AQUIS RESORT AT THE GREAT BARRIER REEF PTY LTD

ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1

CHAPTER 8

COASTAL PROCESSES

8. COASTAL PROCESSES

8.1 ELEVATED SEA LEVELS

8.1.1 Existing Situation

a) Tidal planes

The astronomical tidal planes published in the official Maritime Safety Queensland Tide Tables 2013 for Cairns are given in **Table 8-1** below. The main importance of the tidal planes is the contribution that normal tides make to the overall combined elevated water levels during cyclonic storms as discussed later in this section.

TABLE 8-1 TIDAL PLANES AT CAIRNS

TIDAL PLANES	QLD TIDES 2013 (TO AHD) M
Highest Astronomical Tide (HAT)	1.86
Mean High Water Spring (MHWS)	0.98
Mean High Water Neap (MHWN)	0.40
Mean Sea Level (MSL)	0.16
Mean Low Water Neap (MLWN)	-0.18
Mean Low Water Spring (MLWS)	-0.76
Lowest Astronomical Tide (LAT	-1.64

Source: **Appendix L** (Table 3-1).

These are current tidal planes. An allowance for sea level rise (SLR) associated with climate change as adopted by EHP has been made (refer **Section 3.6.6**):

- 0.4 m for 2060 (50 years)
- 0.8 m for 2100 (100 years).

b) Cyclone-induced Water Levels

Tropical cyclones pose a considerable threat to the Cairns region, with a cyclone affecting the region on average once every two years. One of the main effects of a cyclone is elevated water level arising from storm surge and other effects.

<u>Components of Elevated Water Levels</u>

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 this surge and astronomical tide and its assessment takes into account the random nature of surge and tide combinations. This combined level can be considered as the 'still' water level during a cyclonic event.

As a cyclone approaches land, the waves caused by the associated winds supplement this 'still' water level and produce an increase in water level at the shoreline. These increases are due to 'wave effects' and include wave setup and wave runup – for these to occur requires that a shoreline exists at the elevated 'still' water level. When these waves break at the shoreline, momentum carries the water up the beach. This is called wave runup. Therefore, the ultimate water level experienced during a cyclone will include the tide at the time, surge (wind setup and pressure effects) and the wave effects (wave setup and runup).

Areas of land sufficiently remote from the predicted limit of maximum shoreline erosion will be protected from direct wave attack. The major effect behind the dunes therefore is the elevated water level.

The combined water level arising from a cyclone is a result of the following factors:

- astronomical tide at the time (e.g. low, high, incoming, outgoing)
- storm surge (the increase in sea level due to low air pressure associated with a cyclone)
- wave setup (the increase is sea level due to cyclonic winds creating larger waves)
- wave runup (the increase in sea level due to waves breaking on a sloping shore as long as such a shore exists).

The term 'storm tide' is used quite loosely in disaster management literature and is usually taken to refer to the combined effect of all of the above components (rather than just the first two, which is technically correct).

Storm tide modelling involves generating a statistically significant number of random storm surge and tide combinations based on methodologies developed by James Cook University and the Australian Bureau of Meteorology. All storm tide studies in Queensland are required to adhere to a manual based on this methodology.

Probability of Occurrence

The probability of occurrence of an event (e.g. cyclone, flood, earthquake, tsunami) is expressed in terms of one or both of the following:

- **Average Recurrence Interval (ARI)** – the annual period between events of the specified magnitude, expressed in years (i.e. 100 year or 1000 year ARI).
- **Annual Exceedance Probability (AEP)** – the probability that events of the specified magnitude occur in one year, expressed as a percent (i.e. 1% AEP or 0.1% AEP). This is the preferred terminology.

These are related concepts in that ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP (i.e. 100 year ARI = 0.1% AEP). Note that the old approach of referring to probability as, for example, the '1 in 100 year flood', while being statistically identical to 100 year ARI, is no longer in official usage as it implies that rare events are in some way separated by fixed periods of time. The preferred terminology is AEP.

Storm Tide Levels

BMT WBM completed a storm tide study for the Cairns Region in 2013 (unpublished – held by CRC) 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 8-2 shows the peak storm tide at three northern beached locations including the Aquis Resort site.

