AQUIS RESORT AT THE GREAT BARRIER REEF PTY LTD

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 8

APPENDIX J

COASTAL PROCESSES

A part of BMT in Energy and Environment

AQUIS Resort at Great Barrier Reef Coastal Processes Assessments Report to Support EIS

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AQUIS Resort at Great Barrier Reef Coastal Processes Assessments Report to Support EIS

Prepared for:	AQUIS Resort at Great Barrier Reef Pty Ltd
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1 Introduction

BMT WBM has been commission to carry out some of the hydraulic studies relating to this development including coastal processes, flooding and water quality. This report relates to the coastal processes component.

The AQUIS site is located approximately six kilometres north of the current Barron River entrance in the Barron River delta between Richters Creek and Yorkeys Creek. However, the proposed development is located approximately 600m from the shoreline and as such coastal erosion is not of concern for the proposal. However, the site will be inundated by storm surge during significant cyclonic events.

This report describes the existing coastal environment, specific site coastal constraints including legislative constraints, opportunities for development, and an assessment of development impacts on the environment.

Key components in relation to Coastal processes to be addressed are:

a. Design and extreme event water levels across the site.

b. Shoreline and creek mouth bank stability and erosion.

c. Potential for partial loss of frontal dune with wave overtopping in direct hit severe to extreme cyclone events including wave set-up, run-up and overtopping volume.

d. Long term shoreline trends particularly in relation to the consistency ongoing sediment supply from the Barron River.

e. Potential for impacts relating to major channel changes and in particular the risk that Thomatis Creek becomes the major channel.

f. Emergency evacuation and management, co-ordinated with emergency flood management.

g. Planning / legislative requirements and project compliance.

2 Methodology

This report has relied on several previous State Government studies into the Barron River Delta and associated coastal processes and beach erosion These studies were completed in the 1980s and are called the Barron River Delta Investigation (BRDI) by the then Queensland Department of Harbours and Marine (H&M) in 1981 and the Mulgrave Shire Northern Beaches Report (MSNBR) by the then Queensland Beach Protection Authority (BPA) in 1984. These have considered the flood plain and coastal processes for the Barron River Delta in detail including comprehensive investigations of geology, floods, sediment movements, channel stability and coastal processes. This report included information on a range of processes from those that are expected to remain stable over centuries e.g. geological, to daily varying wave littoral processes such as wind, wave and sediment transport conditions.

No new data collection or process analyses have been carried out for this study.

3 Site Resources and Values

3.1 Location and Background

The AQUIS site is located approximately six kilometres north of the current Barron River entrance in the Barron River delta between Richters Creek and Yorkeys Creek. Richters Creek is a major distributary of the Barron River and the associated interactions are a key consideration. Several studies into coastal processes and beach erosion in the region have been completed since the 1980s. Of particular interest are the Barron River Delta Investigation (BRDI) by the then Queensland Department of Harbours and Marine (H&M) in 1981 and the Mulgrave Shire Northern Beaches Report (MSNBR) by the then Queensland Beach Protection Authority (BPA) in 1984. These have considered the flood plain and coastal processes for the Barron River Delta in detail including comprehensive investigations of geology, floods, sediment movements, channel stability and coastal processes. This report included information on a range of processes from those that are expected to remain stable over centuries e.g. geological, to daily varying wave littoral processes such as wind, wave and sediment transport conditions.

In terms of coastal processes these reports found that in geological timescales the beaches have been accreting (refer Figure 3-1) but that local disturbances such as interruptions to the fluvial supply from rivers such as the Barron River (refer Figure 3-2) have caused large scale disturbances. These fluctuations pre-date the arrival of Europeans and are a natural rather than anthropogenic occurrence. The Barron River delta is the largest source of sediment to the northern beaches and supplies about 23,000 m^3 annually.

Coastal data has continued to be collected since the 1980's by the BPA and now Department of Environment and Heritage Protection (DEHP) on the processes that change daily and for which longer datasets can provide meaningful statistical information. These are:

- Wave recording off Double Island;
- Beach profile surveys at the beaches to the north and the south; and
- Storm Surge recording at Trinity Inlet.

An analysis of the more recently collected data was added to the MSNBR data set by WBM in 2005 to form the technical basis for a Shoreline Erosion Management Plan (WBM 2005). The subject of Greenhouse induced sea level rise was not considered at the time of the MSNBR and was included in the later WBM report. Details of these data sets and the associated coastal processes are given in Chapter 3.

3.2 Geological Background

The previously mentioned significant studies of the Barron River Delta were carried out by the Queensland Government in the 1980's. Much of the background information for this report is taken from these studies. It is known that the Barron River entrance has switched locally during the time of European settlement (refer Figure 3-2), the location of the River in more distant times is less certain. Marine seismic profiles show a relatively young major channel across the former land surfaces northeast of the present Richters Creek mouth. This channel appears to be a continuation of a former river course identifiable onshore leading from Kamerunga to Smithfield and then northeast towards the Richters Creek mouth. The Barron River may have occupied this course during the late Pleistocene and switched to its present position sometime during the late Pleistocene or early Holocene. It appears unlikely that major channel switching has occurred during the middle and late Holocene i.e. the last 6,000 years.

Figure 3-1 Quaternary Geology of Trinity Bay

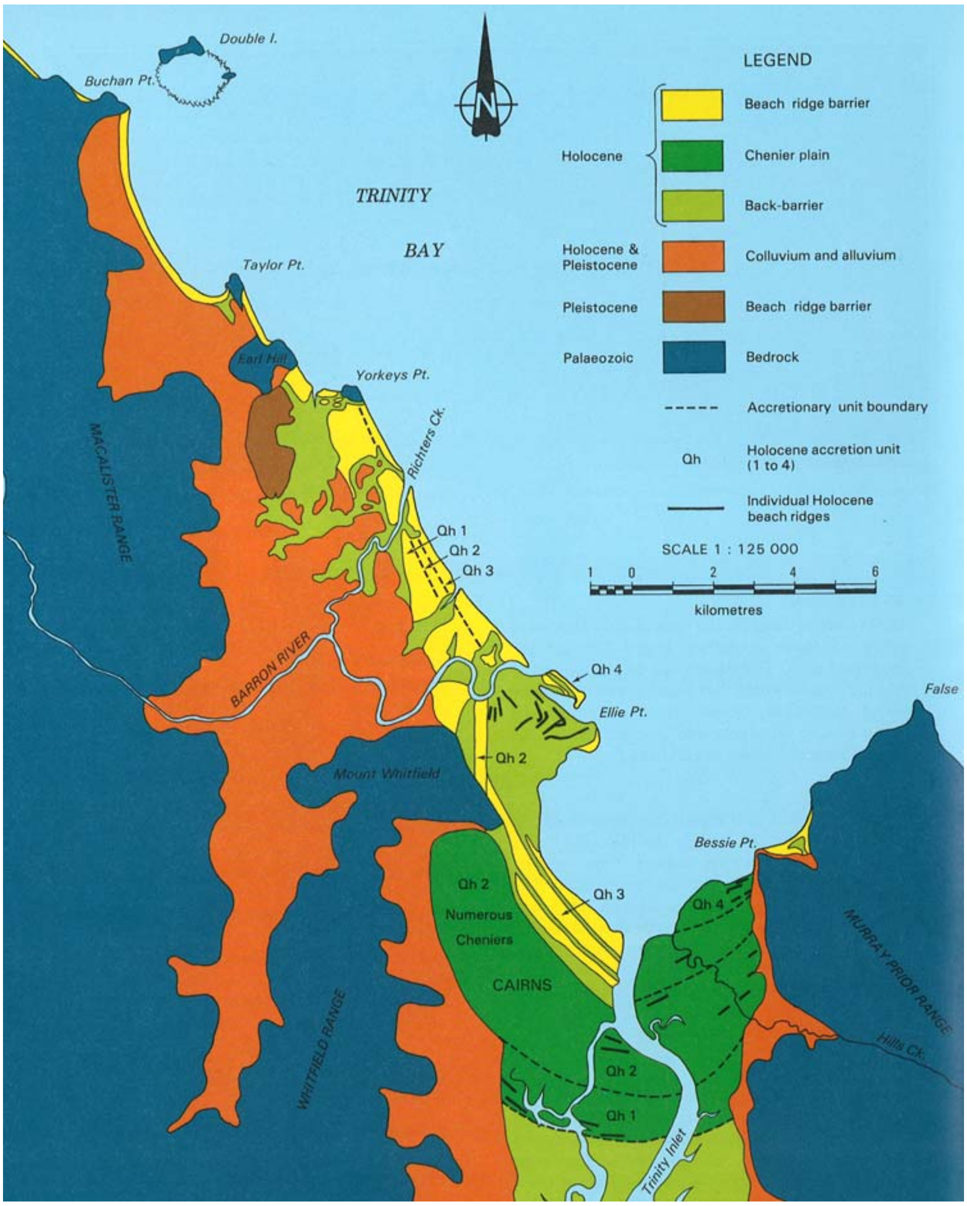

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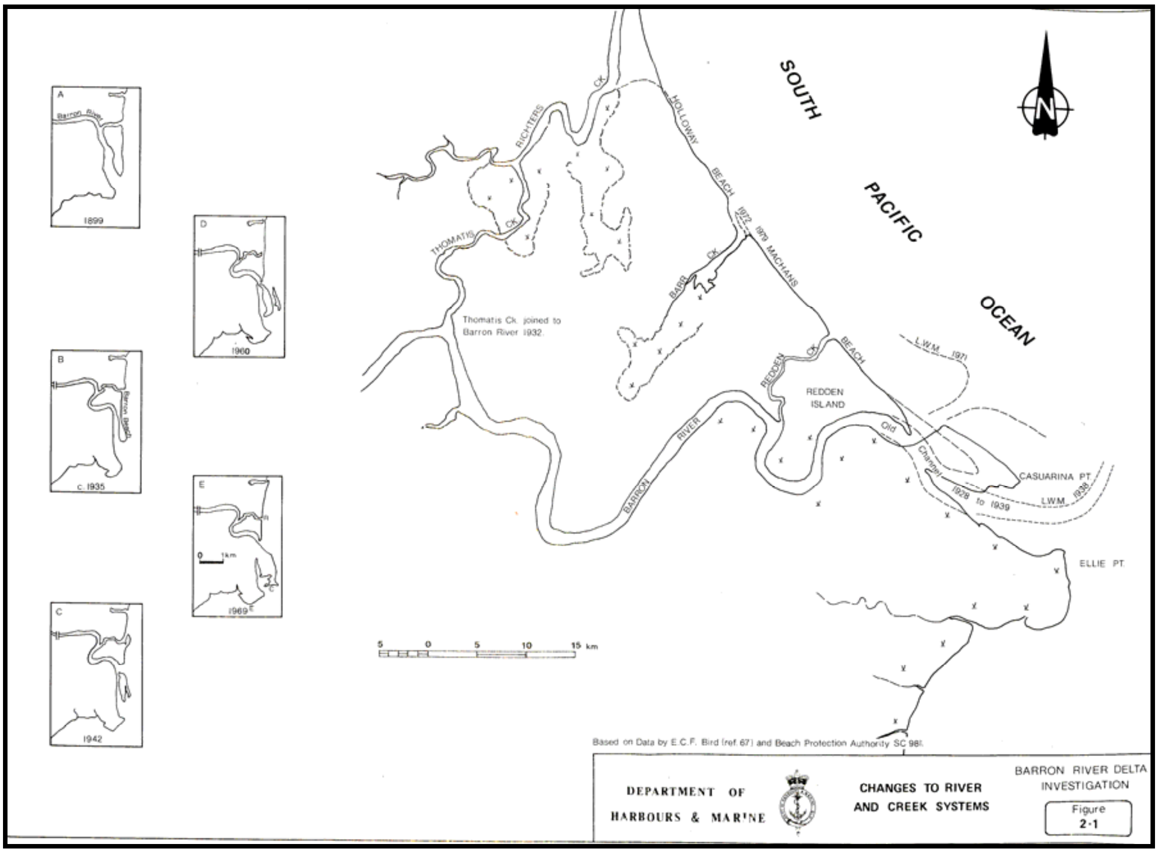
Figure 3-2 Recent Barron River Entrance Changes (from H&M 1981)



3.3 Current Coastal Processes

Coastal processes are the result of various climatic and oceanic processes interacting with the shoreline. As such the recording and analysis of winds, waves, tides, storms and sediments can lead to an increased knowledge of the processes that may cause erosion or accretion of the shoreline. A description of these parameters and the associated interpretations are given below with potential impact on the proposal given in later chapters.

3.4 Sediment Supply

Generally the Barron River and its tributaries supply sand to the coastal zone, initially to their ebb tide deltas and then the predominant south easterly winds and associated waves move the sand onto the beaches and northwards. The major sand supply from the Barron River bar onto the beach to the north was interrupted when the river formed a new entrance in 1939. The direct linkage of sediment transport from the old bar at Ellie Point was cut and sediment supply was directed into forming a new ebb tide bar. This interruption to supply was felt at Machans Beach and Holloways Beach for many decades as an “erosion shadow” i.e. the sand that would normally be transported to these beaches was used in building the bar system at the new entrance.

