6.2 Climate

6.2.1 Introduction

This section discusses local climate characteristics, seasonal conditions and potential extreme climatic events including cyclones, flooding, drought and bushfires within the CSG fields study area. Non climate associated hazards and risks are described in Section 10.

6.2.2 Existing Environmental Values

The CSG fields study area is characterised by an inland sub-tropical climate with cool winters and hot summers. The majority of the annual rainfall occurs during the summer months. In general, the year round climate is dry, with winter months being more arid than summer months.

The Bureau of Meteorology (BOM) operates several meteorological sites within or near the CSG fields study area, including Emerald, Springsure, Rolleston, Taroom, Brigalow, Injune, Roma Airport, Roma Post Office, Miles and Surat. The location of the meteorological sites is shown in Figure 7.2.1 with a summary of local climatic conditions described below.

6.2.2.1 Temperature

The average daily temperature across all the BOM sites in the study area ranges from 20.7 °C to 34.1 °C in summer (January) and from 5.1 °C to 21.0 °C in winter (July). Emerald is warmer than other sites in terms of both daily minimum and daily maximum temperature as it is the most northern site. Mean daily maximum and minimum temperature data recorded at each of the monitoring sites are presented in Figure 6.2.1.

6.2.2.2 Rainfall and Evaporation

The CSG fields study area experiences an average annual rainfall of 623 mm, with Brigalow reporting the highest annual average rainfall of 700 mm, and Emerald reporting the lowest annual average rainfall of 515 mm. Rainfall data is presented in Figure 6.2.2.

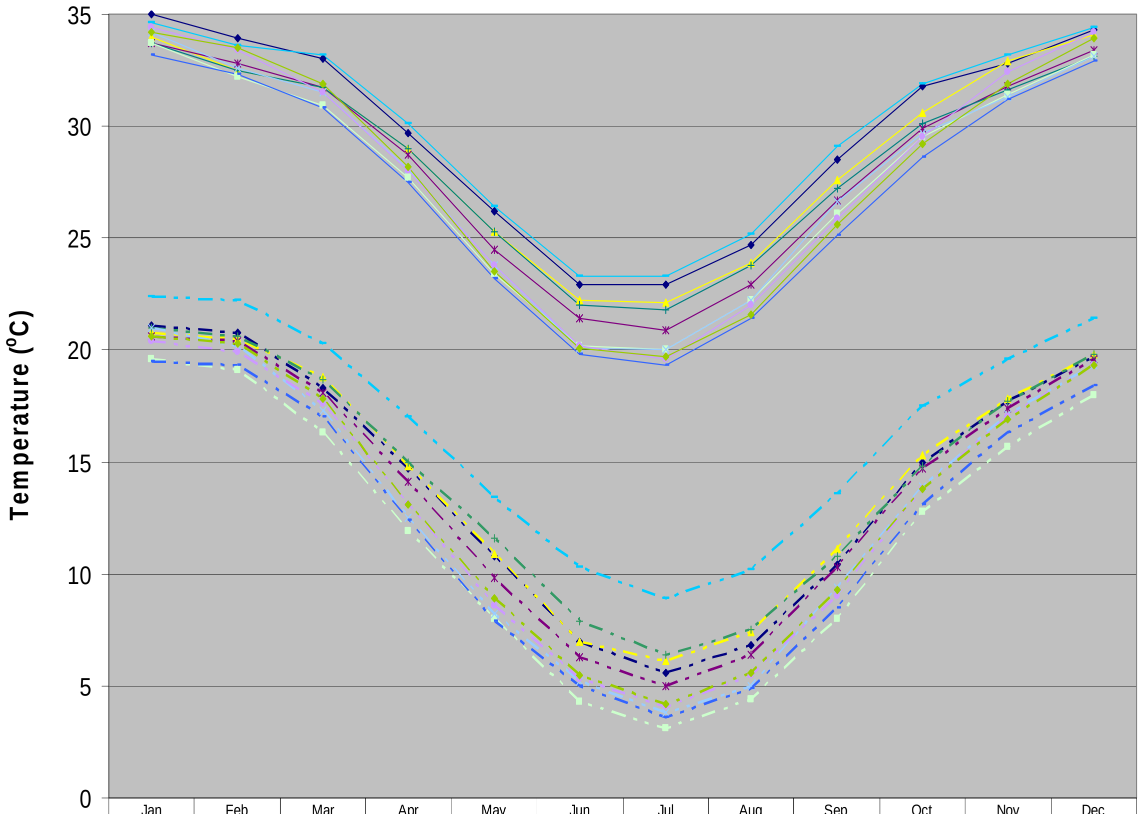
The highest average monthly rainfall occurs over the summer months of December through to February, with over 80 mm falling per month (when averaged across all sites). Rainfall in the winter months (April to September) approximates 30 mm per month.

