Unpublished data extracted from the "Climate Change in Australia" projections by Leanne Webb (CSIRO Division of Marine and Atmospheric Research)

Mean Rainfall % Change

season	2030	2030	2030	2050	2050	2050	2050	2050	2050	2050	2050	2050	2070	2070	2070	2070	2070	2070	2070	2070	2070
	A1B	A1B	A1B	B1	B1	B1	A1B	A1B	A1B	A1FI	A1FI	A1FI	B1	B1	B1	A1B	A1B	A1B	A1FI	A1FI	A1FI
	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90
ratio	0.31	0.31	0.31	0.379	0.379	0.379	0.528	0.528	0.528	0.621	0.621	0.621	0.517	0.517	0.517	0.735	0.735	0.735	1	1	1
ann	-10.1	-3.2	4.2	-12.4	-3.9	5.1	-17.2	-5.4	7.1	-20.2	-6.3	8.4	-16.8	-5.3	7.0	-23.9	-7.5	9.9	-32.6	-10.2	13.5
djf	-9.9	-1.8	7.0	-12.1	-2.2	8.6	-16.8	-3.1	12.0	-19.8	-3.6	14.1	-16.5	-3.0	11.7	-23.4	-4.2	16.7	-31.8	-5.8	22.7
mam	-14.9	-4.9	7.2	-18.2	-6.0	8.8	-25.3	-8.4	12.2	-29.8	-9.8	14.4	-24.8	-8.2	12.0	-35.3	-11.6	17.0	-48.0	-15.8	23.2
jja	-10.8	-1.7	8.8	-13.2	-2.1	10.8	-18.3	-2.9	15.0	-21.5	-3.4	17.7	-17.9	-2.9	14.7	-25.5	-4.1	20.9	-34.7	-5.5	28.5
son	-13.0	-5.3	4.1	-15.9	-6.5	5.0	-22.2	-9.0	7.0	-26.1	-10.6	8.3	-21.7	-8.8	6.9	-30.9	-12.5	9.8	-42.0	-17.1	13.3

Mean Temperature Change (°C)

season	2030	2030	2030	2050	2050	2050	2050	2050	2050	2050	2050	2050	2070	2070	2070	2070	2070	2070	2070	2070	2070
	A1B	A1B	A1B	B1	B1	B1	A1B	A1B	A1B	A1FI	A1FI	A1FI	B1	B1	B1	A1B	A1B	A1B	A1FI	A1FI	A1FI
	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90	10	50	90
ratio	0.31	0.31	0.31	0.379	0.379	0.379	0.528	0.528	0.528	0.621	0.621	0.621	0.517	0.517	0.517	0.735	0.735	0.735	1	1	1
ann	0.6	0.8	1.2	0.7	1.0	1.4	1.0	1.4	2.0	1.2	1.7	2.3	1.0	1.4	1.9	1.4	2.0	2.7	1.9	2.7	3.7
djf	0.5	0.8	1.2	0.7	1.0	1.4	0.9	1.4	2.0	1.1	1.6	2.3	0.9	1.4	1.9	1.3	1.9	2.8	1.8	2.6	3.8
mam	0.6	0.8	1.2	0.7	1.0	1.4	1.0	1.4	2.0	1.1	1.6	2.3	0.9	1.4	1.9	1.3	1.9	2.8	1.8	2.7	3.8
jja	0.6	0.8	1.2	0.7	1.0	1.4	1.0	1.4	2.0	1.2	1.7	2.3	1.0	1.4	2.0	1.4	2.0	2.8	1.9	2.7	3.8
son	0.6	0.8	1.2	0.7	1.0	1.5	1.0	1.4	2.0	1.1	1.7	2.4	0.9	1.4	2.0	1.3	2.0	2.8	1.8	2.7	3.9

Extract from Connel Wagner 2008 Curtis Island Road / Bridge Concept Design

BMT WBM Pty Ltd
Level 11, 490 Upper Edward Street
Brisbane 4000
Queensland Australia
PO Box 203 Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.wbmpl.com.au

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To:	**URS Australia Pty. Ltd.**	**CC:**	
Attention:	Rob Ully	**Date:**	31 March 2008
Fax No:	Email	**Document Ref:**	F.B16752.001.doc
From	Ian Teakle	**No of pages including this one**	4

Dear Rob

RE: 16752 – GLNG

The following memo summarises the available data regarding elevated water levels and extreme wave heights at the proposed Gladstone LNG facility on Curtis Island.