Similarly the growth of the Richters Creek bar following the permanent connection of Thomatis/Richters Creek to the Barron River around 1932 starved sand supply to the beaches further north, in particular Yorkeys Knob, while the new entrance bar formed. The more recent build-up of substantial quantities of sand at Yorkeys Knob is an indication that the supply from the Richters Creek bar has returned. However, concern regarding the increased Barron River flows through Thomatis/Richters Creek (up to 35% in the 1980s) lead to a significant study (H&M 1981) into the stabilisation of the bifurcation to prevent further flow diversion into this tributary. Some of these works were carried out and the entrance has remained stable.

3.4.1 Waves

The Cairns region is located within the lagoon of the Great Barrier Reef and is generally exposed to relatively low wave energy from locally generated wind waves. However, tropical cyclones are often present in the region during summer and these can present extreme, although relatively short lived events in terms of waves and storm surge.

As part of the WBM 2005 study, EPA (now DEHP) was requested to produce a report for the period May 1975 to May 2005. This request was made so that comparisons could be made with the previous report (BPA 1981). There are many different methods available for interpreting and analysing wave data including the method of handling gaps in the data as well as the parameters used in the spectral analysis of the individual wave records. Therefore, for consistency over the 30 year intervening period it was considered desirable to apply similar techniques so that any reported differences were related to the wave conditions rather than the analysis methodology.

Of particular interest are the wave height exceedance plots for each period (1975 to 1981 and 1975 to 2005) as shown in Figure 3-3 and Figure 3-4. A comparison of these indicates a slight decrease in wave height of about 5-10% for the extended period. This is consistent with general weather observations that indicate a reduction in cyclone activity in last 20 years to 2005. Therefore, it is considered that the longer record is more likely to represent the long term average wave conditions. However, it must be noted that there can be considerable variation in the weather from year to year and more intense storms or stormy periods are statistically possible. This has recently been experienced with more frequent cyclones and floods in Queensland.

In the plot of 1975 to 2005, a tendency to higher wave heights can be seen in the lower percentage exceedances (i.e. less frequent storm events). This is because the data recording frequency has increased from once every 12 hours in 1975 to once every hour since 1995. This means that the peak wave condition in a storm is now better resolved and recorded as a higher level.

In summary it can be said that the wave conditions are generally consistent with a significant wave height of about 1.0m being exceeded 2% of the time and a 1: 100 year maximum significant cyclone wave height being about 3.25m (refer Figure 3-5). The consistency of the wave data indicates that there would be no long-term changes to coastal processes from this component alone.

Figure 3-3 Data from BPA 1975 - 1981

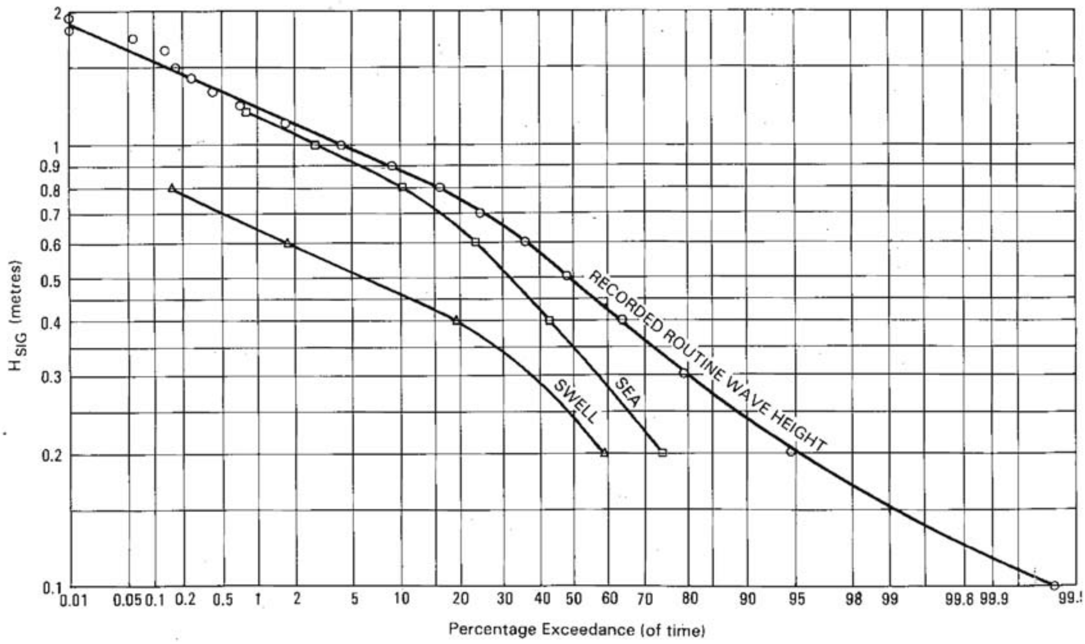
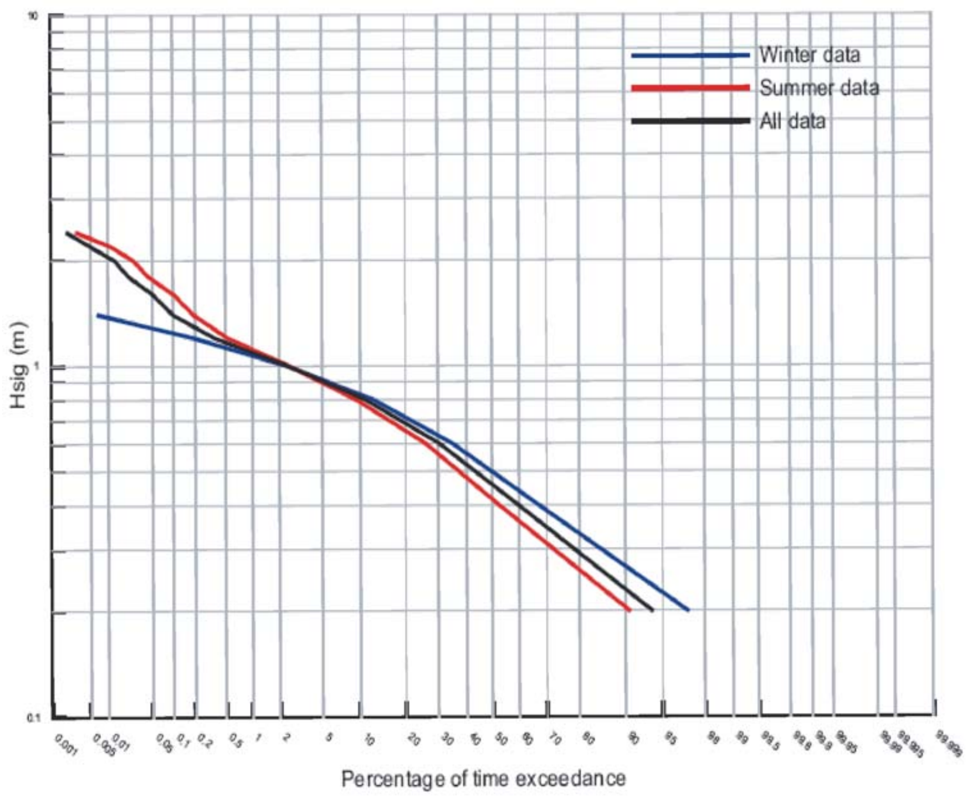
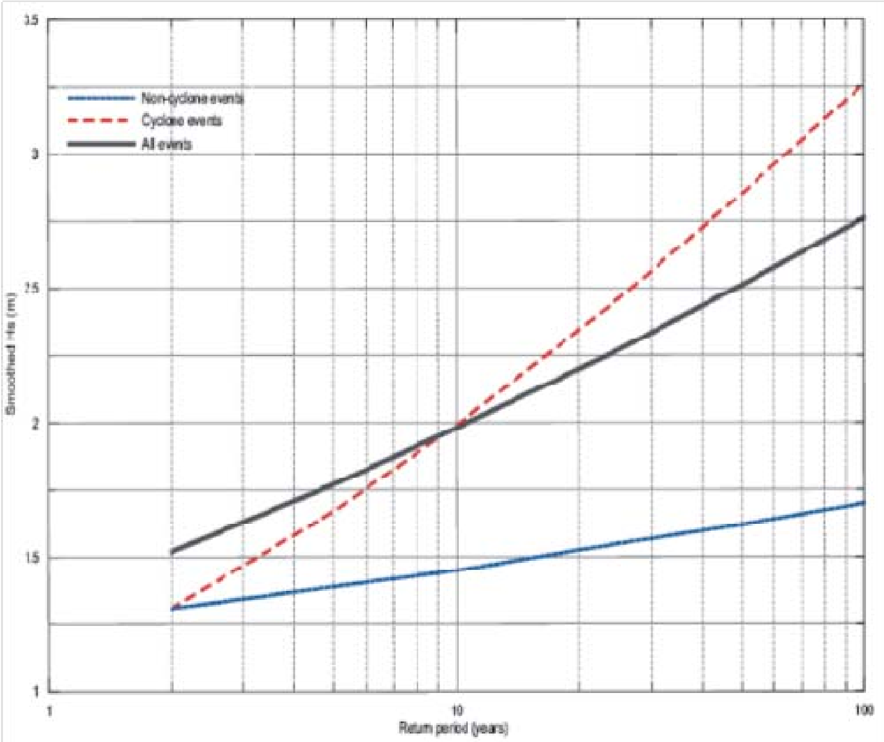


Figure 3-4 All Data from DEHP 1975 – 2005



BMT WBM

Figure 3-5 Cyclone Data from DEHP 1975 – 2005

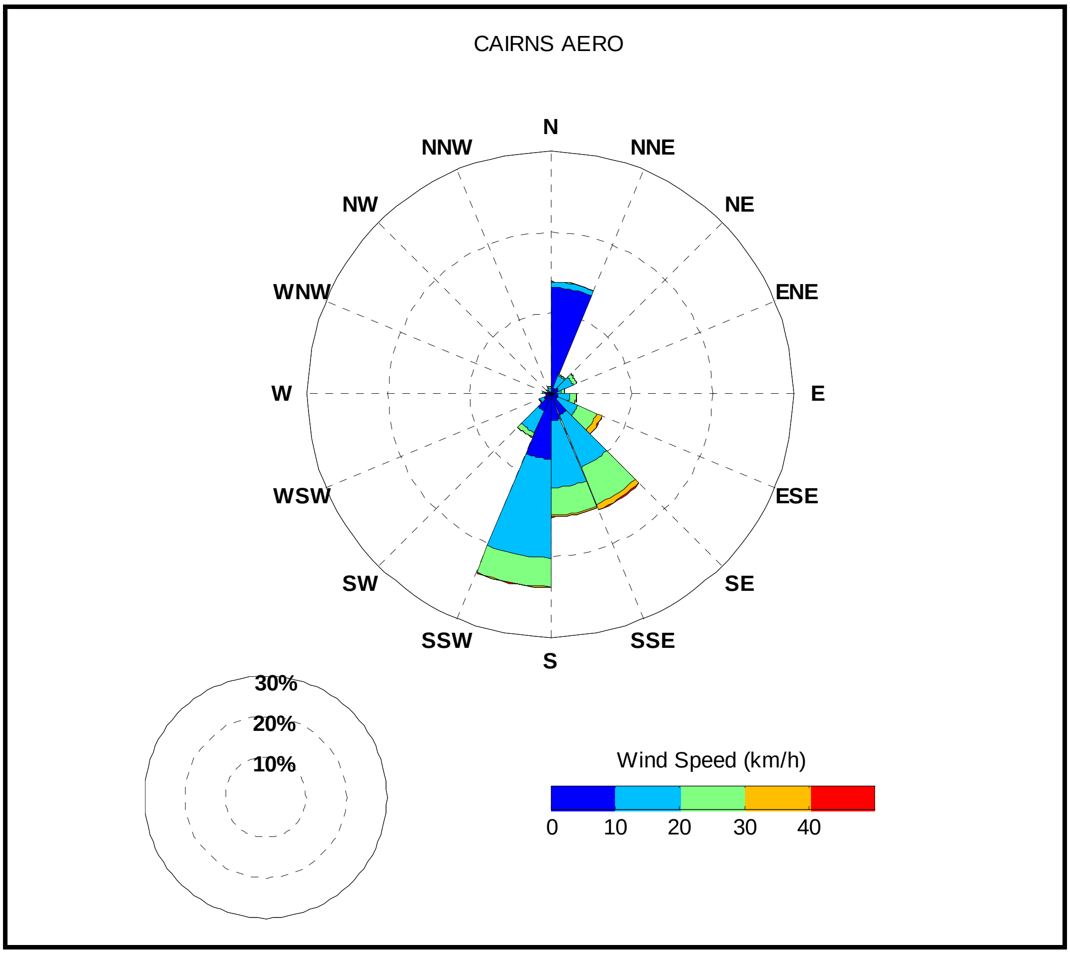


3.4.2 Wind

Wind data for the Cairns region is generally taken from two sites being Cairns Airport and Low Isles. Because of the topography of the Yarrabah Peninsula it is generally considered that Cairns Airport data is suited to Trinity Inlet but Low Isles better represents the northern beaches and the current proposed development.

