Climate and climate change 7

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7 Climate and climate change

7.1 Introduction

This section describes the climatic conditions, including seasonal conditions, extremes of climate and natural or induced hazards that may affect management of the GFD Project area and surrounds.

The GFD Project area is in the Surat and Bowen basins in southern and central Queensland approximately 400 km from the coast. It is a predominantly rural area and is characterised by a variety of landscapes including steep hills and mountains, undulating hills, floodplains, creeks, riparian areas and towns. The region has a subtropical climate but alterations in terrain contribute to local climate variability across the region.

The potential impacts to the GFD Project activities arising from climate and climate change are described, and mitigation measures are identified. Full details of the climate, natural hazards and climate change assessment are provided in Appendix I: Climate, natural hazards and climate change.

This section has been prepared in accordance with section 4.1 of the GFD Project *Terms of reference for an environmental impact statement*, issued March 2013. The index to locate where each ToR requirement is met within the EIS is included in Appendix B: Terms of reference cross-reference.

7.2 Regulatory context

This EIS has been prepared in accordance with the State and Commonwealth regulatory context described within Appendix C: Regulatory framework. The legislation, policies and guidelines that apply to climate and climate change and the potential impacts on the GFD Project are outlined in Table 7–1. Santos GLNG's climate change policy outlining its position and response to climate change is provided in Appendix G: Corporate environmental policy.

Table 7–1 Regulatory context of the GFD Project – climate

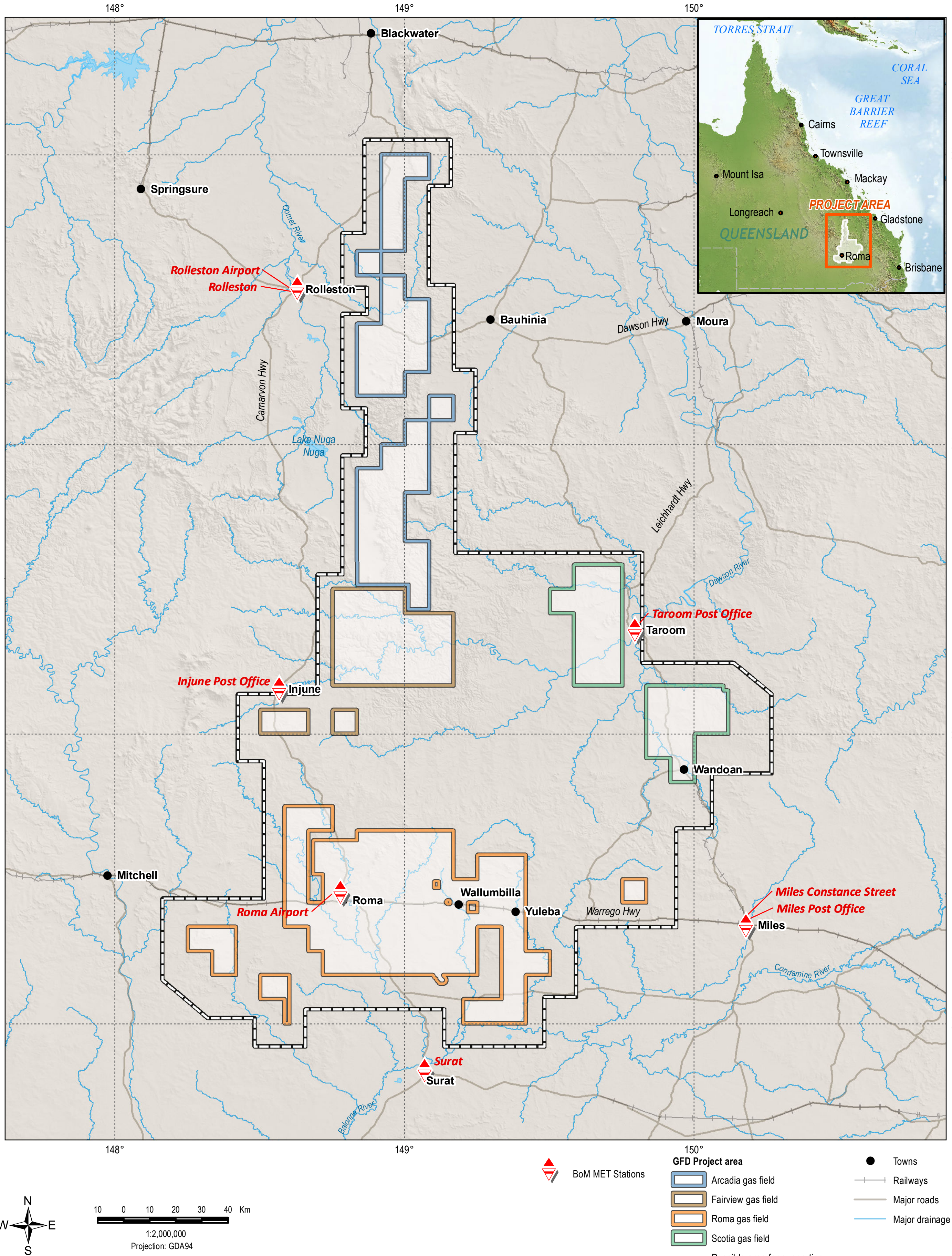
Legislation, policy, or guideline	Relevance to the GFD Project
National Climate Change Adaptation Framework This framework outlines Australia's approach to climate change adaptation. The framework covers a range of actions to address key demands from business and the community for targeted information on climate change impacts and adaptation options.	The *National Climate Change Adaptation Framework* was developed to help decision-makers understand and incorporate climate change into policy and operational decisions at all scales and across identified sectors. By developing the GFD Project to be consistent with the national framework, Santos GLNG will base its operational planning decisions on risks, vulnerabilities and resulting strategies for the GFD Project derived from consistent datasets sourced from the National Climate Change Adaptation Research Facility.
State Planning Policy (SPP) The single SPP introduced in December 2013 defines Queensland Government policies about matters of State interest in land use planning and development. Natural hazards such as bushfires, flooding and landslides are among the State interests addressed in the SPP.	Santos GLNG will operate the GFD Project in a manner that is consistent with the SPP and planning scheme requirements by implementing a range of management plans designed to minimise impacts from natural hazards.

7.3 Assessment methodology

This assessment describes the climate values and assesses the potential impacts as a result of climate-related hazards to the GFD Project.

For the purposes of describing the GFD Project area's climate values, data were sourced from the Bureau of Meteorology (BoM) meteorological observation stations (shown in Figure 7-1) and BoM's national climate database.

Impacts were assessed using the risk assessment methodology, which considers the likelihood and consequence of a potential impact to assess its level of risk. The full description of the risk assessment methodology is described in section 5.6.3 of Section 5: Assessment framework and in Appendix I: Climate, natural hazards and climate change. A summary of the impact assessment is provided in section 7.7.



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GFD PROJECT EIS

METEOROLOGICAL OBSERVATION STATIONS

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CLIMATE AND CLIMATE CHANGE

Figure: **7-1**

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7.4 Environmental values

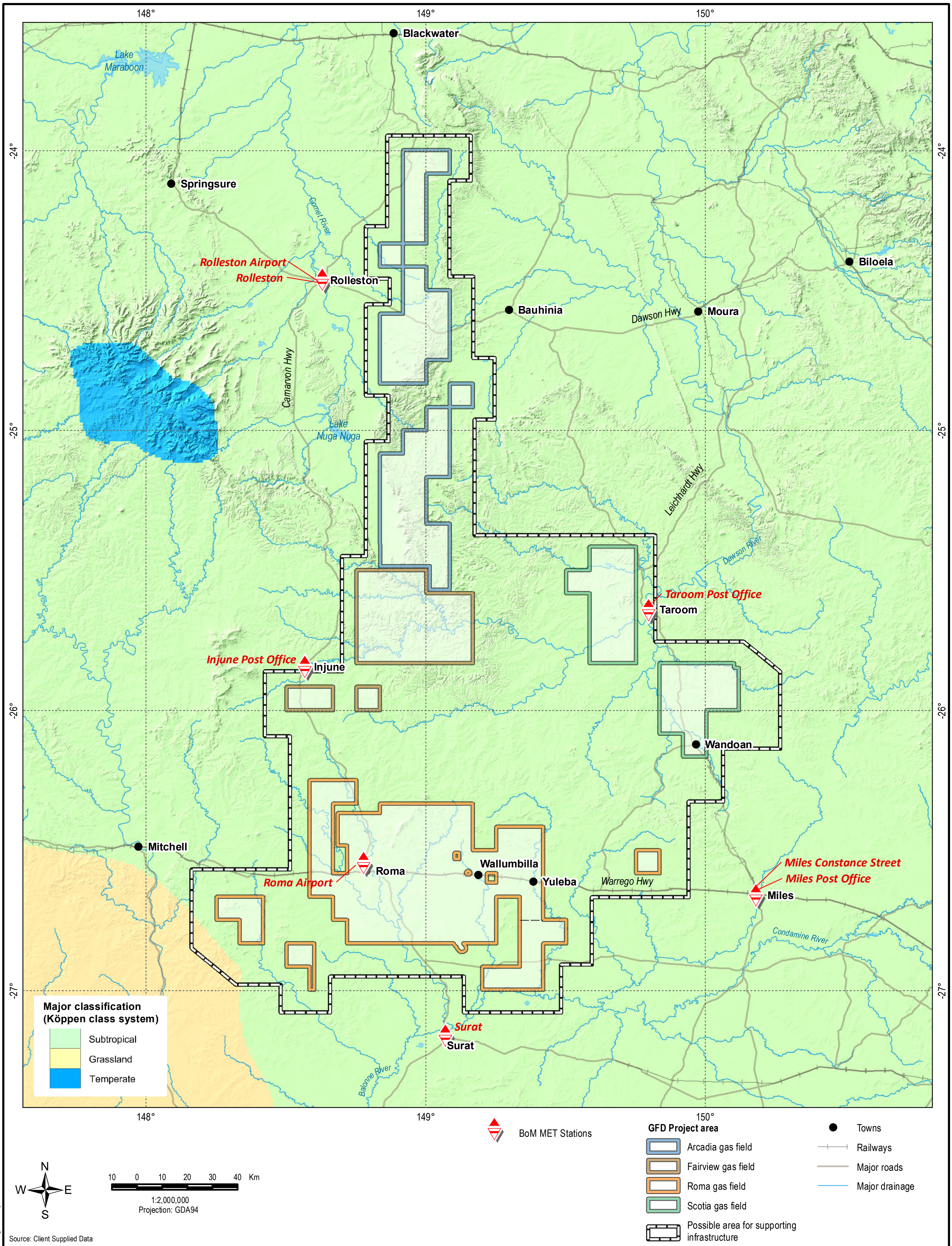
7.4.1 Regional climate

The regional climate is classified as subtropical with moderately dry winters and dry hot summers (BoM, 2012). Changes in terrain across the GFD Project area contribute to some variability in local climate.

