Meeting the New Queensland Coastal Plan Storm Surge Requirements for Redland City Council

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ABSTRACT

Cardno was commissioned by Redland City Council (RCC) to undertake a detailed storm tide hazard study, with the purpose to identify, understand and quantify the risks associated with the possibility of extreme storm tides for use in long-term town-planning and for emergency response needs and to meet the new Queensland Coastal Management Plan (2011).

RCC located on Moreton Bay in South-East Queensland, is known to be affected by a range of large scale storm systems with the potential of generating significant storm tide levels. The main types of storm systems are tropical cyclones and East Coast Lows (ECLs). Both types of storm systems can cause substantial rises in water level on the open coast and also within Moreton Bay through wind and wave set-up, and reduced atmospheric pressure. The impact on sea water levels of tropical cyclones is different to the impact of an ECL. Tropical cyclones result in a relatively localised elevated water level which persists for a short time. In South-East Queensland, intense tropical cyclones are relatively infrequent. More frequent ECL's may have produce a lower residual water level compared to an intense tropical cyclone, however these storms influence a larger stretch of coastline and may persist for hours increasing the likelihood of joint occurrence with high astronomical tide conditions.

This paper presents the methodology used to determine the peak storm tide levels within the study area for a range of return periods from 20 to 10,000 year Average Recurrence Interval (ARI). This paper further presents how this data is used for planning purposes and the development of more local models to provide Council with more refined detail necessary to meet the new Queensland Coastal Management Plan and their emergency planning responsibilities both for the current storm conditions and future climate change scenarios.

INTRODUCTION

The Department of Environment and Resource Management (DERM) released the '*Queensland Coastal Plan*' in March 2011 (DERM, 2011). At the time of the preparation of this paper this had not been formally adopted by the Queensland Goverment, but it does provide direction and guidance about the management of coastal land for Council's to consider. One of the specific items that is identified in this plan is the management of storm surge and the predicted impact of future climate change on the storm surge levels.

Cardno was commissioned by Redland City Council (RCC) to undertake a detailed storm tide hazard study. The purpose of the storm tide hazard study was to identify, understand and quantify the risks associated with the possibility of extreme storm tides for use in long-term town-planning and for emergency response needs.

Redland City Council is located on Moreton Bay in South-East Queensland. The City covers the coastal extents from Tingalpa Creek in the north to the Logan River in the south and includes Southern Moreton Bay Islands, North Stradbroke Island (Point Lookout and from Amity Point to Dunwich) and Tingalpa Creek (Thorneside to Capalaba), as shown on Figure 1.