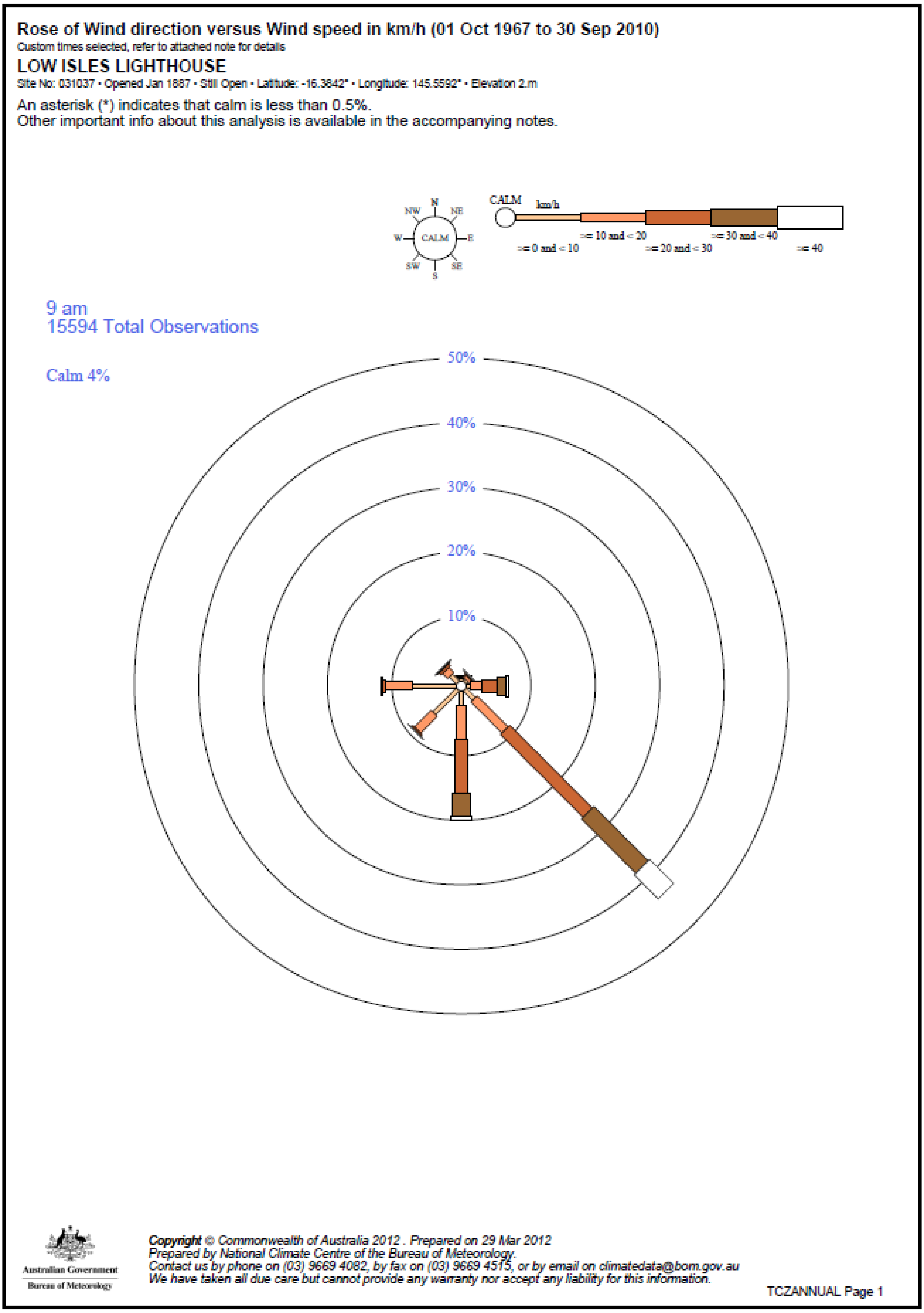
Wind data at Cairns Airport have been collected since 1948 to present. The wind rose corresponding to the period 1948 to 2011 is shown in Figure 3-6 and shows a predominance of SE to SSW winds (summer) and N to NNE winds (winter).

Figure 3-6 Cairns Aero Long Term Average Wind Rose (1948 to 2011)



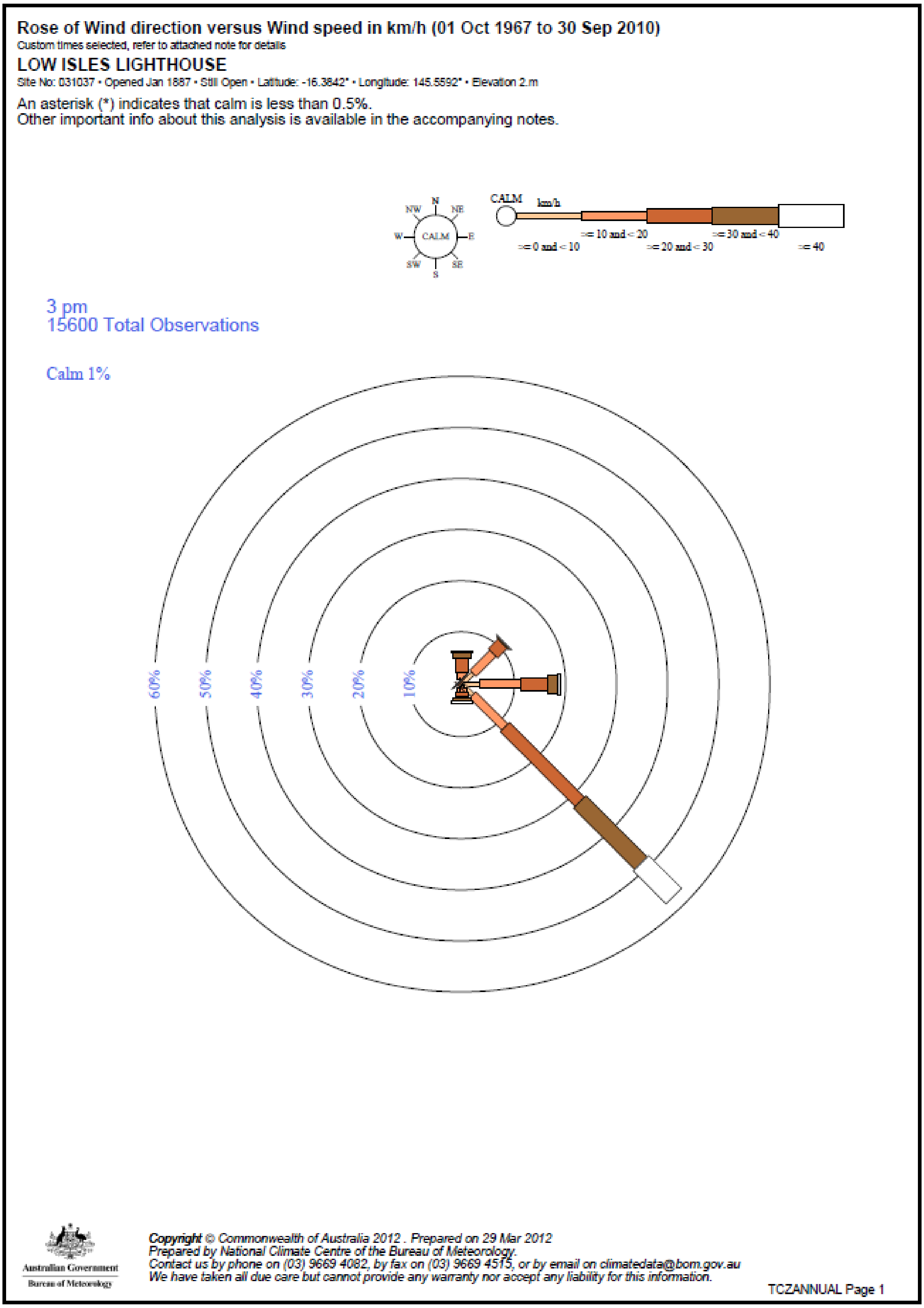
Wind data at Low Isles have been collected since 1967 to present. The wind roses corresponding to 9am and 3pm for the period 1967 to 2010 are shown in Figure 3-7 and Figure 3-8 showing a predominance of SE to SSW winds (summer) and N to NNE winds (winter).

Figure 3-7 Low Isles 9am Long Term Average Wind Rose (1967 to 2010)



BMT WBM

Figure 3-8 Low Isles 3pmLong Term Average Wind Rose (1967 to 2010)



3.4.3 Sea Level Rise

Consideration needs to be given to the potential for coastal recession associated with an expected sea level rise (SLR) due to the Greenhouse Effect. Most recent predictions of SLR have been provided by the Intergovernmental Panel on Climate Change (IPCC 2007) which predicts sea level rise using world atmospheric models on a 5 yearly basis for different scenarios. Current predictions of sea level rise for the mid case scenario are 0.4m for 2060 (50 years) and 0.8m for 2100 (100 years).

3.4.4 Tide and Storm Surge

3.4.4.1 Tidal Planes

The astronomical tidal planes published in the Official Maritime Safety Queensland Tide Tables 2013 are given in Table 3-1 below. The main importance of the tidal planes is the contribution that normal tides make to the overall combined elevated water levels during storms. Therefore, it is more beneficial to consider storm tide and storm tide plus greenhouse effects, as discussed later, as they involve higher combined water levels.

Table 3-1 Tidal Planes at Cairns

Tidal Planes	Qld Tides 2013 (To AHD) m
Highest Astronomical Tide	1.86
Mean High Water Spring	0.98
Mean High Water Neap	0.40
Mean Sea Level	0.16
Mean Low Water Neap	-0.18
Mean Low Water Spring	-0.76
Lowest Astronomical Tide	-1.64

3.4.4.2 Storm Tide

The phenomenon called storm surge is the combination of several components that result in an increase in mean sea level as a cyclone approaches the coast. The components include lower atmospheric pressure and wind setup causing an elevated water surface that is pushed in front of the moving cyclone. Storm tide is the combination of tide and surge and its assessment takes into account the random nature of surge and tide combinations.

As the cyclone approaches land the waves caused by the associated winds also produce an increase in water level at the shoreline called wave setup. When these waves break at the shoreline momentum carries the water up the beach. This is called wave run-up. Therefore the ultimate water level experienced during a cyclone will include the surge (wind setup and pressure effects) and the wave effects (wave setup and run-up).

Storm tide modelling involves generating a statistically significant number of random storm surge and tide combinations. The Queensland Government has adopted a technically comprehensive and peer reviewed method of assessing storm tide risk based on methodologies developed by James Cook University and the Australian Bureau of Meteorology. This methodology is detailed in the publication *Queensland Climate Change and Community Vulnerability to Tropical Cyclones: Ocean Hazards Assessment Stage 1 – Review of Technical Requirements and Operational Manual* (QG 2001and 2004) and all storm tide studies in Queensland are required to adhere to this manual.

BMT WBM completed a storm tide study for the Cairns Region in 2013 (unpublished – held by Cairns Regional Council) using this methodology and the tables below are taken from that report. The study site is closest to model output location 164 (MGA94 zone 55: 365437.2, 8139948). Table 3-2 shows the peak storm tide near the site.

Table 3-2 Peak Storm Tide (Surge Plus Tide Only)

	Peak Storm Tide Level (mAHD).				
Location / AEP	1%	0.5%	0.2%	0.1%	0.01%
Cairns North Beach	1.99	2.24	2.65	3.02	4.11
Trinity Beach	1.86	2.06	2.37	2.63	3.19
Study Site (Location 164)	1.95	2.17	2.50	2.75	3.44

The final level that seawater will reach will include all of the components (tide + surge + wave set up + wave run-up). Table 3-3 shows the combined storm tide plus wind and wave effects.

Table 3-3 Peak Storm Tide Including Wave Effects AEPs

	Peak Storm Tide Level including Wave Setup and Wave Runup (mAHD).				
Location / AEP	1%	0.5%	0.2%	0.1%	0.01%
Cairns North Beach	3.15	3.45	3.92	4.29	5.40
Trinity Beach	2.98	3.26	3.59	3.86	4.48
Study Site (Location 164)	3.11	3.38	3.75	3.99	4.69

Note: AEP is the Annual Exceedance Probability and is the probability that the water level will be exceeded in one year

If we project these levels into the future and add 0.8m sea level rise (predicted for 2100) then the final level that seawater will reach is modelled using sea level rise and again includes all of the components (tide + surge + set-up + run-up) modelled using the sea level rise. Table 3-4 Projected 2100 1% AEP Storm Tide Including Wave Effects and Sea Level Rise

shows the combined storm tide plus wind and wave effects for a 1% AEP i.e. the level that is the maximum level predicted to be reached in 100 years. The time scale of 100 years is used as it represents the design life of the buildings and the built environment.

