Australia Pacific LNG Project

Volume 3: Gas Pipeline

Chapter 4: Climate and Climate Change Adaptation

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4 Climate and climate change adaptation

4.1 Introduction

This chapter provides information on the existing climate of the south central Queensland region and explores predictions of climate change in the region of the Australia Pacific LNG Project's gas pipeline. The gas pipeline route spans from Curtis Island on the coast, to south central Queensland near Roma. It describes the potential impacts of climate change on the gas pipeline and associated works based on current knowledge.

Greenhouse gas (GHG) emissions, their impacts and mitigation strategies specific to the gas pipeline are discussed in detail in Volume 3 Chapter 14.

This chapter addresses 3.1.1 Climate and 3.1.2 Climate Change Adaptation of the environmental impact statement (EIS) terms of reference in Sections 4.2 and 4.3.

Throughout the life of the Australia Pacific LNG Project (the Project), including site preparation, construction, operation, decommissioning and rehabilitation, the Project will be influenced by the climate. The Australia Pacific LNG's sustainability principles will be applied to developing strategies for the gas pipeline to ensure that climate induced impacts do not cause conditions which adversely impact the Project or the environment.

Of Australia Pacific LNG's 12 sustainability principles, as discussed in the sustainability chapter Volume 1 Chapter 3, the relevant sustainability principles for climate over the pipeline are as follows:

- Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas
- Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.

Under these principles, climate and climate change values are reflected by identifying and assessing climate change risks, and developing climate change adaptation strategies to mitigate its impact on project assets and activities.

4.2 Climate

4.2.1 Climate over the pipeline area

Information in this section relates to climate in the south central region of Queensland. Meteorological data from the Bureau of Meteorology (BOM) monitoring stations at Taroom near the middle of the gas pipeline and Thangool, near the north of the gas pipeline and just south of Biloela (BOM 2009a), have been used to characterise the climate in the region along the Australia Pacific LNG gas pipeline route.

The Taroom and Thangool monitoring stations have been selected for their close proximity to the proposed gas pipeline and the availability of data. The meteorological parameters measured at the Taroom and Thangool monitoring stations include long-term temperature, solar radiation, atmospheric pressure, rainfall and relative humidity. The parameters used from each site are summarised in Table 4.1. Refer to Volume 5 Attachment 30 for more details.

The gas pipeline traverses from the gas fields region to the coastal LNG facility. Information from BOM stations located at Roma, Miles and Dalby for the gas fields, and Gladstone airport and Radar Hill for the Gladstone area, are provided in Volume 2 Chapter 4 and Volume 4 Chapter 4 respectively.

Table 4.1 Summary of Bureau of Meteorology monitoring stations and parameters

Region	Location	Latitude/longitude	Record period	Parameters
Taroom	Post Office	25.64 °S 149.80 °E	1870 – 2009	Temperature, solar exposure, relative humidity, rainfall and surface pressure
Thangool	Airport	24.49 °S 150.57 °E	1929 – 2009	Temperature, solar exposure, relative humidity, rainfall and surface pressure

Of the climatic conditions presented in this section the main element raised is that construction be done during the 'dry season', where practicable, for elements such as the construction of gas pipeline creek crossings. The more extreme weather events include big storms, floods, heat waves and bushfires which may result in impacts such as sedimentation, erosion, stormwater management, containment of waste in bunding and tailings dams, health and safety risks to personnel and interruption to transportation.

These impacts are discussed further in Volume 3 Chapter 11 – Water resources, Volume 3 Chapter 5 – Topography, geomorphology, geology, soils and land contamination and Volume 3 Chapter 17 – Traffic and transport. The construction methods and management strategies for these issues are dealt with in Volume 3 Chapter 24 – Environmental management plans, which include management measures for sediment and erosion control, geology and soils, transport, surface water, and health and safety.

4.2.2 Wind speed and direction

The monitoring stations BOM operates at Taroom and Thangool are the closest monitoring stations to the Project's gas pipeline. However, BOM do not operate automatic weather stations at these locations, so hourly average recordings of wind speed and directions are not collected. Therefore, the following information is from the CALMET meteorological model. Refer to Volume 3 Chapter 13 for more information.

The available information suggests that Taroom is a relatively light wind site, with an average 9:00am wind speed of 2.3m/s and an average 3:00pm wind speed of 2.75m/s. The wind direction is generally variable from the north to west south west, with a small percentage of winds from the northwest predominantly during spring.

The available information suggests Thangool has distinct variation in wind direction over the seasons. There is a slight predominance of easterly winds accounting for 30% of the summer wind. Autumn shows a distinct preference of southeasterly and southwesterly winds, with very little wind from the west to north sector. Winter is dominated by southwesterly winds, attributable to the passage of cold fronts, accounting for 46% of the wind. Spring also shows a distinct preference to northwesterly and northerly winds, most likely due to the initialization of the Australian monsoon and the development of the Cloncurry heat low.

At the start of the gas pipeline, the wind speed and direction characteristics of the gas fields are predominantly north and northeasterly the year round and tend to be of moderate wind speed the majority of the time. Refer to Volume 2 Chapter 4 for more information on the climate of the gas fields.

At the end of the gas pipeline, diurnal variations in wind flow across the Gladstone region are strongly influence by sea breezes, resulting in a high percentage of easterly daytime winds. The sea breeze generally develops around 10:00 to 11:00am each day, and is often preceded by a shift in wind direction from the more southerly and westerly night time drainage flows.

The wind speeds recorded at Gladstone airport indicate the sea breezes recorded in this region are predominantly greater than five metres per second. Refer to Volume 4 Chapter 4 for more details on the climate of Gladstone.

4.2.3 Temperature and solar radiation

The average maximum daily temperature recorded at the sites during summer ranges from 33.3°C at Taroom to 33.2°C at Thangool. The average minimum daily temperature recorded at the sites during winter ranges from 5.9°C at Taroom to 6.3°C at Thangool. On average, daily temperatures tend to increase to the north across the project area, with Thangool typically recording higher temperatures throughout the year than Taroom to the south.

Average daily solar exposure (MJ/m^2) at Taroom and Thangool shows a seasonal pattern whereby summertime solar exposure is 1.6 times greater than that of the winter time.

At the start of the gas pipeline, the daily temperatures tend to increase to west across the gas fields area, with Roma typically recording higher temperatures (33.4°C) than Miles to the east and Dalby (31.8°C) further to the east. Refer to Volume 2 Chapter 4 for more details on the climate of the gas fields.

At the end of the gas pipeline, in Gladstone, the annual average maximum temperature of 27.2°C and an average minimum temperature of 18.0°C. Refer to Volume 4 Chapter 4 for more details on the climate of Gladstone.