Elevated Water Levels

Water levels at the coast during cyclones may be substantially higher than normal tides due to storm surge effects. Storm surges are increases in water level caused by onshore wind stresses and reduced atmospheric pressure.

The storm tide level is the result of tide plus surge. The surge may peak at any stage of the tidal cycle. Hence abnormally high storm tide levels may result from extreme surge peaks coinciding with moderate to high tides, or moderate surges coinciding with high tides. The probability of an extreme surge peak coinciding with a spring high tide is low.

A comprehensive study of storm tide probabilities in the Yepoon region was undertaken for the Beach Protection Authority by Blain Bremner and Williams (1985). The nearest calculation sites for this study were at the Fitzroy River entrance and at Cape Capricorn on Curtis Island. The calculated 100 year ARI storm tide levels (excluding wave set-up) at these sites were 3.5m AHD and 2.9m AHD respectively. Any storm surge on the open coast will propagate into Port Curtis and be influenced by
local processes as well.

A more recent comprehensive study by the Queensland Government examines storm tide vulnerability and potential increases in sea level from Greenhouse and more intense cyclonic effects on coastal communities. The report "Queensland Climate Change and Community Vulnerability to Tropical Cyclones: Ocean Hazards Assessment – Stage 3 Report", (Queensland Government, 2004) includes calculated storm tide levels at Gladstone. This study incorporated more detailed modeling on a nearshore grid of approximately 550m, which extended into Port Curtis.
The present day (2003) predicted storm tide levels in the region from the abovementioned study are listed in Table 1 for various recurrence intervals excluding wave-set up and climate change effects.

Table 1 Peak Storm Tide Levels (Present Day 2003)

Location	**Storm Tide Level (m AHD)**		
	100 year ARI	500 year ARI	1000 year ARI
Gladstone	2.82	3.51	3.8
Tannum Sands	2.50	3.05	3.31

Source: Queensland Government (2004)

It can be seen that there is some amplification (increase) in the predicted storm tide level moving into Port Curtis from the south. The resolution of the model (approximately 550m) is such that not all features would be accurately represented. That is, there is a possibility that slightly greater amplification and hence storm tide levels would occur to the proposed LNG facility site on Curtis Island than have been reported for Gladstone in Table 1.

The above storm tide levels do not contain provisions for sea level rise due to Greenhouse effects, other climate change influences or wave set-up and run-up. Wave set-up and run-up only occur near or at the shoreline. The additional coastal inundation caused by wave set-up and run-up on top of the storm tide would need to be assessed for the design of onshore facilities that are within the wave impact zone.

With respect to climate change, there is significant scientific opinion that baseline changes to climate may occur within the design life of much of our coastal and ocean community infrastructure. However, despite the growing body of scientific literature and knowledge, there are still no definitive predictions of its effects or potential impacts.

For example, there are still uncertainties as to the actual magnitude and rate of rise of mean sea level as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. This has lead to various scenarios being adopted by the Inter-governmental Panel on Climate Change (IPCC). They are based on the range of model results available and dependent upon the amount of future emissions assumed. The Institution of Engineers Australia, National Committee on Coastal and Ocean Engineering recommends that these values be used for planning and design.

The Fourth Assessment Report of the International Panel on Climate Change (2007) reports that global sea level rise is projected to be 18–59 cm by year 2100 relative to 1990 levels. These projections do not include a contribution from ice flow rates, however if these were to continue to grow linearly with global warming, then the upper ranges of sea level rise would increase by a further 10 to 20 cm (by year 2100 relative to 1990) (IPCC, 2007). There is an acknowledged risk that the contribution of ice sheets to sea level rise this century may be substantially higher than this.

The climate models predict that there will be a not-insignificant regional variation in future sea level rise, predominantly due to spatial variations in the contribution made by ocean thermal expansion. Predictions reported by the CSIRO (2007) indicate that future sea level rise along the eastern Australian coastline may be up to 12 cm greater than the global average by 2100.

In summary the total mean sea level rise along the eastern Australian coastline is estimated to be in the range 28–91 cm by the year 2100. This will occur gradually at first as we continue to accelerate from the historic rate of 1.7 mm per year and then more rapidly as the year 2100 is approached.