Evaporation records are only available for Brigalow, Roma and Miles. The evaporation data is measured using evaporation pans filled with water. Records indicate evaporation is highest from November through to February, with a mean daily evaporation rate of 7.3 mm (approximately 219 mm per month). The winter months of June, July and August have daily evaporation rates of approximately 3 mm (approximately 90 mm per month) (Figure 6.2.3).

6.2.2.3 Relative Humidity

Relative humidity is the term used to describe the amount of water vapour in the air relative to the saturation point at a given temperature. A graphical representation of the monthly average relative humidity data (at 9 am and 3 pm) for each of the monitoring sites within the CSG fields study area are shown in Figure 6.2.4. Relative humidity is observed to be higher at 9 am, ranging from 50 % to 70 % on average, and lower at 3 pm, with values ranging from 30 % to 45 %. The diurnal variations in temperature which (in general) correspond to lower temperatures in the morning and higher temperatures in the afternoon is the primary reason for this observed trend in the relative humidity and is the result of the changes in the water holding capacity of the atmosphere.

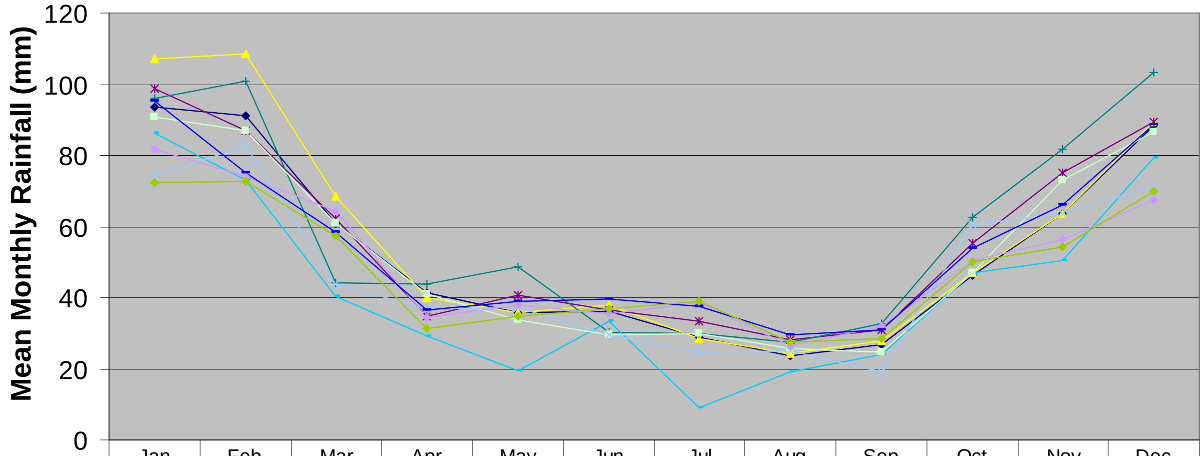
For most sites, relative humidity is higher in winter than in summer, with September and October (spring) reporting the lowest relative humidity levels.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston Max	35.0	33.9	33.0	29.7	26.2	22.9	22.9	24.7	28.5	31.8	32.8	34.3
Rolleston Min	21.1	20.8	18.3	14.7	10.8	7.0	5.6	6.8	10.4	15.0	17.7	19.7
Springsure Max	34.0	32.5	31.7	29.0	25.3	22.2	22.1	23.9	27.6	30.6	32.9	34.1
Springsure Min	20.8	20.5	18.8	14.8	10.9	7.0	6.1	7.4	11.1	15.3	17.8	19.8
Taroom Max	33.7	32.8	31.7	28.7	24.5	21.4	20.9	22.9	26.7	29.9	31.8	33.4
Taroom Min	20.6	20.4	18.1	14.1	9.8	6.3	5.0	6.4	10.3	14.7	17.4	19.6
Brigalow Max	33.7	32.5	31.7	29.0	25.3	22.0	21.8	23.8	27.2	30.1	31.6	33.1
Brigalow Min	21.0	20.6	18.7	15.0	11.6	7.9	6.4	7.5	10.8	14.8	17.7	19.8
Emerald Max	34.6	33.6	33.2	30.1	26.4	23.3	23.3	25.2	29.1	31.9	33.2	34.4
Emerald Min	22.4	22.2	20.3	17.0	13.4	10.3	8.9	10.2	13.6	17.5	19.6	21.4
Injune Max	33.7	32.2	30.9	27.7	23.4	20.2	20.0	22.2	26.1	29.5	31.4	33.2
Injune Min	19.6	19.1	16.3	11.9	8.0	4.3	3.1	4.4	8.0	12.8	15.7	18.0
Roma Airport Max	34.2	32.6	31.5	28.1	23.8	20.1	20.0	22.2	26.6	29.7	31.3	33.1
Roma Airport Min	21.0	20.2	17.3	12.5	8.2	5.2	3.8	5.0	9.4	13.9	17.1	19.3
Roma Post Office Max	34.4	33.4	31.5	28.0	23.8	20.2	19.6	22.0	25.9	29.5	32.4	34.2
Roma Post Office Min	20.4	19.9	17.6	13.1	8.6	5.3	4.1	5.5	9.0	13.8	17.0	19.3
Miles Max	33.2	32.3	30.8	27.5	23.2	19.8	19.3	21.4	25.1	28.6	31.2	32.9
Miles Min	19.5	19.3	17.0	12.4	7.9	5.0	3.6	4.9	8.5	13.1	16.3	18.4
Surat Max	34.2	33.5	31.9	28.2	23.5	20.1	19.7	21.6	25.6	29.2	31.9	33.9
Surat Min	20.6	20.3	17.8	13.1	8.9	5.5	4.2	5.6	9.3	13.8	16.9	19.3