Table 3-4 Projected 2100 1% AEP Storm Tide Including Wave Effects and Sea Level Rise

	Projected 2100 1%AEP Storm Tide including Wave Setup and Wave Runup (mAHD)
Location	0.8m SLR
Cairns North Beach	4.04
Trinity Beach	3.86
Study Site (Location 164)	3.91

Regarding "mega-extreme" events that are sometimes mentioned, it can be seen from Table 3-3 that a 0.01% AEP event (1:10,000 year) has a predicted combined storm tide, wave setup and wave run-up level of 4.69m AHD.

Therefore, it is recommended that any safe refuge considerations should include the extreme case and as such it is recommended that a level of 5m AHD is used giving about 0.3m freeboard on the predicted extreme water level. It should be noted at this stage that it is expected that flooding considerations have recommended flooding levels several metres above this value (refer Flooding Assessments Stage 2 Report).

3.4.5 Tsunami

The most definitive work on Tsunami Risk for the Australian coastline has been carried out by Geoscience Australia and is called the national offshore Probabilistic Tsunami Hazard Assessment (PTHA). The national offshore PTHA considers the tsunami hazard posed to the entire Australian coast by tsunami caused by subduction zone earthquakes in the Indian and Pacific Oceans. These regions are known to have produced major tsunamigenic events in recorded history and are the most likely sources of future events.

The hazard maps are defined at a bathymetry water depth contour of 100m offshore. This normally falls outside of the Great Barrier Reef or other reef systems. The 100m depth contour is chosen because:

- estimating the tsunami closer to the coast requires high resolution bathymetric data which does not always exist for the entire coast
- estimating the tsunami closer to the coast is a more computational and time intensive task.

These maps help to identify the areas which are most likely to be at risk to damaging tsunami waves and are used by Australian emergency managers in understanding the tsunami hazard to Australia.

However, the maps cannot be used directly to infer how far a tsunami will inundate onshore (inundation extent), how high above sea level they will reach on land (run-up), the extent of damage or any other onshore phenomena. To estimate the onshore tsunami impact, detailed bathymetry and topography of the specific region concerned is required for input to a detailed inundation model. The catalogue of tsunami events used to derive the national offshore PTHA can be used by emergency managers, researchers and individuals however to develop detailed inundation models at any onshore location.

An excerpt from the mapping for the Cairns Region is shown in Figure 3-9 (0.02% AEP). This map indicates the expected wave height in 100m of water depth outside of the Barrier Reef is 1.2m. As this wave propagates towards shore it will lose considerable energy passing through the reef but will gain height as it traverses shallow water near the shore and shoals.

The Cairns Regional Council has produced a Tsunami Evacuation Guide which recommends evacuation to high ground when a tsunami warning is given. The map relevant to the project site is shown in Figure 3-10. It should be noted that this guideline warns that "*Until the Tsunami alert system is developed further, the Bureau of Meteorology will only be able to advise that a Tsunami is approaching. It will not be able to indicate how high the wave is. As a result, Cairns City Council has developed the attached maps to assist the community should a Tsunami alert be issued*".

Figure 3-9 AEP 1% Tsunami Risk for Cairns (Geoscience Australia)

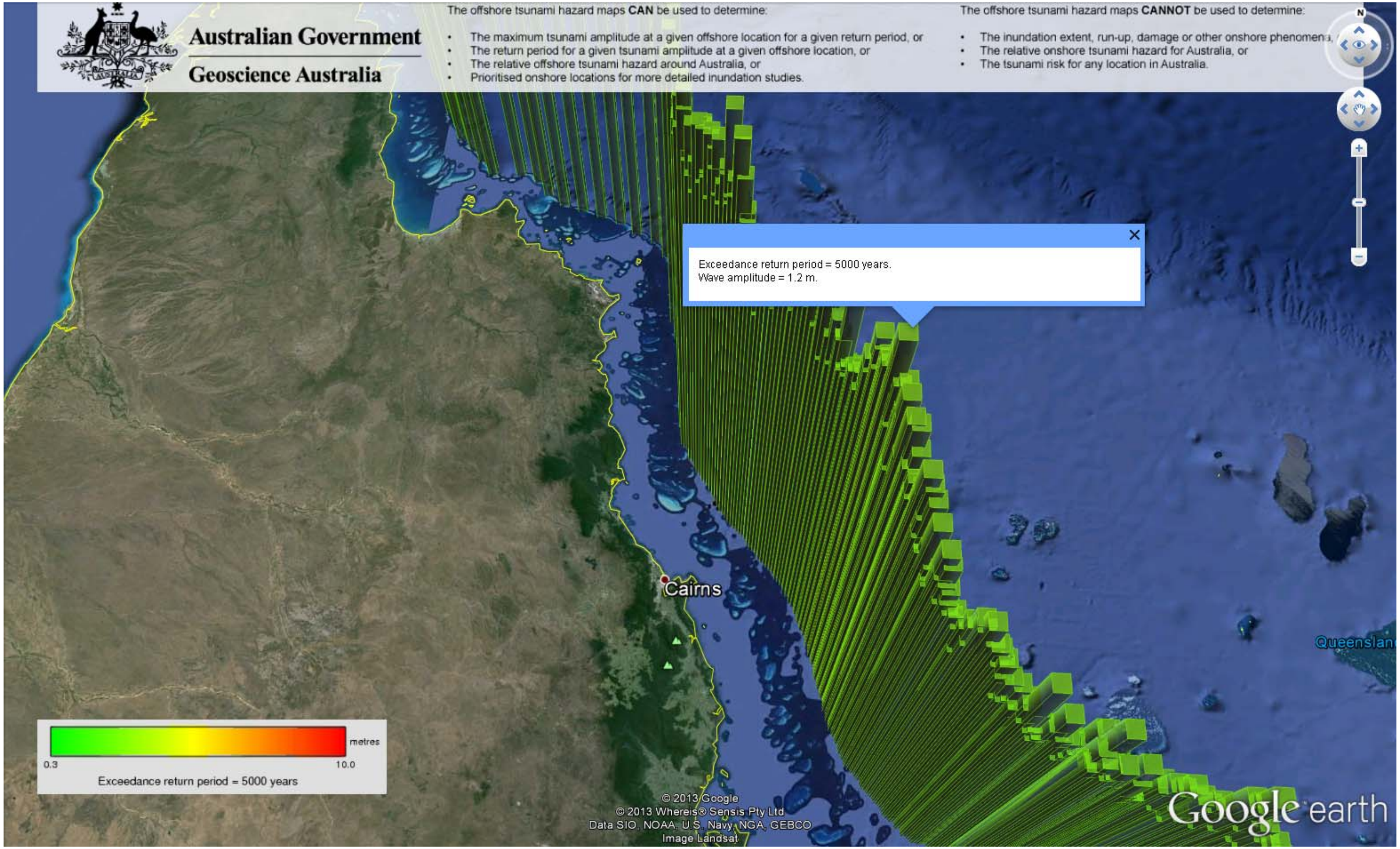
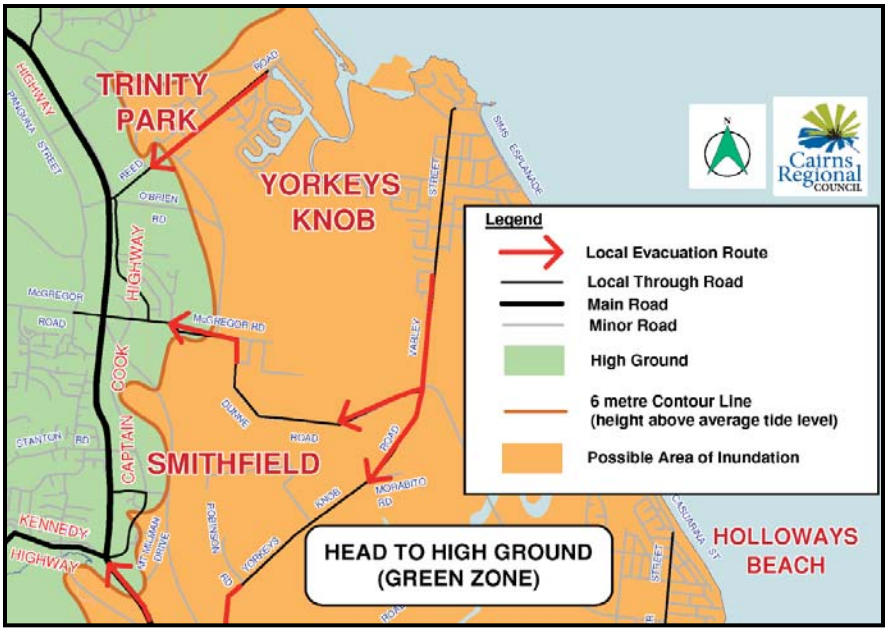


Figure 3-10 Cairns Regional Council Tsunami Evacuation Plan



3.4.6 Longshore Sand Transport

The long-term erosion or accretion of a beach is primarily related to the sand budget at the beach. The main component of the sand budget is the longshore transport of sand into and out of the beach unit. If these are equal then the beach will be stable in the long term although there may be reversible short term fluctuations in response to storms.

The main factors that impact on sediment supply and longshore sand transport are:

- Sources and sinks such as river or creek entrances and sand extraction sites. In particular for the proposed development the ongoing supply of sediment from the Barron River and Richters Creek is essential for beach stability.
- Frequency and location of storms and cyclones.
- Headlands or structures that may interrupt supply.
- Beach alignment changes that may alter the longshore transport resulting from wave action.

A summary of the longshore transport rates calculated as part of the previous studies at several beaches is given below. Differentials in longshore sand transport rates give an indication of long term erosion or accretion potential.

The MSNBR carried out comprehensive analyses of the net northward longshore transport of sand along the Cairns beaches with calculations at selected beaches. The following values were adopted:

- Trinity Beach 12,500 m^3/a.
- Yorkeys Knob 8,000 m^3/a.
- Holloways Beach 10,000 m^3/a.

This resulted in the prediction of accretion of sand on Yorkeys Knob in the order of 2000 m^3/a. Analysis of survey data after the construction of the Yorkeys Point groyne indicates that Yorkeys Knob beach north of the Richters Creek bar accreted at a rate of 10,000m3/a between 1979 and 1994 which is consistent with the predicted values.

3.4.7 Short Term Storm Erosion Potential

Storm erosion occurs when increased wave heights and water levels result in the erosion of material from the upper shoreline. On open coasts, the eroded material is taken offshore where it is deposited as a sand bar located in the vicinity of the wave break area. After the storm event the sediment is slowly transported onshore, often over many months or several years, rebuilding the beach.

The potential for short-term storm erosion due to severe wave and elevated sea water levels (surge conditions) has been predicted using the simple cross-shore equilibrium profile model of Vellinga (1983). This empirical model calculates upper shoreline erosion associated with storm induced surge and wave conditions. The amount of shoreline recession is determined from the significant wave height, the storm surge plus tide level and the initial beach profile shape. The model assumes the volume of material eroded from the upper shoreline and deposited offshore is balanced by a setback of the shoreline.

Storm erosion assessment was performed at locations where sufficient offshore profile data was available. This information was gained from previous surveys of the study area reported by WBM (2005).

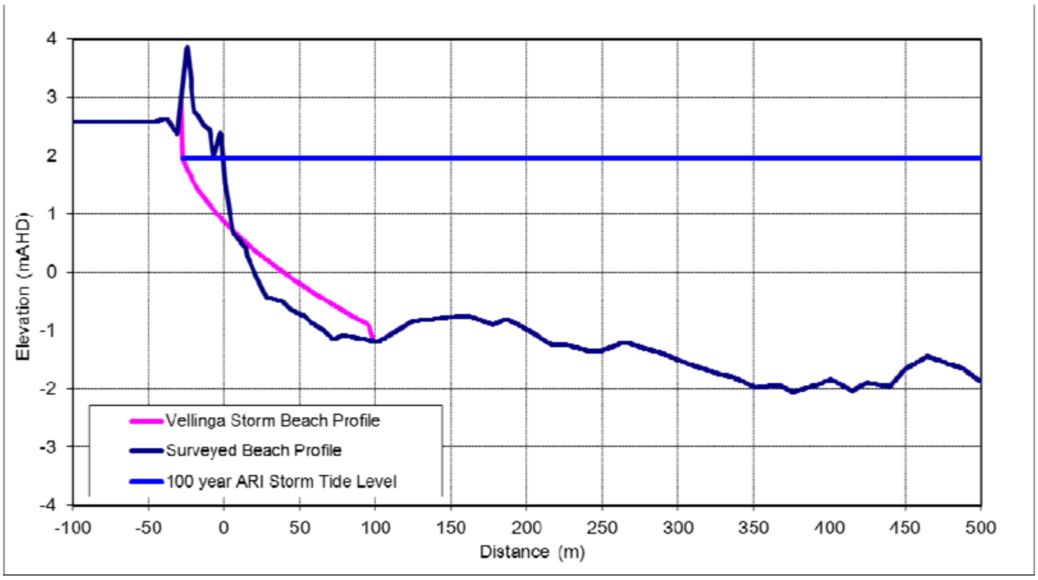
Design water level and wave conditions for the study site were obtained from the Cairns Storm Tide Study Review (BMT WBM, 2013). The design storm defined for this assessment combined the 1% AEP cyclonic design water level (1.95mAHD) with the 2% AEP cyclonic design wave height (2.85m). This design storm definition follows guidance for storm erosion assessments described in the Queensland Coastal Hazard Technical Guide (Queensland Government, 2013).

