RED HILL
MINING LEASE

ENVIRONMENTAL IMPACT STATEMENT

Section 04
Climate, Natural Hazards and Climate Change

Section 04 Climate, Natural Hazards and Climate Change

4.1 Climate

This section describes rainfall patterns, humidity, air temperature, wind (speed and direction), stability class and mixing height within the region of the Red Hill Mining Lease. Information presented in this section provides a basis for a range of other studies included in this environmental impact statement (EIS).

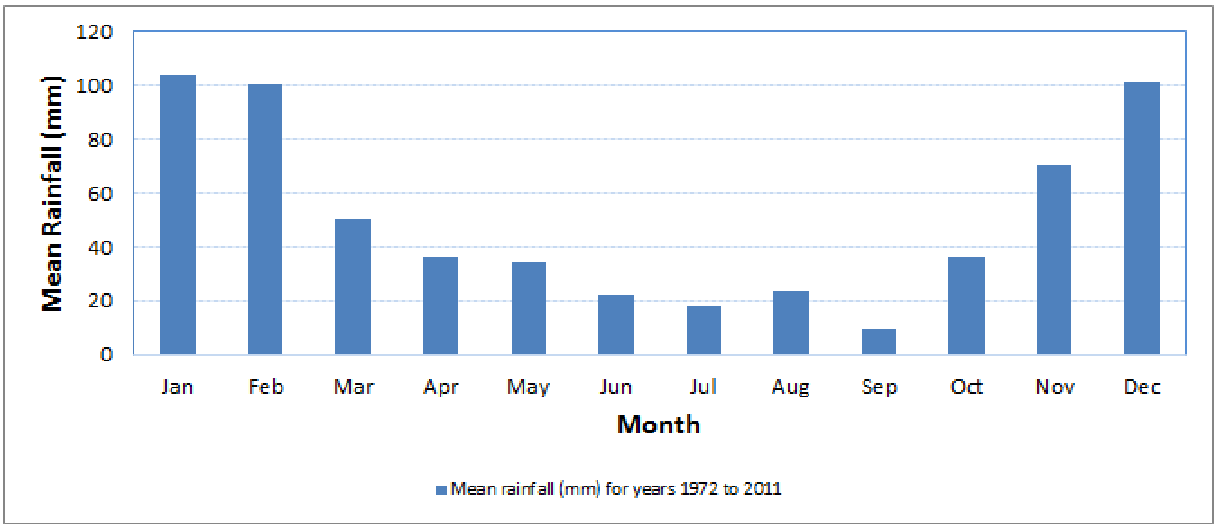
Data for long term climate statistics have been sourced from the Bureau of Meteorology (BoM) climate statistics for the Moranbah water treatment plant (WTP), which is located in Moranbah, to the south-east of the EIS study area.

Data from the BoM have been supplemented by numerically simulated data developed using the meteorological models CALifornia METeorological Model (CALMET) and the air pollution model (TAPM). The modelled data were used to generate hourly records of wind speed, wind direction and air temperature, because the BoM data from the Moranbah WTP is only recorded twice a day, at 9.00am and 3.00pm. Additionally, the numerically simulated data provide site-specific parameters that cannot be directly measured, such as mixing height and stability class. Details of the setup and application of these models are provided in the Air Quality Technical Report included as **Appendix L**.

4.2 Rainfall Patterns

The mean annual rainfall at Moranbah is approximately 600 millimetres of which approximately 80 per cent is received between the months of November through March. Monthly mean rainfall values for the period January 1972 through December 2011 are presented in **Figure 4-1**.

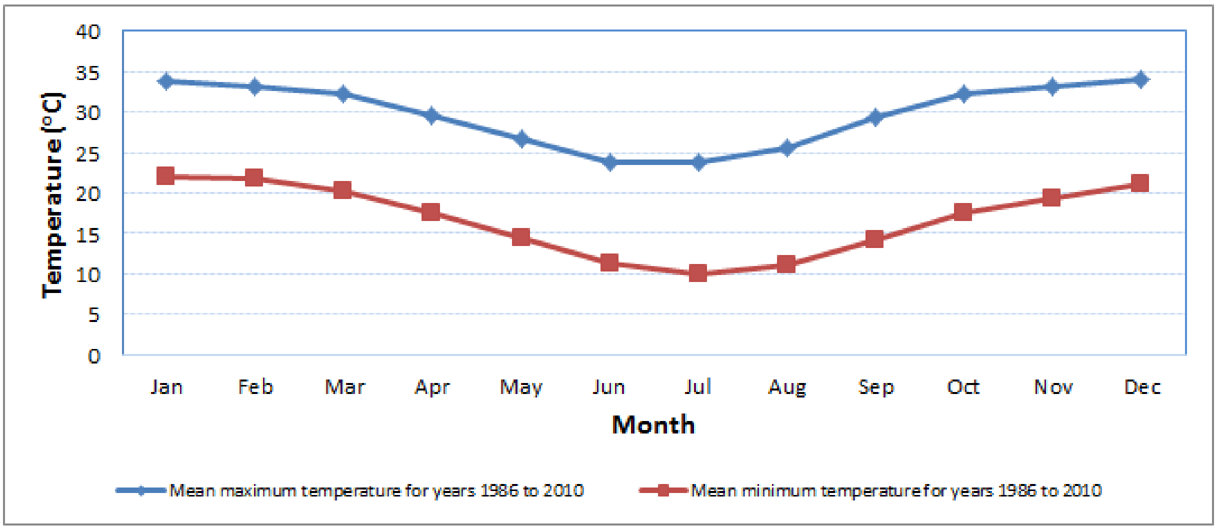
Figure 4-1 Mean Rainfall Statistics, Moranbah Water Treatment Plant (1972-2011)



4.3 Air Temperature

Long term ambient air temperature statistics for the mean maximum and mean minimum from Moranbah WTP suggest that the maximum daily temperatures in summer average between 33.1 degrees Celsius (°C) and 34°C with overnight minimums averaging between 21.1°C and 21.9°C. During winter, the maximum daily temperatures average between 23.8°C and 25.5°C with overnight minimums averaging between 9.9°C and 11.2°C (**Figure 4-2**).

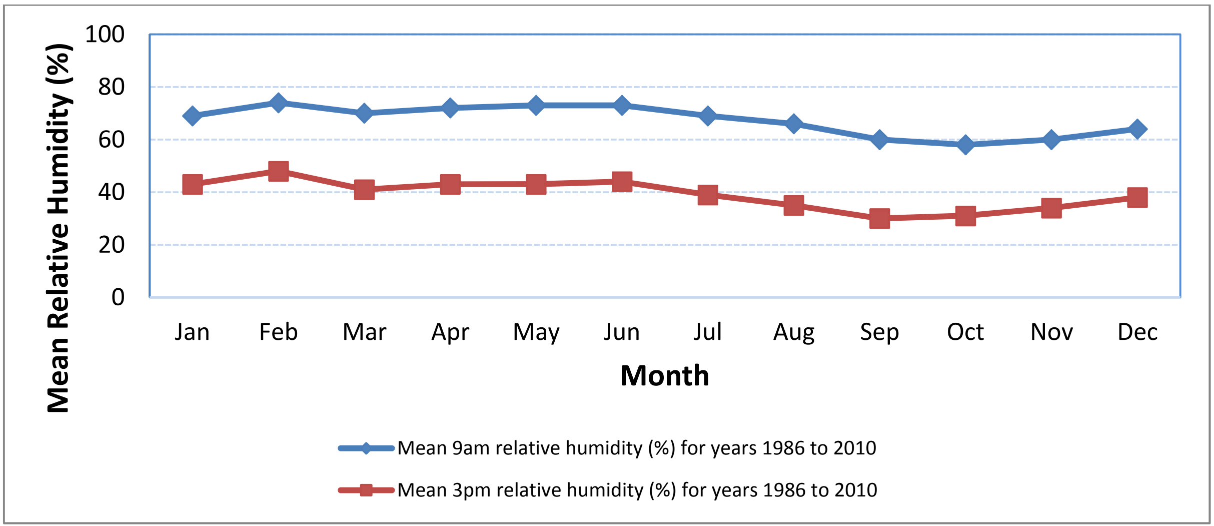
Figure 4-2 Mean Air Temperature Statistics, Moranbah Water Treatment Plant (1986-2010)