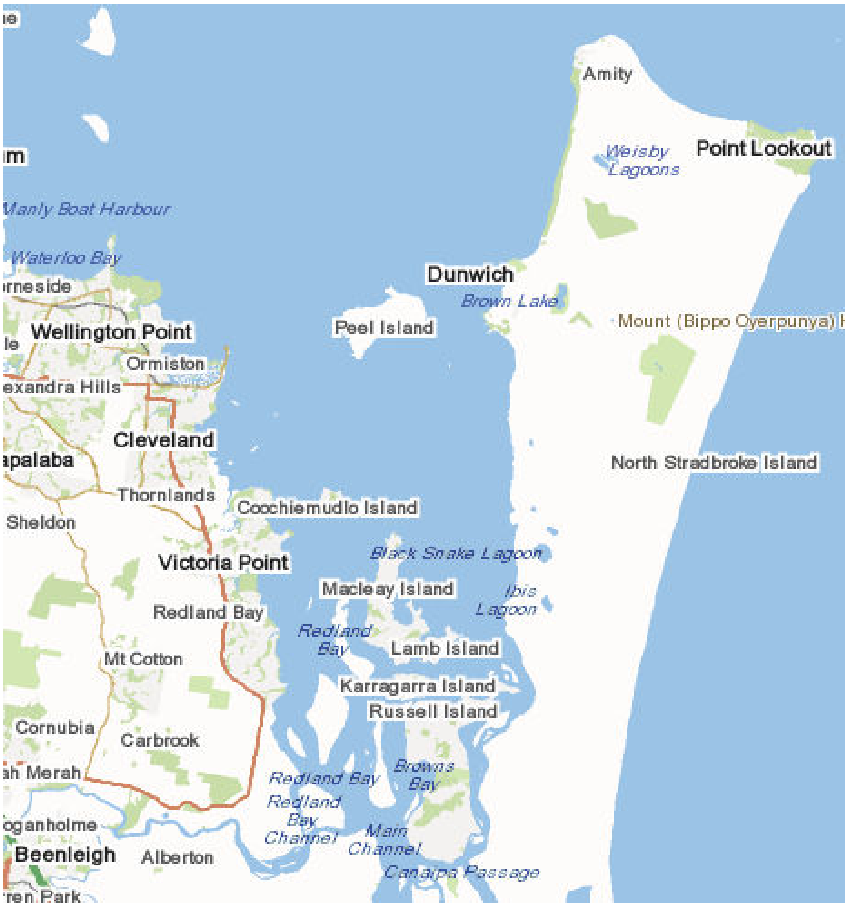

Figure 1 Redland City Council Shoreline Extents

BACKGROUND

In Queensland the period between December and March is a time of heightened storm activity, with the most severe atmospheric disturbances taking the form of tropical cyclones. These low pressure systems are generated in offshore tropical waters and may increase in intensity as they approach the land bringing high winds, rain, elevated water levels and waves. Severe tropical cyclone events have the potential to track as far south as Moreton Bay, however, the region is more commonly affected by decaying tropical storms, transitioning extra tropical storms, sub tropical storms and 'east coast lows' (ECLs).

The region is known to be affected by a wide range of large scale storm systems with the potential of generating significant increases in local sea levels, called "storm tide". Storm tide is the combination of the storm surge, the normal astronomical tide, and wave set-up. Storm tide levels are given as a height measured from a datum (commonly AHD or local LAT). When the storm tide level exceeds the highest astronomical tide (HAT), localised flooding may occur and large waves can cause significant erosion of beaches and sand dunes.

The main types of storm systems within the regional are tropical cyclones and ECLs. ECLs occur more frequently and they are often the design storm event up to the 50 to 100 year Average Recurrence Interval (ARI). The impact on sea water levels of Tropical cyclones is different to the impact of an ECL. Tropical cyclones result in a relatively localised elevated water level which persists for a short time. Intense tropical cyclones impacts on the South-East Queensland coastline are relatively infrequent compared to ECL's. In the Moreton Bay region, design water levels from on ECL's may have a lesser impact to sea water level, however influence a larger stretch of coastline and may persist for hours.

METHOD

Model Setup

The storm tide assessment was made using the Delft3D modelling system. The Delft3D suite of models is capable of simulating a range of processes - wind and pressure fields, tidal forcing, hydrodynamic and wave processes. The model system was used to investigate tide and storm surge for Moreton Bay based on local bathymetry and cyclonic wind and wave conditions, as well as some aspects of east coast lows. A series of nested models was developed to overcome the conflicting requirements of large model extent and nearshore resolution, without compromising accuracy whilst still maintaining practical computational times. Using the Delft3D nested grid approach, a total of four separate, interlinked, grids were developed with variable gird resolution which extended north of Fraser Island, south of the NSW border and more than 150km's offshore. Figure 2 presents a plan view of the model system outline.