TABLE 8-2 PEAK STORM TIDE AT THE AQUIS RESORT SITE (SURGE PLUS TIDE ONLY)

LOCATION / AEP	PEAK STORM TIDE LEVEL (m AHD)				
	1%	0.5%	0.2%	0.1%	0.01%
Cairns North	1.99	2.24	2.65	3.02	4.11
Trinity Beach	1.86	2.06	2.37	2.63	3.19
Aquis Resort site (Location 164)	1.95	2.17	2.50	2.75	3.44

Source: **Appendix L** (Table 3-2).

Modelling of cyclone-induced water level has been undertaken and this reveals that the peak level for a cyclone with an AEP of 1% (equivalent to an ARI of 100 years) is 3.11 m AHD and for an AEP of 0.01% (equivalent to an ARI of 10,000 years) is 4.69 m AHD. When a projected 0.8 m SLR predicted for the year 2100 is included, the levels above would rise to 3.91 and 5.49 m AHD respectively.

Peak Water Levels

The final level that seawater will reach will include all of the components described (surge + tide + setup + runup). **Table 8-3** shows this final level for modelled locations, combining storm tide and wind and wave effects. The final row in this table adds in the effect of predicted sea level rise to the year 2100.

TABLE 8-3 PEAK WATER LEVEL AT THE AQUIS RESORT SITE INCLUDING WAVE EFFECTS

LOCATION / AEP	PEAK STORM TIDE LEVEL INCLUDING WAVE SETUP AND WAVE RUNUP (m AHD)				
	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) – predicted sea level with no SLR	3.11	3.38	3.75	3.99	4.69
Study Site (Location 164) – predicted sea level + SLR to 2100 (0.8 m)	3.91	4.18	4.55	4.79	5.49

Source: **Appendix L** (based on Table 3-3 plus sea level rise).

Existing levels across the site typically vary from less than 1 m AHD to 5 m AHD but are generally between about 1 m and 3 m AHD. This means that for a 1% AEP event and 0.8 m SLR, the site as it is currently would be flooded to a depth of between 1 m and 3 m (not allowing for attenuation of the surge).

Further discussion of cyclone-induced water levels is included in **Chapter 12** (Hazards) where the results of flooding (**Chapter 9**) are included to determine appropriate design water levels.

The levels described above are those experienced at the coast. It is a very complex task to propagate storm tide effects inland and the conventional response is to assign a hazard rating based on ground level and the storm tide level at the coast. In Cairns, CRC has published a Storm Tide Evacuation Guide (CRC no date) for residents to follow in the event of a cyclone. It provides maps that show predicted flooding associated with a cyclone. An extract is included in **Figure 8-1**.