4.4 Humidity

The mean relative humidity measured at 9am and 3pm at the Moranbah WTP are presented in **Figure 4-3**. The mean monthly relative humidity at 9am ranges from 58 per cent (in October) to 74 per cent (in February). Records of mean relative humidity at 3pm indicate that humidity is lowest in September (30 per cent) and highest at February (48 per cent).

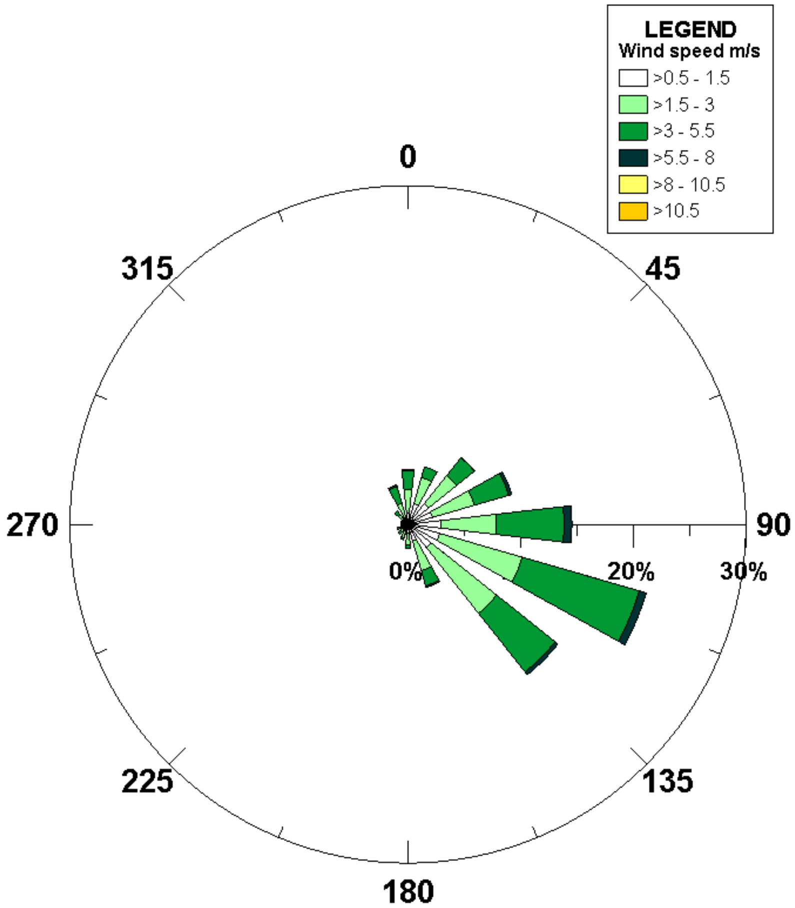
Figure 4-3 Mean Relative Humidity Statistics, Moranbah Water Treatment Plant (1986-2010)



4.5 Wind

Wind speed and wind direction data are only recorded twice daily at the Moranbah WTP. Therefore, in order to present a more complete picture of the temporal and seasonal variability in the wind fields within the study region, numerically simulated wind fields (CALMET) for the three-year period 2007 through 2009 were developed for the EIS study area (details of the development of site-specific meteorological fields are presented in **Appendix L**). The wind rose for the three-year period is presented in **Figure 4-4**.

Figure 4-4 Wind Rose for the EIS Study Area (CALMET 2007 – 2009)



The wind directions in the vicinity of the project are predominantly from the east-north-east through to the east-south-east. The plot highlights that the site generally experiences low to moderate winds reaching a maximum of approximately 7.5 metres per second (m/s) and an average speed over all hours of approximately 2.7 m/s. The EIS study area is characterised by very infrequent winds from the west.

Analysis of wind speed and direction for the numerically simulated data for each season is shown as wind roses in **Figure 4-5**. Data suggest that the maximum summer wind speeds are approximately 7.5 m/s with the predominant wind direction being from the east-south-east. An average wind speed of approximately 2.9 m/s is predicted during summer months. Maximum autumn wind speeds are approximately 7.5 m/s and predominantly from the east-south-east and south-east. An average wind speed of approximately 2.6 m/s is predicted during the autumn months. Winds during the winter tended to be predominantly from south-east and east-south-east directions. The maximum and average wind speed predicted for the winter months is approximately 6.6 m/s and approximately 2.3 m/s, respectively. Maximum wind speed during spring was approximately 7.2 m/s, with the majority of winds from the north through east-south-east. The average wind speed during spring months is predicted to be approximately 3 m/s.

Annual variability in wind speed and wind direction for 2007 through 2009 is presented in **Appendix L**.

4.6 Stability Class

Stability of the atmosphere is determined by a combination of horizontal turbulence caused by the wind and vertical turbulence caused by the solar heating of the ground surface. Stability cannot be measured directly; instead it must be inferred from available data, either measured or numerically simulated.

The Pasquill-Gifford scale defines stability on a scale from A to G, with stability class A being the least stable, occurring during strong daytime sun and stability class G being the most stable condition, occurring during low wind speeds at night. For any given wind speed the stability category may be characterised by two or three categories depending on the time of day and the amount of cloud present. In meteorological models such as CALMET, the stability classes F and G are combined.

A summary of the numerically simulated hourly stability class data for three years (2007 through to 2009) is presented in **Figure 4-6**. Stability class F is predicted to occur most frequently (42.8 per cent), indicating that the dominant conditions are moderately to very stable, with very little lateral and vertical diffusion.

The frequency of strongly convective (unstable) conditions at the EIS study area, represented by stability class A, is low at two per cent of hours during the three years simulated. This category requires strong sunlight and low wind speeds through the day, and is characterised by vertical movement of air.