Time (Month)

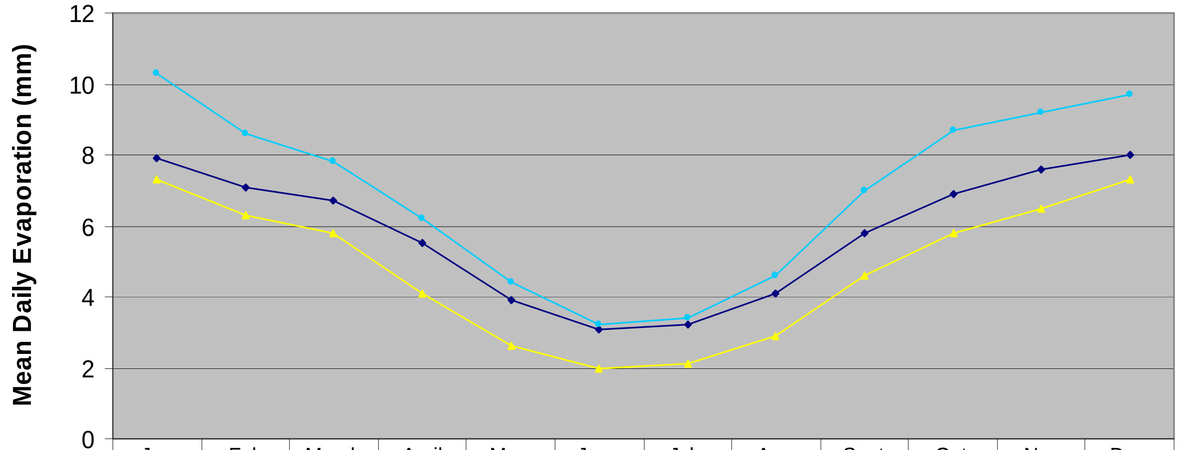
Figure 6.2.1 Mean Daily Maximum and Minimum Temperatures (°C) at Sites within the CSG Fields Study Area



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston	93.6	91.0	60.9	41.3	35.8	36.2	28.9	23.5	26.7	46.2	63.7	88.2
Springsure	107.3	108.4	68.4	40.1	35.9	38.0	28.6	24.3	27.8	47.1	63.8	89.4
Taroom	98.9	87.1	62.1	34.9	40.8	36.4	33.5	28.2	30.9	55.4	75.0	89.4
Brigalow	95.9	100.9	44.1	43.7	48.7	30.2	29.8	27.4	32.8	62.7	81.8	103.4
Emerald	86.1	73.0	40.3	29.3	19.5	33.4	9.1	19.2	24.1	47.1	50.5	79.4
Injune	90.9	86.8	61.0	40.9	33.7	29.7	29.9	25.6	24.7	47.1	73.1	86.6
Roma Airport	74.2	82.7	43.7	36.8	37.2	29.6	24.7	24.9	19.1	60.5	63.6	71.4
Roma Post Office	81.8	74.1	64.4	34.6	37.8	35.6	38.6	26.6	32.1	50.3	56.2	67.5
Miles	95.2	75.0	58.6	36.6	39.1	39.6	37.5	29.4	30.8	54.0	66.0	88.6
Surat	72.5	72.6	57.4	31.2	34.7	37.0	38.9	27.5	28.4	50.1	54.4	70.0