Regional climate classified according to the Köppen and thermal climate classification methods (using rainfall, temperature and humidity data from 1961 to 1990) is presented in Figure 7-2 and Figure 7-3 respectively. Further detail on these methods is included in Appendix I: Climate, natural hazards and climate change assessment.

The annual median rainfall mapped in Figure 7-4 shows that the whole region receives between 500 millimetres and 1,000 (mm).

The annual mean temperature for the majority of the region is 21°C; however, the annual mean reaches 24°C in the north of the GFD Project area around Rolleston, Moura and Biloela, as shown in Figure 7-5.



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KÖPPEN CLIMATE CLASSIFICATION

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CLIMATE AND CLIMATE CHANGE

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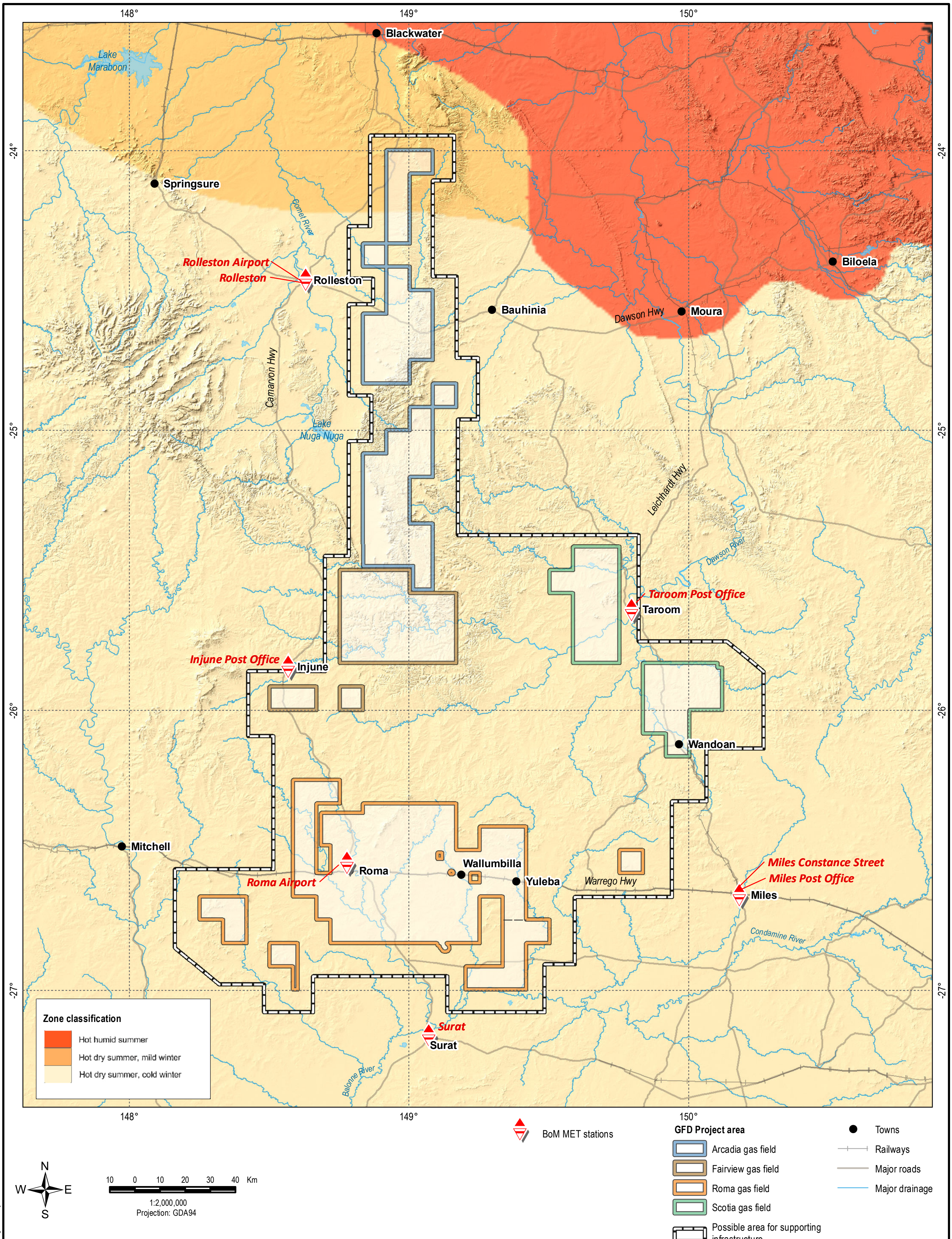

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REGIONAL CLIMATE (THERMAL CLIMATE CLASSIFICATION)

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CLIMATE AND CLIMATE CHANGE

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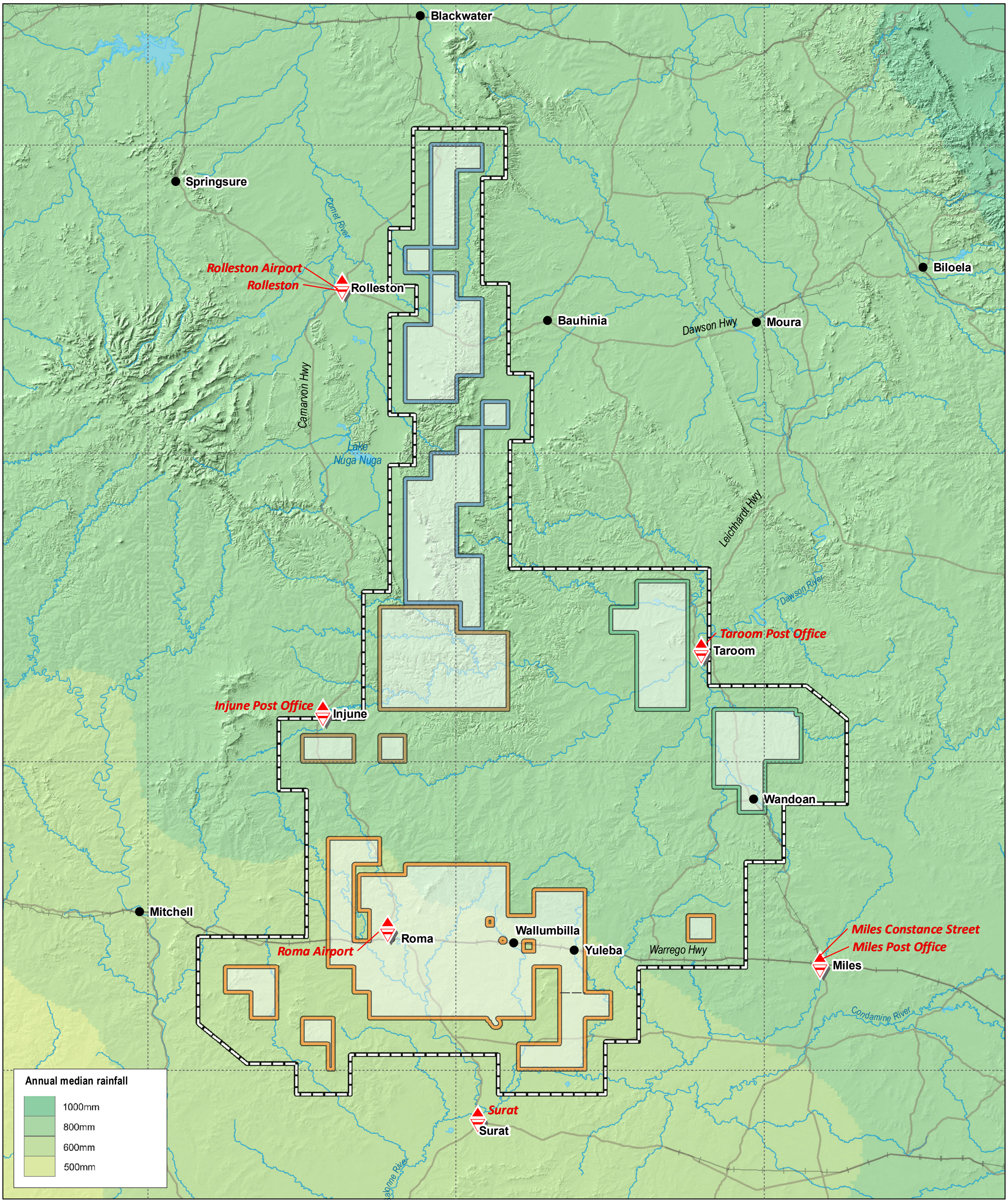