Figure 4-5 Seasonal Wind Rose for the EIS Study Area (CALMET 2007 – 2009)

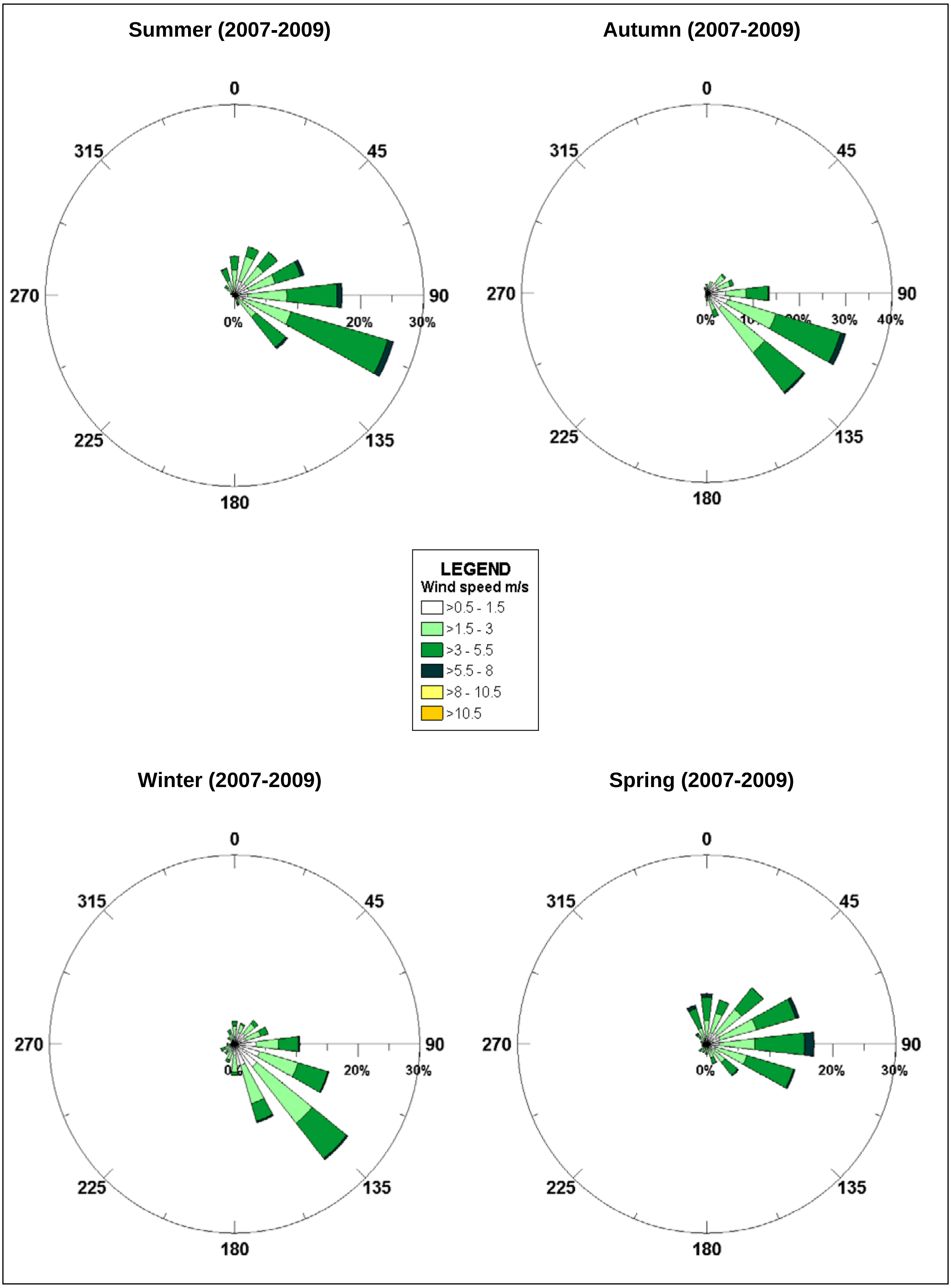
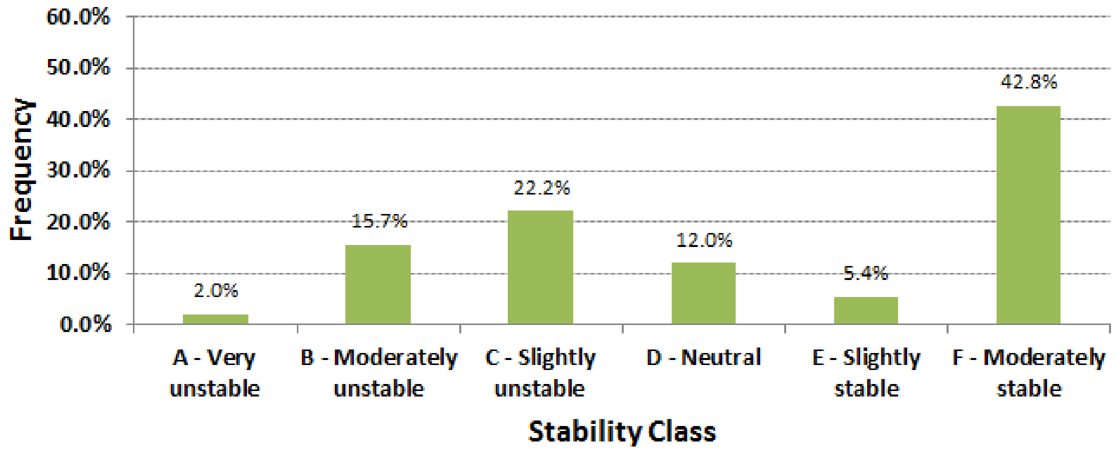


Figure 4-6 Frequency of Stability Class for the EIS Study Area (CALMET 2007-2009)



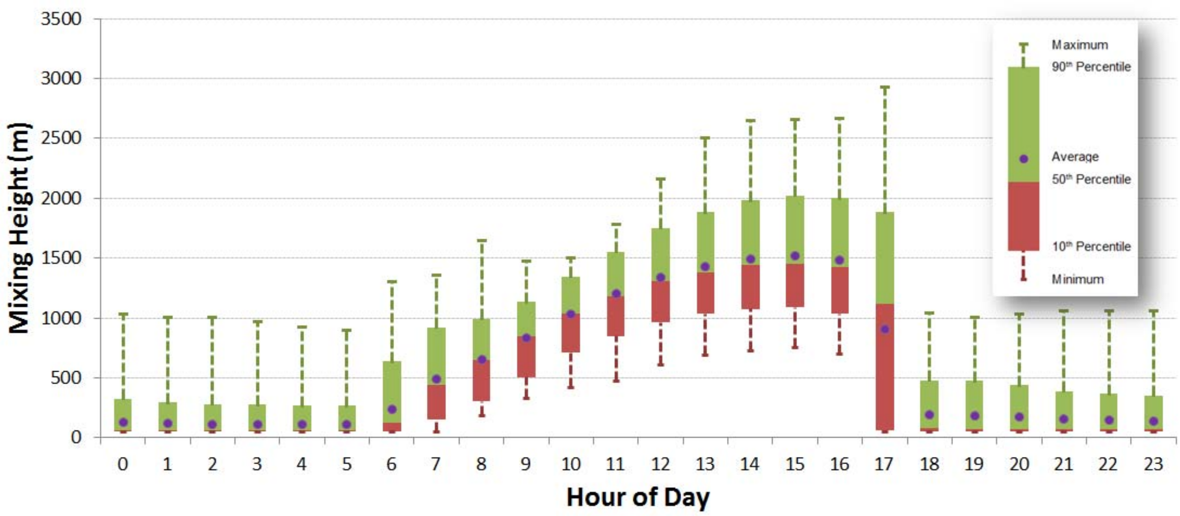
4.7 Mixing Heights

The mixing height quantifies the vertical height of mixing in the atmosphere and is a modelled parameter that is not able to be measured directly. Numerically simulated hourly mixing height data are presented in **Figure 4-7** for the three-year period of 2007 through to 2009. **Figure 4-7** shows the mixing height as a function of the hour of the day at the location of the EIS study area. The graph represents the typical growth of the boundary layer, whereby the mixing height is generally lowest during the night and into the early morning and highest during the late afternoon.