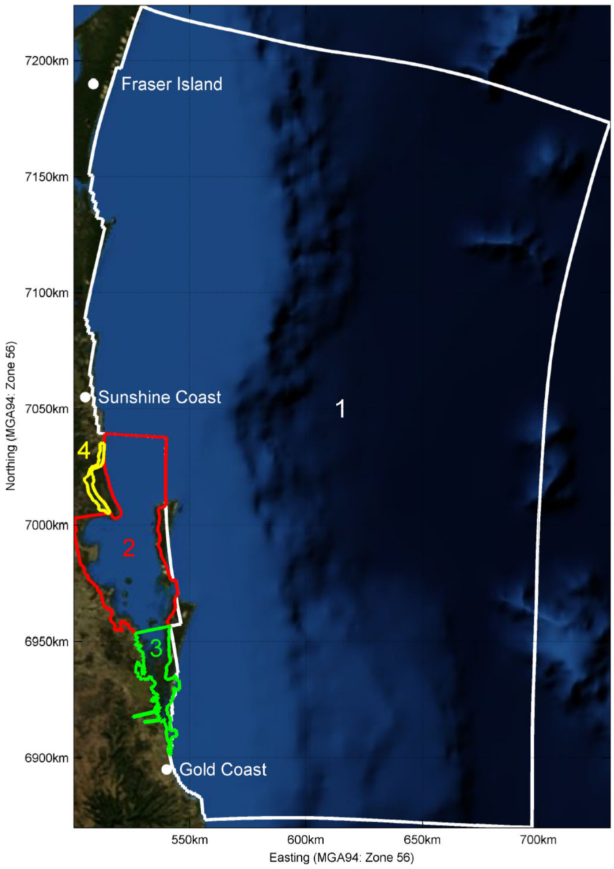

Figure 2 Wave, Storm Surge and Tide Model System Extent.

The Delft3D model was built using local specific bathymetry, tidal water level, cyclone and wind data, and wave data. The model system includes coupled hydrodynamic and wave forcing from a SWAN model system based on the interaction between swell wave forcing and astronomical tide at the entrance to Moreton Bay – see Treloar *et al* (2010).

Calibration

Calibration of the model was undertaken in two stages to ensure the accurate representation of water levels within the model area for prescribed conditions.

The first stage involved tidal calibration to ensure the spring and neap cycle was accurately described for all points within the model. A comparison between water levels modelled by Delft3D with predicted tide levels at points within the model was made. The calibration was found to be generally good with modelled water levels within 0.1m of predicted water levels which represents a good calibration.

The second stage of calibration involved using the Delft3D model to simulate recent tropical cyclone and tropical low events which occurred in Queensland (TC Daisy, TC Dinah, March 2004 event). The resulting wave conditions and storm surge predictions for points within the model were compared against actual data recorded at the Brisbane Bar, Gold Coast and Mooloolaba during these events. The correlation between the modelled and measured storm surge for these events showed that the model system was able to simulate storm surge well. Figure 3 presents a time series comparision of modelled and measured storm surge and water levels from an ECL in Marhc 2004. Cardno Lawson Treloar (2010) presents the calibration of the wind, wave and hydrodynamic model systems.

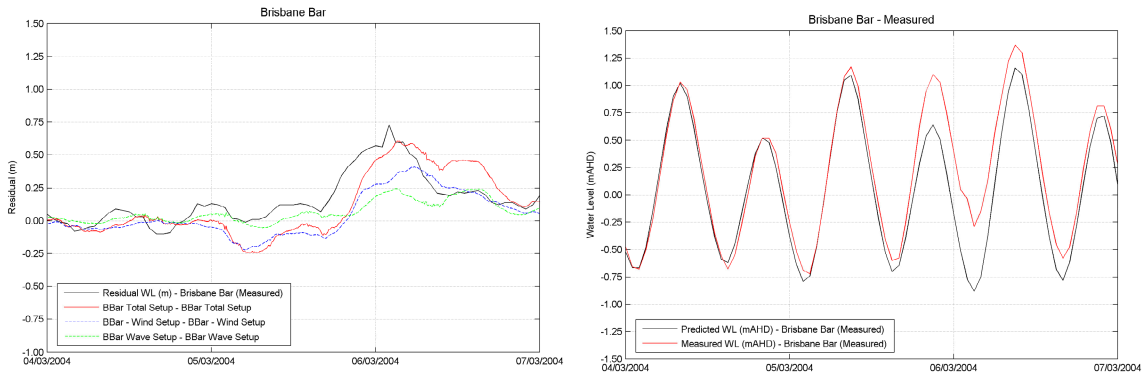

Figure 3 Comparision of Model and Measured Residual Water Levels (upper) and Predicated and Measured Water Levels (lower) at Brisbane Bar.

The outcome from calibration provides confidence that the Delft3D model was able to reliably simulate storm tide over the whole of South-East Queensland, accounting for local processes within Moreton Bay.

Design Event Modelling

Cardno completed a comprehensive assessment of over 6,000 synthetic cyclonic and non-cyclonic design storm events through Moreton Bay. Cardno has analysed the database of the 6,000 design storm events developed in the Cardno (2009) study and selected for the various coastlines in RCC the most appropriate design event for a specified ARI. Design storm events were selected for the following scenarios:-

- 20, 50, 100, 1000 and 10000 years ARI for the present climate scenario; and
- 100, 1000 and 10000 years ARI for a 'Greenhouse' enhanced climate scenario. That is an increase in the cyclone intensity only. The increase in Sea Level Rise is included following the simulations.