Table 3-5 lists the predicted erosion results for beach profile locations relevant to the study area. The storm erosion distance is measured landward from the position where the design water level intersects the beach profile and varies primarily due to the initial beach profile and volume of material assumed available in the upper shoreline. Vellinga (1983) predicts more setback for steeper initial profiles since a greater volume of sand is required to achieve the ultimate storm profile. An example storm erosion assessment result for a location MU 223.0 at Yorkeys Knob is shown in Figure 3-11.

Table 3-5 Vellinga Model Erosion Estimates

Location	Vellinga Storm Erosion Potential (m)
MU 219.0	34
MU 219.5	32
MU 220.0	42
MU 222.0	30
MU 222.5	6
MU 223.0	28

Figure 3-11 Example Storm Erosion Assessment Results at Location MU 223.0



It is noted that no attempt to verify the Vellinga (1983) model estimates has been undertaken and the assessment is assumed to provide conservative erosion potentials. The calculations consider the upper shoreline to consist of erodible material only and therefore erosion will be overestimated in areas where rock, dense vegetation and/or manmade structures exist.

The mean storm erosion width estimate across the study area (between existing residential development at Yorkeys Knob and Holloways Beach) is approximately 29m with an upper value of 42m.

3.4.8 Wave Overtopping

The existing natural surface profile in front of the project site is variable with a general elevation of about 2.0m AHD. It is assumed that the site itself will be filled to this level before landscaping.

At this level, a 0.2% AEP (500 year) storm tide alone (2.50m AHD) will inundate the site across the frontal dunes as well as by earlier penetration into the creeks. This storm tide level is expected to be associated with offshore wave conditions in the order of 3.5m Hs. The extreme elevated water level, assuming run-up will occur, is expected to be 3.75mAHD at present or 3.91mAHD in 2100 (with climate change sea level rise). Under a cyclonic event lasting several hours these waves are expected to cause significant damage or complete erosion of the frontal dunes allowing depth limited waves will begin to propagate across the foreshore and dunal area towards the site.

At 0.01% AEP storm tide level (3.44m AHD) inundation and some depth limited wave action are expected to extend across the foreshore and dunal area to the proposed building and infrastructure. It is unlikely that wave set up or run up will occur in this scenario and wave energy will be significantly dissipated by natural surface roughness and turbulence. The design of these elements may require consideration of armouring against wave attack at final design stage. The sizing of any armour will be dependent on the details of infrastructure and the design return period used.

3.4.9 Erosion Prone Area

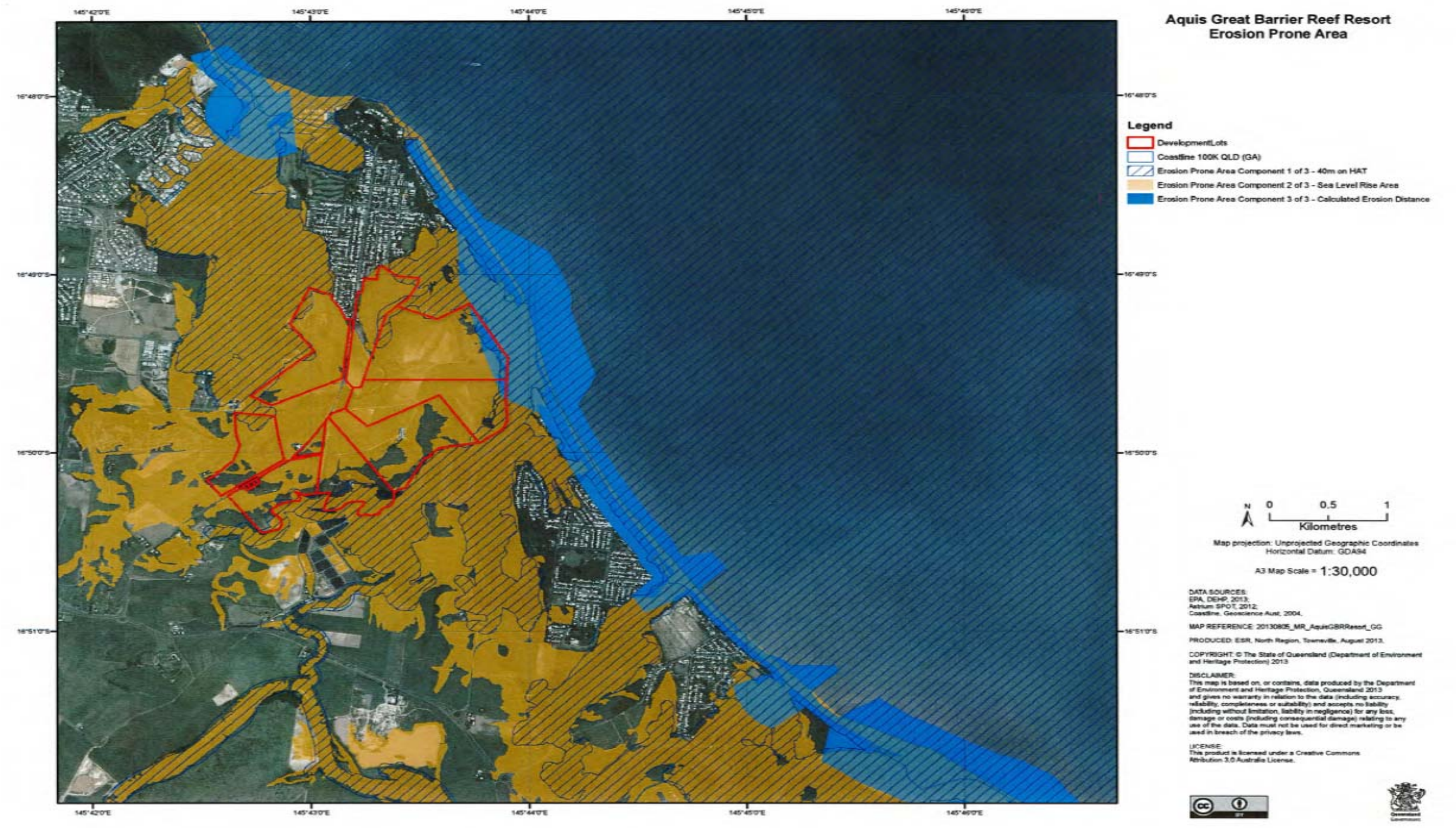
The current legislation includes three components to a declared Coastal Management District based on erosion prone area. These include:

- Extent of current HAT + 40m;
- Calculated shoreline erosion based on the original BPA formula (refer 3.4.9.1); and
- HAT + 0.8m to take into account future sea level rise to 2100.

These extents have been mapped by DEHP (refer Figure 3-12).

This section reviews previous technical coastal studies where the expected shoreline erosion due to coastal processes over the selected planning period has been assessed. The background to the calculations and the results are given below.

Figure 3-12 DEHP Erosion Prone Area Mapping



3.4.9.1 Introduction

The then Beach Protection Authority (BPA) introduced the concept of an erosion prone area width for a beach in the 1980s. These calculations included the short term (storm and cyclonic erosion) and the long term trends over the planning period of 50 years as well as applying a 40% safety factor and including a dune scarp component. Although the calculations are for a 50 year planning period the resulting calculated widths have been applied as ambulatory values by BPA and DEHP i.e. the width remains constant even if erosion or accretion occurs. Also the calculated width is taken from the seaward toe of the frontal dune which is usually interpreted as the seaward edge of vegetation.

The erosion prone area widths were calculated for the entire eastern Queensland coastline by the then BPA in the early 1980s and represent the area that is prone to erosion. It is generally recommended that erosion prone areas be retained free of development where possible to accommodate erosion and avoid the need for protection measures which may be expensive and detrimental to beach amenity. Plans showing the erosion prone area widths were sent to all relevant Local Authorities in the 1980's to assist in their forward planning. These calculated widths have generally been found to be a robust estimation of the potential erosion width and recently several independent analyses, using updated and local data, generally result in variations of less than 20%.

Therefore a discussion of the components considered and the calculation methodology for an erosion prone area width is given below to assist in the understanding of statements relating to these widths and the implications for infrastructure and development within these areas.

3.4.9.2 Basic Considerations

Erosion prone area widths are determined to identify the potential extent of erosion of the dune system over a specified planning period. Both short term (cyclone-related) and longer term (gradual) trends are included in the assessment together with an allowance for potential sea level rise associated with the Greenhouse Effect. Provision must also be included for a factor of safety on the estimates and an allowance made for slumping of the dune scarp following erosion. The following relationship has been used by the Beach Protection Authority for determination of the erosion prone area widths. This formula continues to be recognised by EPA as a reasonable method of assessing shoreline recession risk.

$$E = [(N \times R) + C + G] \times (1 + F) + D$$

Where E = Erosion Prone Area Width (metres)

N = Planning Period (years)

R = Rate of Long Term Erosion (metres/year)

C = Short Term Erosion from the design cyclone (metres)

G = Erosion due to Greenhouse Effect (metres)

F = Factor of Safety

D = Dune Scarp Component

The various components in the above relationship are determined on the basis of the characteristics of the individual beaches together with presently accepted practices as discussed below with the calculated erosion prone area widths presented in Section 3.4.9.9.

3.4.9.3 Planning Period

The duration of the planning period (N) influences the erosion prone area width calculations by effecting:

- The total extent of gradual long term erosion;
- The extent of possible sea level rise due to the Greenhouse Effect; and
- The selection of design cyclone conditions which are based on an accepted risk level.

In accordance with current DEHP policy, a planning period of 50 years is used. If a longer design life is expected then the long term erosion component may increase. However, it should be noted that as the shoreline south of the Yorkeys Headland control point moves westward then the long term component will decrease as the angle of the shoreline to dominant wave action will increase which results in decreased longshore transport.

3.4.9.4 Rate of Long Term Erosion

The rate of long term erosion (R) can be estimated by extrapolating past trends and/or determining any deficit in the local sediment budget. Consideration is also given to local features and/or characteristics which may influence the potential extent of long term erosion.

As discussed in Section 2.2 (Geology) sediment has consistently been discharged from the Barron River delta during the Holocene period with the only interruptions being Barron River entrance changes when new bars have formed (erosive impact) and the connection of Thomatis Creek to the Barron River (re-distribution – neutral overall impact). Even though the 1939 entrance change reduced sand supply to the beaches immediately north of the entrance, the impacts from a similar event in the future, where development was threatened, could be mitigated by terminal structures (e.g. Machans and Holloways beaches) or beach and dune nourishment from old bar sand reserves at Ellie Point. The proposed development is not at threat from shoreline erosion although the loss of frontal dunes may increase wave penetration during cyclones.

3.4.9.5 Short Term Erosion

Short term erosion (C) of the upper beach and dune can occur from time to time, associated with cyclone or severe storm events. Such events usually involve co-existing storm surges and high waves. Storm erosion involves the movement of sand from the upper beach and dune in the offshore direction. This sand would be returned gradually to the upper beach by wave and wind action over a relatively longer period of time. In cases where the dune is low and overtopped, sand may also be carried landwards.

Where appropriate the erosion distance can be calculated on the basis that a characterised equilibrium beach profile is developed during the cyclone attack and that this profile provides a volume balance between the material eroded from the upper beach/dune and that deposited on the lower zone of the beach slope. The empirical Edelman method as modified by Vellinga, 1983 can be used for this type of calculation. This method predicts an equilibrium profile based on the wave height and grain size of the dune sand.

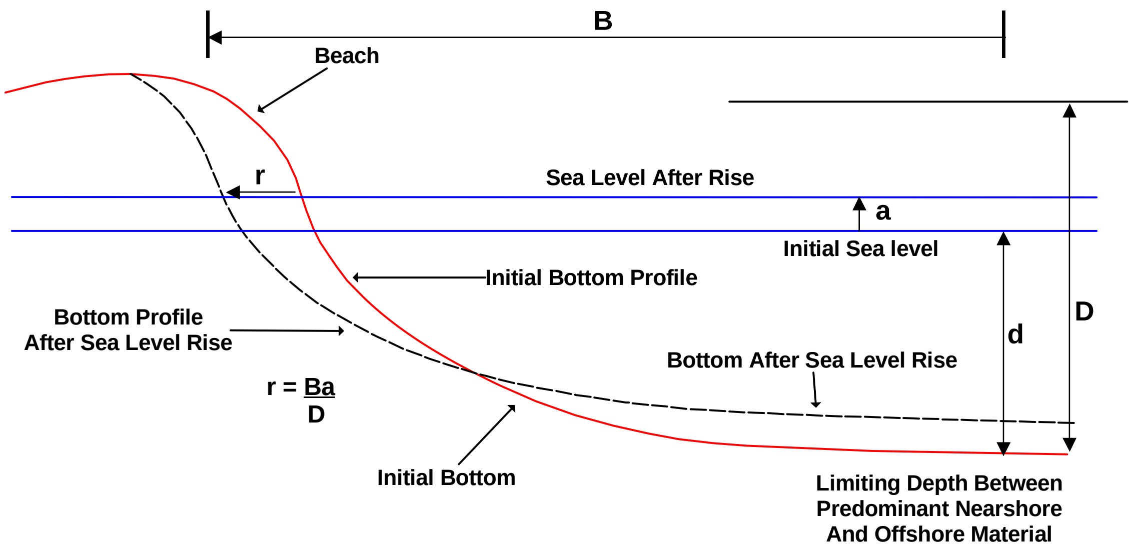
3.4.9.6 Erosion Due to Greenhouse Effect

Provision is required for coastal recession associated with an expected sea level rise due to the Greenhouse Effect (G). It is impossible to state conclusively by how much the sea will rise, and no policy yet exists regarding the appropriate provision which should be made in the design of new coastal developments. However, the Intergovernmental Panel on Climate Change predicts sea level rise using world atmospheric models on a 5 yearly basis. Currently the EPA uses a predicted rise of 0.4m for a 50 year planning timeframe.