4.2.4 Rainfall

The annual pattern of rainfall illustrates the sub-tropical climate in the region where 52% (Taroom) and 54% (Thangool) of the annual precipitation occurs during the monsoonal months of November to February.

The annual average rainfall across the region ranges between 661mm at Thangool and 671mm at Taroom, with the maximum monthly average rainfall occurring in January at both Thangool (97mm) and Taroom (98mm). Annual rainfall predominantly occurs during the monsoonal summer. While this area is considered to have a sub-tropical climate the relatively low amount of annual rainfall illustrates the dry, semi-arid nature of the central Queensland region. On average, the total rainfall during the monsoonal months is marginally more than twice that of the drier months. Taroom peak rainfall events are typically higher (up to two times) than the more northerly Thangool region.

At the start of the gas pipeline, the rainfall characteristics of the gas fields have been described as subtropical, where 50% (Roma), 51% (Miles) and 57% (Dalby) of annual precipitation occurs during the monsoonal months. The annual average rainfall across the region ranges between 558mm at Roma and 649mm at Miles. Refer to Volume 2 Chapter 4 for more details on the climate of the gas fields.

At the end of the gas pipeline, the rainfall characteristics of Gladstone are consistent with the subtropical climate. The annual average rainfall at Radar Hill is 873.2mm/year. Refer to Volume 4 Chapter 4 for more details on the climate of Gladstone.

4.2.5 Relative humidity

Relative humidity has been analysed from long-term averages based on daily measurements collected at 9:00am and 3:00pm at Taroom and Thangool. The analysis indicates the cooler late autumn and winter months (May to July) tend to be marginally more humid than the warmer spring and summer months (September to December). This trend appears to be more significant for relative humidity in the morning than in the afternoon when surface heating has taken place all day, as the range in the monthly averages is greater during the morning than in the afternoon. The analysis also indicates the highest average relative humidity in the afternoon is in February, while in the morning the highest monthly average occurs in June.

In regard to average daily variations, the analysis indicates relative humidity is, on average, 62% higher at 9:00am than at 3:00pm across the region.

4.2.6 Surface pressure

Monitoring data from Taroom and Thangool have been used to characterise the mean sea-level pressure in the region during the period 2002 to 2009.

The longer term cycles are evident in the seasonal fluctuations of mean sea-level pressure, which fluctuates around an average pressure of 1019 hectopascals (hPa) during the drier winter months (May to August), and 1011hPa during the wetter summer months (November to February) for both Taroom and Thangool. Within this seasonal cycle, mean sea-level pressure fluctuates on a diurnal basis between three to four hectopascals, with solar heating of the ground during the midday to afternoon period, reducing the atmospheric pressure above the ground. At night when the temperature falls, atmospheric pressure increases again.

At the start of the gas pipeline, the surface pressure characteristics in the gas fields fluctuate around 1020hPa in the drier winter months (May to August) and 1010hPa during the wetter summer months (November to February). Refer to Volume 2 Chapter 4 for more details on the climate of the gas fields.

At the end of the gas pipeline, the surface pressure characteristics of Gladstone are low pressure during January and July, and high pressure during April and October. Refer to Volume 4 Chapter 4 for more details on the climate of Gladstone.

4.2.7 Climate extremes

Droughts

Periodic drought is part of the Australian weather pattern. Major Australian droughts that have affected this region include 1963-68, 1972-73, 1982-83 and 1991-95 (BOM 2009b).

Part of Gladstone Regional Council and all of Banana Shire and Western Downs Regional Council are currently 'drought declared' with some areas of the gas pipeline drought declared since 2000 (Department of Primary Industries and Fisheries 2009).

Floods

The proposed gas pipeline route crosses watercourses at 27 locations. This represents the larger creeks and the Calliope River, which fall within three river basins; the Condamine, Dawson and Coastal (refer to Volume 3 Chapter 11 – Water resources).

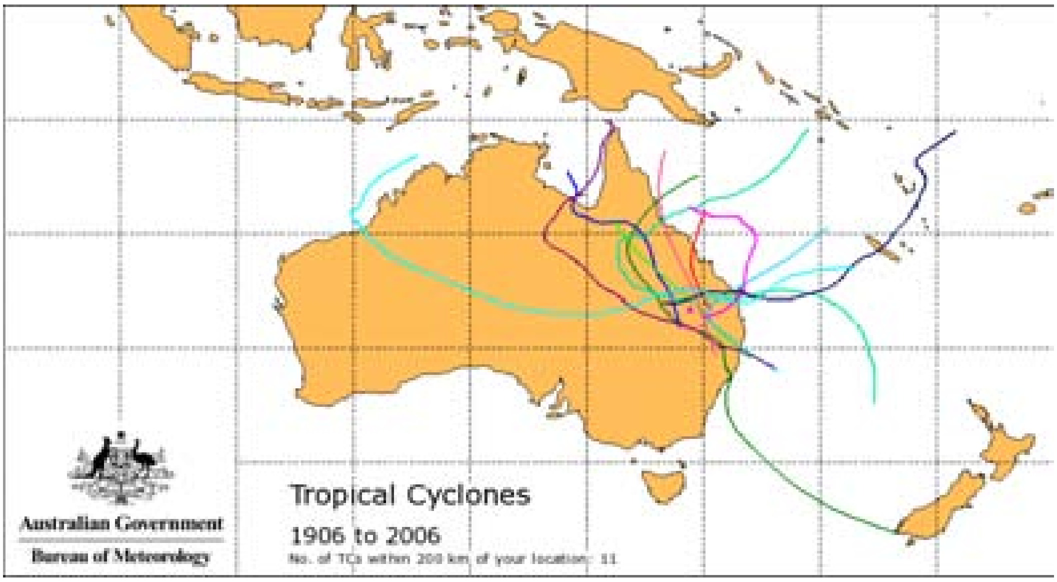
According to the BOM, 'major floods generally only occur in the first half of the year although records indicate they may also occur in late spring' (BOM 2009c).

In the coastal region, which the gas pipeline traverses, most of the region's recorded flood events are typically due to tropical cyclone activity occurring within the summer months. Ex-tropical cyclone Beni brought small-scale flooding to the greater Gladstone area, which occurred in February 2003 within the Boyne River catchment.

The gas pipeline creek crossings will need to be constructed during the 'dry' season where practicable to minimise flood impact risks, construction delays and damage to plant and machinery.

Tropical cyclones

The gas pipeline region spans from Curtis Island on the coast to south central Queensland near Roma. Queensland is susceptible to cyclones which develop over tropical waters in northern Australia. While there are more cyclones over the coast, there were 11 tropical cyclones within a 200km radius of Roma from 1906 to 2006 (BOM 2009d). Figure 4.1 includes notable tropical cyclone events such as Althea, Wanda, Cliff and Gertie.