Time (Month)

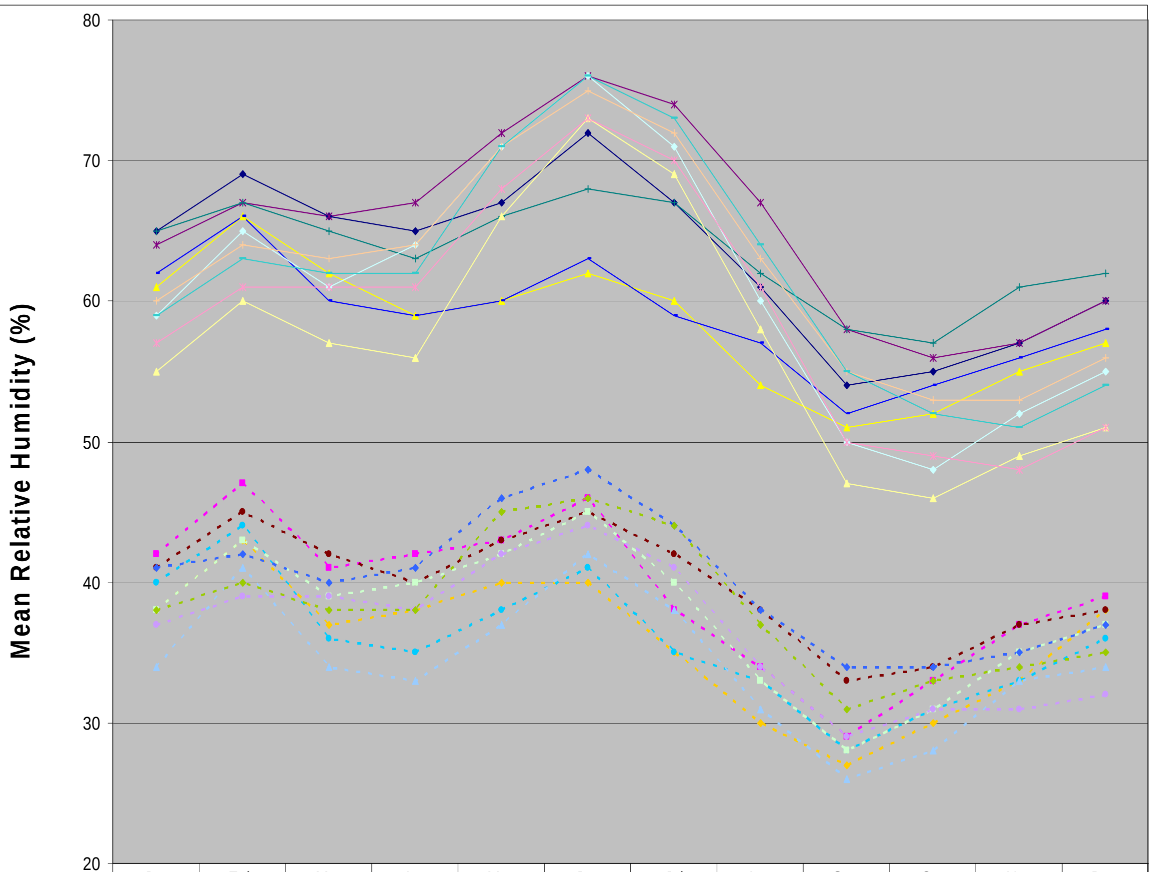
Figure 6.2.2 Mean Monthly Rainfall (mm) at Sites within the CSG Fields Study Area



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Brigalow	7.9	7.1	6.7	5.5	3.9	3.1	3.2	4.1	5.8	6.9	7.6	8
Roma Airport	10.3	8.6	7.8	6.2	4.4	3.2	3.4	4.6	7	8.7	9.2	9.7
Miles	7.3	6.3	5.8	4.1	2.6	2	2.1	2.9	4.6	5.8	6.5	7.3

Time (Month)

Figure 6.2.3 Mean Daily Evaporation (mm) at Sites within the CSG Fields Study Area