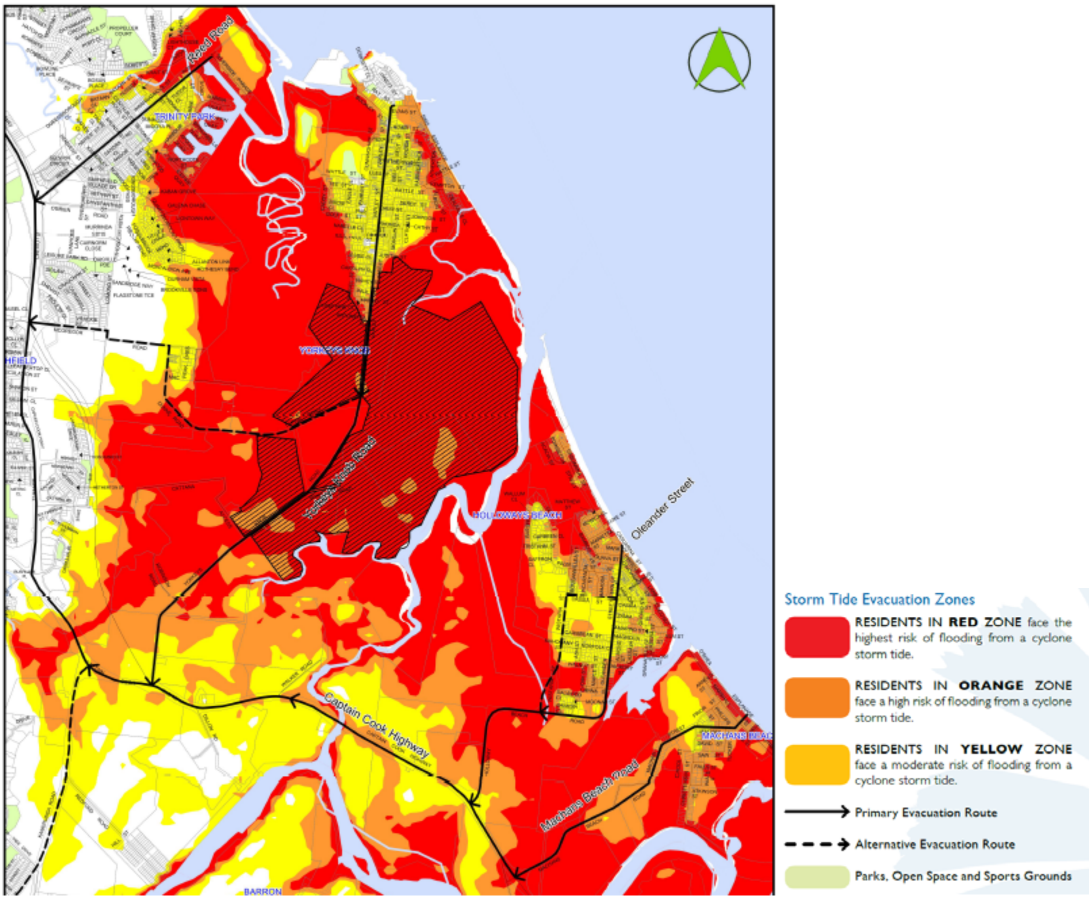

Figure 8-1 Storm tide evacuation zones.

Source: CRC (n.d.) Storm Tide Evacuation Guide.

Figure 8-1shows that the site is considered to have the highest risk of storm tide inundation. Such mapping is used for hazard response (see **Chapter 12** – Hazards) and provides little advice on design.

Table 8-2 shows that a 0.01% AEP event (10,000 year ARI) at the Aquis Resort site has a predicted a storm tide level of 3.44 m AHD while **Table 8-3** reveals that this level rises to 4.69 m AHD when wave setup and wave runup are added. Because of the existence of the dune in the area at an elevation of between 3.0 m and 3.5 m AHD, there will not be 'wave effects' from such an event as the absence of a beach at a high enough level to sustain wave runup means that this effect will be absent and the likely maximum elevated water level will be between these values. The adopted level of 4.69 m AHD is considered to be conservative.

Existing topography for the site (2012 LiDAR) shows that the natural surface profile north of the site is variable, with a general elevation of about 2.0 m to 2.5 m AHD and inconsistent narrow dune elevations of between 3.0 m and 3.5 m AHD at the shoreline. Wave effects during a cyclonic storm surge (setup and runup) will only occur when the storm tide level (surge + tide) is below the dune crest level (between 3.0 m and 3.5 m AHD).

The 1% storm tide level (tide + surge only) for the site is predicted to be 1.95 m AHD (which is below dune height), with the 1% storm tide plus wave effects (including wave setup and runup) predicted to be 3.22 m AHD.

The inclusion of the predicted year 2100 SLR of 0.8 m will elevate these levels to 2.75 m and 3.91 m AHD respectively, meaning that the site will be inundated at that time (natural surface level between 2.0 m and 2.5 m AHD). These levels indicate that while wave setup and runup will occur today, if sea level rise is realised then at some point the dunes will be inundated without setup or runup. This is not a critical constraint for the site as inundation will occur via Richters Creek when the storm tide level reaches top of bank levels (about 2.5 m AHD).