In assessing the coastal recession associated with an increase in mean sea level, consideration has been given to the geography of the area, existing beach profiles and sediment characteristics. It is considered that beach ridges are likely to be predominantly wave formed with the coarser particles being moved onshore to the upper beach face/dune and the finer particles remaining in the nearshore zone. This has resulted in beach profiles with two distinct slopes; a steep upper beach face with coarse sand and a flat nearshore zone with fine sand.

The standard method of Per Bruun (refer Figure 3-13) for predicting beach response to sea level rise is based on the upper beach/dune sand eroding and depositing in the nearshore zone to maintain the same depths below mean sea level. This rule is not applicable in north Queensland where the beach sand is sorted as described above. Therefore an alternative assessment using recession at the existing beach slope is also used and a nominal value selected based on the two analyses.

Figure 3-13 Bruun Rule for Shoreline Response to Rising Sea Level



3.4.9.7 Factor of Safety

A factor of safety (F) is included in the assessments of the short term, long term and Greenhouse Effect erosion components to provide for uncertainties and error margins in the calculation procedures. In accordance with current policies, this factor of safety has been set at 40%.

3.4.9.8 Dune Scarp Component

The erosion prone areas are specified as measured from the toe of the frontal dune. The short and long term erosion components provide a measure of the recession of the dune toe. The dune scarp component (D) provides for the horizontal distance between the toe and the crest after slumping to a stable slope (about 1 in 3).

3.4.9.9 Erosion Prone Area Width for Project Site

For the beach between Richters Creek entrance and Yorkeys Knob the then BPA declared an erosion prone area of 40m at the protected northern end of the beach and 70m at the unprotected southern end in 1984. This included a short term erosion component of 25m and a long term rate of nil for the protected northern end and of 0.4m/a for the unprotected southern end. A dune scarp component of 5m was included but not the impact of sea level rise due to the Greenhouse effect.

The more recent assessments (WBM 2005) of the impact of sea level rise have adopted a nominal width of 10m (for a 100 year planning period the predicted 100 year SLR of 0.8m lead to an expected width of 20m). It is considered that all the values adopted in the assessment are still acceptable and adopted an erosion prone area width including Greenhouse effects of 50m for the northern end and 80m for the southern end. Further recent detailed analysis of storm erosion suggests that the short term erosion component is likely to be 30-40m rather than 20-25m. Therefore, a conservative value of 20m has been added to the previous values. The resulting recommended erosion prone area width in metres is:

E = (((50yr x 0.4m/a) + 40m + 10m) x 1.4) + 5m = 103m (adopt 105m)

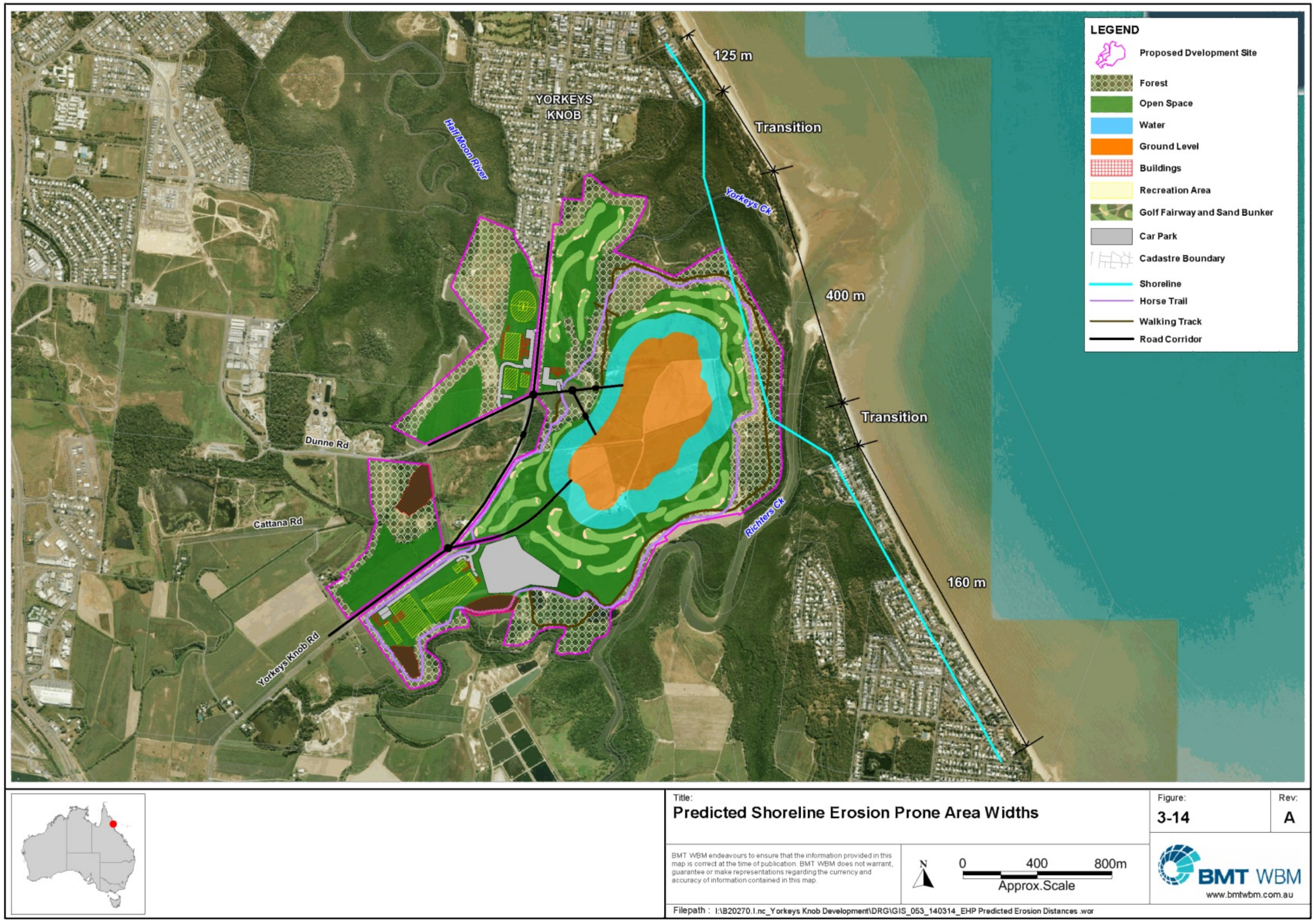
In the area between Yorkeys Creek and Richters Creek a default value of 400m was used by the then BPA in consideration of the likely movement of the entrances to the creeks over time. This is an indication of channel meander widths and is not suggestive of wave erosion processes. The more recent assessments (WBM 2005) considered that this value is still acceptable as no further information is available on likely creek meandering.

South of the Richters Creek entrance the then BPA declared an erosion prone area of 105m in 1984. This included a short term erosion component of 20m, a long term rate of 1.0m/a and a dune scarp component of 5m but has not included the impact of sea level rise due to the Greenhouse effect. It is considered that all the values adopted in the assessment are still acceptable. Recent regional assessments of the impact of sea level rise have adopted a nominal width of 10m (for a 100 year planning period the predicted 100 year SLR of 0.8m lead to an expected width of 20m). Further recent detailed analysis of storm erosion suggests that the short term erosion component is likely to be 30-40m rather than 20-25m. Therefore, a conservative value of 20m has been added to the previous values. The resulting recommended erosion prone area is:

E = (((50yr x 1.0m/a) + 40m + 10m) x 1.4) + 5m = 145m

The shoreline erosion widths are shown in Figure 3-14 below. While the predicted shoreline erosion is within the site boundary, the proposed buildings and infrastructure are just outside.

Figure 3-14 Predicted Shoreline Erosion Prone Area Widths



3.5 Legislation

Development and land management activities in the coastal zone in Queensland are regulated under a number of different Acts, including the *Coastal Protection and Management Act 1995* and the *Sustainable Planning Act 2009*. Under these Acts, different planning instruments apply constraints and/or requirements upon development activities. These instruments include:

- Queensland Coastal Plan (QCP);
- State Development Assessment Provisions (SDAP); and
- Coastal Protection State Planning Regulatory Provisions (SPRP).

Each of these instruments has particular focus for development in the erosion prone area (EPA), storm-tide inundation area (STIA) and coastal management district (CMD), and relate in particular to the coastal hazards of erosion, sea-level rise (SLR) and defined storm tide events (DSTE).

Other coastal matters considered under these instruments include ecological values and ecosystems, and public access. These matters are considered in other AQUIS studies.

3.5.1 Queensland Coastal Plan

3.5.1.1 Legislative Requirement

The QCP is a planning instrument under the *Coastal Protection and Management Act 1995* which guides managers of land and coastal resources within the coastal zone. For the purposes of development assessment, the SDAP and Coastal Protection SPRP are the relevant assessment instruments, as the QCP applies only to management of coastal land.

In relation to the EPA and CMD, the QCP has two relevant policies:

- 2 Buildings and structures in erosion prone areas; and
- 7 Buildings and structures on State coastal land.

The QCP requires buildings and structures in the EPA to be located as landward as possible in a manner that minimises the need for erosion protection works (2.1). If the land is reserved State land, the development needs to be in accordance with the purpose of the reserve (2.2). This will apply for the aspects of the development which do occur on reserved land.

If the land is State coastal land (usually the CMD) there needs to be proof of a public need for the development to support use and enjoyment of the coast (7.1). The development must also complement the local landscape character (7.2). These provisions do not apply to freehold land.

Other policies under the QCP include areas of high ecological significance (HES) (4), indigenous cultural heritage (5) and public access (6). Relevant considerations under these policies include avoiding adverse impacts on areas of HES (but see Coastal Protection SPRP 3.2.4), encouraging Traditional Owners to participate in planning for the management of the coast, and maintaining or enhancing public access except where there was a net public benefit. These policies are further reflected under the Coastal Protection SPRP (see Section 3.5.3.1).

3.5.1.2 *Mitigation Options*

The project infrastructure shown in the IAS concept plans is located approximately 600m landward of the current shoreline and is outside of the calculated shoreline erosion prone area (maximum 400m) and at the western extent of the Holocene accretion zone which is the result of continued accretion over the last 6000 years due to sediment discharge from the Barron River.

The assessment of coastal erosion in this report indicates that the landward location of the proposed development will ensure it has no impact on coastal processes.

3.5.2 State Development Assessment Provisions

3.5.2.1 *Legislative Requirements*

The SDAP represent the collection of planning requirements under all referral jurisdictions that previously existed under the Integrated Development Assessment System (IDAS). It is a planning instrument used by the Single Assessment and Referral Agency (SARA).[1] The SDAP applies when assessing development applications.

Module 10: Coastal protection applies to tidal works and other development in the CMD and coastal zone. This module is based on one overarching purpose: 'to ensure development in coastal areas (1) is managed to protect and conserve environmental, social and economic coastal resources, (2) enhances the resilience of coastal communities to coastal hazards.' This is achieved by either by meeting the acceptable outcomes or performance outcomes of the assessment table, or by meeting the purpose of the module.

Table 3-6 summarises the relevant outcomes for the proposed development. Proposed/potential compliance is discussed below. In summary, the SDAP require development in the EPA and CMD to consider and account for coastal hazards, including by planning for SLR and evacuation during a DSTE. Other concerns are the need to avoid adverse impacts on coastal resources and values, including matters of state environmental significance (MSES),[2] and maintaining public access to the foreshore.

NB – where compliance with the relevant performance outcome or acceptable outcome cannot be established, development may still be approved *as long as it complies with the purpose of the module*.