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rolleston 9am	65	69	66	65	67	72	67	61	54	55	57	60
Rolleston 3pm	42	47	41	42	43	46	38	34	29	33	37	39
Springsure 9am	61	66	62	59	60	62	60	54	51	52	55	57
Springsure 3pm	38	43	37	38	40	40	35	30	27	30	33	38
Taroom 9am	64	67	66	67	72	76	74	67	58	56	57	60
Taroom 3pm	41	45	42	40	43	45	42	38	33	34	37	38
Brigalow 9am	65	67	65	63	66	68	67	62	58	57	61	62
Emerald 9am	62	66	60	59	60	63	59	57	52	54	56	58
Emerald 3pm	40	44	36	35	38	41	35	33	28	31	33	36
Injune 9am	59	65	61	64	71	76	71	60	50	48	52	55
Injune 3pm	38	43	39	40	42	45	40	33	28	31	35	37
Roma Airport 9am	55	60	57	56	66	73	69	58	47	46	49	51
Roma Airport 3pm	34	41	34	33	37	42	38	31	26	28	33	34
Roma Post Office 9am	57	61	61	61	68	73	70	61	50	49	48	51
Roma Post Office 3pm	37	39	39	38	42	44	41	34	29	31	31	32
Miles 9am	60	64	63	64	71	75	72	63	55	53	53	56
Miles 3pm	41	42	40	41	46	48	44	38	34	34	35	37
Surat 9am	59	63	62	62	71	76	73	64	55	52	51	54
Surat 3pm	38	40	38	38	45	46	44	37	31	33	34	35

Time (Month)

Figure 6.2.4 Mean 9 am and 3 pm Relative Humidity (%) at Sites within the CSG Fields Study Area

6.2.2.4 Wind

Hourly records of wind speed and wind direction were obtained for the BOM site at Roma Airport. The wind rose plot for Roma Airport during 2003 is presented in Figure 6.2.5. The most dominant wind directions observed at this location are from the north-northeast and northeast.

There is no observational data available for Fairview. In order to develop site-specific wind fields, numerical modelling was conducted using The Air Pollution Model (TAPM) developed by the Australian Commonwealth Scientific Research Organisation CSIRO (refer Section 6.8). A wind rose plot for Fairview derived from TAPM modelling (refer Section 6.8) is depicted in Figure 6.2.6. Winds are predominantly from the northeast. Wind speeds at Fairview are predicted to be lower than those experienced at Roma Airport. This wind speed difference may reflect influences of local terrain and surface roughness.

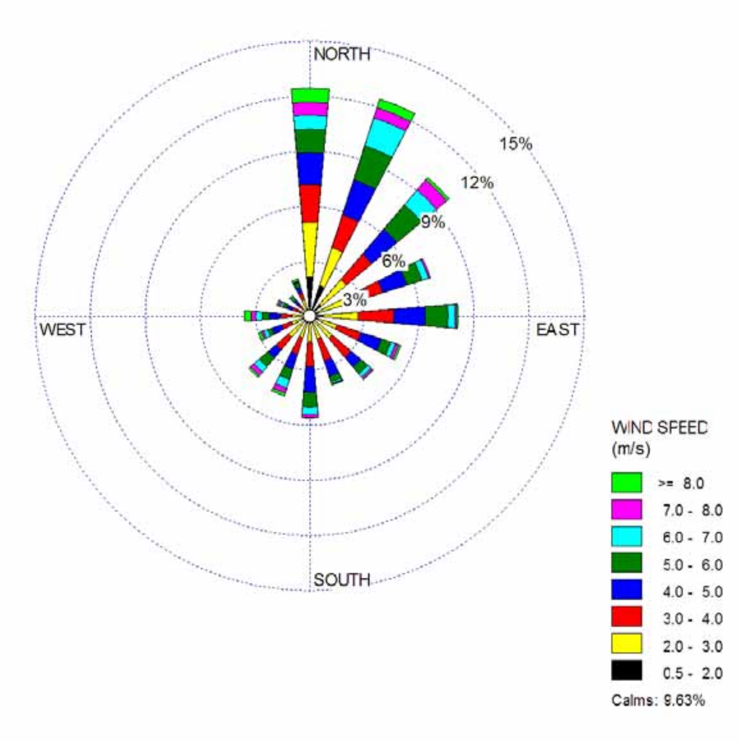


Figure 6.2.5 Wind Rose for Roma Airport for 2003, Derived from Bureau of Meteorology Observational Data.