Tropical cyclone Gertie
Tropical cyclone Althea
Tropical cyclone Wanda
Tropical cyclone Cliff

Figure 4.1 Tropical cyclones within 200km of Roma (1906–2006) (BOM 2009d)

Storm surge and storm tide

When tropical cyclones track over the ocean their extreme winds and low pressure result in an elevated dome of water travelling as a long period wave. As this surge approaches the coastline, it can be affected by the seabed slope and coastline shape causing it to amplify in height. When this surge is combined with the normal tide on the day, it becomes a storm tide at landfall.

Tropical cyclone tracks are erratic and difficult to predict in advance, although research and technology are leading to improvements in this capability. This means severe weather warnings are also improved and consequently mitigative measures are increasingly more reliable.

Less intense tropical cyclone activity and extra-tropical low pressure systems producing surges most likely would go unnoticed when combined with the lower tide ranges. Nevertheless, these can alter the normal currents and water levels from their predicted or forecast values. The occurrence of a major storm tide in Gladstone is primarily dependent on tropical cyclone track direction, forward speed, the radius to maximum winds and the wind strength due to the cyclone central pressure, coupled with the state of the tide at the time the cyclone makes landfall.

Storm tide studies have been undertaken for most of the Queensland coastline. Figure 4.2 shows storm tide heights above highest astronomical tide (HAT) for selected locations along the east coast and Gladstone is highlighted (orange border). Each coloured vertical bar corresponds to a nominated average return period (ARI). Gladstone is one of the locations with a higher storm tide risk profile and its vulnerability to inundation will depend on elevations of existing urban areas and the design level of the gas pipeline reclamation areas.

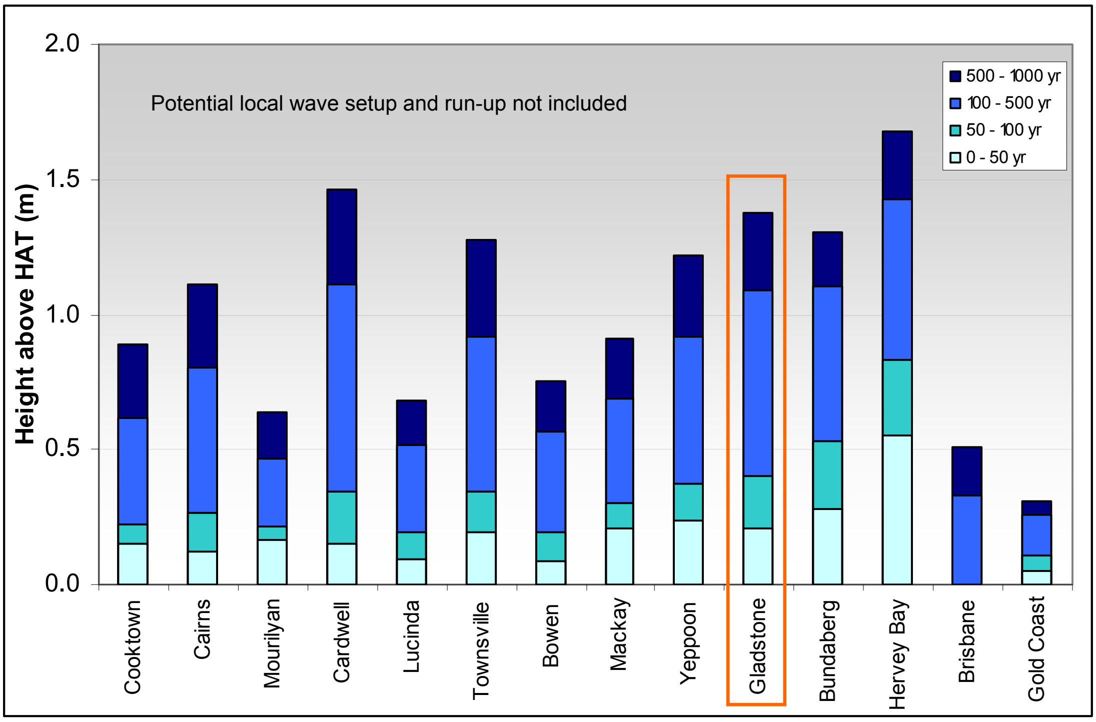


Figure 4.2 Storm tide height above highest astronomical tide (metres) – Queensland east coast locations

Frequency of thunderstorms and lightning strikes

The frequency of thunderstorms has been estimated from maps developed by the BOM for Australia. The BOM has analysed ten years (1990 to 1999) of records of thunder-days from 300 monitoring sites around Australia to produce a map of average annual thunder-days. A thunder-day is defined as 'an observational day...during which thunder is heard at the station. Precipitation need not occur' (Huschke 1959). An observational day is defined from midnight to midnight local standard time.

The frequency of lightning activity has been estimated from maps of lightning flash density developed by the BOM. Eight years of data has been analysed (1995 to 2002) from ground-based lightning detectors and NASA satellite-based instruments. The lightning flash density is defined as the number of flashes of a specific type occurring over unit area in unit time (Kuleshov et al. 2006). Total flash density is made up of cloud-to-ground flashes and intracloud flashes. Total flash density and cloud-to-ground flash densities are presented here.

Table 4.2 summarises the thunder-day and lightning flash density information for the Australia Pacific LNG gas fields and gas pipeline.

Table 4.2 Project gas fields and gas pipeline areas – annual average thunder days, total lightning flash density and cloud-to-ground flash density

Parameter	Australia Pacific LNG gas-fields and pipeline
Thunder days (annual average – 1990-1999)	10 to 30 thunder-days per year
Total lightning flash density[1] (annual average – 1995-2002)	5 to 10 flashes per km^2 per year
Cloud-to-ground lightning flash density[2] (annual average – 1995-2002)	1 to 3 flashes per km^2 per year

1 Total lightning flash density: flashes per square kilometre per year

2 Cloud-to-ground flash density: flashes per square kilometre per year

4.2.8 Impacts of weather patterns and extremes of climate on project

When designing and constructing the gas pipeline, particular regard has been given to the historical weather patterns and climate extremes. The south central Queensland region has a sub-tropical climate, which is characterised by a moderately distinctive wet and dry season, high temperatures and humidity.

Historical weather patterns show that summertime weather activity generates the wetter spring and summer months relative to the drier autumn and winter months when the solar incidence is less intense. Construction methods and scheduling will be implemented in a way that ensures personnel and the environment is protected. Methods and timing of construction include ensuring erosion and sediment control measures and stormwater management measures are appropriately constructed and sized to deal with anticipated amount of rainfall and appropriate shelter is available for the workforce in chances of severe weather. Appropriate personal protection will be given to personnel to protect them from the weather.

Overall, south central Queensland does not experience a typical weather pattern that will restrict construction or operation. The inclusion of appropriate measures, such as site stormwater management systems, and waste containment systems will ensure personnel and the environment are protected.