The mixing height decreases in the late afternoon, particularly after sunset, due to the change from surface heating from the sun to a net heat loss overnight.

Average early morning (midnight to 6am) mixing heights range from 110 to 240 metres above ground level, and average late evening (6pm to midnight) mixing height ranges from 140 metres to 190 metres. Average mixing height predicted during the day time (7am to 5pm) ranges from 490 metres to 1,510 metres. Low mixing heights typically translate to stagnant air with little vertical motion, while high mixing heights allow vertical mixing and good dispersion of pollutants.

Figure 4-7 Mixing Height by Time of Day for the EIS Study Area (CALMET 2007-2009)



4.8 Temperature Inversions

Temperature inversions are phenomena that occur when the normal temperature profile of the atmosphere changes from decreasing temperature with height (typically a reduction of 1°C per 100 metres for neutral conditions) to a state where temperature increases with height over a portion of the atmosphere. Temperature inversions often create the worst-case meteorological conditions for air dispersion and noise transmission and, thus, are critical conditions for adverse impacts at nearby locations.

Temperature inversions are measured by simultaneous near-surface measurements at different heights, typically 10 and 50 metres. No on site temperature measurements are available to determine the frequency of temperature inversions. Consequently, modelled temperature data for 2007 through 2009 have been analysed at heights of 10 to 375 metres. Based on an inversion criterion of at least 3°C per 100 metres, the predicted frequency of inversion conditions is approximately seven per cent of the year at these heights.

4.9 Extremes of Climate

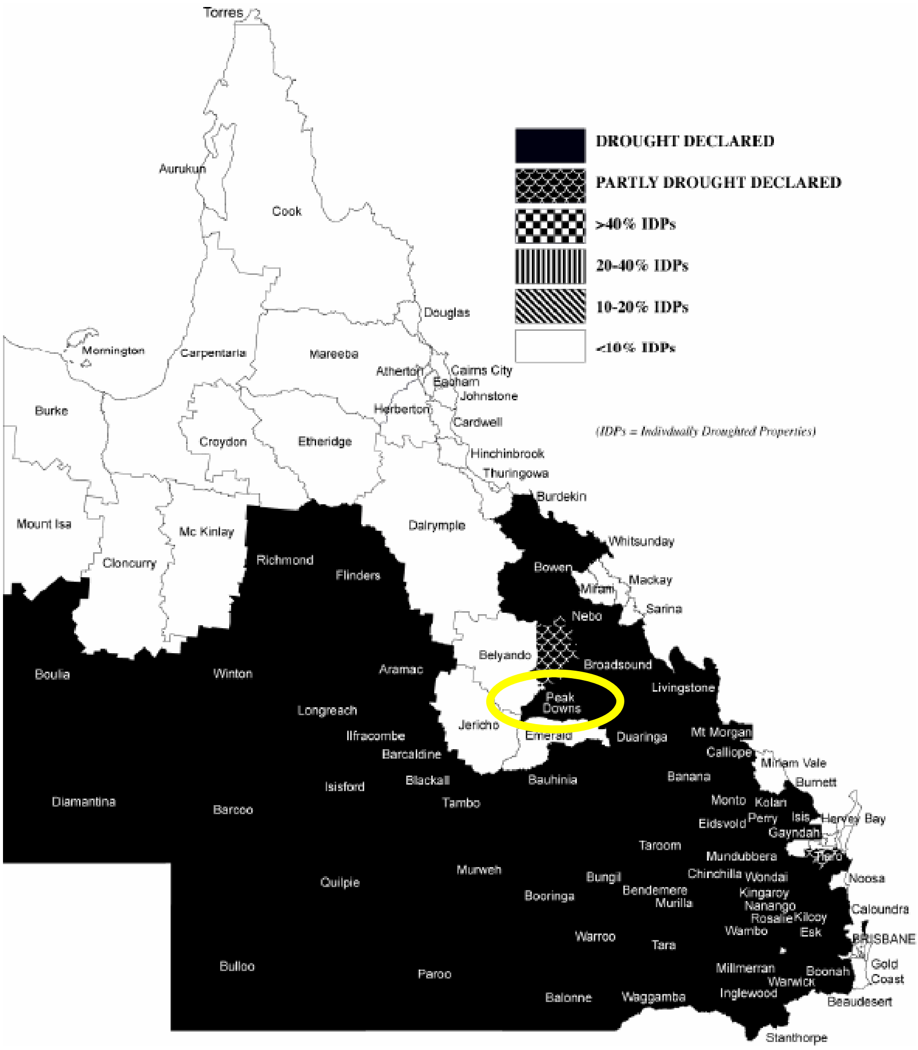
This section describes the project's vulnerability to natural hazards such as drought, floods, bushfires, storm events and climate change.

4.9.1 Drought

The Queensland Government issues monthly state-wide drought situation reports. Reports are available on the Long Paddock website from January 1995 through to the present. Recent periods of long term droughts (consecutive years of below average rainfall) in the Central Queensland region include 1991 through 1995 and 2001 through 2007. In particular, for the Peak Downs region, information contained on the Long Paddock website suggests that the region was in drought for the period September 1992 through February 1999, and again from May 2002 through February 2008. Refer to **Figure 4-8**, which shows the Peak Downs region indicated in yellow.

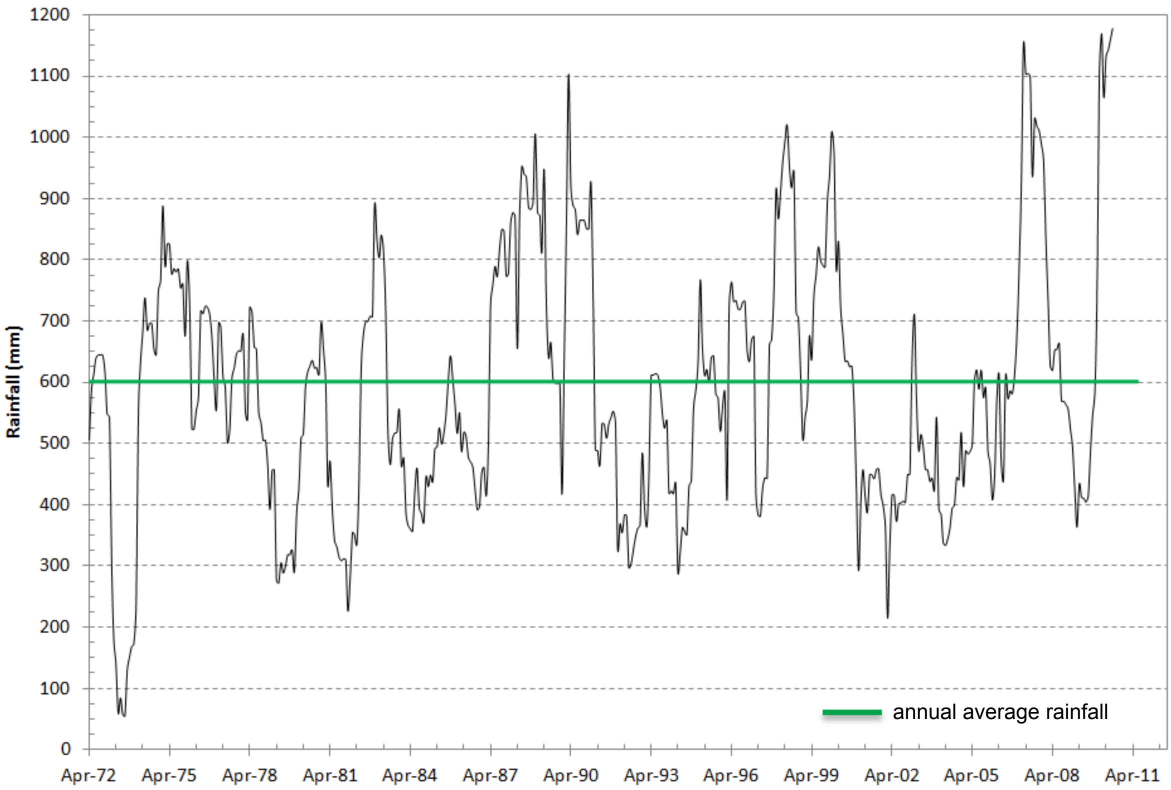
Rainfall data from the Moranbah WTP presented in **Figure 4-9** highlight the variability in the annual rainfall amount (280 to 1,109 millimetres per year (mm/yr)) for the period April 1972 through June 2011, when compared with the data set annual average rainfall of 601 mm/yr. The data set annual average rainfall is indicated by the green line.