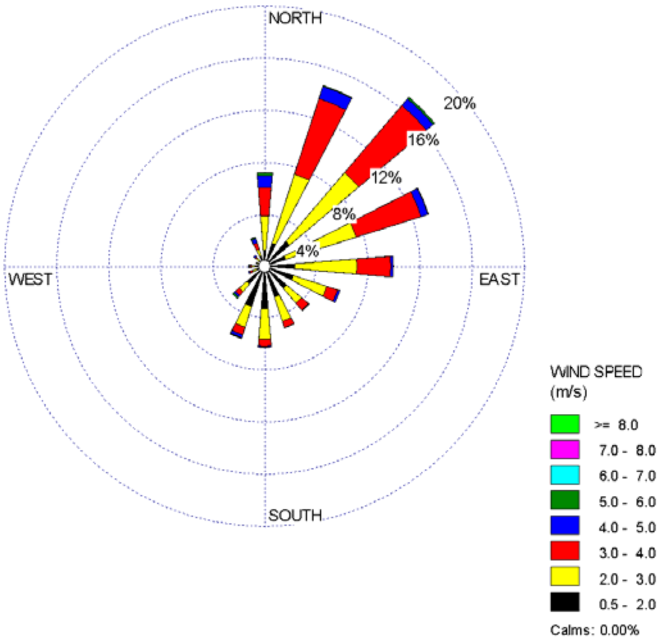


Figure 6.2.6 Wind Rose at Fairview for 2006, Derived from TAPM Modelling Data

6.2.2.5 Atmospheric Stability

Atmospheric stability is derived from wind and temperature profile data. The parameter characterises conditions that lead to enhanced atmospheric dispersion (i.e. unstable conditions) or poor atmospheric dispersion (i.e. stable conditions).

Table 6.2.1 shows the predicted percentages of stability classes for Roma (from BOM data) and Fairview (from TAPM generated data) The stability categories indicate a high proportion of neutral conditions for Roma (34.9 %), and a high proportion of stable conditions for Fairview (43.2 % for slightly stable and stable categories combined).

Table 6.2.1 Stability Categories for Roma and Fairview Predicted by TAPM for 2003 and 2006 Respectively

Stability Category	Roma Airport	Fairview	Description of Category
A	0.7 %	3.5 %	Extremely Unstable
B	12.4 %	17.1 %	Unstable
C	16.1 %	12.8 %	Slightly Unstable
D	34.9 %	23.4 %	Neutral
E	20.5 %	15.4 %	Slightly Stable
F	15.5 %	27.8 %	Stable

6.2.2.6 Mixing Height

Hourly mixing height data at the CSG fields locations have been generated using TAPM for both the Roma (2003) and Fairview (2006) sites. Figure 6.2.7 presents this data as box-and-whisker plots by hour of day. Mixing heights at Roma are very low at night (mostly less than 100 m), but rise sharply after sunrise, peaking in the afternoon hours to altitudes between 400 m to 1,700 m for the majority of the days (10 to 90 percentile). Daily maximum mixing height is lower in the winter than the summer due to reduced solar heating effects. At Fairview, mixing height data has a similar diurnal pattern to that of Roma, but peaks at lower altitudes (500 m to 1,400 m) for the majority of the days (10 to 90 percentile).