The Australian Bureau of Meteorology (BOM) and CSIRO have projected regional climate change scenarios as a result of the enhanced greenhouse effect. The projections are based upon leading international climate change research and conclusions from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007). The future predictions from this report indicate an increase in the intensity of cyclones in Queensland.

This study has adopted a change in maximum wind speed condition for potential greenhouse related climate change on tropical cyclones within the study area. For the potential greenhouse related change to wind speed in the planning period between 2050 and 2100, the maximum wind speed for each simulation event has been increased by 10%.

Each design cyclone event was modelled in the Delft3D model system using a coupled Flow-Wave-Flow modelling approach which models the hydrodynamic and wave conditions together and the results were used to develop a Defined Storm Tide Event (DSTE) at each location for the selected ARI's.

Local Modelling

In order to improve the accuracy of predicted inundation and provide more accurate assessment of the extent and duration of inundation, local hydraulic models have been established at 2 key areas within RCC; Raby Bay and Waterloo Bay. Figure 5 and 6 show the model extent of these areas respectively.

The local hydraulic models have been developed based the following datasets

- Bathymetric survey provided by Council,
- Aerial Laser Survey flown in 2009,

- Bathymetric survey of canals in Aquatic Paradise and Raby Bay completed by Port of Brisbane (2009/2010); and
- Stormwater / Hydraulic structure information provided by Council.

Storm tide time series of water level is extracted from the Delft3D Storm Tide model. This water level is applied to the ocean boundary of the local hydraulic models.

RESULTS

From the modelling it was possible to provide spatial analysis of the design storm tide levels to identify, analyse, and evaluate the storm tide risk. The spatial analysis has included estimation of inundation extents, depths, duration and properties inundated for the design 20, 50, 100, 1,000 and 10,000 year ARI storm tide events. Rather the providing numerous hard copy maps for Council, data layers have been produced for the for incorporation into RCC's mapping system.

Planning levels for developments within RCC have been prepared for the 2100 planning period has been established and also incorporated as a digital data set. The 2100 planning levels along the RCC coastline based on:-

- 100-years ARI Storm tide;
- Freeboard of 0.3m;
- Allowance for enhanced greenhouse conditions (increased cyclone wind speed of 10%); and
- Sea level rise allowance (0.8m for 2100).

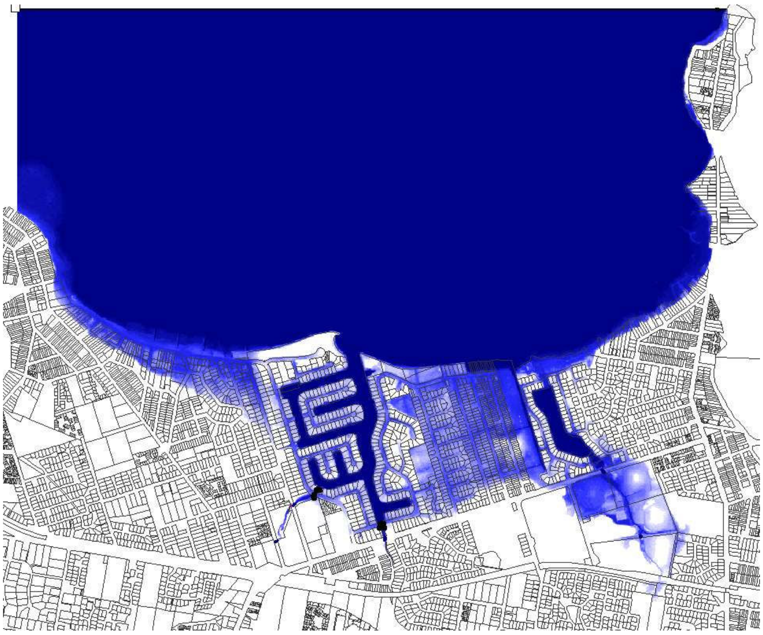

Figure 4 Waterloo Bay – Final Adopted Planning Levels – Detail Local Study Results

PLANNING IMPLICATIONS

The economic benefits associated with future development of the coastal zone must be weighed against the potential consequences resulting from storm tide damage. There is a level of risk associated with the development of low lying areas in terms of community safety and damage to property. Planning levels have been recommended by the Department of Environment and Resource Management (DERM) for future development in Queensland. These levels reflect the anticipated changing circumstances from greenhouse induced future climate change (increased cyclone intensity and sea level rise).