Under an extreme event of 0.01% AEP with a storm tide level of 3.44 m AHD, the dunes will be inundated and consequently, no wave setup and runup is expected. However, depth-limited waves are then expected to extend across the foreshore and dunal area towards the site.

c) Tsunami

Off-shore earthquakes have the potential to generate tsunamis, as do underwater volcanos and landslides. The amplitude of the wave / s depends on the amount of displacement in the water column caused by the triggering event, the off-shore bathymetry, and gradient of the shoreline. According to the BoM, tsunamis are recorded in Australia about once every two years.

The CRC has published a *Cairns Tsunami Evacuation Guide* for residents in the Cairns area (CRC 2007). The information guide provides a map showing the 6 m AHD contour and advises that once a tsunami warning is given, residents are to move to higher ground above the 6 m AHD contour.

Based on information provided by Geoscience Australia (Granger et al. 1999), the 0.02% AEP wave height in 100 m of water depth outside of the Great Barrier Reef is 1.2 m. Although hazard maps produced by Geosciences Australia 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, they cannot be used directly to infer:

- how far a tsunami will inundate on-shore (inundation extent)
- how high above sea level they will reach on land (runup)
- the extent of damage or
- any other on-shore phenomena.

To estimate the on-shore tsunami impact, detailed bathymetry and topography of the specific region concerned is required for input to a detailed inundation model. However, in the absence of such data, the catalog of tsunami events can be used by emergency managers, researchers and individuals to develop detailed inundation models at any on-shore location.

Recent modelling to propagate this 1.2 m wave through the reef and lagoon carried out by DSITIA (Boswood 2013) shows an amplification factor of 0.2 – 0.5 for near-shore areas in the Cairns region (see **Figure 8-2**). This means that the 1.2 m tsunami wave height outside the reef could be about 0.2 m to 0. 6 m in the near-shore zone near the site.

The study notes that:

> These conclusions are based on amplification factors at the 10 m depth contour based on closed land boundaries. They do not take into consideration the height of coastal dunes or the shoaling nature of the tsunami shoreward of this depth. Cross-sections extracted from the model runs suggest there could be substantial further shoaling and amplification of the tsunami as it continues to propagate to the coast. It is also possible that an amplification factor of less than 1 may still produce a tsunami that may cause inundation for north Queensland communities. Detailed inundation modelling would be required to assess the full risk for coastal communities.