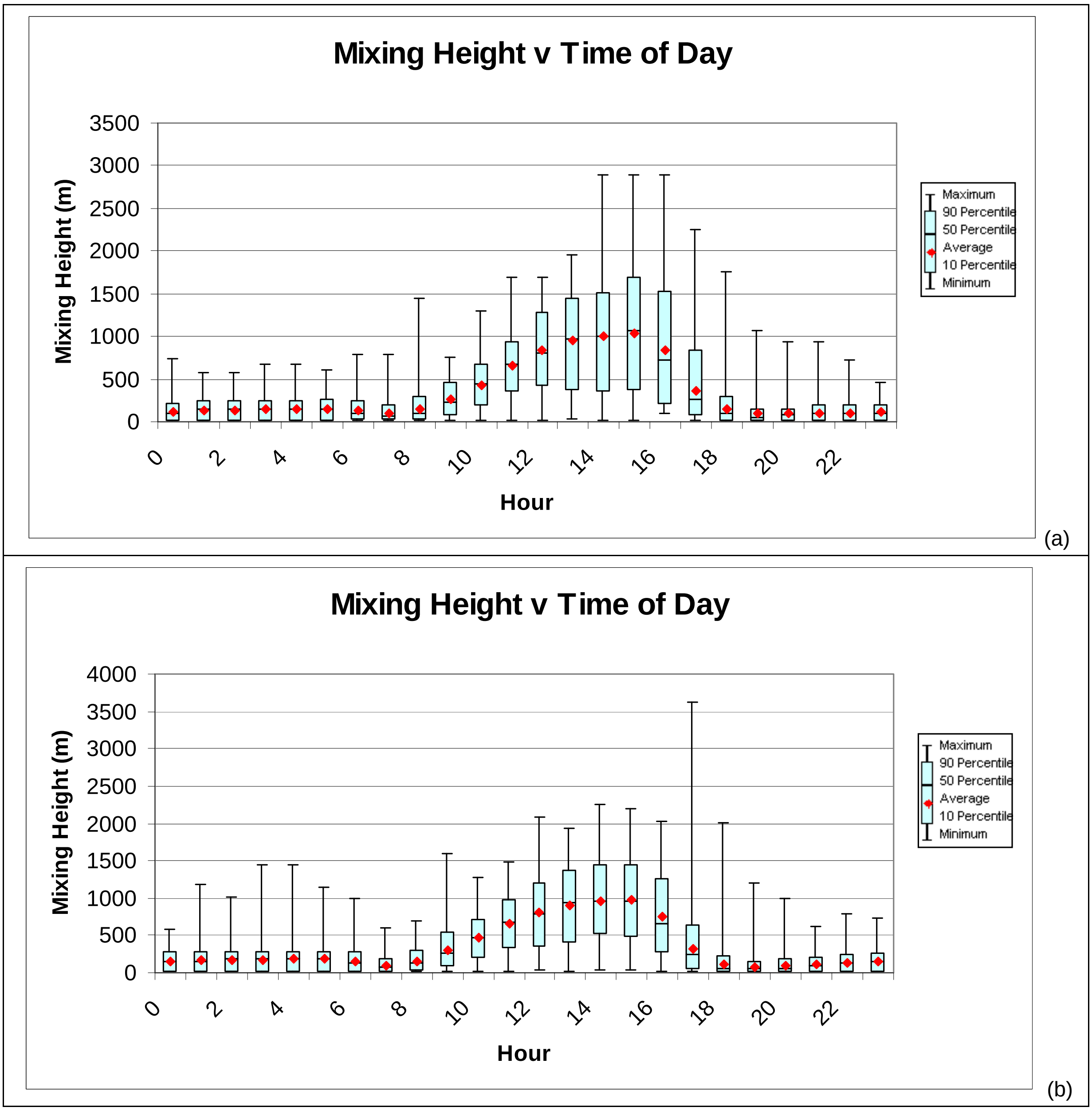


Figure 6.2.7 Mixing Height Data for (a) Roma, 2003, and (b) Fairview, 2006

6.2.2.7 Extremes of Climate

Extremes of climate include droughts, floods and cyclones. The CSG fields area (like much of inland Queensland) experiences drought and flood conditions close to major rivers, however does not typically experience cyclones. A Construction Management Plan will need to address the effects that extremes of climate may have on construction. Each of these potential extremes of climate and their relevance to the study area is described below. A recent study by the CSIRO and BOM (2007) (CSIRO and BOM (2007), Climate Change in Australia – Technical Report) has shown that these extremes of climate may increase with forecast climate change.

Drought

Drought affected areas are declared by the Commonwealth Department of Agriculture, Fisheries and Forestry as areas of "Exceptional Circumstances" (EC). EC comprise weather conditions based on historical records that are rare, severe and prolonged, occurring only once in every 20 - 25 years (DAFF 2009) which includes exceptionally high temperatures, low rainfall and low soil moisture (Hennessey et al. 2008).

EC declared areas include the Western Downs-Maranoa which includes a large proportion of the proposed Roma CSG fields and the Duaringa-Bauhinia declared area which includes a smaller proportion of the Fairview CSG fields. The extent of drought declared land within the CSG study area is shown as part of the entire GLNG Project area in Figure 7.2.7.

Floods

The CSG fields study area is located within the Condamine-Balonne and Fitzroy River Basins. The two river basins contain extensive but largely ephemeral stream networks with summer rainfall (October to April) dominant and periods of low to zero flow during winter when the streams become a series of isolated waterholes. The catchments comprise some out-of-bank/flash flooding rainfall events mostly during wet season (BOM, 2008). A summary of the three major river catchments is provided below with further detail provided in Section 6.5.

Condamine-Balonne River Catchment

The Roma CSG fields area lies within the Condamine-Balonne catchment. The catchment contains extensive, but largely ephemeral or intermittent stream networks with summer rainfall dominant and periods of low to zero flow during which time the streams become a series of waterholes. The topography is predominantly flat with wide alluvial floodplains. Major streams within the Upper Balonne River Catchment include Bungil Creek, Wallumbilla Creek, Yuleba Creek and minor tributaries. Bungil Creek flows roughly north to south. Wallumbilla and Yuleba Creeks flow to the south-southwest. The three creeks discharge to the Balonne River, which in turn flows to the Murray Darling Basin. Another principal stream, Bungeworgorai Creek, is located in the western portion of the proposed CSG fields operations and flows in a south-westerly direction, discharging into Bungil Creek.