[1] Department of State Development, Infrastructure and Planning (DSDIP)
[2] MSES are identified under the DSDIP's draft *Matters of National and State Significance: State Planning Policy fact sheet* (http://www.dsdip.qld.gov.au/resources/policy/state-planning/draft-spp-fact-sheet-mnses.pdf)

Table 3-6 SDAP outcomes and suggested compliance

Relevant performance outcome	Relevant acceptable outcome
All development	
PO1 Development in a coastal hazard area[3] is compatible with the level of severity of the coastal hazard.	**AO1.1** Development is located outside a high coastal hazard area[4] unless it is: (1) Coastal-dependent development; (2) Temporary, readily relocatable, or able to be abandoned; (3) Essential community service infrastructure; (4) Small-to-medium tourist development; (5) Development that is compatible with temporary inundation due to its nature or function; or (6) Within an existing built-up urban area, or is redevelopment of build structures that cannot be relocated or abandoned
PO2 Development siting, layout and access in a coastal hazard area responds to a potential coastal hazard and minimises risks to personal safety and property	**AO2.1** Development within a coastal hazard area is located, designed, constructed and operated to maintain or enhance the community's resilience to defined storm tide events and coastal erosion by limiting the exposure of people and structures to coastal hazard impacts and ensuring: (1) Habitable rooms of built structures are located above the DSTE level and any additional freeboard level that would ordinarily apply in a flood prone area under a relevant planning scheme standard; or (2) A safe refuge is available for people within the premises during a DSTE; or (3) At least one evacuation route remains possible for emergency evacuations during a DSTE, including consideration of the capacity of the route to support the evacuation of the entire local population with a reasonable short time frame (for example, 12 hours). AND **AO2.2** Development within a coastal hazard area is located, designed and constructed to ensure exposed structures can sustain flooding from a DSTE

[3] **Coastal hazard area** means a STIA or ERA
[4] **High coastal hazard area** means (1) the part of the EPA that is within the CMD, (2) land that is projected to be permanently inundated due to 0.8m SLR by 2100, or (3) the part of the STIA that is projected to be temporarily inundated to a depth of one metre or more during a DSTE

Relevant performance outcome	Relevant acceptable outcome
PO3 Development directly, indirectly and cumulatively avoids an unacceptable increase in the severity of the coastal hazard, and does not significantly increase the potential for damage on the premises or to other premises	**AO3.1** Development avoids increasing the number of premises from which people would need to be evacuated to prevent death or injury from a DSTE
PO5 Natural processes and the protective function of landforms and vegetation are maintained in coastal hazard areas	**AO5.1** Development in an EPA within the CMD: (1) Maintains vegetation in coastal landforms where its removal or damage may: a. destabilise the area and increase the potential for erosion; or b. interrupt natural sediment trapping processes or dune or land building processes (2) Maintains sediment volumes of dunes and near-shore coastal landforms or where a reduction in sediment volumes cannot be avoided, increased risks to development from coastal erosion are mitigated by location, design, construction and operating standards; (3) Maintains physical coastal processes outside the development footprint for the development, including longshore transport of sediment along the coast; (4) Reduces the risk of shoreline erosion for areas adjacent to the development footprint unless the development is an erosion control structure; and (5) Reduces the risk of shoreline erosion for areas adjacent to the development footprint to the maximum extent feasible in the case of erosion control structures AND **AO5.2** Development in a STIA is located, designed, constructed and operated to: (1) Maintain dune crest heights, or where a reduction in crest heights cannot be avoided, mitigate risks to development from wave overtopping and storm surge inundation; and (2) Maintain or enhance coastal ecosystems and natural features such as mangroves and coastal wetlands, between the development and tidal waters, where the coastal ecosystems and natural features protect or buffer communities and infrastructure from SLR and impacts from storm-tide inundation

Relevant performance outcome	Relevant acceptable outcome
PO6 EPAs in a CMD are maintained as development free buffers, or where permanent buildings or structures exist, coastal erosion risks are avoided or mitigated	**AO6.1** Development locates built structures outside the part of the CMD that is the EOA unless the development is: (1) Coastal-dependent development; (2) Temporary, readily relocatable or able to be abandoned; (3) Essential community service infrastructure; (4) Located landward of an applicable coastal building line; (5) Located landward of the alignment of habitable buildings if there is no coastal building line, and on a lot that is less than 2000m^2 in size; (6) Redevelopment of existing built structures; (7) Coastal protection work; or (8) Located landward of other permanent built structures that are likely to be defended from coastal erosion, if it is demonstrated that development cannot reasonably be located outside the EPA

Relevant performance outcome	Relevant acceptable outcome
PO7 Development avoids or minimises adverse impacts on coastal resources and their values, to the maximum extent reasonable	**AO7.5** Measures are to be incorporated as part of siting and design of the development to protect and retain identified ecological values and underlying ecosystem processes within or adjacent to the development site to the greatest extent practicable. This includes: (1) Maintaining or restoring vegetated buffers between development and coastal waters to the extent practicable, unless the development is within ports or airports, or is marine development; (2) Maintaining or enhancing the connectivity of ecosystems in consideration of the cumulative effect of the development in addition to existing developed areas; and (3) Retaining coastal wetlands, seagrass beds and other locally important feeding, nesting or breeding sites for native wildlife AND **AO7.6** Measures are incorporated as part of siting and design of the development to maintain or enhance water quality to achieve the environmental values and water quality objectives outline in the *Environmental Protection (Water) Policy 2009* AND **AO7.7** Development avoids the disturbance of acid sulphate soils, or where it is demonstrated that this is not possible, the disturbance of acid sulphate soils is carefully managed to minimise and mitigate the adverse effects of the disturbance on coastal resources

Relevant performance outcome	Relevant acceptable outcome
PO9 Development avoids adverse impacts on MSES, or where this is not reasonably possible, impacts are minimised and residual impacts are offset	**AO9.1** Development: (1) Is set back from MSES; (2) Avoids interrupting, interfering or otherwise adversely impact underling natural ecosystem components or processes and interactions that affect or maintain the MSES, such as water quality, hydrology, geomorphology and biological processes; or (3) Incorporates measures as part of its location and design to protect and retain MSES and underlying ecosystem processes within and adjacent to the development site to the greatest extent practicable **AO9.2** An environmental offset is provided for any unavoidable significant residual impact on MSES caused by the development

Relevant performance outcome	Relevant acceptable outcome
PO10 Development maintains or enhances general public access to or along the foreshore, unless this is contrary to the protection of coastal resources or public safety	**A10.1** Development adjacent to state coastal land or tidal water: (1) Demonstrates that restrictions to public access are necessary for: a. the safe and secure operation of development; or b. the maintenance of coastal landforms and coastal habitat; (2) Separates residential, tourist and retail development from tidal water with public access or public access facilities; or (3) Maintains existing public access (including public access infrastructure that has been approved by the local government or relevant authority) through the site to the foreshore for: a. pedestrians, via access points including approved walking tracks, boardwalks and viewing platforms; or b. vehicles, via access points including approved roads or tracks AND **AO10.2** Development adjacent to state coastal land, including land under tidal water: (1) Is located and designed to: a. allow safe and unimpeded access to, over, under or around built structures located on, over or along the foreshore; and b. ensure emergency vehicles can access the area near the development; or (2) Minimises and offsets any loss of access to and along the foreshore within two kilometres of the existing access points, and the access is located and designed to be consistent with (1)(a and (b)

Relevant performance outcome	Relevant acceptable outcome
PO12 Further development of canals, dry land marinas and artificial waterways avoids or minimises adverse impacts on coastal resources and their values, and does not contribute to: (1) Degradation of water quality; (2) An increase in the risk of flooding; or (3) Degradation and loss of MSES (including, but not limited to, coastal wetlands, fish habitat areas and migratory species habitat)	**AO12.1** The design, construction and operation of artificial tidal waterways maintains the tidal prism volume of the natural waterway to which it is connected AND **AO12.2** The design, construction and operation of artificial tidal waterways does not increase the number of premises vulnerable to flooding from a DSTE AND **AO12.3** The location of artificial waterways avoids MSES, or does not result in any significant adverse effect on MSES
Reconfiguring a lot	
PO1 EPAs in a CMD are maintained as development free buffers, or where permanent buildings or structures exist, coastal erosion risks are avoided or mitigated.	**AO1.1** Where reconfiguring a lot is proposed within the CMD, the EPA within the lot, or land within 40m of the foreshore (whichever is greater), is surrendered to the State for public use unless: (1) The development is in a port or is for coastal-dependent development; or (2) The surrender of the land will not enhance coastal management outcomes, for example, because there is already substantial development seaward of the lot

3.5.2.2 Mitigation Options

In general the proposed development siting, outside of the erosion prone area, satisfies many of the legislative requirements. The recognition of inundation potential and elevation of the development above this level minimises risks to personal safety and property. The above aspects have been recognised and incorporated in the mitigation recommendations in the following ways:

- Inundation – it has been recommended that habitable levels and emergency provisions be located above design water levels. The podium level for the development has been set above the probable maximum flood and above extreme storm tide level.
- Shoreline erosion – it has been recommended that the proposed development is located landward of the predicted shoreline erosion. Consideration has also been given to wave protection for seaward facing elements of the development however as this will not occur until extreme water levels (cyclonic storm surge) after the frontal dunes have been overtopped and waves can propagate across the 600m of foreshore seaward of the proposed development it is not considered necessary.

The overarching purpose of these recommendations is to protect occupants during extreme weather events and reduce the likelihood of damage to structures during these events.

Emergency flood and cyclone event management is dealt with in the Flooding Assessments Stage 2 Report Chapter 5.3.

3.5.3 Coastal Protection State Planning Regulatory Provision

3.5.3.1 Legislative Requirements

The Coastal Protection SPRP is also an assessment instrument that applies to development in the CMD. The Coastal Protection SPRP requires developers of land to consider whether or not land within the EPA should be left undeveloped (3.2.1(1)). This would potentially draw upon outcomes identified in the SDAP. For areas within the STIA, the vulnerability of the site and needs for evacuation must also be considered (3.2.1(2)). To the greatest extent practicable, EPAs are to remain undeveloped apart from temporary or relocatable structures for safety and recreational purposes only (3.2.2(1).

The Coastal Protection SPRP also requires the safeguarding of biodiversity (3.2.3(1)). This is primarily achieved through protecting significant wildlife habitats such as beaches important for roosting, nesting and breeding for turtles, birds or crocodiles, and other shorebird feeding and roosting habitat; and by retaining native vegetation, especially riparian vegetation (3.2.3(2)). Development for tourism purposes may disturb areas of high ecological significance (HES) (3.2.4).

No net loss of public access to the foreshore unless it compromises the provision or operation of infrastructure of state economic significance or the protection of coastal resources (3.2.5).

3.5.3.2 Mitigation Options

Significant pre-feasibility design effort has established that the proposed development can be progressed on the site whilst meeting all relevant design standards required in a flood plain and in some proximity to the shoreline.

As noted in regards to the SDAP requirements, the interaction of the development with significant ecological features will be designed to either avoid or offset the loss of these areas. Any loss of public access is likely to be mitigated by economic significance of the development.

4 Opportunities and Constraints

The proposed development is well set back from the coast and is outside the shoreline erosion prone area. As such it is not likely to influence coastal process of longshore and cross-shore sand transport and is not likely to encounter shoreline erosion. Existing adjacent communities will be under severe threat while the proposed development is still several hundreds of metres from the shoreline.

However it will experience elevated water levels during storm events and depth limited wave penetration to the proposed development infrastructure during very extreme events. The proposed development will need to be elevated and protected such that storm event water levels and wave attack do not pose a threat. It should be noted that flood levels will dominate storm tide levels in water level design considerations (refer Flooding Assessments Stage 2 Report) with the podium level proposed to be above the Probable Maximum Flood level at RL- 7.5mAHD.

With regard to river migration it is noted that the development is in a major delta and extreme events can cause significant changes in a short time. However, the available studies have indicated that the major changes in recent times have been in the lower estuary below the Thomatis Creek bifurcation. Concern regarding the stability of the Thomatis Creek bifurcation was such that a major study recommended erosion mitigations options for the site. Some of these options have been implemented and the creek currently appears stable with significant mangrove populations in the lower sections with the exception of one bend adjacent to a farm where riparian vegetation has been lost and bank erosion is occurring.

These elements will need to be catered for in the proposed development by:

- elevating the built environment above extreme water levels;
- including armouring of the built environment against wave and waterway attack for extreme events;
- lodge a sufficient bond to allow Thomatis Creek bifurcation and channel erosion stabilisation works to be undertaken if channel flows increase in the tributary.