BoM MET Stations

GFD Project area

Arcadia gas field

Fairview gas field

Roma gas field

Scotia gas field

Possible area for supporting infrastructure

Towns

Railways

Major roads

Major drainage

N E S W

10 0 10 20 30 40 Km

1:2,000,000

Projection: GDA94

Source: Client Supplied Data

Santos GLNG Project

GFD PROJECT EIS

REGIONAL ANNUAL MEDIAN RAINFALL

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CLIMATE AND CLIMATE CHANGE

Figure: 7-4

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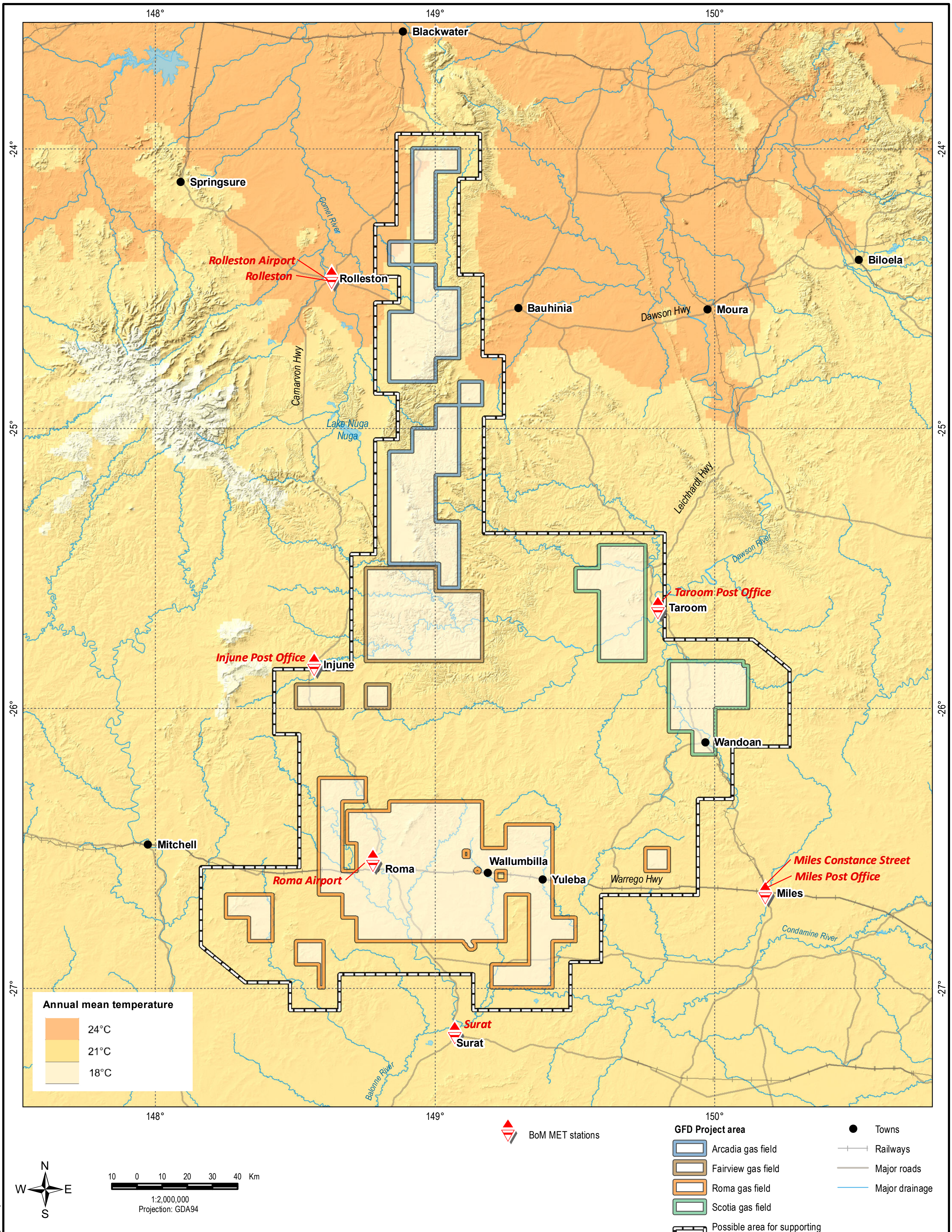

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Santos GLNG Project

GFD PROJECT EIS

REGIONAL ANNUAL MEAN TEMPERATURE

URS

CLIMATE AND CLIMATE CHANGE

Figure: 7-5

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7.4.2 Local climate

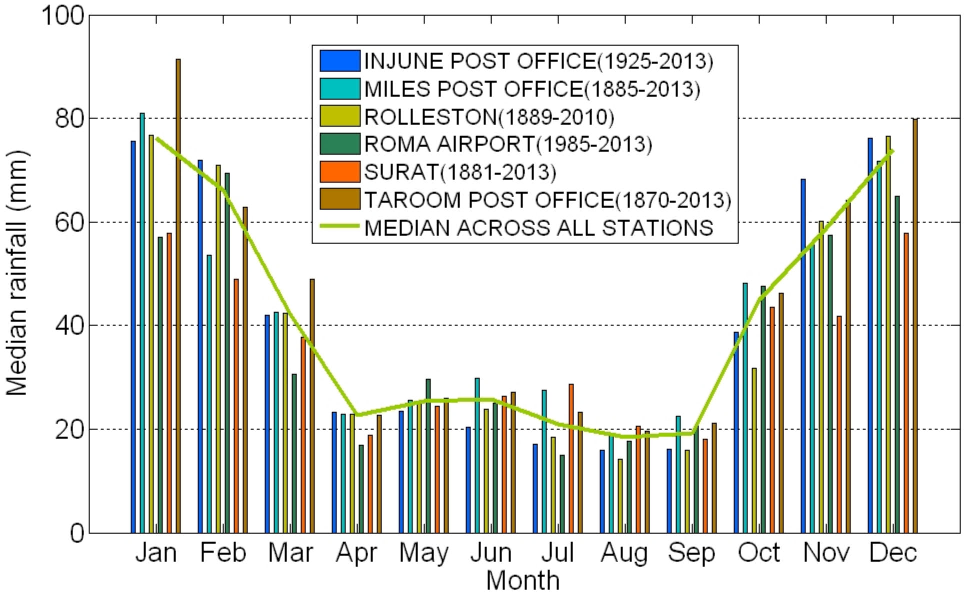
Local climate is described using data observed at the eight BoM observation stations shown in Figure 7-1. While available data from the BoM have been considered, not all meteorological variables are recorded at each station; as a result, some data sets are incomplete or of different lengths.

7.4.2.1 Rainfall

Rainfall is at its highest from late spring through to the end of summer. The wettest month is January, with a median rainfall of 98 mm measured at Taroom Post Office. The driest months of the year are April to September. In these months, median rainfall is between 14.2 mm at Rolleston in August and 29.8 mm at Miles Post Office in June.

Monthly median rainfall is shown in Figure 7-6[1].

Figure 7-6 Monthly median rainfall

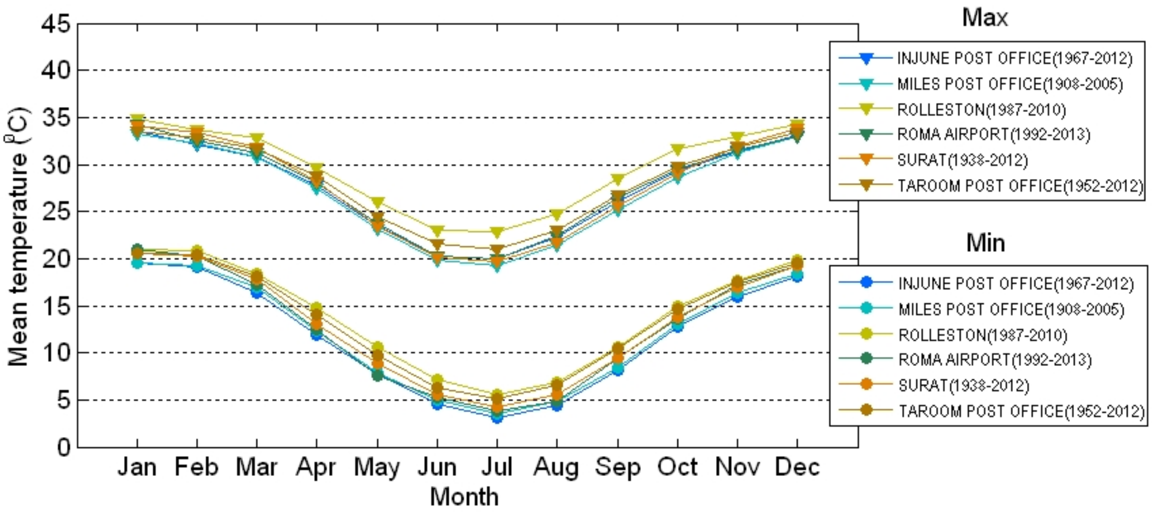


7.4.2.2 Temperature

Figure 7-7 shows that the monthly maximum and minimum average temperature is similar for all of the nominated BoM stations. The mean monthly maximum temperature ranges from 19.3 °C in July (Miles Post Office) to 34.8 °C in January (Rolleston). The lowest mean minimum temperatures are experienced in June, July and August. The mean minimum temperature is 3.1 °C in July at Injune Post Office.

[1] Rainfall is not monitored at Rolleston Airport and Miles Constance Street.

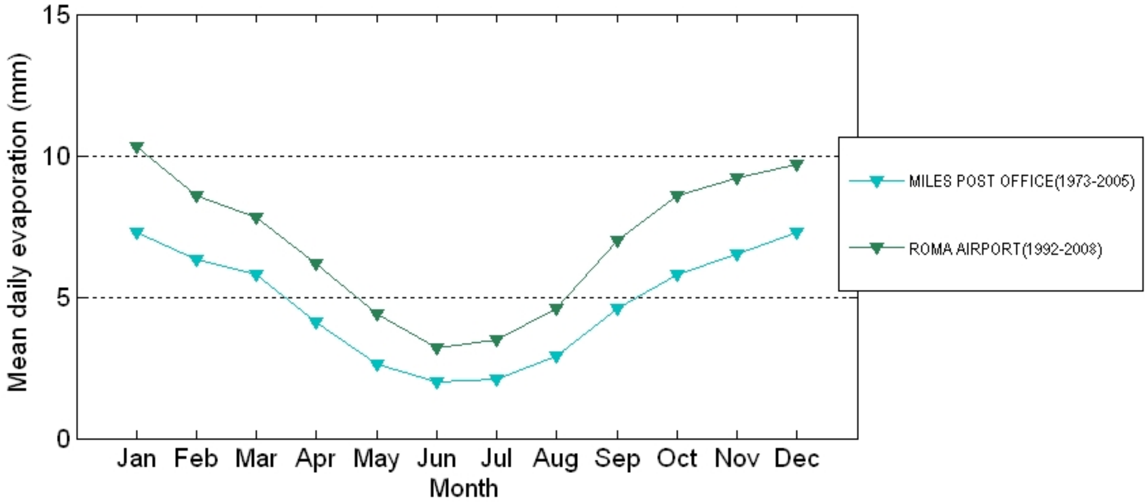
Figure 7-7 Mean maximum and minimum temperature



7.4.2.3 Evaporation

Mean daily evaporation rates for each month at Roma Airport and Miles Post Office are shown in Figure 7-8.