Further information regarding mitigation measures can be found in Volume 3 Chapters 5, Volume 3 Chapter 9 and Volume 3 Chapter 11.

4.3 Climate change

While there are inherent uncertainties surrounding predicted impacts, this section describes the gas pipeline vulnerabilities to climate change and identifies possible adaptation strategies.

4.3.1 Methodology

Effective climate change adaptation requires an awareness of the risks posed by climate change, and an understanding of the relative significance of those risks.

A climate change adaptation risk assessment was conducted to assess how alterations to weather patterns and rising sea level have the potential to impact on the gas pipeline. The climate change predictions from Commonwealth Scientific and Industrial Research Organisation (CSIRO), which has published the most comprehensive data to date, were compiled ahead of a climate change adaptation risk assessment workshop.

The risk assessment process was conducted in accordance with the Risk Management Standard AS/NZS 3100:2009 and the Australian government publication 'Climate Change Impacts & Risk Management – A Guide for Business and Government' (2006). Attendees at the workshop included key decision-makers on the Project, along with engineers and environmental specialists. Risks identified were analysed and assessed using the Australia Pacific LNG risk matrix (refer to Volume 1 Chapter 1) and then screened for identification of mitigation measures. Existing measures were explored during the risk assessment process and further mitigation actions were brought forward to be included into the design criteria and operating strategies.

The climate change risk assessment process was conducted to assess the project's vulnerabilities to climate change and describe possible and preferred adaptation strategies. This was a requirement of the EIS terms of reference Section 3.1.2 – Climate change adaptation. The climate projections used in the risk assessment are provided in Section 4.3.2. Section 4.3.3 provides the risk mitigation measures which treat the identified risks and have been incorporated into the design criteria and operating strategies.

Australia Pacific LNG's cooperative approach to adaptation to climate change is described in Section 4.3.4.

4.3.2 Climate projections

To assess the project's vulnerability to climate change, predictions have been gathered from CSIRO, and the Queensland Government. These are referenced in the sections below.

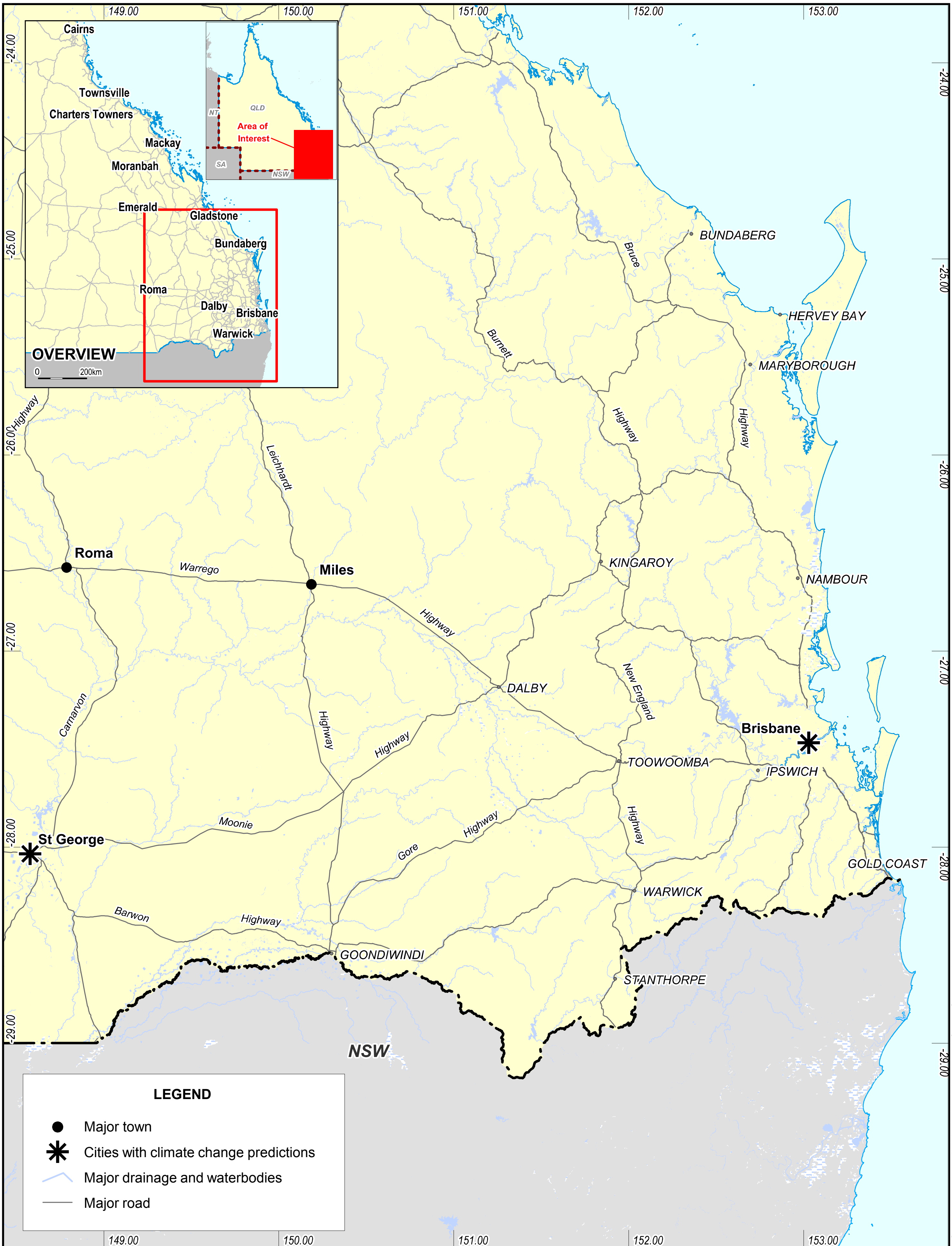
CSIRO projections are available for years 2030, 2050 and 2070. The Project is estimated to operate for 30 years starting in 2014 with LNG production train, making projections for 2050 the most fitting scenario. Where appropriate 2050 projections have been used, but where predictions are published only for the 2030 and 2070 time horizons, both have been reported and used in the assessment process.

The emissions scenarios referred to in this chapter include A1B, B1 and A1FI (CSIRO 2008), where:

- B1 scenario refers to a global agreement that brings about dramatic reductions in global emissions.
- A1B scenario refers to mid range levels of global emission.
- A1FI scenario refers to high levels of emissions, in line with recent global emissions.

Changes in the climate of Australia by 2030 do not vary greatly from one emission scenario to another. However, changes by 2070 are heavily dependent on the emission scenario, because the scenarios are highly divergent beyond 2030. The best projections for the region have been sought, but the models have not all been based upon the same emissions scenarios.