Defined Storm Tide Event (DSTE)

The DSTE has implications for future land use planning within areas affected by storm tide inundation and also for emergency response planning for existing communities. Current guidelines adopt the 1% Annual Exceedence Probability (AEP) event as the preferred basis for determining the natural hazard management area (storm tide) which is consistent with the *State Planning Policy 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*. The adopted storm tide event should also include appropriate allowances for future sea level rise and wave set-up.

It was recommended that the DSTE level adopted by RCC should be based on the 1% AEP event (that is, the approximate 100-years ARI event) and include appropriate allowances for future sea level rise storm surge and wave set-up. In this instance, the 100-years ARI storm tide event that includes enhanced climate change conditions should be adopted as the base for the DSTE.

The 100-years ARI level is applicable for non-essential infrastructure. Critical infrastructure such as hospitals, police stations and evacuation centres may be required to be designed to withstand more rare design conditions, including climate change allowances.

Planning Level Recommendations for Sea Level Rise
The Queensland Coastal Plan (DERM 2011) provides the guidance for incorporating sea level rise into planning level considerations summarized in Table 1 below.

Table 1 Projected Sea Level Rise for the Year of the End of Asset Life, Qld Coastal Plan (DERM 2011)

Year of End of Planning Period	Projected Sea Level Rise (relative to 1990 levels)
Year 2050	0.3 m
Year 2060	0.4 m
Year 2070	0.5 m
Year 2080	0.6 m
Year 2090	0.7 m
Year 2100	0.8 m

For committed development, the planning period is defined by the type of development being undertaken. Table 2 provides a guide to planning periods associated with various forms of development. The planning period from this table defines the applicable sea level rise (from Table 1).

Table 2 Coastal Protection Planning Period for Development Subject to Development Commitment, Qld Coastal Plan (DERM 2011)

Type of Development	Planning Period (based on anticipated asset life)
Short term tourist accommodation	40 years
Residential dwelling, excluding unit blocks of 7 +	50 years
Residential dwelling unit blocks of 7+	60 years
Industrial building	40 years
Commercial building (multiple storeys)	60 years

For development not subject to a development commitment, a planning period of 100-years must be adopted requiring a 0.8m allowance for sea level rise, as well as the projected increase in cyclone intensity.

Freeboard
An additional allowance of 0.3m is recommended as a freeboard to habitable floor levels. This figure takes into account uncertainties associated with the data used in the study, and the confidence interval associated with the investigation techniques applied at this study site.

CONCLUSION

The analysis completed by Cardno provided Redland City Council with the necessary information to allow them to move their planning process forward with the consideration of storm tide. The detailed modelling and conversion ton GIS databases provided Council with a visual on on-line tool for their staff to utilise.

The planning implications recommends the adoption of the 100-years ARI storm tide level for the Defined Storm Tide Event (DSTE) in line with the Queensland Coastal Policy (DERM 2011). The 100-years ARI storm tide event includes an allowance for the effect of climate change on cyclone intensity. In addition to the DSTE (that is, the 100-years ARI storm tide level) an allowance for sea level rise should be included. Finally a freeboard level of 0.3m should also be included to habitable floor levels to allow for the relatively short duration data sets and confidence in modelling systems applied in this study.

TAKE HOME MESSAGE

The Redland study has demonstrated the technical and planning beneifits of detailed hydraulic modelling by local governments to meet the requirements of the Queensland Coastal Management Plan.

REFERENCES

Cardno Lawson Treloar (2009): Storm Tide Hazard Study, Redland Shire and Logan City Councils. Report LJ8824/R2504 Prepared for Redland Shire and Logan City Councils.

Department of Environment and Resource Management (2011) Queensland Coastal Plan.

IPCC (2007): Summary for Policymakers. In; Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the intergovernmental Panel on Climate Change.

Treloar P. D., Taylor D. R and Prenzler P. (2010): Investigation of Wave Induced Storm Surge Within A Large Coastal Embayment – Moreton Bay (Australia). *Coastal Engineering 2010 - Proceedings of the 32nd Internation Conference on Coastal Engineering.* Shanghai, July 2010.