Figure 7-8 Mean daily evaporation

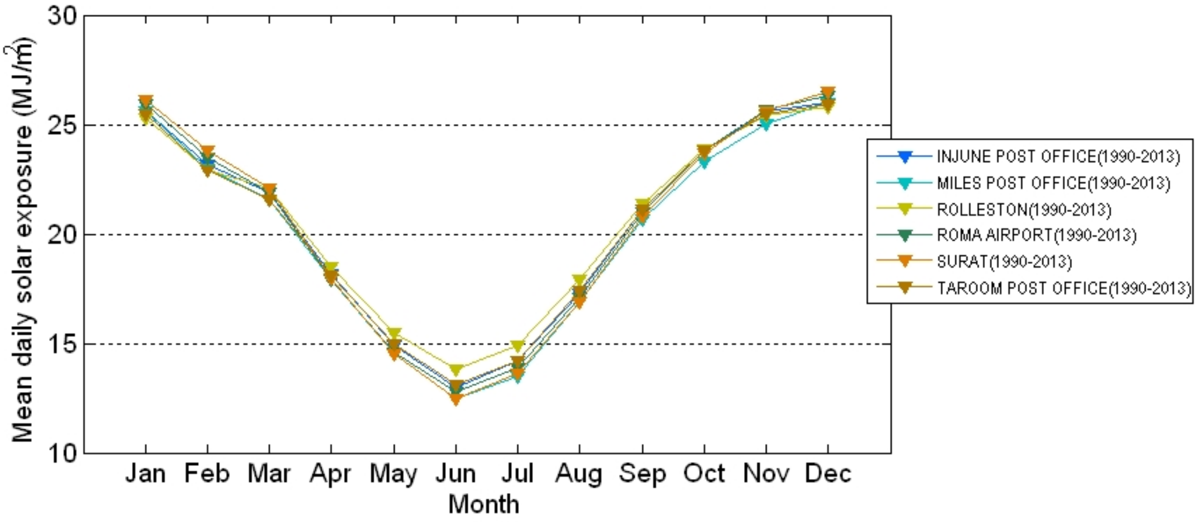


The mean daily evaporation is highest between the summer months of November and February, when the mean daily evaporation rate is 8.3 mm (approximately 248 mm of evaporation per month). The winter months of June and July have a mean daily evaporation of approximately 3 mm, or 90 mm per month. For the whole year evaporation exceeds rainfall, which creates a surface water deficit.

7.4.2.4 Solar exposure

Figure 7-9 shows that mean daily solar exposure is highest in the summer months. In November to January, the mean daily solar exposure was in excess of 25 megajoules per square metre (MJ/m^2) at nominated BoM stations, which is approximately 750 MJ/m^2 per month. The lowest mean daily solar exposure of 12 MJ/m^2 was observed at Surat in June, which is approximately 360 MJ/m^2 per month and half the summer peak. The Rolleston and Surat records indicate that the solar exposure variation between winter and summer is greatest in the south and lowest in the north of the GFD Project area.

Figure 7-9 Mean daily solar exposure



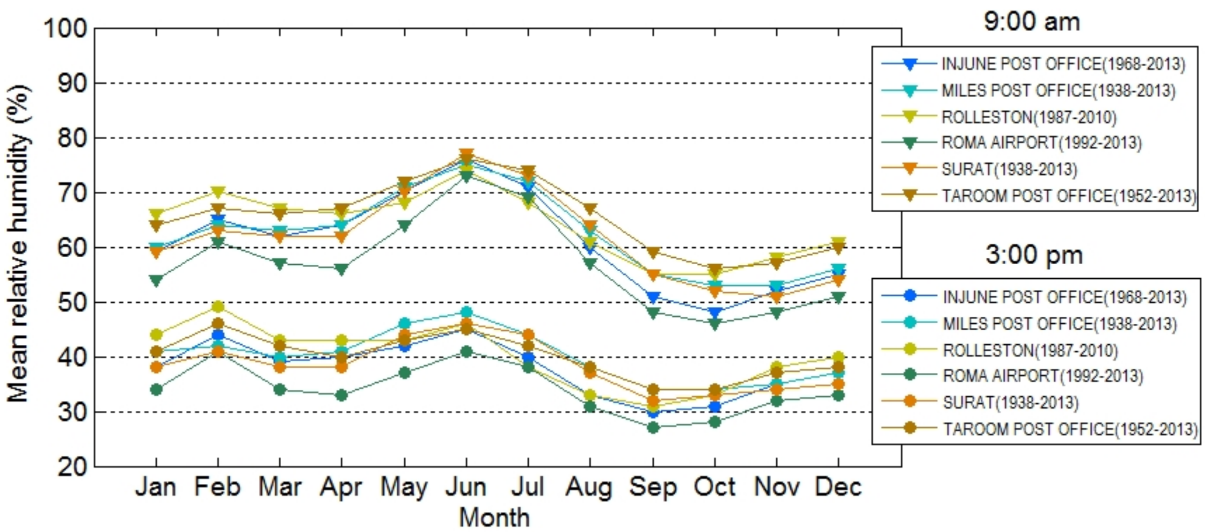
7.4.2.5 Relative humidity

Observed monthly average 9:00 am and 3:00 pm relative humidity is shown in Figure 7-10.

Mean monthly 9:00 am relative humidity varies throughout the year with two peaks occurring in February and June. The highest 9:00 am relative humidity was observed in June for nominated BoM stations. The highest 9:00 am mean monthly relative humidity observation of 77% was made at Surat.

Mean monthly 3:00 pm relative humidity peaks in February and June. Mean monthly relative humidity ranges from 27% to 49% while at 9:00 am the relative humidity readings range between 66% and 76%.

Figure 7-10 Mean relative humidity



7.4.2.6 Wind speed and direction

The mean morning wind speed (9:00 am) and afternoon wind speed (3:00 pm) in kilometres per hour (km/hour) are shown in Figure 7-11 and Figure 7-12. The highest wind speeds are observed at Roma Airport at 9:00 am and 3:00 pm in the south of the GFD Project area. For observations taken at 9:00 am and 3:00 pm, the lowest wind speeds were observed in the winter months of May to July.

Figure 7-11 Mean morning wind speed (9:00 am)

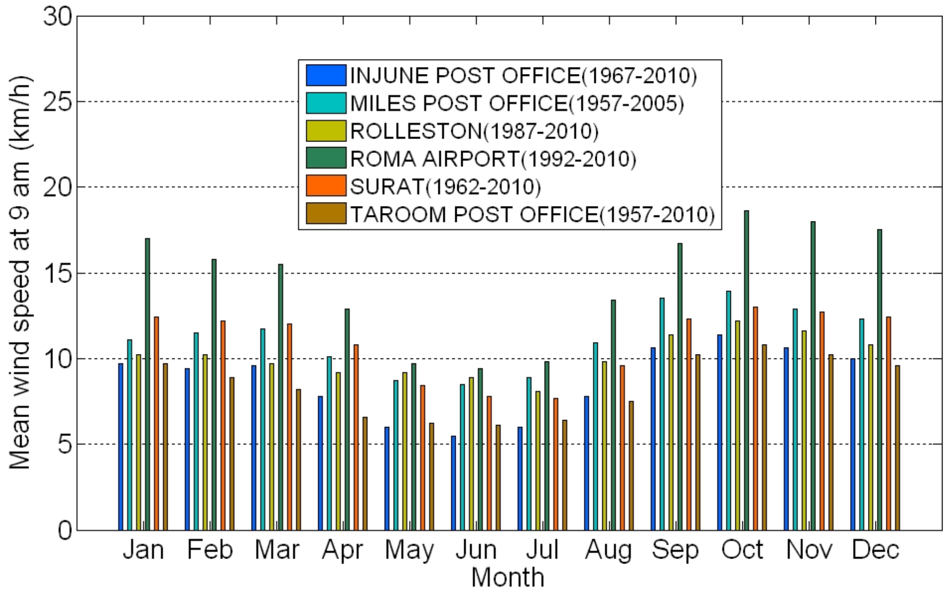
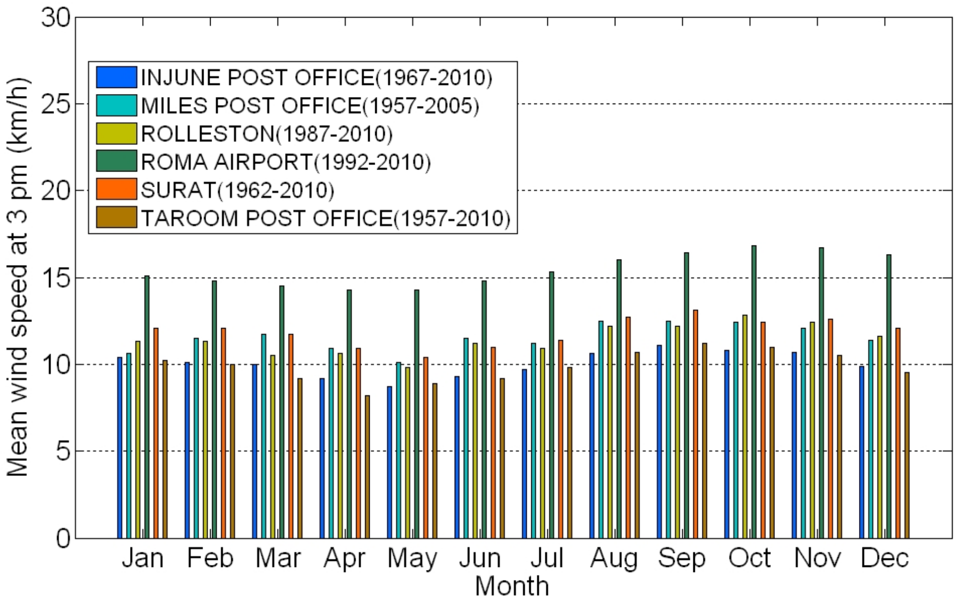


Figure 7-12 Mean afternoon wind speed (3:00 pm)

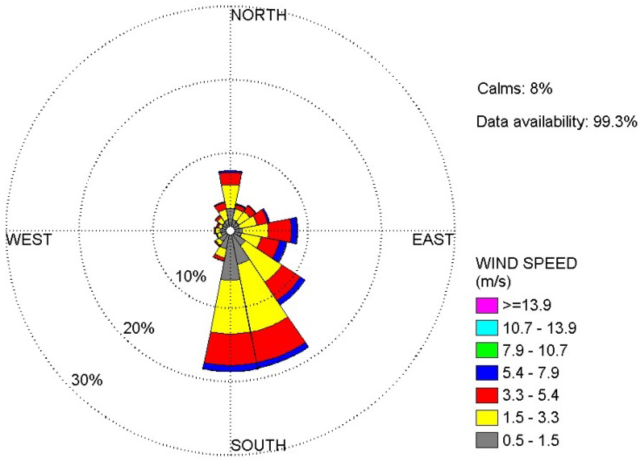


Long-term wind speed, direction and frequency records are displayed as wind rose plots in Figure 7-13. In the north of the GFD Project area (Rolleston Airport), the predominant winds and strongest winds were out of the south or south-southeast quarter, with the strongest winds yielding velocities of between 5.4 metres per second (m/s) and 7.9 m/s. In the south of the GFD Project area (Roma Airport), winds from the north and northeast quarter dominate, with the strongest winds ranging from 7.9 m/s and 10.7 m/s.

