes to the climate, assess the impact of changes and determine and implement adaptation strategies.

12.8 Conclusion

12.8.1 Climate

Assessment of current climate information available for the project region reveals:

- The project site experiences a tropical climate characterised by high variability rainfall, temperature and evaporation.
- Seasonal temperatures for the project region are typical of the tropical Queensland climate, with warmer summer months during December, January and February and cooler winter months in June, July and August.
- The median rainfall for the region is approximately 550 mm, with 69% of the annual mean rainfall occurring between December and March.
- The project region experiences on average, higher relative humidity in the morning.
- Winds experienced for the site are either from the N to NNE, approximately 23% of the time or from the E to SE, approximately 47% of the time.

Extremes of climates including temperature extremes, droughts, floods, extreme winds, tropical cyclones and bushfire risk were discussed, including the likelihood of occurrence.

Risks to the environment associated with impacts to the project caused by extremes of climate were assessed as low to medium for all potential impacts. Medium risk scores relate to impacts including rehabilitation success being compromised, release of potentially hazardous waste to waterways, overflow from mine pits, and damage/destruction of mine infrastructure, causing release of contaminants due to cyclones or bushfire. Current and future controls are expected to reduce the risk of potential impacts (under the current climate experienced at the project site) to an acceptable level.

12.8.2 Climate Change

The residual risk for impacts from climate change was assessed as low for all potential impacts except the following medium risks:

- Rehabilitation success may be compromised during final rehabilitation due to increases in average temperature, decreases in average rainfall, increased frequency and duration of droughts or a combination of these factors.
- Water supply to the mine may become more reliant on off-site sources or may cease due to an increase in the frequency and duration of droughts.

The proponent will continually monitor actual and predicted climate changes to determine the likely success of rehabilitation strategies. These will be amended over the life of the mine to provide the best probability of rehabilitation success, considering a range of inputs such as climate, ecology and soils.

Detailed design and planning of site water management will consider water supply under conditions of increased frequency and duration of droughts.