The Queensland Government Ocean Hazards Assessment Study referred to above, examined the potential implications for storm tide statistics of three specific Greenhouse scenarios:

a) Combined effect of an increase in Maximum Potential Intensity (MPI) of 10% and a poleward shift in tracks of 1.3°

b) Increase in frequency of tropical cyclones of 10%

c) Mean Sea Level rise of 0.3 m.

The mean sea level rise component (c) has an almost linear effect on the resultant storm tide levels while the 10% increase in cyclone frequency (b) has negligible impact. The combined increase in intensity and poleward shift in tracks (a) becomes increasingly significant with large return periods.

The resultant storm tide levels predicted with the combined Greenhouse scenarios are presented in
Table 2.

Table 2 Peak Storm Tide Levels (Combined Greenhouse Scenarios 50 year Planning Period)

Location	**Storm Tide Level (m AHD)**		
	100 year ARI	500 year ARI	1000 year ARI
Gladstone	3.33	4.18	4.51
Tannum Sands	2.95	3.64	3.94

Source: Queensland Government (2004)

The abovementioned report emphasises that the chosen values in the Greenhouse scenarios are not necessarily endorsed, although care has been taken to propose reasonable values. The intention was to demonstrate the sensitivity of the storm tide frequency curves to these climate change scenarios.

It should be noted the use of 0.3m for mean sea level rise is also supported by other Queensland Government Policies, though it should be further noted that this value was derived for a 50-year planning period. For a 100-year planning period a mean sea level rise based on IPCC (2007) of 55 cm (mid-range) to 91 cm (high-range) is considered to be an appropriate allowance. The midto high-range storm tide levels for Combined Greenhouse Scenarios over a 100 year planning period have been derived and are provided in Table 3.

Table 3 Peak Storm Tide Levels (Combined Greenhouse Scenarios 100 year Planning Period)

Location	**Storm Tide Level (m AHD)**		
	100 year ARI	500 year ARI	1000 year ARI
Gladstone	3.58/3.94*	4.43/4.79	4.76/5.12
Tannum Sands	3.20/3.56	3.89/4.25	4.19/4.55

*Mid-range/High-range sea level rise by 2100.

The choice of a 50- or 100-year planning period should be based upon an assessment of the component lifetime, risk of failure and options for future adaptation to changing climate conditions. When choosing between mid- and high-range values, the precautionary principle should be applied in weighing up the risk of failure and options for future adaptation.

Extreme Wave Conditions

As part of the Wiggins Island Coal Terminal EIS (Connell Wagner, 2007), BMT WBM undertook modelling of wave conditions within Port Curtis. Both the penetration of long-period swell and the generation of local wind-waves by cyclonic winds were investigated.

The swell penetration modelling demonstrated that long period ocean swells are generally blocked by Facing Island and the southern boundary of the harbour westwards from South Trees Inlet. Swell does not propagate far enough into the Port of Gladstone to have a significant impact at the location of the proposed LNG facilities.

Local wind wave modelling results show that locally generated wind waves have the potential to be larger at the location of the proposed LNG facility than ocean swell waves penetrating to the site. Local wind waves were modelled for a cyclonic 50 m/s wind speed and a variety of wind directions, with a water level of 3.4 m AHD approximately corresponding to a 100 year ARI storm tide. No assessment was made of the annual exceedance probability of these combinations of wind speed, direction and water level.

Significant wave heights at proposed LNG facility were found to be greatest for winds blowing from the westerly quadrant due to the relatively unconstricted fetch in this direction. In the channel immediately offshore of the proposed LNG facility the channel depth is approximately – 12 m AHD. The 50 m/s wind generated significant wave heights (Hs) between 2.5 - 3.0 m, depending on direction. In general the spectral peak period (Tp) of incident waves generated by such a cyclonic wind would be around 5 s.

References

Blain, Bremner and Williams Pty Ltd (1985). Storm Tide Statistics, Yeppoon Region. Report prepared for the Beach Protection Authority of Queensland, January 1985.

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IPCC (2007). Climate Change 2007: The Physical Scientific Basis. Cambridge University Press.

James Cook University (2004). Queensland Climate Change and Community Vulnerability to Tropical Cyclones: Ocean Hazards Assessment – Stage 3. Surge Plus Tide Statistics for Selected Open Coast Locations along the Queensland East Coast. Report prepared by the Marine Modelling Unit, JCU working through the CRC Reef for the Australian Bureau of Meteorology (BoM) in conjunction with the Queensland Environmental Protection Agency (EPA).