Several cities have climate change predictions presented in the Climate Change in Australia Cities Summaries (CSIRO 2007) including St George and Brisbane, as shown in Figure 4.3 . For this study, predictions for St George have been considered as representative of the geographical region of central south Queensland while predictions for Brisbane, Rockhampton and Gladstone have been considered as representative of the region of the east coast of Queensland.



SOURCE INFORMATION

Major drainage and waterbodies (based on 250k topography)
Commonwealth of Australia (Geoscience Australia) 2009

Roads and Towns
Department of Main Roads 2009

0 50 100km

SCALE - 1 : 2,750,000 (at A4)
Latitude/Longitude
Geocentric Datum of Australia 1994

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AUSTRALIA PACIFIC LNG PROJECT

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Figure 4.3 - Cities for which climate change predictions are presented by CSIRO

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Temperature change

The information in Table 4.3 summarises the predicted mean temperature change for St George in the south central Queensland region, and Rockhampton in the Gladstone region. The table provides the 10, 50 and 90th percentiles of the likely change in the mean temperature. In St George by 2050, the predicted increase in mean temperature is 3.6°C, which was chosen as the basis for determining climate change impacts in the risk assessment.

To calculate the average temperature in 2050, the predicted mean temperature change of 3.6°C is added to the historical average temperature.

In Rockhampton by 2050, the predicted increase in average temperature is 1.4°C.

Table 4.3 Mean degrees temperature change for St George and Rockhampton (°C)[1]

	2030			2050		
	Average (50%)	Range (10–90%)		Average (50%)	Range (10–90%)	
St George	1.1	0.7	1.6	3.6	2.4	5.2
Rockhampton	0.8	0.6	1.2	1.4	1.0	2.0

1 A1B Predictions (2030) and A1FI (2050), 50% percentile and range (CSIRO 2007)

Precipitation change

The information in Table 4.4 summarises the predicted percentage of rainfall change for St George in the south central Queensland region, and Rockhampton in the Gladstone region. The table provides the 10, 50 and 90th percentiles of the likely change in the mean precipitation. In St George by 2050, the predicted decrease in mean rainfall is 10% annually. This has been chosen as the basis for determining climate change impacts in the risk assessment.

To calculate the average precipitation in 2050 the predicted mean precipitation change 10% is subtracted from the historical average precipitation (CSIRO 2007).

In Rockhampton by 2050, the predicted decrease in mean rainfall is 5.4% annually.

Table 4.4 Mean rainfall change for St George and Rockhampton (%)[1]

	2030			2050		
	Average (50%)	Range (10–90%)		Average (50%)	Range (10–90%)	
St George	-3	-12	5	-10	-35	17
Rockhampton	-3.2	-10.1	4.2	-5.4	-17.2	7.1

1 A1B Predictions (2030) and A1FI (2050), 50% percentile and range (CSIRO 2007)

As well as a decrease in annual rainfall, an increase in daily precipitation intensity (rain per rain-day) and the number of dry days is also predicted. The future precipitation regime will have longer dry spells interrupted by heavier precipitation events. Changes to extreme events would have the potential to increase erosion and flood frequency, with implications for agriculture, forestry, river flow, water quality, and the design standards of infrastructure. Drought occurrence is projected to increase over most of Australia (CSIRO 2007).

Sea level rise

Sea level rise is not anticipated to affect the majority of the gas pipeline, since it begins at the gas fields around 400km inland and 200 metres above sea level, and traverses the landscape to Gladstone.

The information in Table 4.5 summarises the predicted rise in global sea level. Global climate models indicate mean sea level rise on the east coast of Australia may be greater than the global mean sea level rise. Scenario 3 (high end) was developed considering the possible high end risk identified in Intergovernmental Panel on Climate Change (IPCC) fourth report, and includes some new evidence on icesheet dynamics (Department of Climate Change (DCC) 2009).

Table 4.5 Global average sea rise scenarios (metres)

Year	Scenario 1	Scenario 2	Scenario 3
	B1	**A1FI**	**High end**
2030	0.132	0.146	0.200
2070	0.333	0.471	0.700

Source: DCC (2009)

As shown in Figure 4.4, an increase in sea level causes a non-linear increase in frequency of high sea-level events (DCC 2009). For the Gladstone region, for a 0.1 metre sea level rise, the frequency of high sea-level events increases two-fold. For a 0.5 metre sea level rise, the frequency of high sea-level events increases by 1,000 times.

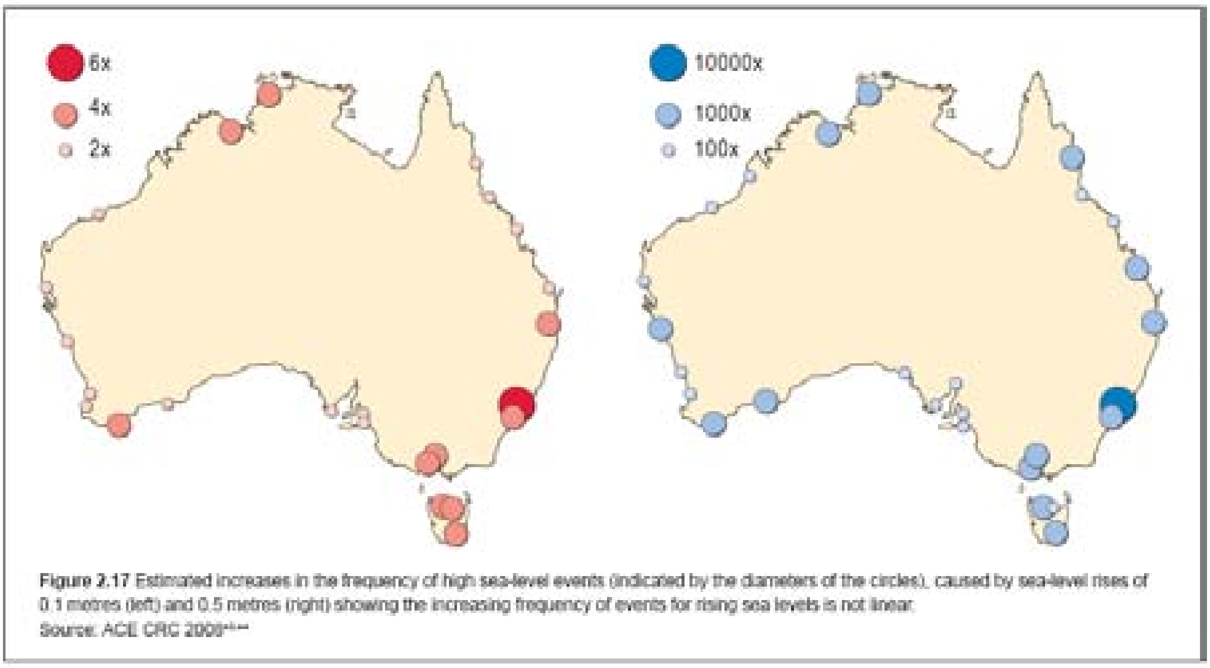


Figure 4.4 Estimated increases in high sea-level events (0.1m and 0.5m) (DCC 2009)

Storm surge and storm tides

Storm tide is not anticipated to affect the majority of the gas pipeline as it begins at the gas fields around 400km inland and 200 metres above sea level and traverses the landscape to Gladstone.