Figure 7-13 Wind roses

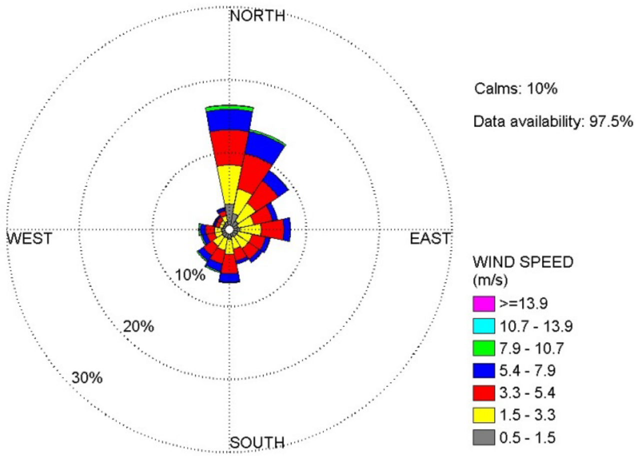
Rolleston Airport (35129)

2010 to 2012



Roma Airport (43091)

1997 to 2012



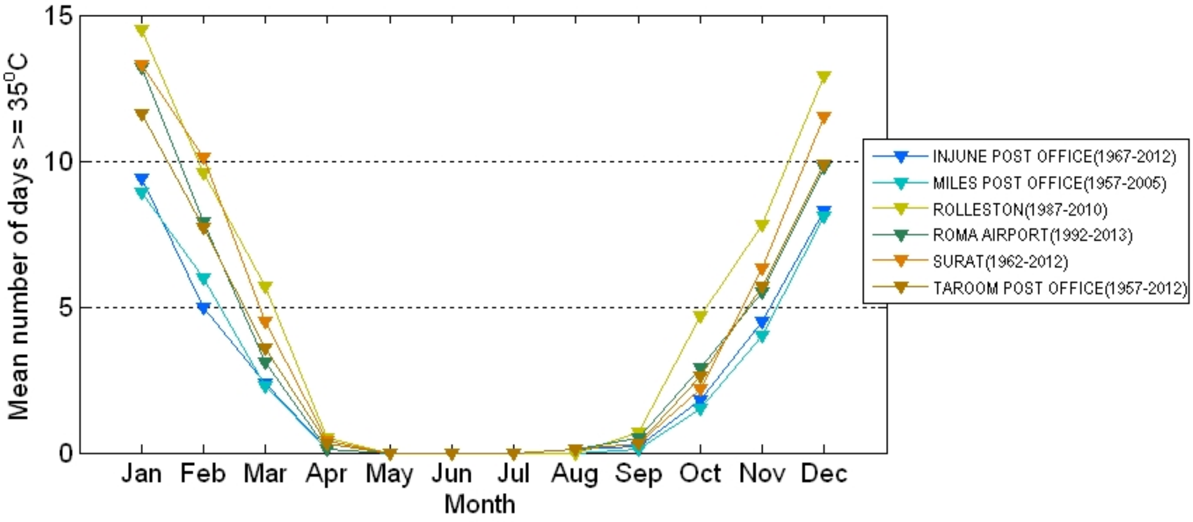
7.4.3 Natural hazards

Natural hazards include extreme temperatures, floods, bushfires, droughts, severe storms and cyclones. Extreme climate events can cause sedimentation, erosion, and stormwater damage, damage to infrastructure, as well as health and safety risks to the GFD Project workforce and the general population. This section describes the potential for these extreme climate events to occur in the GFD Project area and the projected changes to these hazards as a result of climate change.

7.4.3.1 Extreme temperatures and heatwaves

The subtropical climatic zone of the region is characterised by hot summers and is prone to extreme temperature events, which is illustrated by the number of hot days exceeding 35 ˚C shown in Figure 7-14.

Figure 7-14 Average number of days exceeding 35 ˚C



7.4.3.2 Extreme rainfall and flooding

The GFD Project area is located within the Condamine-Balonne and Fitzroy River basins. These two basins experience seasonal flow as the subtropical climate brings significant rainfall in the summer months of November to April and minimal rainfall in the cooler months of May to October. Major rain intensity is strongly associated with La Niña and has the ability to cause extensive regional flooding in Queensland, like that experienced in 2011.

Portions of the GFD Project area and the Condamine-Balonne Basin were affected by flooding from December 2010 to February 2011. The floods were attributed to a severe La Niña event in the Pacific Ocean. Enhanced rainfall conditions overwhelmed the ephemeral networks and caused one of the most devastating weather events in Queensland's recorded history. The Fitzroy River Basin has a long and well-documented history of floods, dating back to 1859, and like the Condamine-Balonne Basin, was also affected by extensive and widespread flooding in 2011, recording a flood level of 9.2 m on the Rockhampton gauge. The highest recorded flood occurred in January 1918 which reached 10.1 m on the Rockhampton gauge (BoM, 2013).

Santos GLNG has previously undertaken flood risk modelling for the GLNG Project. Flood levels for both the 50 and 100 year ARI (average recurrence interval) event were investigated along waterways within a 5 km radius of proposed hub and campsite areas. This same procedure will be applied to the GFD Project prior to final location of permanent major infrastructure. This information allows Santos GLNG to determine appropriate locations for major infrastructure for the GFD Project so they are not impacted by 50 /100 year ARI flood events as appropriate.

7.4.3.3 Bushfires

A combination of high vegetation density, high temperatures, strong winds and low humidity increases fire risk. The fire season for most of southern central Queensland extends from spring to mid-summer. The greatest danger occurs after the dry winter/spring period, before the onset of wet weather in summer.

The Queensland Rural Fire Service has mapped bushfire risk across the Banana Shire and Maranoa, Central Highlands and Western Downs regional council areas (Queensland Rural Fire Service, 2013). This is shown in Figure 7-15. The southern region of the GFD Project area is characterised by predominantly low fire risk. Further north, the GFD Project area is assessed to have a predominantly medium fire risk, with small areas of high fire risk.

The cleared pasture around Roma has the lowest fire hazard despite relatively low rainfall and high winds. This is a function of the limited vegetation available to act as fuel in these cleared areas.

7.4.3.4 Drought

Drought is an extended period of months or years when a region experiences a rainfall deficiency below 10% of records for the period in question. The most recent drought experienced in Queensland was from 2001 to 2008, this was also the most severe drought on record. The previous worst recorded drought was the Federation Drought from 1898 to 1903.

7.4.3.5 Severe storms and lightning strikes

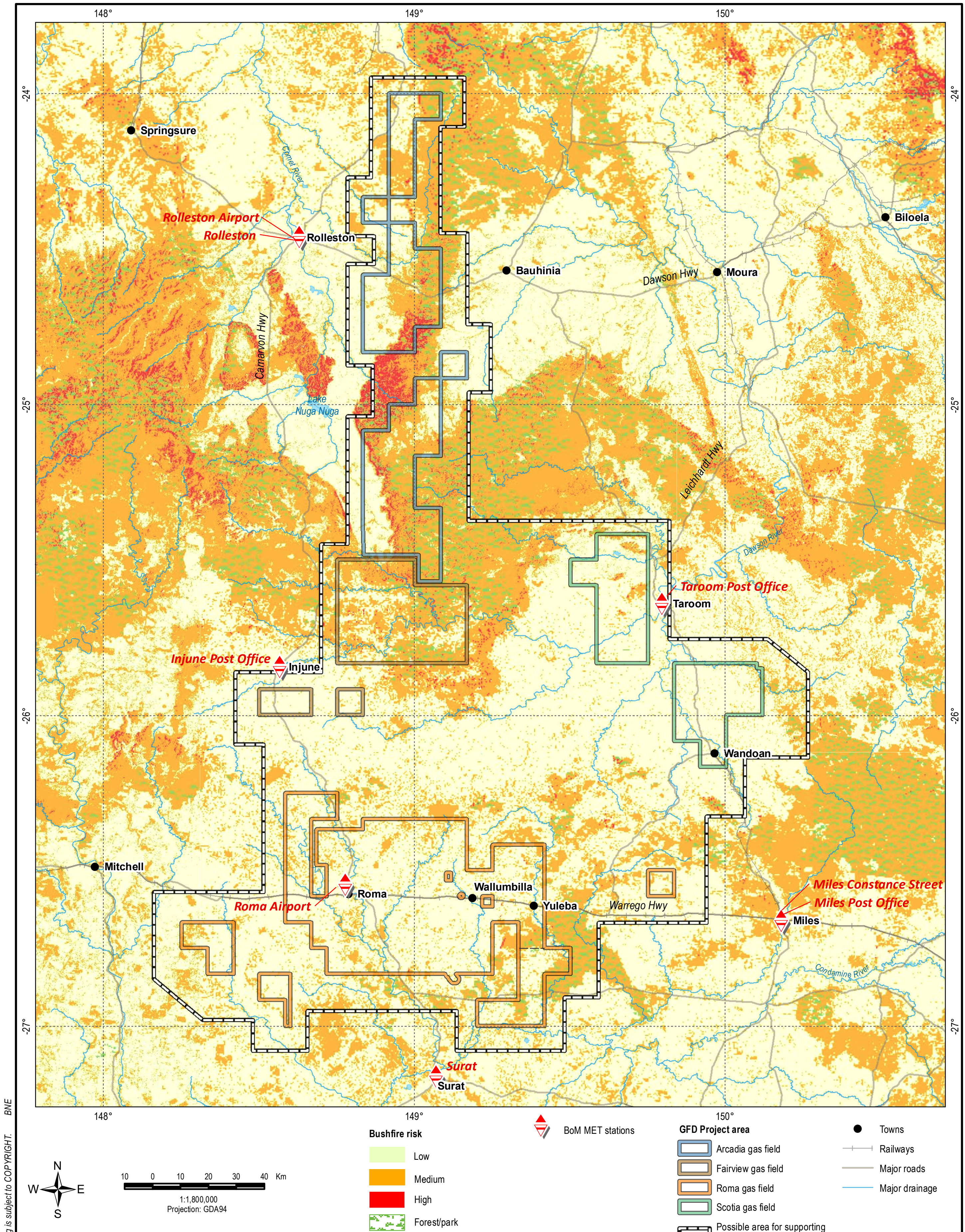
Severe storms are the most frequently occurring natural hazard in Queensland. They can result in severe events such as heavy rains, damaging strong winds, hail, flash floods, and lightning that can lead to bushfires. Most severe storms in Queensland occur between the months of September and March (Department of Emergency Services, 2007).