Figure 4-8 Queensland Drought Report – January 2008 (DERM Long Paddock 2008)



www.LongPaddock.qld.gov.au

Figure 4-9 Annual Average Rainfall from Data Obtained from the Moranbah WTP



4.9.2 Flood

The Isaac River flows generally to the east of the existing Goonyella Riverside and Broadmeadow (GRB) mine complex. Flooding within the existing GRB mine complex and the Red Hill Mining Lease area can vary by storm location, extent and duration. Several tributaries of the Isaac River traverse through, or around, the existing GRB mine complex and EIS study area. The region is characterised with semi-arid climate, yet can also be prone to infrequent widespread high rainfall events that can occur in tropical regions. The area is approximately 150 kilometres from the coast (direct line distance), which limits the frequency of typical intense tropical weather influences from the coast to reach the Isaac River catchment in most years, and hence this characterises the typical semi-arid climate that is commonly observed in the region.

There is reasonable potential for major tropical rainfall events to occasionally extend inland to the EIS study area. Idealised flood-producing mechanisms in the Isaac River catchment (i.e. extreme floods) would require the combination of a large tropical storm to occur in the area, and the spatial extents of the storm to extend across the majority of the catchment. The last major flood in this reach of the Isaac River caused by an ex-tropical cyclone occurred in the early 1990s after tropical cyclone 'Joy' crossed the coast.

Localised flooding could also occur in the tributaries due to high intensity thunderstorms or long duration storms centred over these smaller catchments.

A detailed surface water study was completed for the project (refer to **Section 7.2.2.6**). The study included an assessment of the hydrology of the project's catchment area and flood modelling

(**Appendix I4**) and a geomorphologic impact assessment (**Appendix I6**). Hydrological and hydraulic models were developed and used to estimate flood behaviour for frequent and large design floods.

4.9.3 Storm Events

The BoM publishes plots of the annual average number of tropical cyclones per year (**Figure 4-10**), average annual thunder days (**Figure 4-11**), and the annual average lightening ground flash density (**Figure 4-12**).

The information presented in these figures suggests that the region including the EIS study area may experience on average between up to 0.2 cyclones per year, 15 to 20 thunder days per year and between one and three ground lightning flashes per square kilometre per year.

4.9.4 Rainfall Extremes

Rainfall extremes are an important consideration in relation to erosion and sediment control and water management particularly during construction activities. **Table 4-1** shows that while some very high daily rainfall totals have occurred over the data period it is relatively rare to have rainfall events exceeding 25 millimetres in one day. Rainfall is more likely in the months of November-April.

Table 4-1 Rainfall Extremes Moranbah Water Treatment Plant 1972-2012 (BoM)

Month	Highest Monthly Rainfall (mm)	Highest Daily Rainfall (mm)	Mean Number of Days Where Rainfall > 25 mm	Mean Number of Rain Days
January	315	120.4	1.4	8.5
February	347.4	150.8	1.1	8.2
March	268	164.8	0.6	5.5
April	271	143.8	0.4	4.3
May	196.6	58	0.4	3.8
June	170.3	43.4	0.3	3.2
July	103.6	60	0.2	2.6
August	247.3	150.8	0.3	2.2
September	60.7	27.6	0.0	2.2
October	146.6	73.8	0.4	4
November	220.3	86	1.0	6.2
December	350	201.3	1.4	7.3
Annual	**1,109.2**	**164.8**	**7.5**	**58**