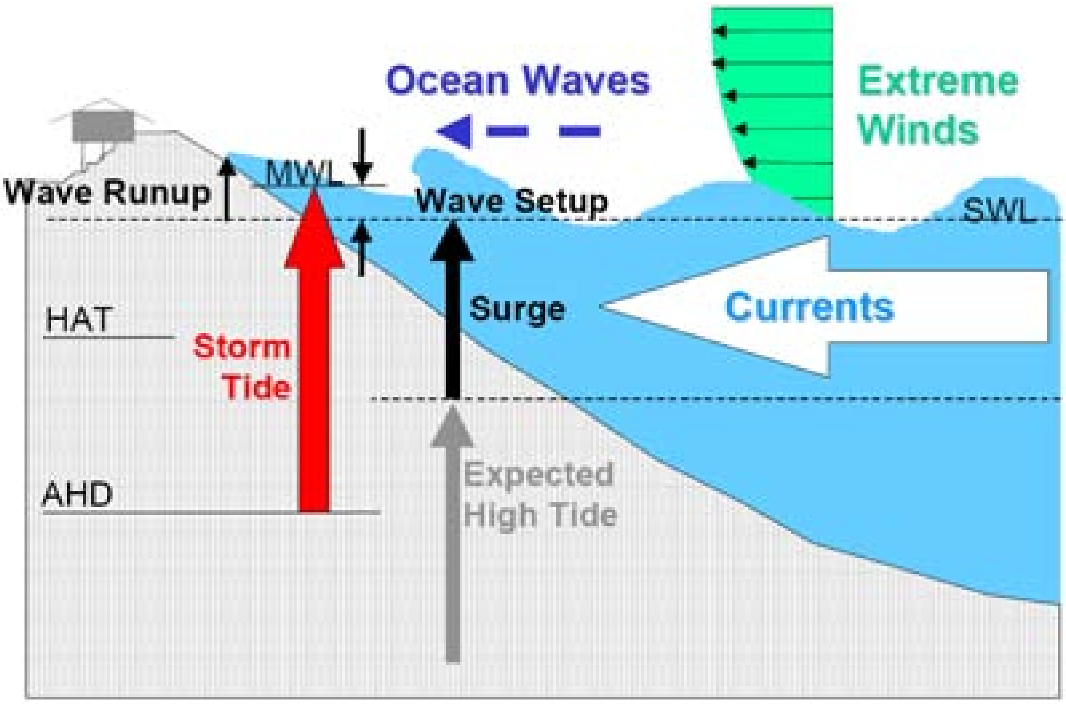
A study by the former Department of Natural Resources and Mines (DNRM) (2004) to determine the frequency of occurrence of storm tides for open waters in Queensland, including Gladstone, predicted storm tides for both present conditions and those where the implications of climate change are represented. Storm surge levels are not total water levels – total water levels consist of other components such as wave setup and run-up associated with a wave zone, as shown in Figure 4.5.

For open waters in Gladstone (Auckland Point) the 2004 study predicted storm tide levels as provided in Table 4.6. This study assumed the climate change scenarios based on a 50-year planning period.

The report provides results based on the combination of three scenarios, being a mean sea level rise of 0.3m by 2050, an increase of 10% in frequency of tropical cyclones, and a pole ward shift of 1.3° and increase of 10% in maximum intensity of tropical cyclones. These three scenarios are not the same at the IPCC models (A1B, B1 and A1FI) but are the most relevant and available storm tide prediction data for this region.

Table 4.6 Storm tide ARI for Gladstone (DNRM 2004)

Location	Storm tide ARI (m AHD)					
	100 year		500 year		1000 year	
	2004	Climate Change	2004	Climate Change	2004	Climate Change
Gladstone	2.82	3.33	3.51	4.18	3.80	4.41



Storm Tide = astronomical tide + storm surge + wave setup + waves
(Queensland Climate Change and Community Vulnerability to Tropical Cyclones Ocean hazard Assessment – Stage 1, 2001)

Figure 4.5 Storm tide, wave setup, wave run-up (Queensland Government 2001)

To estimate total water levels in Gladstone for a 100-year average recurrence interval (ARI) storm tide event, the 2004 study was used as a starting point. Wave heights can be estimated for a 1 in 50 year wind speed and combined with the storm tide. Table 4.7 summarises components of the indicative total water level.

Storm tide, an allowance for wave setup and crest level combine to give the total water level of 5.6m above Australian height datum (AHD). Wave crest level is derived from the significant wave height and contains some profile asymmetry associated with the highest waves.

Table 4.7 Total storm tide water level estimate

Significant wave height	1 in 100 yr	
Storm tide (incl. climate change) (DNRM 2004)	3.33	m AHD
Wave setup allowance	0.4	m
Wave crest (1 in 50yr AEP)	1.8	m
Total water level	5.6	m AHD

Humidity

The information in Table 4.8 summarises the predicted percent of relative humidity change for St George and Brisbane. The table provides the 10, 50 and 90th percentiles of the likely change in the humidity. By 2070 the predicted change in average humidity is -1.6% which has been chosen as the basis for determining climate change impacts in the risk assessment. To calculate the average humidity in 2070, the predicted percent of relative humidity change of -1.6% is added to the historical average relative humidity. By 2070 the predicted change in average humidity is -0.2%.

Table 4.8 Percentage of relative humidity change (CSIRO 2009)

	2030			2070		
	%	Range (A1B)		%	Range (A1F1)	
St George	-0.5	-1.7	0.7	-1.6	-5.6	2.2
Brisbane	-0.1	-1.1	0.7	-0.2	-3.6	3.0

Cyclones

There are three components of tropical cyclones combining to make the total hazard – strong winds, intense rainfall and induced ocean effects including extreme waves. Climate change may affect the frequency, severity, unpredictability and position of cyclones. There is some indication precipitation rates may increase by 20% to 30% during tropical cyclones (CSIRO 2007). Precipitation change and extreme waves have been discussed in Section 4.3.2.

Projections of tropical cyclones in the Australian region are limited, but the available studies suggest there maybe an increase in the number of tropical cyclones in the more intensive categories (Categories 3 to 5) but a possible decrease in the total number of cyclones (Department of Climate Change 2009)

Bushfires

Projections of fire risk have been undertaken in the vicinity of the gas pipeline, from Charleville to Rockhampton for 2020 and 2050 (Lucas et al. 2007). Fire risk is a rating calculated based on observations of temperature, relative humidity and wind speed combined with an estimate of the fuel state to predict the fire behaviour (Lucas et al. 2007).