Thunderstorms generate lightning, which has the potential to impact both directly and indirectly (e.g. bushfires) on GFD Project infrastructure. BoM has mapped the mean annual number of thunder-days between 1990 and 1999, and the lightning total flash density and lightning ground flash density across Australia between 1995 and 2006. The GFD Project area experiences an average of:

- 20 to 35 thunder days/year
- 5 to 10 lightning flashes/km^2/year
- 1 to 3 lightning ground flashes/km^2/year (Kuleshov *et al*., 2006).

7.4.3.6 Cyclones

Queensland experiences an average of 4.7 tropical cyclones per year (Queensland Government, 2010). Figure 7-16 shows the tropical cyclones that were active within 200 km of Roma between 1970 and 2006 (BoM, 2013a). Cyclones rarely have a direct effect on the GFD Project area, which is located approximately 400 km inland. However, the weakening of tropical cyclone systems is associated with flooding in inland regions and can result in significant periods of rain (Queensland Government, 2012). BoM records indicate that there have been 10 cyclones in the past 100 years that have crossed the GFD Project area (based on data within 200 km of Roma).



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BUSHFIRE RISK ASSESSMENT

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CLIMATE AND CLIMATE CHANGE

Figure: **7-15**

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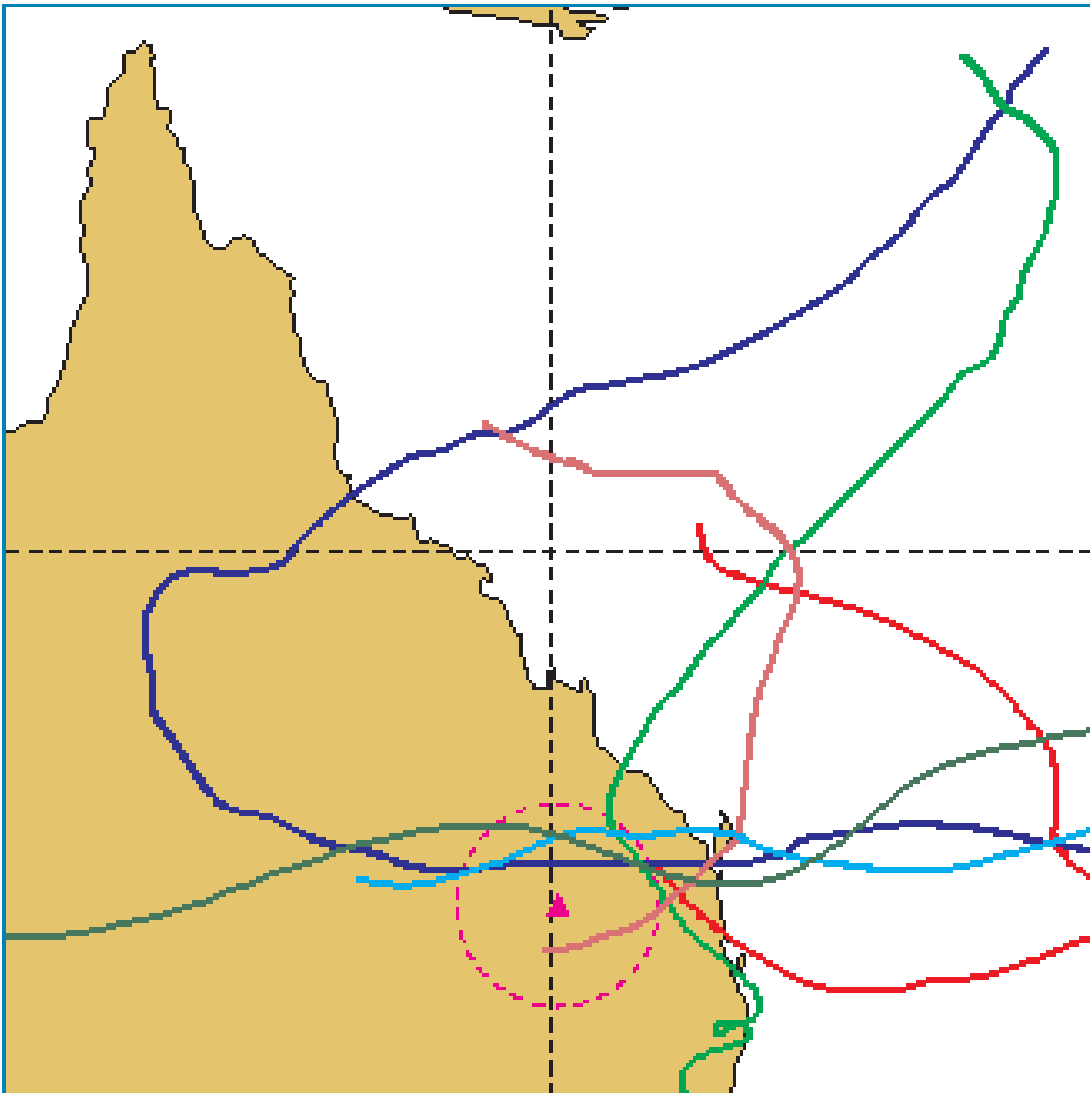

Source: The Australian Tropical Cyclone Database, Ausralian Government Bureau of Meteorology

Santos GLNG Project

GFD PROJECT EIS

TROPICAL CYCLONE TRACKS (1970 TO 2006) WITHIN 200KM OF ROMA

URS

CLIMATE AND CLIMATE CHANGE

Figure: 7-16

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7.4.4 Projected changes to natural hazards

7.4.4.1 Extreme temperatures and heatwaves

The Australian climate has been warming each decade since the 1950s, with the average daily maximum temperature in Australia increasing by a total of 0.75 ˚C since 1910 (CSIRO and BoM, 2012). Despite the occurrence of natural climate variability, such as El Niño and La Niña events leading to hot droughts (e.g. 2002–03) and cooler wet periods (e.g. 2010–11), the long-term warming trend has prevailed. This is consistent with the global trend with the increase in anthropogenic greenhouse gas emissions understood to be the main contributor.

Australian average temperatures are projected to increase by 0.6 ˚C to 1.5 ˚C by 2030, compared with the climate of 1980 to 1999 (CSIRO and BoM, 2012). By 2070, using the Intergovernmental Panel on Climate Change's greenhouse gas emission scenarios, the projected warming is between 1.0 ˚C and 5.0 ˚C.

A near doubling of very hot days (>40 ˚C) within the Central Queensland region by 2030 is projected. It is predicted that there will be three times as many hot days by 2050 with runs of 3 to 5 consecutive very hot days occurring up to six times per year by 2050.

In the Maranoa region a near doubling of very hot days (>40 ˚C) by 2030 is projected with up to four times as many very hot days by 2050. Runs of consecutive very hot days are projected to occur once every 10 years by 2030 and once every 2 years by 2050.

7.4.4.2 Extreme rainfall and flooding

A decline in annual and seasonal average rainfall and associated increase in the frequency of dry years is expected, but it is likely that rainfall events will be more intense during wet periods. An increase in 24-hour rainfall intensities of 3.9% (Queensland east coast median) and 4.2% (southeast Queensland median) by 2055, relative to that of the base period 1980–1999 (Queensland Government, 2012), is predicted.

7.4.4.3 Bushfires

A decline in annual and seasonal average rainfall, particularly in winter and spring, will lead to more severe droughts and provide more favourable conditions for bushfires if vegetation is available as fuel. Drier, hotter conditions resulting from decreases in annual rainfall, higher potential evaporation and increased temperatures are likely to increase local bushfire risk.

7.4.4.4 Drought

Due to projected changes in rainfall and increases in evaporation, 20% more drought months are anticipated across Australia by 2030 and 40% more across eastern Australia relative to the period 1980–1999 (BoM and CSIRO, 2007). Projections have shown that by 2030, exceptionally low soil moisture years are likely to affect approximately 7% of Queensland and occur once every 13 years on average (BoM and CSIRO, 2008). Based on these projections, it is expected that droughts will occur in the GFD Project area during the life of the GFD Project.

7.4.4.5 Severe storms and lightning strikes

Severe storms and lightning strikes are predicted by determining the likelihood of the large-scale environmental conditions favourable to these events and inferring the risk of occurrence.

In Australia, favourable conditions for the formation of cool-season tornadoes are likely to be reduced under global warming (Kounkou et al., 2007) but there is no information specific to the GFD Project area. No change is predicted for the frequency of hail (Niall and Walsh, 2005) and information relating to the change in frequency of lightning strikes is not available for the GFD Project area.

7.4.4.6 Cyclones

Global and regional climate models have been used to predict changes in the frequency and intensity of cyclones in Australia (BoM and CSIRO, 2007). Studies by Walsh *et al.* (2004) and Leslie *et al.* (2007) indicate that there will be little or no significant change in tropical cyclone frequency off the east coast of Australia. A third study based on CSIRO simulations shows a decrease of 9% in cyclone frequency off eastern Australia.