Major floods tend to develop lower in the catchment relative to catchment headwater areas, and result from heavy rainfall over any of the large tributaries which enter the main Balonne River (BOM, 2008). Records of large floods along the Balonne River extend back as far as 1890 at St George. Major floods occur regularly, on average every two years. The worst flooding occurred in 1942, 1950, 1956, 1975, 1976, 1983 (twice), 1988 and 1996 (BOM, 2008). Major floods generally only occur in the first half of the year and in late spring.   The most significant effects of flooding along the Balonne River are the widespread inundation of adjacent agricultural land (BOM, 2008a) however major flooding requires a large scale rainfall situation over the Condamine-Balonne River catchment.

Fitzroy River Catchment

The Upper Dawson and Comet Rivers discharge into the Fitzroy River, which enters marine waters near Rockhampton. The Fairview CSG fields area lies within the Upper Dawson River catchment that extends upstream and westwards from Taroom, encompassing the townships of Injune and Wandoan. The catchment contains extensive but largely ephemeral or intermittent stream networks.

The Arcadia Valley, Denison, Comet and Mahalo CSG field areas are located within the Comet-Brown sub-catchment, extending from the Carnarvon Ranges north to Emerald. Major flooding requires a large scale rainfall situation over the vast Fitzroy River catchment. The following can be used as a rough guide to the likelihood of flooding in the catchment.

Flood potential within the Fitzroy Catchment occurs with rainfalls in excess of 200 mm (48 hours), with potentially significant moderate to major flooding, particularly in the middle to lower reaches of the Dawson River catchment downstream of Taroom (BOM, 2008b). The Fitzroy River at Rockhampton has a long and well documented history of flooding, with flood records dating back to 1859. The highest recorded flood occurred in January 1918 and reached 10.11 m (Rockhampton gauge). The most recent flood for the Fitzroy River was in 2008 and caused flooding within Emerald, its second largest flood on record registering 15.36 m on the Emerald gauge (BOM, 2008b).

Bushfires

The climatic factors which exert most influence over conditions conducive to the generation of bushfires 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 which constitute 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. After winter, the fuel is very dry from the lack of rainfall during the winter months, and the temperatures increase.

The CSG fields are located within the following Local Government areas (LGAs); Roma Regional Council, Central Highlands Regional Council, Banana Shire Council and Dalby Regional Council. The Rural Fire Service and Queensland Fire and Rescue Service (RFS, 2009) modelled the bushfire risk in these LGAs based on factors of slope, aspect and vegetation. The Roma CSG fields primarily comprise low risk areas with minor areas of medium to high bushfire risk. To the north, the Fairview CSG fields comprises more extensive areas of medium to high bushfire risk (refer Figures 7.2.8 to 7.2.10).

Bushfire management strategies currently employed by Santos include the provision of water supply for fire fighting, especially near compressors and other project buildings, as well as creating an asset protection zone of at least 20 m to minimise fuel load, especially in medium to high risk bushfire hazard areas.

6.2.3 Potential Impacts and Mitigation Measures

The climatic conditions over the full extent of the CSG fields are prone to periodic, high intensity rainfall events. These events may give rise to locally severe surface sheet, rill and gully erosion, particularly in areas that have been cleared for exploratory drilling and/or disturbed as a result of construction activities associated with the development of the production well leases. The impact of erosion in an area will vary considerably depending on the soil type, the overall surface slope and form and the topographic position in the landscape with respect to the potential for surface water runon and runoff. Erosion potential and management strategies to minimise sediment loss from disturbed areas is addressed in Sections 6.3 and in Appendix L1. Storm events also have the potential to impact on waste containment systems including associated water storage dams, and these potential impacts are discussed in Section 3.

Natural hazards are not considered a major risk to the study area. However, both flood and drought events may become an issue at some point during the expected life of the CSG fields development program. These issues are considered further in Section 6.5. Additionally, an Emergency Management Plan, which will address all foreseeable site specific risks such as fire and flooding including appropriate contact details of emergency services agencies, will be incorporated into the project EMP. The risk of natural hazards is considered as part of the business risk management process, with appropriate controls and monitoring under an Emergency Management Plan being a fundamental part of the risk management process (refer Section 10).