Changes in the risk of fire are summarised as percentile differences from 1974 to 2007 levels in Table 4.9 and Table 4.10. The authors of this study have used two global warming scenarios, low (Mark2) and high (Mark3). These scenarios are consistent with, but not the same as, the IPCC models (B1, A1B and A1FI) (CSIRO 2008)

Projections for 2050 in Charleville indicate that when the global warming scenario is low, the fire risk rises +39.4%. When the global warming scenario is high, the fire risk increases by 204.9%. These percentage changes are relative to small baseline frequencies, where at present (1973 to 2007) the annual average number of extreme fire danger days at Charleville is 6.8 days and in a high global warming scenario the prediction is 20.9 days by 2050.

Projections for 2050 in Rockhampton indicate that when the global warming scenario is low, the fire risk rises +5%. When the global warming scenario is high, the fire risk increases by 140%. These percentage changes are relative to very small baseline frequencies, where at present (1973 to 2007) the annual average number of extreme fire danger days at Rockhampton is 0.6 days and in a high global warming scenario the prediction is 1.5 days by 2050.

The bushfire risk tends to decrease to the north and east of the project area, correlating to the climate which becomes wetter closer to the tropical north and closer to the Queensland coast.

Table 4.9 Percentile change in fire risk from average 1974-2007 levels in Charleville

Global warming scenario	2020	2050
Low (Mark2)	19	39.4
High (Mark3)	49.6	204.9

Source: Lucas et al. 2007

Table 4.10 Percentile change in fire risk from average 1974-2007 levels in Rockhampton

Global warming scenario	2020	2050
Low (Mark2)	5	5
High (Mark3)	30	140

Source: Lucas et al. 2007

4.3.3 Climate change adaptation

The following sections describe the climate change risk mitigation measures that have been incorporated into the design criteria and operating strategies. Alternative and further adaptation measures have been considered and documented in the risk assessment process, and will be taken forward into the design phases of the project. Climate change risk will continue to be reviewed during project implementation.

Elevated temperatures

Design for flexibility in relation to operating temperatures is part of the design considerations. Safe work procedures will be implemented for hot conditions.

These measures, which are included in the design of the gas pipeline and associated infrastructure, assist in adapting to climate change.

The residual risk to the gas pipeline was determined to be negligible.

Precipitation change

During heavy rainfall intensity events, safe systems of work are to be implemented. This will include the management of journey management plans, taking into consideration BOM storm warning and weather forecasts, and providing safe driver training to personnel. Design of water crossing, pond walls, roads and other water affected infrastructure will be designed to standards which include safety contingencies for increased intensity of precipitation events.

Changes in precipitation frequency may cause groundwater levels to decrease. The use of treated associated water is designed to be used by the project for all the Project's water needs where possible, to prevent increased pressure on groundwater resources.

Erosion which may result from precipitation intensity and frequency change will be treated with engineering solutions in accordance with erosion control guidelines.

These measures, which are included in the design of the gas pipeline and associated infrastructure, assist in adapting to climate change.

The residual risk to the gas pipeline and associated infrastructure was determined to be low. This relates to the potential for increased intensity of rainfall to cause localised flooding of water affected infrastructure, such as ponds and water course crossings.

Humidity

The impacts of humidity change are considered to be low because the decrease is still well within the design range of the gas pipeline and associated infrastructure.

The residual risk to the gas pipeline and the associated infrastructure was determined to be negligible.

Sea level change

Sea level rise scenarios at the higher end were considered in the risk assessment process. For the gas pipeline infrastructure, which will be placed under the floor of Gladstone Harbour, sea level rise is unlikely to have any material effect.

The residual risk to the gas pipeline and the associated infrastructure was determined to be negligible.

Coastal erosion

Coastal erosion arises as a combination of more high intensity weather events, storm surge, currents and extreme waves, more intense rainfall, wind action and higher sea level. For the gas pipeline infrastructure, coastal erosion may also translate to higher erosion and displacement pressures on the gas pipeline placed under the floor of the Narrows. The preferred method of design is to place the gas pipeline using horizontal directional drilling or to provide erosion measures for trenches. The gas pipeline will be covered by around 2m of existing stable sediment, and anti-scour materials will be placed at development locations that are at risk of erosion.

These measures, which are included in the design of the gas pipeline, assist in adapting to climate change. Further alternative adaptation measures which may be considered include slope stability measures for the tidal flats.

The residual risk to the gas pipeline and the associated infrastructure was determined to be negligible.

Cyclones

Structural elements for the gas pipeline and associated infrastructure will be designed and constructed taking into consideration the building code for cyclone regions, with adjustment for more intense and frequent cyclones.

To preserve the health and safety of the Project's workforce, the implementation of a journey management system, emergency response plans, safe driver training and storm warnings for field personnel will be included in the operations systems.

These measures, which are included in the design of the gas pipeline, assist in adapting to climate change. Further alternative adaptation measures which may be considered include extended journey management plans to include contact with onsite personnel about weather warnings and maintain updates to Bureau of Meteorology weather forecasts, and design temporary accommodation facilities and enclosures for extreme wind events.

The residual risk to the gas pipeline and the associated infrastructure was determined to be low. This is due to the potential for more intense cyclones to present a health and safety risk to the workforce.

Flooding

The increase in precipitation intensity may result in increased localised areas of flooding.

To preserve the health and safety of personnel the implementation of a journey management system, emergency response plans, safe driver training and storm warnings for field personnel will be included in the operations systems.

These measures, which are included in the design of the gas pipeline, assist in adapting to climate change. Further alternative adaptation measures which may be considered include multiple exit roads for critical plant and infrastructure, to prevent road closures affecting access.

The residual risk to the gas pipeline and the associated infrastructure was determined to be low. This is due to the potential for flooding to affect access to critical plant and infrastructure.

Bushfires

Bushfire breaks have been designed to maintain clearance around aboveground services and fenced surface facilities. Weather forecasting services and fire danger warnings will be used to withdraw personnel from high fire risk areas.

It is also the intention to continue to work cooperatively with the rural fire service to share information and receive advice. Controlled burning will be used where appropriate to manage fire risk.

These measures, which are included in the design of the gas pipeline, assist in adapting to climate change. Further alternative adaptation measures which may be considered include multiple exit roads for critical plant and infrastructure to prevent road closures effecting access, and extended journey management plans to include a fire danger strategy.

The residual risk to the gas pipeline and the associated infrastructure was determined to be low. This is due to the potential for bushfires to affect associated infrastructure along the gas pipeline or personnel working on the gas pipeline for maintenance.