However, the three studies report a significant increase in the intensity of severe Category 3–5 cyclones. Walsh *et al.* (2004) and Leslie *et al* (2007) predicted an increase of intensity of these storms of 56% and 22% respectively by 2050. The variation in these projections is due to the lack of good observational data and the limited ability of global climate models to represent cyclone behaviour.

7.5 Potential impacts

Potential impacts that may occur as a result of climate-related hazards are outlined in Table 7–2.

Table 7–2 Potential impacts relevant to climate

Climate-related hazards	Potential impact
Extreme temperatures and heatwaves	• Heat-related health impacts • Increased energy demand • Heat-induced damage to infrastructure • Increased risk of bushfire • Change in range of invasive weed and pest species.
Increase in rainfall intensity and flooding	• Exceedance in capacity of water management facilities resulting in localised flooding and increased erosion risk • Degradation and failure of essential infrastructure
More frequent droughts	• Water shortage • Increased dust • Soil shrinkage and movement • Less effective rehabilitation.
Increase in storms events and intensity of cyclones	• Increased damage to infrastructure • Increased workforce injuries • More frequent and prolonged interruptions to operations.

7.6 Mitigation measures

Santos GLNG has adopted the Santos Limited policies and procedures that are applicable to the GFD Project. These policies are outlined in section 6.3.2 of Section 6: Management framework.

Section 6.3.3 of Section 6: Management framework introduces the structured framework developed and implemented by Santos GLNG that is also applicable to the GFD Project to ensure effective environmental, health and safety practices across GFD Project activities and operations.

7.6.1 Management standards

The corporate standards relevant to climate, natural hazards and climate change adaptation are outlined in Table 7–3.

Table 7–3 Hazard and management standards relevant to climate

Standard	Key requirements
Environment, Health, and Safety Management Standard (EHSMS)19 Climate change	One the key element of EHSMS19 is climate change risk and adaptation. Santos GLNG recognises that climate change can pose different risks to its activities and considers these when undertaking risk assessments. In particular, incremental changes in climate variables such as ambient temperature, and changes in the occurrence and intensity of extreme events have the potential to significantly impact on Santos GLNG's operations and workforce. EHSMS19 requires that adaptation to physical aspects of climate change is to be factored into Santos GLNG's risk management process which is guided by EHSMS09 Managing environmental health and safety risks.
EHSMS09 Managing environmental health and safety risks	Adaptation to physical aspects of climate change is to be factored into Santos GLNG's risk management process guided by EHSMS09. A risk register may include the risk of extreme weather events including storms and cyclones and would be developed in accordance with EHSMS09.
EHSMS13 Emergency preparedness	Santos GLNG will implement an emergency response plan in accordance with EHSMS13. The emergency response plan will consider relevant identified risks.
Health and Safety Hazard Standard (HSHS)05 Working in hot environments	HSHS05 sets out control strategies and mandatory heat stress and awareness training for workforce and sub-contractors. HSHS05 also requires suitable control strategies to be implemented, such as air conditioned refuge and/or shade.
Environment Hazard Standard (EHS)05 Air emissions	In accordance with Santos GLNG's EHS05 Air emissions, Santos GLNG will implement specific procedures and a suite of controls based on the GLNG Project construction management plans to address dust and air quality impacts. Control measures may include: • Temporary use of cover crops to stabilise bare soil stockpiles or other bare soil areas • Where practicable, organic mulching and/or planting of bare soil surfaces will be undertaken to reduce the effects of dust generation and wind and water erosion • Long-term access roads with the potential for dust development will be upgraded with gravel or bitumen where practicable • Watering of the right of way, access tracks and soil and demolition spoil stockpiles will be undertaken on an as-required basis to minimise the potential for dust generation • Use of coal seam water where practicable for dust suppression with approval and in accordance with the Land release management plan.
EHS09 Pest plants and animals	In accordance with EHS09 Pest Plants and Animals, Santos GLNG will implement the Rehabilitation management plan and the Pest and weed management plan to control risks posed by certain plant species for invasiveness as a result of climate change risks.

7.6.2 Management plans

Santos GLNG is committed to implementing the mitigation measures in Table 7–4 to manage potential climate and climate change related impacts. These measures will be incorporated into Santos GLNG's management framework for the GFD Project, as described in Appendix Y: Draft environmental management plan.

Table 7–4 Mitigation measures – climate and climate change

Management plan	Mitigation measures
Bushfire management plan	The plan provides clear direction for Santos GLNG gas fields operations on how to prepare for and respond to the risk of bushfire. The four main objectives include: • Reduce the likelihood of ignition • Reduce the likelihood of personnel being exposed to bushfires • Increase the level of bushfire protection • Increase the level of emergency response preparedness. This is an operational document and is not included in this EIS.
Emergency response plan (ERP)	The ERP forms part of Santos GLNG's overall emergency response. It is supplementary to the Queensland incident management plan and provides the necessary information to deal with emergencies at the asset level. This is an operational document and is not included in this EIS.
GFD Project environmental protocol for constraints planning and field development (Constraints protocol)	The Constraints protocol applies to all gas field related activities. The scope of the Constraints protocol is to: • Enable Santos GLNG to comply with all relevant State and Federal statutory approvals and legislation • Support Santos GLNG's environmental policies and the General Environmental Duty (GED) as outlined in the *Environmental Protection Act 1994* (Qld) • Promote the avoidance, minimisation, mitigation and management of direct and indirect adverse environmental impacts associated with land disturbances • Minimise cumulative impacts on environmental values. The Constraints protocol provides a framework to guide placement of infrastructure and adopts the following management principles: • Avoidance — avoiding direct and indirect impacts • Minimisation — minimise potential impacts • Mitigation — implement mitigation and management measures • Remediation and rehabilitation — actively remediate and rehabilitate impacted areas • Offset — offset residual adverse impacts in accordance with regulatory requirements. The Constraints protocol enables the systematic identification and assessment of environmental values and the application of development constraints to effectively avoid and / or manage environmental impacts. In accordance with the Constraints protocol, Santos GLNG will consider the risks associated with flood events in the selection of infrastructure locations.
Draft environmental management plan (Draft EM Plan)	The Draft EM Plan identifies the environmental values potentially affected by the GFD Project and proposes measures to manage the risk of potential adverse impact to these environmental values. The Draft EM Plan comprises: • Environmental values potentially affected by the GFD Project • Environmental management objectives and associated management measures • Environmental monitoring and reporting • Coal seam water management • Proposed conditions.
Journey management plan	Journey management plans are developed on an as needs basis (normally by contractors) to specify travel issues, including which roads are to be used. They are operational and journey specific and are not included in this EIS.
Land release management plan (LRMP)	The LRMP addresses the management of releases of water to land in Santos GLNG's gas fields, including: • Coal seam water use for irrigation, construction and operations purposes • Treated sewage effluent releases to land • Use of treated sewage effluent for construction and operations purposes • Low point drain water releases to land

Management plan	Mitigation measures
	• Hydrostatic test water releases to land. The document includes the principles, methods and controls to effectively manage and minimise the risk environmental harm being caused by release of water to land.
Pest and weed management plan (PWMP)	The management of pest and weed species will be undertaken in accordance with the PWMP. The plan includes measures such as: • Identification of pest and weed species and areas of infestation • Avoidance of traversing and placing infrastructure in areas of known infestation • Prevention of the spread of pest and weed species by implementing appropriate work practices and promotion of risk awareness • Control of identified pest and weeds through containment, reduction or eradication as required by legislation.
Queensland incident management plan (QIMP)	The QIMP describes the use of the Santos GLNG incident management framework, including the procedures and systems that apply to the Santos GLNG operations and activities. It is an operational document and not included in this EIS.
Rehabilitation management plan	The Rehabilitation management plan outlines the rehabilitation objectives for Project-related disturbances within the GFD Project area. This includes the phasing of rehabilitation to first achieve stabilisation and subsequently final rehabilitation for disturbances to land (i.e. ground surface). The Rehabilitation management plan: • Describes Santos GLNG's approach to rehabilitation • Identifies key rehabilitation objectives and criteria to deem rehabilitation success • Outlines general rehabilitation actions to be undertaken by Santos GLNG when rehabilitation a disturbance • Provides an overview of monitoring and maintenance actions to be conducted on rehabilitated areas.

7.6.3 Adaptation strategies

The key climate change effects for the GFD Project are primarily associated with increased extreme storm events, extreme heat related risks, and drier conditions. Santos GLNG is committed to the following actions to mitigate the effects of climate change on the GFD Project:

- Avoidance – the location of infrastructure will consider the potential risks of atmospheric and climate factors (storms events / cyclones, duration and ranges of temperature and rainfall).
- Mitigation – the following mitigation measures will consider the range of atmospheric and climatic factors:
  - Engineering design specifications
  - Inspection and maintenance programs
  - Procedures, control strategies and awareness training on the management of potential risks associated atmospheric and climate factors.
- Management plans- the following management plans will also consider the risk of atmospheric and climatic factors:
  - Bushfire management plan
  - Emergency response plan
  - Journey management plan
  - Rehabilitation management plan.

7.7 Risk assessment

As discussed in section 7.3, impacts were assessed using the risk assessment methodology. As the GFD Project area covers a large geographical area, the general nature of potential impacts to environmental values associated with GFD Project activities are identified and assessed within this section.

Table 7–5 summarises the assessment undertaken for the potential impacts climate and climate change on the population in the GFD Project area, and the GFD Project's workforce and infrastructure. For each identified potential impact, the assessment considered:

- The potential pre-mitigated risk, which that only the Constraints protocol has been applied and the potential impacts are at their greatest
- The mitigation measures that will be used to manage the potential impacts. These measures may reduce either or both the likelihood and consequence of the potential impacts
- The residual risk of the potential impact after the implementation of mitigation measures. The residual risk takes into account the potential for impact that remains after the mitigation measures are applied.