Figure 4-10 Annual Average Number of Tropical Cyclones

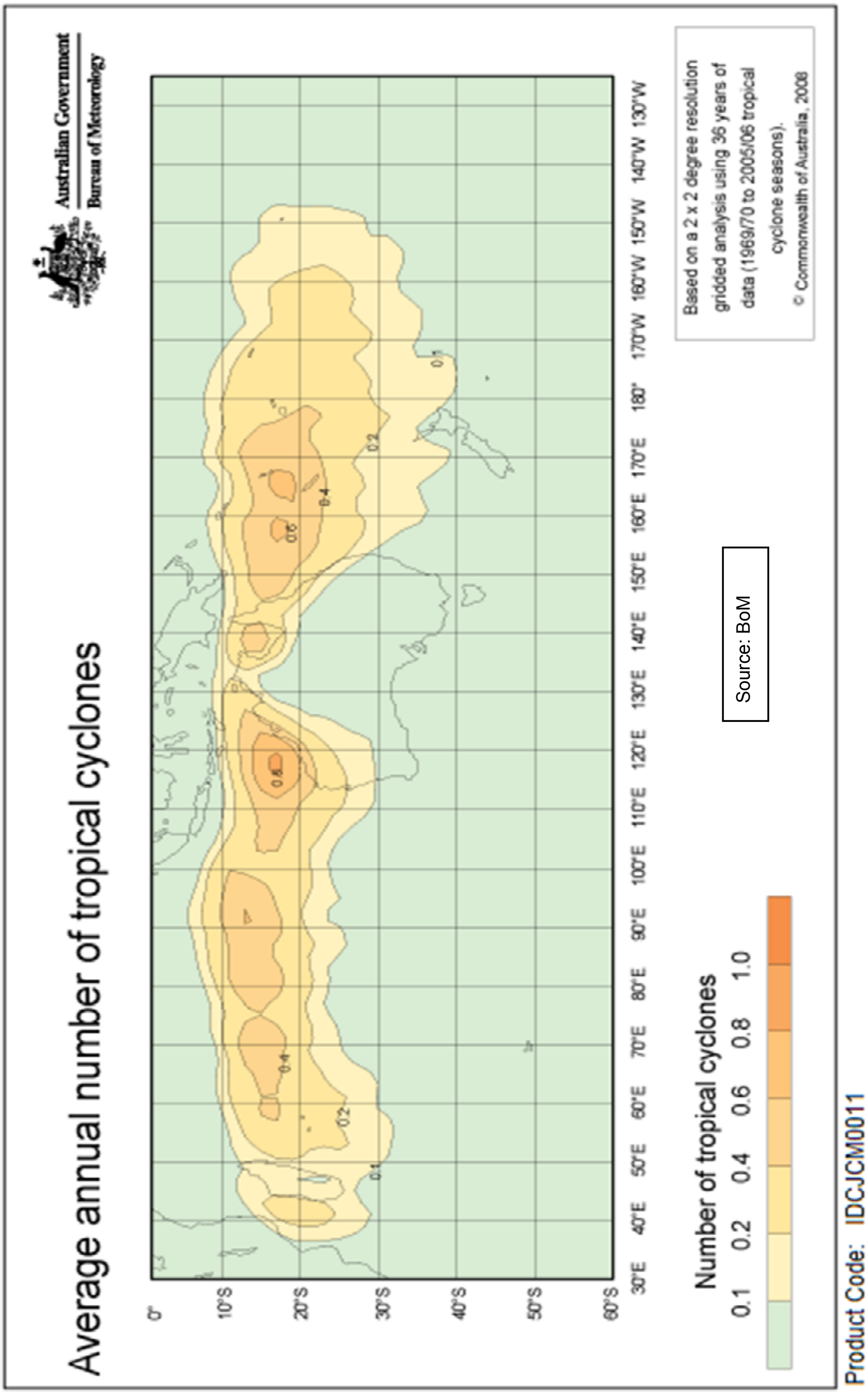


Figure 4-11 Annual Average Number of Thunder Days

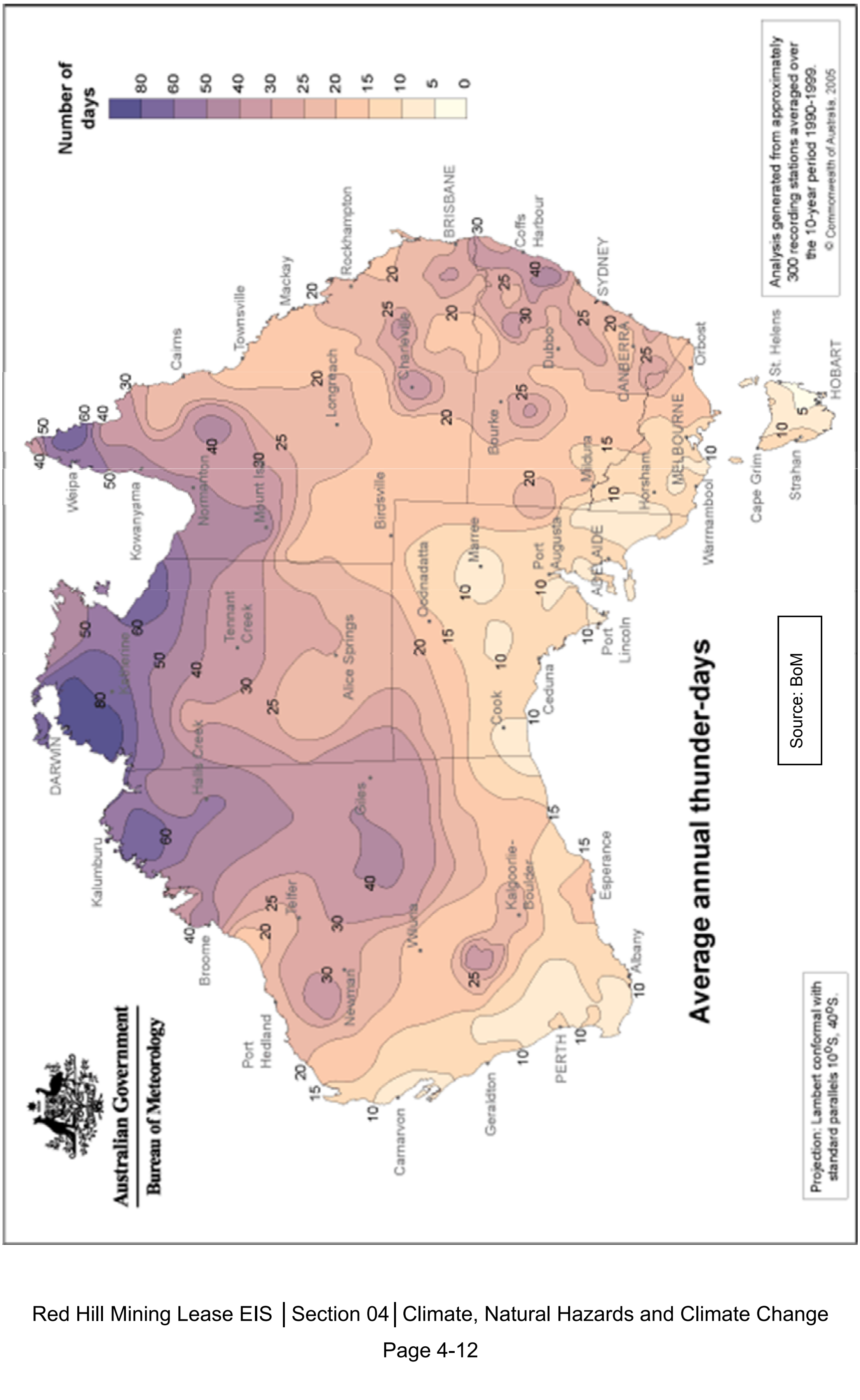
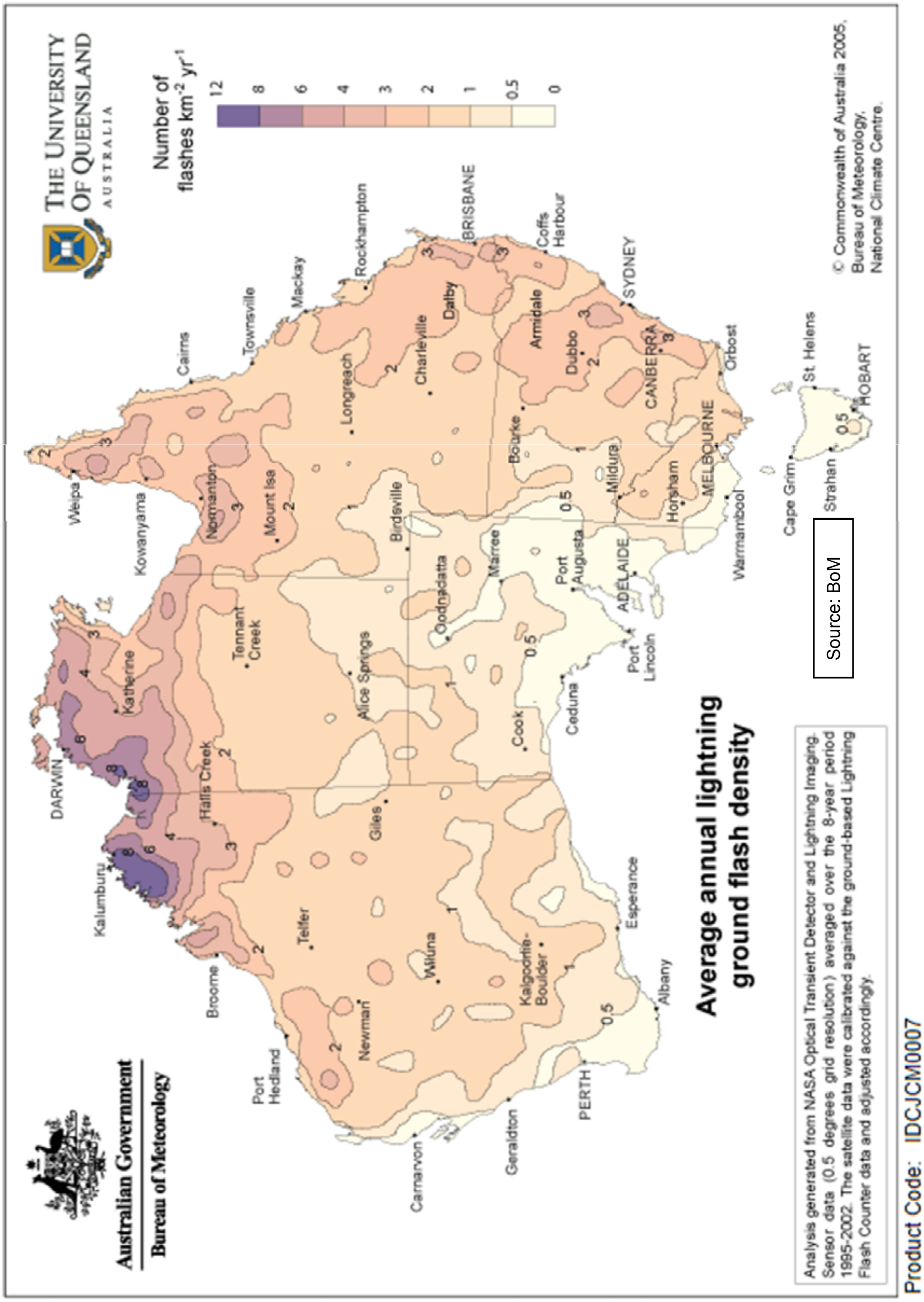