5 Description of the Project

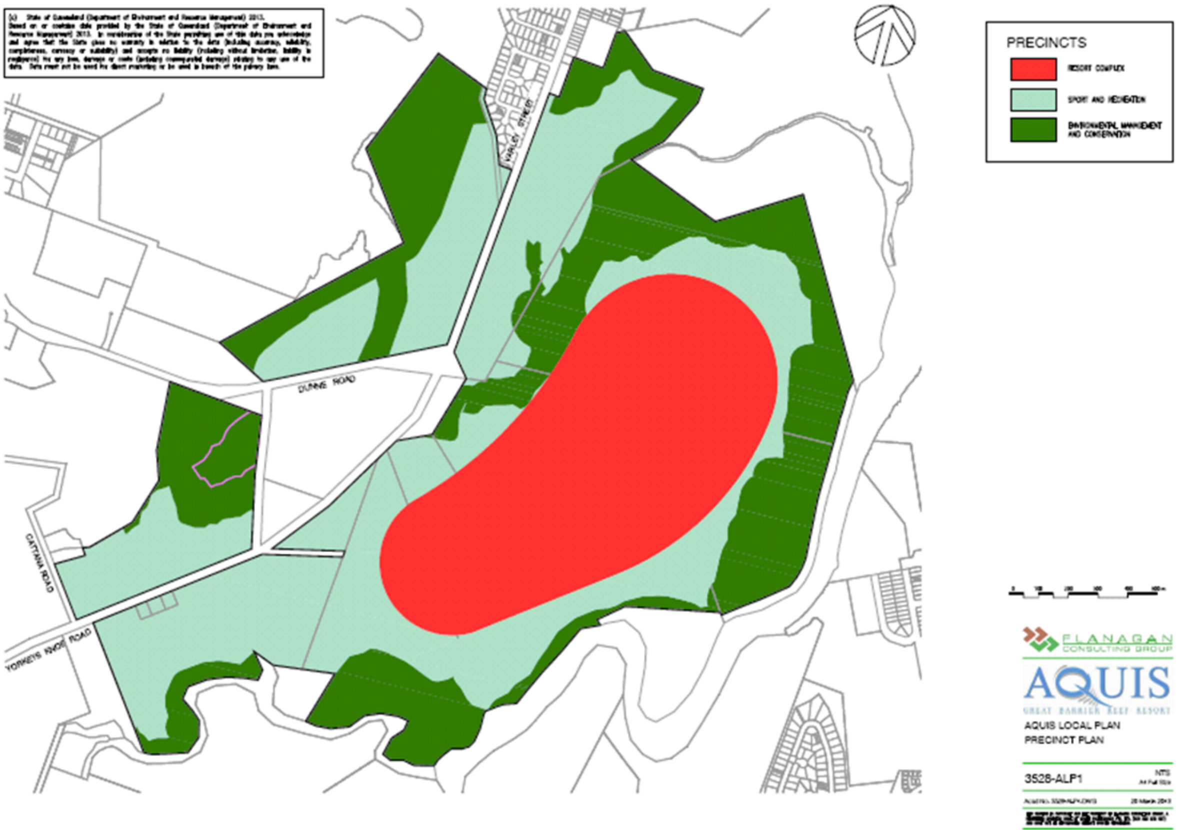
5.1 Precincts

The Aquis Resort includes the following key features, distributed over three precincts:

- Resort Complex precinct (73 ha including 33 ha lake).
- Sports and Recreation precinct (155 ha).
- Environment Conservation and Management precinct (113 ha).

The Precincts are shown on The Aquis Land Use Plan shown below on **Figure 5-1**.The Concept Features Plan (**Figure 5-2**) shows more details of likely features that may occupy the various precincts.

Figure 5-1 AQUIS Local Plan Precinct Plan ALP1



The distribution of land uses within the precincts is shown on the Aquis Local Plan Concept Master Plan ALP 2. **Figure5-2**.

Figure 5-2 AQUIS Local Plan Concept Master Plan ALP-2

Aquis Resort involves an anticipated capital investment of **$8.15 billion AUD** from 2014 to 2024

ELEMENT	NO	GFA (M2)
Hotel rooms/suites configured in 8 towers	7500	625,000
Casinos	2	40,000
Convention and exposition	1	23,000
Theatres	2	5,000
Retail		10,000
Aquarium	1	2,250
Rainforest		2500
Circulation/shared space/back of house/services		350,000
Guest/staff parking	1400	80,000
Landscaping/lagoons/pools/entry water feature		110,000

The aquarium and rainforest are architectural features and not stand-alone uses. The proposal does not include any permanent residential elements.

The resort complex will be constructed over a basement level which will incorporate back-of-house support facilities including:

- kitchens
- staff facilities
- stores
- laundry
- refuse collection
- security
- maintenance facilities
- staff and guest parking facilities

6 Likely Impacts and Management Needs

6.1 Potential Impacts

Chapter 3 details the full range of coastal processes occurring at or near the proposed development. The significance of these in relation to the proposed development is described below.

6.1.1 Storm Tide Inundation

Storm tide inundation levels are generally above the existing natural surface level for events of 0.2% AEP (500 year) or greater. This will cause inundation as well as allowing waves to propagate towards the proposed development. Allowance should be made for this by raising the buildings and facilities above these levels and protecting these assets from wave attack during these extreme events.

6.1.2 Shoreline Erosion

Several assessments of shoreline erosion over a 2% AEP planning period have indicated a maximum landward extent of erosion prone area of 400m. The proposed development should be located clear of this zone. It is noted that significant existing residential development both to the north and south of the proposed development are located closer to the shoreline.

6.1.3 Loss of Sediment Supply due to Barron River Changes

At the present time both the Barron River and Richters Creek are discharging sediment to the littoral system as evidenced by well-formed bars at the entrances and the nourished nature of the beaches north to Yorkeys Knob. It is likely that over time the average annual fluvial sediment discharge load will remain unchanged although the balance between Richters Creek discharge and the Barron River discharge may vary over time.

As discussed earlier sediment has consistently been discharged from the Barron River delta during the Holocene period with the only interruptions to sand supply to the beaches to the north being Barron River entrance changes when new bars have formed (erosive impact) and the connection of Thomatis Creek to the Barron River (re-distribution – neutral overall impact).

Even though the 1939 entrance change reduced sand supply to the beaches immediately north of the entrance for a significant period in anthropogenic terms (approximately 60 years), the impacts from a similar event in the future, where development was threatened, could again be mitigated by terminal structures (e.g. the seawalls at Machans and Holloways beaches) or beach and dune nourishment from old bar sand reserves at Ellie Point. It should be noted that existing residential development would be completely lost before any impact was observed at the proposed development site.

6.2 Management of Coastal Processes

6.2.1 Cyclonic Storm Tide

It is recommended that the appropriate allowances for storm tide inundation from extreme events be incorporated in the design in the following ways:

- Inundation - habitable levels and emergency provisions should be located above design water levels. The design water level will be appropriate to the level of safety required for each infrastructure component e.g. evacuation shelters will be at higher levels that day-to-day accommodation. This is addressed further in consideration of emergency flood and cyclone event management in the Flooding Assessments Stage 2 Report Chapter 5.3.
- Wave exposure – the proposed development is located landward of the predicted maximum shoreline erosion and as such is not at risk from shoreline erosion. Extreme water levels during cyclones may allow waves to propagate across the foreshore seaward of the proposed development and consideration has also been given to wave protection for seaward facing elements of the development. However, as the overtopping of the frontal dunes will not occur until extreme water levels and waves still need to propagate across the 600m of foreshore seaward of the proposed development wave protection is not considered necessary.

6.2.2 Estuary and Shoreline Dynamics

The Barron River has a history of switching channels although the evidence during the Holocene period is that the major change has been near the entrance (BRDI 1981 and MSNBR 1984). During the 1970s there was concern over increasing flows in Thomatis/Richters Creek (then estimated at 35% of Barron River discharge). However, due to some stabilisation works subsequent to the investigations, the entrance to Thomatis Creek has remained stable and mangroves have colonised the area and the banks further downstream (refer Figure 6-1 and Figure 6-2).

Figure 6-1 Thomatis Creek Entrance 2002 (Google Earth)

Figure 6-2 Thomatis Creek Entrance 2011 (Aerial Photo)

If future extreme floods threaten to destabilise the entrance to Thomatis Creek, further stabilisation works could be implemented to constrict flows. The full range of mitigation works recommended in the BRDI report has not yet been implemented.

The ocean entrance to Richters Creek has remained stable during the period 1952 – 2011 (refer Figure 6-3 and Figure 6-4). The stability of the entrance to Thomatis Creek and the current Barron River entrance and bar indicate that the Thomatis/Richters Creek system will remain stable into the future unless extreme unforseen events intervene.

Figure 6-3 Richters Creek Entrance 1952 – 1982 (BPA)

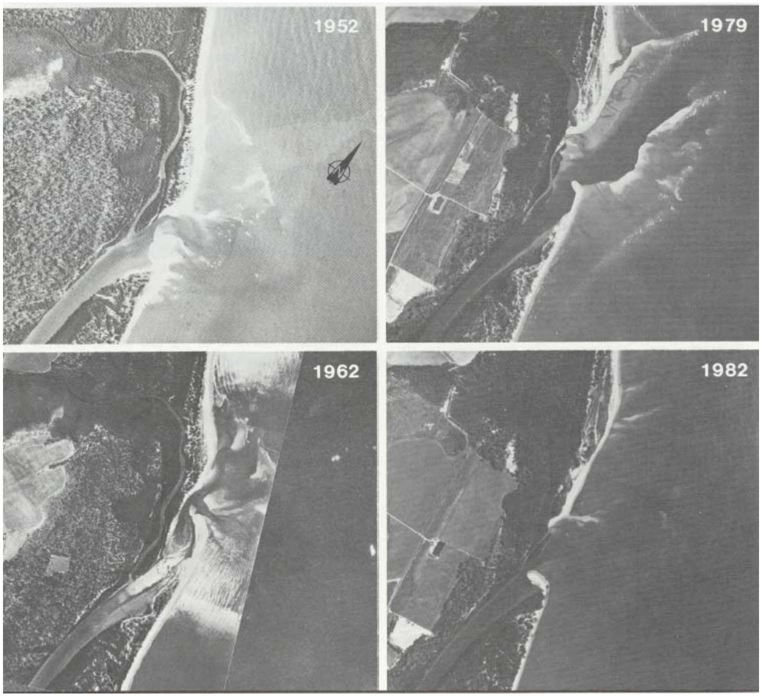


Figure 6-4 Richters Creek Entrance 2011 (Aerial Photo)

6.2.3 Coastal Erosion

The project infrastructure is located approximately 600m landward of the current shoreline and is outside of the calculated shoreline erosion prone area (maximum 400m) and at the western extent of the Holocene accretion zone which is the result of continued accretion over the last 6000 years due to sediment discharge from the Barron River (refer Figure 3-1).

The landward location of the proposed development will ensure it has no impact on coastal processes and is not a threat from shoreline erosion although the loss of frontal dunes may increase wave penetration during cyclones. Any future shoreline recession in the area between Holloways Beach and Yorkeys Knob will impact on the existing residential areas such that mitigating actions will need to be taken to protect these communities well before any threat is experienced by the proposed development.

6.2.4 Extreme Event Erosion and Waves

The existing natural surface profile in front of the project site is variable with a general elevation of about 2.5m AHD. It is assumed that the site itself will be filled to this level before landscaping.

At this level, a 0.2% AEP (500 year) storm tide alone (2.50mAHD) will begin to inundate the site across the frontal dunes as well as by earlier penetration into the creeks. This storm tide level is expected to be associated with offshore wave conditions in the order of 3.5m Hs. The extreme elevated water level, assuming run-up will occur, is expected to be 3.75mAHD at present or 3.91mAHD in 2100. Under a cyclonic event lasting several hours these waves are expected to cause significant damage or complete erosion of the frontal dunes allowing depth limited waves will begin to propagate across the foreshore and dunal area towards the site.

At 0.01% AEP storm tide level (3.44m AHD) inundation and some depth limited wave action are expected to extend across the foreshore and dunal area to the proposed building and infrastructure. It is unlikely that wave set up or run up will occur in this scenario and wave energy will be significantly dissipated by natural surface roughness and turbulence. The design of these elements may require consideration of armouring against wave attack at final design stage. The sizing of any armour will be dependent on the details of infrastructure and the design return period used

6.2.5 Emergency Event Management

This is addressed in detail in terms of combined flood and cyclone event emergency management in the Flooding Assessment Stage 2 Report Chapter 5.3.

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8 Qualifications

This report has been prepared using available information within the allocated time to demonstrate that the proposed development can be feasibly built and operated within a coastal management district where the major constraint is storm tide level and associated wave action in extreme events. The proposed development is well set back from the shoreline resulting in a low risk of environmental harm or environmental nuisance in relation to coastal protection works.

Whilst previous (1980s) and recent (2000s) studies have provided detailed and reliable information to assist in the assessments, more detailed work will be required to allow refinement of the development in subsequent stages of investigation. Chapter 6 of this report describes additional elements of refinement required.

The accuracy of this report is therefore limited to the exactness of the information used in the creation of the report.

9 Acronyms

AEP – Annual Exceedance Probability

AHD – Australian Height Datum

BPA – Beach Protection Authority

BRDI – Barron River Delta Investigation

CMD – Coastal management District

DEHP – Queensland Department of Heritage and Protection

DSTE – Design Storm Tide Event

EPA – Queensland Environmental Protection Agency

EPA – erosion prone area

HAT – Highest Astronomical Tide

HES – high environmental significance

Hs – Significant Wave height

IAS – Impact Assessment Statement

IDAS - Integrated Development Assessment System

MSNBR – Mulgrave Shire Northern Beaches Report

QCP – Queensland Coastal Plan

SDAP – Queensland State Development Assessment Provisions

SPRP – Queensland Coastal Protection State Planning Regulatory Provisions

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