Table 7–5 Risk assessment – climate and climate change

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Extreme temperatures and heatwaves								
Heatwave health risks and reduced productivity for the GFD Project workforce	Construction	Possible	Minor	Low	HSHS05 sets out control strategies and mandatory heat stress and awareness training for workforce and sub-contractors. HSHS05 also requires suitable control strategies to be implemented, such as air conditioned refuge and/or shade. Santos GLNG will implement an ERP in accordance with EHSMS13 Emergency preparedness. This will include the relevant Significant Hazard Risk Register developed in accordance with EHSMS09 Managing EHS risks. This will be required during extreme heatwave events which require increased medical supervision, integration of more shade structures, water coolers and scheduled rest breaks, and an increase in the rotation of shifts.	Unlikely	Minor	Low
	Operations	Likely	Minor	Medium		Unlikely	Minor	Low
	Decommissioning	Likely	Minor	Medium		Unlikely	Minor	Low
Increased energy demand for cooling, and inefficiencies in gas compression, power generation and transmission.	Construction	Unlikely	Minor	Low	Engineering design specifications will consider the expected atmospheric and climatic conditions and the potential for a decrease in the efficiency of plant such as gas compression and power generation during high temperatures. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of heatwaves. Engineering design specifications will also consider the expected atmospheric and climatic conditions and the potential for an increase in the demand for cooling during high temperatures. This may include an increase in the use of passive engineering designs such as building orientation, material selection, sunshades, treated windows and insulation.	Remote	Minor	Very low
	Operations	Likely	Minor	Medium		Possible	Minor	Low
	Decommissioning	Likely	Minor	Medium		Possible	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Heat-induced damage to gas and water gathering and transmission pipelines	Construction	Remote	Minor	Very low	Engineering design specifications will consider the expected atmospheric and climatic conditions and the potential increase in the extent and duration of heatwaves. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of heatwaves.	Remote	Minor	Very low
	Operations	Remote	Minor	Very low		Remote	Minor	Very low
	Decommissioning	Remote	Minor	Very low		Remote	Minor	Very low
Increased risk of bushfire in gas fields potentially affecting the GFD Project workforce safety, infrastructure and the surrounding environment.	Construction	Unlikely	Minor	Low	The Bushfire management plan will consider the range of expected atmospheric and climatic conditions and the potential for an increase in the extent and duration of heatwaves. The Bushfire management plan aims to: • Reduce the likelihood of ignition • Reduce the likelihood of personnel being exposed to bushfires • Increase the level of bushfire protection • Increase the level of emergency response preparedness. The ERP forms part of Santos GLNG's overall emergency response and provides the necessary information to deal with emergencies. Journey management plan includes information relating to: communication requirements, call-in procedures, approved roads, weather conditions and potential hazards.	Remote	Minor	Very low
	Operations	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low
Changes in range of invasive weed and pest species.	Construction	Remote	Moderate	Low	In accordance with EHS09 Pest plants and animals, Santos GLNG will implement the Rehabilitation management plan and the PWMP to control risks posed by certain plant species for invasiveness.	Remote	Moderate	Low
	Operations	Remote	Moderate	Low		Remote	Moderate	Low
	Decommissioning	Remote	Moderate	Low		Remote	Moderate	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Increase in rainfall intensity								
Capacity of water management systems (e.g. coal seam water storage, brine storage) exceeded resulting in: • More frequent overflows and localised flooding with potential for erosion • Larger stormwater flows may cause greater water damage to various facilities and infrastructure • Greater risk of contaminated stormwater discharged into receiving environments.	Construction	Unlikely	Minor	Low	In accordance with the Constraints protocol, Santos GLNG will consider the risk associated with flood events in the selection of infrastructure locations. Engineering design specifications will consider the range of expected atmospheric and climatic conditions and the potential for an increase in rainfall intensity and duration, including the risk of isolation by flood water. Dams will be designed in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EHP, 2013).	Remote	Minor	Very low
	Operations	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low
Degradation and failure of materials and structural integrity of essential infrastructure including roads, transmission line, telecommunications, pipelines, foundations of buildings and facilities, etc.	Construction	Remote	Minor	Very Low	Engineering design specifications will consider the range of expected atmospheric and climatic conditions and the potential increase in the extent and duration rainfall events. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of rainfall events.	Remote	Minor	Very low
	Operations	Unlikely	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Unlikely	Minor	Low		Unlikely	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
More frequent droughts due to reduced annual average rainfall and higher evaporation rates								
Water shortage causing GFD Project operations to be restricted, or higher costs for water usage.	Construction	Remote	Minor	Very Low	In accordance with the Draft EM Plan, Santos GLNG will ensure that: • GFD Project will use coal seam water for operational purposes where practicable. • Potable water is trucked in from appropriate water suppliers or extracted from groundwater bores.	Remote	Minor	Very low
	Operations	Remote	Minor	Very Low		Remote	Minor	Very low
	Decommissioning	Remote	Minor	Very Low		Remote	Minor	Very low
More dusty conditions increasing the cost to maintain equipment and water demand for dust suppression.	Construction	Remote	Negligible	Very low	In accordance with Santos GLNG's EHS05 Air emissions, Santos GLNG will implement specific procedure and suite of controls based on the GLNG Project construction management plans to address dust and air quality impacts. Control measures may include: • Temporary use of cover crops to stabilise bare soil stockpiles or other bare soil areas • Where practicable, organic mulching and/or planting of bare soil surfaces will be undertaken to reduce the effects of dust generation and wind and water erosion • Long-term access roads with the potential for dust development will be upgraded with gravel or bitumen where practicable • Watering of the right of way, access tracks and soil and demolition spoil stockpiles will be undertaken on an as-required basis to minimise the potential for dust generation • Use of coal seam water where practicable for dust suppression with approval and in accordance with the LRMP.	Remote	Negligible	Very low
	Operations	Possible	Negligible	Low		Unlikely	Negligible	Very low
	Decommissioning	Possible	Negligible	Low		Unlikely	Negligible	Very low
Damage to buildings and infrastructure due to movement of footings and	Construction	Remote	Minor	Very Low	Engineering design specifications will consider the range of expected atmospheric and climatic conditions and the potential increase in the	Remote	Minor	Very low
	Operations	Unlikely	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Unlikely	Minor	Low		Unlikely	Minor	Low

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
foundations caused by soil shrinkage in long dry periods.					extent and dry periods or rainfall events. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of dry periods or rainfall events.			
More difficult to revegetate disturbed or rehabilitation areas.	Construction	Unlikely	Minor	Low	In accordance with the Rehabilitation management plan, areas of disturbance will be progressively rehabilitated to a pre-clearance state or another stable landform consistent with the surrounding undisturbed areas or to final acceptance criteria.	Unlikely	Minor	Low
	Operations	Likely	Minor	Medium		Possible	Minor	Low
	Decommissioning	Likely	Minor	Medium		Possible	Minor	Low
Increase in intensity and frequency of extreme storms events and cyclones								
Increased damage to essential in-field infrastructure causing temporary cessation of operations or reduction of production output.	Construction	Remote	Moderate	Low	Engineering design specifications will consider the range of expected atmospheric and climatic conditions and the potential increase in the extent and duration of extreme storms and cyclone events including the risk of isolation by flood water. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of extreme storms and cyclone events.	Remote	Moderate	Low
	Operations	Possible	Moderate	Medium		Unlikely	Moderate	Medium
	Decommissioning	Possible	Moderate	Medium		Unlikely	Moderate	Medium
Loss of life or injuries to workforce onsite or travelling to the GFD Project area due to sudden or unpredictable climatic hazards such as extreme storm events, cyclones, flash floods or bushfires.	Construction	Remote	Critical	Medium	Journey management plan includes information relating to: communication requirements, call-in procedures, approved roads, weather conditions and potential hazards. Santos GLNG will implement an ERP in accordance with EHSMS13. This will include the relevant Significant Hazard Risk Register developed in accordance with EHSMS09 Managing EHS Risks. This will include the risk of extreme weather events including storms and cyclones.	Remote	Critical	Medium
	Operations	Remote	Critical	Medium		Remote	Critical	Medium
	Decommissioning	Remote	Critical	Medium		Remote	Critical	Medium

Potential impact	Phase	Pre-mitigated risk			Mitigation and management measures	Residual risk		
		Likelihood	Consequence	Risk		Likelihood	Consequence	Risk
Increased damage or maintenance costs to telecommunications, power supply / reticulation, plant infrastructure and equipment due to increased frequency and length of power outages, and disruption of other services such as telecommunications.	Construction	Remote	Minor	Very Low	Engineering design specifications will consider the range of expected atmospheric and climatic conditions and the potential increase in the extent and duration of extreme storms and cyclone events including the risk of isolation by flood water. Inspection and maintenance programs will consider the potential risk of an increase in the extent and duration of extreme storms and cyclone events.	Remote	Minor	Very low
	Operations	Possible	Minor	Low		Unlikely	Minor	Low
	Decommissioning	Possible	Minor	Low		Unlikely	Minor	Low

7.8 Conclusions

The risk assessment of climate-related hazards detailed in Appendix I: Climate, natural hazards and climate change identified the residual risks shown in Table 7–6. The risk assessment shows that the residual natural hazards and climate change impacts over the life of the GFD Project are considered to range from very low to medium, and that the GFD Project's mitigation measures (outlined in Table 7–4) would accommodate the majority of possible climate change impacts.

Table 7–6 Residual risks relevant to climate

Hazards	Potential impacts	Residual risk		
		Construction	Operations	Decommissioning
Extreme temperatures and heatwaves	Heat-related health impacts	Low	Low	Low
	Increase in energy demand	Very low	Low	Low
	Heat-induced damage to infrastructure	Very low	Very low	Very low
	Increase in risk of bushfire	Very low	Low	Low
	Changes in range of invasive weed and pest species	Low	Low	Low
Increase in rainfall intensity	Exceedance in capacity of water management facilities resulting in localised flooding and increased erosion risk	Very low	Low	Low
	Degradation and failure of essential infrastructure	Very low	Low	Low
More frequent droughts	Water shortage	Very low	Very low	Very low
	Increase in dust	Very low	Very low	Very low
	Soil shrinkage and movement	Very low	Low	Low
	Less effective rehabilitation	Low	Low	Low
Increase in intensity and frequency of extreme storms events and cyclones	Increase in damage to infrastructure	Low	Medium	Medium
	Increase in workforce injuries	Medium	Medium	Medium
	More frequent and prolonged interruptions to operations	Very low	Low	Low