4.3.4 Cooperative approach to climate change adaptation

Both Origin and ConocoPhillips work through the Australian Petroleum Production & Exploration Association (APPEA) as an industry body. APPEA aims to work with governments to achieve credible industry actions and governmental greenhouse policies that address greenhouse concerns in an economically and commercially viable way. APPEA and its member companies are committed to taking action on climate change, including the promotion of natural gas as apart of the Asia-Pacific Economic Cooperation energy work.

APPEA member companies are also committed to reviewing (and if necessary adapting) their risk management strategies (encompassing engineering design, safety and environmental assessments) to reflect new learnings on the likely impacts of climate variability, to complement Government action, to give the community greater confidence about how the greenhouse issue is being addressed (APPEA 2003).

Australia Pacific LNG is involved in regular engagement with key governmental agencies. The aim of meeting with these stakeholders is to share project information as it came to hand, seek guidance about regulators' requirements and expectations for the EIS and approvals process, and to achieve the Project's assessment and approval schedule. As part of this dialogue, the Project has met with the Gladstone Ports Corporation and Maritime Safety Queensland. A cooperative relationship has been established and will continue with these organisations and, where relevant, will discuss climate change adaptation.

Australia Pacific LNG actively engaged with Department of Infrastructure and Planning and Department of Employment, Economic Development and Innovation (DEEDI) through a number of forums, including:

- LNG Executive Group (DEEDI) – meetings approximately bi-monthly with other LNG proponents and senior departmental officers to discuss strategic policy matters
- Common Issues Forum (DEEDI) – fortnightly meetings with other LNG proponents to discuss operational issues of a common nature to the industry, e.g. co-location of gas transmission gas pipeline common-user corridors established by the Queensland Government
- LNG Industry Unit (DEEDI) – separate meetings with proponents are organised where instances of commercial confidentiality is required
- APLNG EIS Project Group Meeting - EIS facilitation is provided through a Department of Infrastructure and Planning project manager and DERM representative each fortnight to ensure that industry is provided with prompt advice on any issues raised
- Input into the Department of Infrastructure and Planning's Water Futures for the CSG water management policy being developed by the Coal Taskforce Unit.

Australia Pacific LNG undertakes to continue its cooperative approach with government, other industry and other sectors to address adaptation to climate change. Australia Pacific LNG will take into account climate change risks of flooding, temperature change and sea level rise in the design process.

4.4 Conclusion

4.4.1 Assessment outcomes

Climate change projections across the life of the Project will be minor in the context of the extremes in climate already experienced within the south central Queensland region.

Gas pipeline infrastructure will be designed and constructed to cope with the existing climate and future potential climate change. Predicted changes in temperature, precipitation, cyclones and bushfires have been considered, and the vulnerabilities of the gas pipeline have been assessed using the appropriate risk assessment process.

Potential consequences of climate change that have been considered include:

- Exposure to higher temperatures
- Flooding from intense rainfall
- Reduction in rainwater availability
- Wave inundation
- Erosion
- Damage from cyclonic conditions
- Damage from bushfires.

Design features for wind action, coastal erosion, flooding and bushfires have been incorporated into the design criteria and will continue to be considered during the detailed design phase. Strategies to mitigate climate change impacts during the construction and operation phases of the Project have been identified.

It was concluded from the risk assessment discussed above that there is currently adequate design controls and strategies in place or planned for to adequately mitigate climate change risk. Climate change risk will continue to be assessed during further stages of project implementation.

A summary of the environmental values, sustainability principles, potential impacts and mitigation measures in relation to climate and climate change associated with the gas pipeline is presented below in Table 4.11. This table also includes the residual risk levels for climate and climate change.

A risk assessment has been undertaken to identify the potential risks, causes and consequences from the climate and climate change. Mitigation measures to reduce the risk have been nominated and the residual risk has been calculated. Further details on the risk assessment methodology are provided in Volume 1 Chapter 4.

Table 4.11 Summary of environmental values, sustainability principles, potential impacts and mitigation measures

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
Life, health and wellbeing of people. Diversity of ecological processes and associated ecosystems. Interruption to business construction, operation or decommissioning phases.	Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas	Sedimentation, erosion, stormwater management, containment of waste in bunding and tailings dams, health and safety risks to personnel and interruption to transportation	Extreme climate events: Droughts Floods Tropical cyclones Storm surge and Storm tide	Refer to construction methods outlined: • Volume 3 Chapter 11– Water resources • Volume 3 Chapter 5 – Topography, geomorphology, geology, soils and land contamination • Volume 3 Chapter 17 – Traffic and transport.	Low
	Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.	Increased health and safety risk to personnel Heat damage to infrastructure Higher cooling and energy demand	Elevated Temperatures	Safe work procedures for hot conditions	Negligible
		Drought Decreased water quality Impacts on rivers and wetlands	Precipitation change	Design to accommodate erosion Journey management plans incorporating storm warnings and weather forecasts Safe driver training	Low

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
		Dust due to dry windy conditions Erosion & sedimentation Increased overland flow runoff			
		Impact on corrosion rates Increase risk of heat stress and dehydration	Humidity	Gas pipeline inspection and maintenance program. Safe work procedures for hot conditions	Negligible
		Inundation of gas pipeline at entry to Gladstone harbour, under Gladstone harbour and rise onto Curtis Island	Sea level change	Gas pipeline design for inundation through the Narrows	Negligible
		Erosion of gas pipeline Displacement pressure on gas pipeline	Coastal erosion	Horizontal directional drilling (gas pipeline covered by around four metres of existing stable sediment) or erosion measures for trenching option Anti-scour materials will be placed at development locations at risk of erosion.	Negligible
		High wind speeds effecting structures	Cyclones	Operational systems to include journey management plans, safe driver training and storm warnings.	Low

Environmental values	Sustainability principles	Potential impacts	Possible causes	Mitigation and management measures	Residual risk level
		Tree fall impact on structures Health and safety risk to personnel		Follow the building code for cyclone regions and predicted increase in wind speeds.	
		Loss of site access Erosion and sedimentation Wash away of personnel, gas pipeline or associated infrastructure	Flooding	Operations systems to include journey management plans, safe driver training and storm warnings.	Negligible
		Bushfire encroaching on the gas pipeline or personnel	Bushfires	Bushfire warnings incorporated in journey management plans Emergency response plan to address bushfire risk. Australia Pacific LNG will continue to work cooperatively with the rural fire service to share information and receive advice.	Negligible

4.4.2 Commitments

To manage potential impacts of climate and climate change associated with the gas pipeline, Australia Pacific LNG will:

- Incorporate adaptive management approach to climate change throughout the life of the Project
- Incorporate the agreed preferred climate change strategies which resulted from the risk assessment into the design process
- Cooperate with government, other industry and other sectors to address adaptation to climate change.

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