Figure 4-12 Annual Average Lightning Ground Flash Density



4.9.5 Bushfires

The climate factors that exert the most influence over bushfire weather are temperature, winds, and humidity (BoM 2009). A combination of high temperature, high winds, and low humidity increases fire danger. In Queensland, spring (particularly late spring) brings a combination of these climatic factors constituting the fire season. During winter, the temperatures and rainfall are low. In summer, while the temperatures are at their hottest, the rainfall also increases, reducing the risk of a significant fire. In the period between winter and summer the fuel is very dry from the lack of rainfall during the winter months and temperatures increase.

The Rural Fire Service and Queensland Fire and Rescue Service have modelled the bushfire risk for Isaac Regional Council (QFRS 2008). The risk modelling examined factors of slope, aspect and vegetation. The mapping shows the EIS study area as being of low bushfire risk, with medium to low bushfire risk in the local area.

4.10 Climate Change

Predicting and responding to climate change impacts is an ongoing area of investigation and research. Recent reports, including *Climate Change in Australia Technical Report* (CSIRO 2007) suggest that the region in which the project is located is likely to be subject to climate change during the life span of the project (active mining for the RHM underground expansion for 20 to 25 years and then additional years as required to achieve rehabilitation objectives) and, thus, climate change has the potential to affect future operations.

The project's vulnerabilities to climate change have been addressed by conducting a risk assessment on the impacts of changes in rainfall, temperatures, rainfall intensity, storm severity, number of windy days, and likelihood of flooding. The methodology and results of this assessment are presented in the following sections. Climate change risk management strategies are also presented to allow the project to adapt to future climate change.

4.10.1 Summary of Predicted Impacts

The following tables summarise the effects currently considered likely in relation to climate change in the vicinity of the project. These effects may include temperature change, rainfall change, relative humidity, sea surface temperature, wind speed and potential evapotranspiration. The data are sourced from *Climate Change in Australia Technical Report* (CSIRO 2007), which represents current information on likely effects of climate change. Projections are relative to the period 1980-1999 (referred to as the 1990 baseline for convenience). The best estimate results (50th percentile) and the medium emissions scenario from the 'IPCC Special Report on Emissions Scenarios' were used (**Table 4-2**), as documented in *Climate Change in Australia Technical Report* (IPCC 2000; CSIRO 2007).

Table 4-2 The Projected Impacts of Climate Change in Queensland in 2030 and 2050

	Temperature Change (ºC)		Rainfall Change (%)		Change in Relative Humidity (%)	
	2030	2050	2030	2050	2030	2050
Annual	+1 to +1.5	+1.5 to +2	-2 to -5	-5 to -10	0.5 to -0.5	-0.5 to -1
Summer	+1 to +1.5	+1.5 to +2	2 to -2	-2 to -5	0.5 to -0.5	0.5 to -0.5
Autumn	+1 to +1.5	+1.5 to +2	-2 to -5	-5 to -10	0.5 to -0.5	0.5 to -0.5
Winter	+0.6 to +1	+1.5 to +2	-5 to -10	-5 to -10	0.5 to -0.5	-0.5 to -1
Spring	+1 to +1.5	+1.5 to +2	-5 to -10	-10 to -20	-0.5 to -1	-0.5 to -1
	Wind Speed Change (%)		**Change in Potential Evapotranspiration (%)**		**Sea Surface Temperature Change (ºC)**	
Annual	+2 to +5	+2 to +5	+2 to +4	+4 to +8	+0.6 to +1	+1 to +1.5
Summer	+2 to +5	+2 to +5	+2 to +4	+4 to +8		
Autumn	2 to -2	2 to -2	+2 to +4	+4 to +8		
Winter	2 to -2	2 to -2	+4 to +8	+4 to +8		
Spring	+5 to +10	+5 to +10	+2 to +4	+4 to +8		

It can be seen in **Table 4-2** that by 2030 the average annual temperature is expected to increase by between 1ºC and 1.5ºC. There is likely to be a corresponding decrease in projected rainfall of between two and five per cent and wind speed is expected to increase by between two and five per cent.

The changes in temperature are expected to be less pronounced in winter. Changes in rainfall are expected to be more pronounced in winter and spring with a reduction expected in the range of 5 to 10 per cent. It is noted that a reduction in rainfall can sometimes lead to a disproportionately greater reduction in water availability as catchment runoff rates are not directly proportional to rainfall.

By 2050, average annual temperature is expected to increase by between 1.5ºC and 2ºC. There is likely to be a corresponding decrease in rainfall of between 5 and 10 per cent, relative humidity is expected to decrease by up to one per cent and wind speed is expected to increase by between two and five per cent.

The changes in temperature are expected to be experienced equally throughout the year. Changes in rainfall are expected to be more pronounced in spring with a reduction of up to 20 per cent. Wind speed increases are expected to be more pronounced in spring and summer with summer wind speeds expected to increase by up to 10 per cent.

In summary, during the life of future project operations it is expected that the local conditions will become hotter, drier and windier. Changes in rainfall and wind speed are expected to be more pronounced in the spring.

The *Climate Change in Queensland* 2007 report notes that a significant proportion of Queensland's agricultural, industrial and mining activity is located in central Queensland and these industries are highly dependent on water resources.

4.10.2 Risk Assessment Methodology

A semi-quantitative risk assessment procedure was used to evaluate the risks as a result of the various potential climate change impacts on mining operations. This approach is consistent with the AS/NZS ISO 31000:2009 *Risk management – Principles and guidelines* and IEC/ISO 31010 *International Standard Risk management – Risk assessment techniques* (International Electrotechnical Commission 2009). The key steps in undertaking the risk assessment involved:

- identification of the potential climatic impacts on mining operation;
- analysis of the risks in terms of consequence and likelihood; and
- evaluation of the risks, including risk ranking to identify priorities for their management.

To assist in the process of assigning levels of consequence and likelihood, the measures outlined in **Table 4-3** and **Table 4-4** were used.

Table 4-3 Measures of Likelihood

Likelihood Rank	Descriptor	Description
A	Almost certain	80% chance of occurring; may occur more than once per year; happens often.
B	Likely	50% chance of occurring; may occur once in a few years; easily happens.
C	Possible	20% chance of occurring; may occur once in 5 years; has happened before.
D	Unlikely	10% chance of occurring; may occur once in 10 years; considered possible.
E	Rare	2% chance of occurring; may occur once in 50 years; considered conceivable.

Table 4-4 Measures of Consequence

Level	Descriptor	Environmental Severity	Mine Site Functionality	Financial (per event/per year)	Public / Workforce Health and Safety
1	Insignificant	Unplanned low level environmental impact.	No loss of use	<$50,000	Low level short-term inconvenience or symptoms. Not medical treatment.
2	Minor	Unplanned minor impact to non-threatened species or their habitat.	Short terms loss of use (all/part) <1 week	$50,000 to $500,000	Objective but reversible disability/impairment. Medical treatment injury.
3	Moderate	Unplanned moderate impact to ecosystem or non-threatened species.	Loss of use (all/part) 1 week to 1 month	$500,000 to $1 million	Moderate irreversible disability or impairment (<30%) to one or more people. Days lost.
4	Major	Unplanned major impact on ecosystem or threatened species.	Loss of use (all/part) 1 month to 1 year	$1 million to $10 million	Single fatality or severe irreversible disability (>30%) to one or more persons.
5	Catastrophic	Unplanned serious or extensive impact on ecosystem or threatened species.	Loss of use (all/part) > 1 year	>$10 million	Multiple fatalities (2-20), or significant irreversible effects to >50 persons.

The risk assessment matrix outlined in **Table 4-5** was used to determine the level of risk based on likelihood and consequence scores. Scenarios with a combined score of 10 or greater are considered to pose a high level of risk. Scenarios with a combined score of between five and nine are considered to pose a medium level of risk. Scenarios with a combined score of less than five are considered to pose a low level of risk.

Table 4-5 Risk Matrix

		Consequence				
		1	2	3	4	5
Likelihood	A	High	High	Extreme	Extreme	Extreme
	B	Moderate	High	High	Extreme	Extreme
	C	Low	Moderate	High	Extreme	Extreme
	D	Low	Low	Moderate	High	Extreme
	E	Low	Low	Moderate	High	High

4.10.3 Results

The results of the risk assessment are presented in **Table 4-6** below. The risk assessment is based on un-mitigated risks.

Table 4-6 Risk Assessment of the Potential Impacts of Climate Change on Mine Operations (unmitigated)

Risk Scenario	Likelihood	Severity	Risk
Reduced process water availability due to decreased rainfall and increased evapotranspiration.	Likely	Moderate	High
Increased flood risk due to increased rainfall intensity.	Possible	Moderate	High
Health impacts such as heat stress on mine site staff from increased temperatures.	Unlikely	Major	High
Increased soil erosion due to decrease in soil moisture and increased rainfall intensity.	Unlikely	Moderate	Moderate
Unsuccessful rehabilitation planting due to reduced average rainfall and more severe storm events.	Unlikely	Moderate	Moderate
Increased maintenance costs for infrastructure due to more severe storm events.	Possible	Minor	Moderate
Decrease in efficiency of equipment due to increased temperature resulting in increased operation costs.	Unlikely	Minor	Low
Increased maintenance costs for infrastructure due to more severe bushfire events due to increased temperatures and evapotranspiration potential.	Unlikely	Minor	Low
Community/workforce isolation due to higher risks of flooding events.	Rare	Minor	Low

4.10.4 Risk Management Measures

Management measures for the risk scenarios in **Table 4-6** that were assessed to be a high or medium risk have been identified in **Table 4-7**. In addition, changes in temperature and rainfall will be addressed in design criteria and allowed for in ongoing management. As scenarios may change, these criteria may need to be updated from time to time.

Table 4-7 Risk Management Measures for Potential Impacts of Climate Change on Mine Operations

Risk Scenario	Mitigation Measures	Cross Reference within the EIS
High Risk		
Reduced process water availability due to decreased rainfall and increased evapotranspiration.	A water supply strategy will be developed, implemented and maintained. This includes details of usage of water from the raw water supply network which has adequate supply to source any shortfall from the mine water management system.	**Section 7.3.2**
Increased flood risk due to increased rainfall intensity.	Emergency response procedures and flood forecasting will be incorporated into operating procedures. The bridge across the Isaac River will be designed so that flows within the Isaac River are not impeded. The Red Hill mine industrial area and mine access will be designed to allow for protection from possible increases in flood levels. Modelling will be undertaken to ensure the detailed design is appropriate to the flood risk.	**Section 7.3.4**
Health impacts on mine site staff from increased temperatures (e.g. heat stress).	Include heat stress measures in health and safety management system.	NA
Moderate Risk		
Increased soil erosion due to decrease in soil moisture and increased rainfall intensity (including access tracks).	Develop erosion and sediment controls for incidental mine gas management areas to match increased risk if changes become apparent. Size sediment traps and basins to match likely future rainfall intensity.	**Section 5.3.3**
Unsuccessful rehabilitation planting due to reduced average rainfall and more severe storm events.	Re-sow affected areas with drought resistant species. Consider alternative methods for establishing ground cover, such as 'hydromulch'.	**Section 5.5**
Increased maintenance costs for infrastructure due to more severe storm events.	Incorporate climate change effects into design criteria.	**Section 7.3.8**

BMA actively explores opportunities to more effectively manage its energy use and greenhouse gas emissions, including:

- Investigating the feasibility of options for capturing and using the methane that would otherwise be released to the atmosphere during mining. Potential uses to be considered in association with the development and operation of the Red Hill mine include supplying gas to the commercial market or for on-site power generation, either directly or via cooperative arrangements with a gas operator.
- Flaring of waste mine methane to substantially reduce its global warming impact. In regard to Red Hill, this may include flaring gas that is drained ahead of and during mining operations and (less

likely but potentially) ventilation air methane (BMA is actively involved in coal industry research into the feasibility of vent air methane abatement).

- The company's business improvement program, which includes measures to increase coal recovery and machine productivity and, thereby, reduce fossil energy use and greenhouse emissions per tonne of product.
- BMA's contribution to and participation in the COAL21 Fund, through which the Australian coal industry is voluntarily funding research, development and demonstration of low emission coal technologies. Through COAL21, BMA has made substantial financial contributions to demonstration projects such as the Callide Oxyfuel (CO2 capture) Project in Central Queensland and the CO2CRC Otway (CO2 geo-sequestration) Project in Victoria, feasibility studies of integrated CO2 capture and storage projects in Queensland and New South Wales and, also in NSW and Qld, state-wide assessments of underground CO2 storage potential.

These activities involve collaborations with a range of stakeholders, including other coal companies, universities and research providers, and state and federal governments.