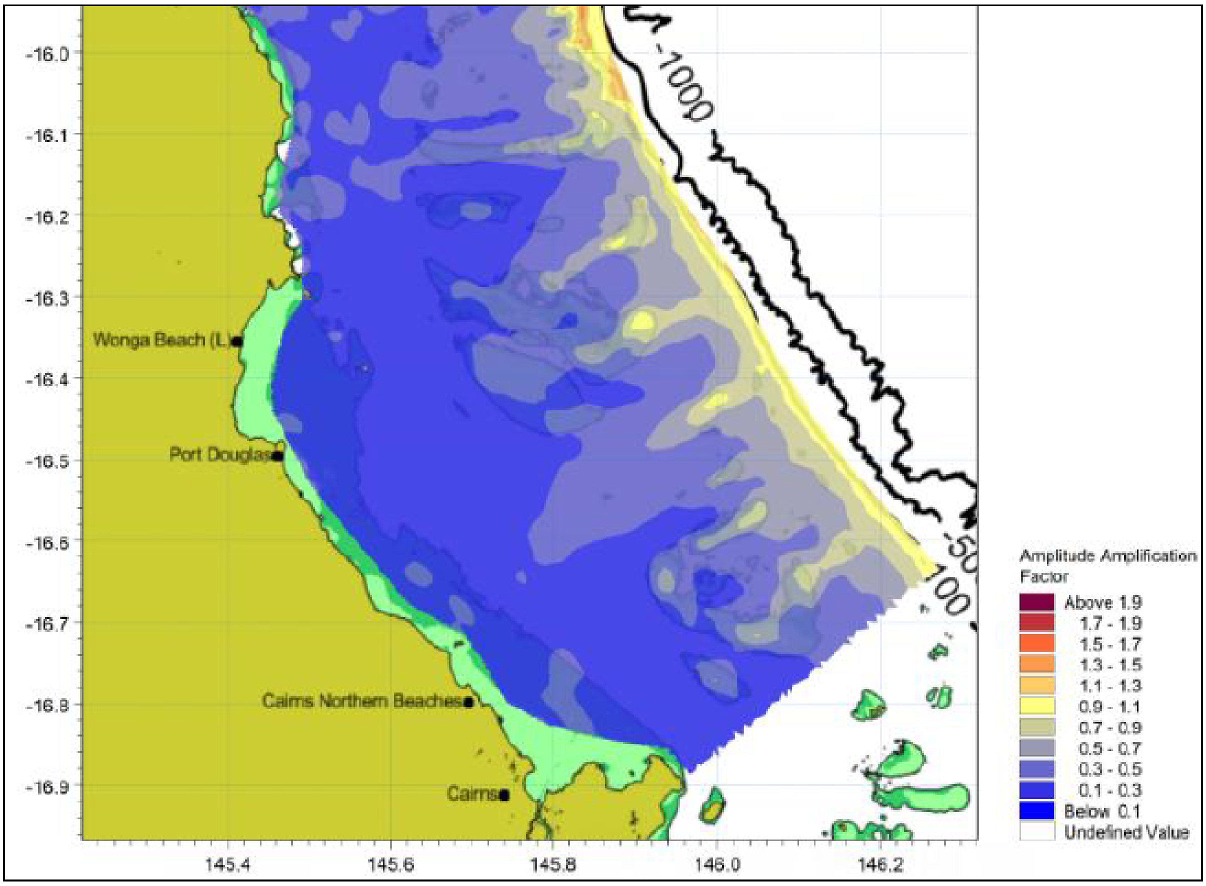

Figure 8-2 Tsunami amplification in reef lagoon (DSITIA modelling).

Source: Boswood (2013).

Considering the above DSITIA modelling and the possible reduced tsunami wave height of 0.2 to 0.6m at the -10 m contour, it is unlikely that a tsunami will shoal significantly as it propagates to the shore. Additional detailed shoreward propagation and inundation modelling would be required to further assess safe refuge heights for coastal communities in the Yorkeys Knob region. However, it is considered that the selection of the +6 m AHD contour by the CRC is a conservative estimate of a safe zone. Further discussion on the response to the hazard of tsunamis is included in **Chapter 12** (Hazards).

8.1.2 Impacts

The development of the project concept design has been based on the following:

- All habitable structures (i.e. in the Resort Complex Precinct) to be designed in accordance with the following combined water level scenarios (as recommended in **Appendix J** – to be considered along with flooding levels and tsunami estimates to determine a 'design envelope').
  - AEP = 1%: level of floors of habitable rooms (3.91 m AHD including 0.8 m SLR)
  - AEP = 0.01%: structural design of habitable structures and provision of safe refuge (5.49 m AHD including 0.8 m SLR).

- The hazard assessment (**Chapter 12**) concludes that a 'shelter in place' approach is appropriate, requiring:
  - safe refuge above the specified water level (**Chapter 9** – Flooding concludes that the minimum level is determined by flooding which produces higher water levels than storm tide or tsunami)
  - structural integrity for safe refuge areas and other emergency equipment in the event of all hazards.

Structures will need to be designed for the loads induced by these events and a range of emergency response measures will be required to be in place. These are outlined in the Integrated Emergency Management Plan (**Section 12.5.2a)**).

The design response to cyclone-induced / tsunami water levels (and flooding) involves filling the Resort Complex Precinct to well above the surrounding ground level. As described in detail in **Chapter 9** (Flooding), this requires the creation of the lake as a flood mitigation solution. The modelling used to assess flooding includes an allowance for elevated tailwater created by storm tide and therefore the two effects are considered.

<u>Cyclone-induced Water Levels</u>

In terms of cyclones and other coastal processes that come from the ocean and propagate inland, the Aquis Resort development is 'downstream' of existing coastal development at Holloways Beach and Yorkeys Knob. Therefore, during cyclonic events these communities will be impacted before the resort.

As **Figure 8-3** shows, the plan extent of a cyclonic surge event is large, such that any blockage caused by the Aquis Resort will be insignificant.

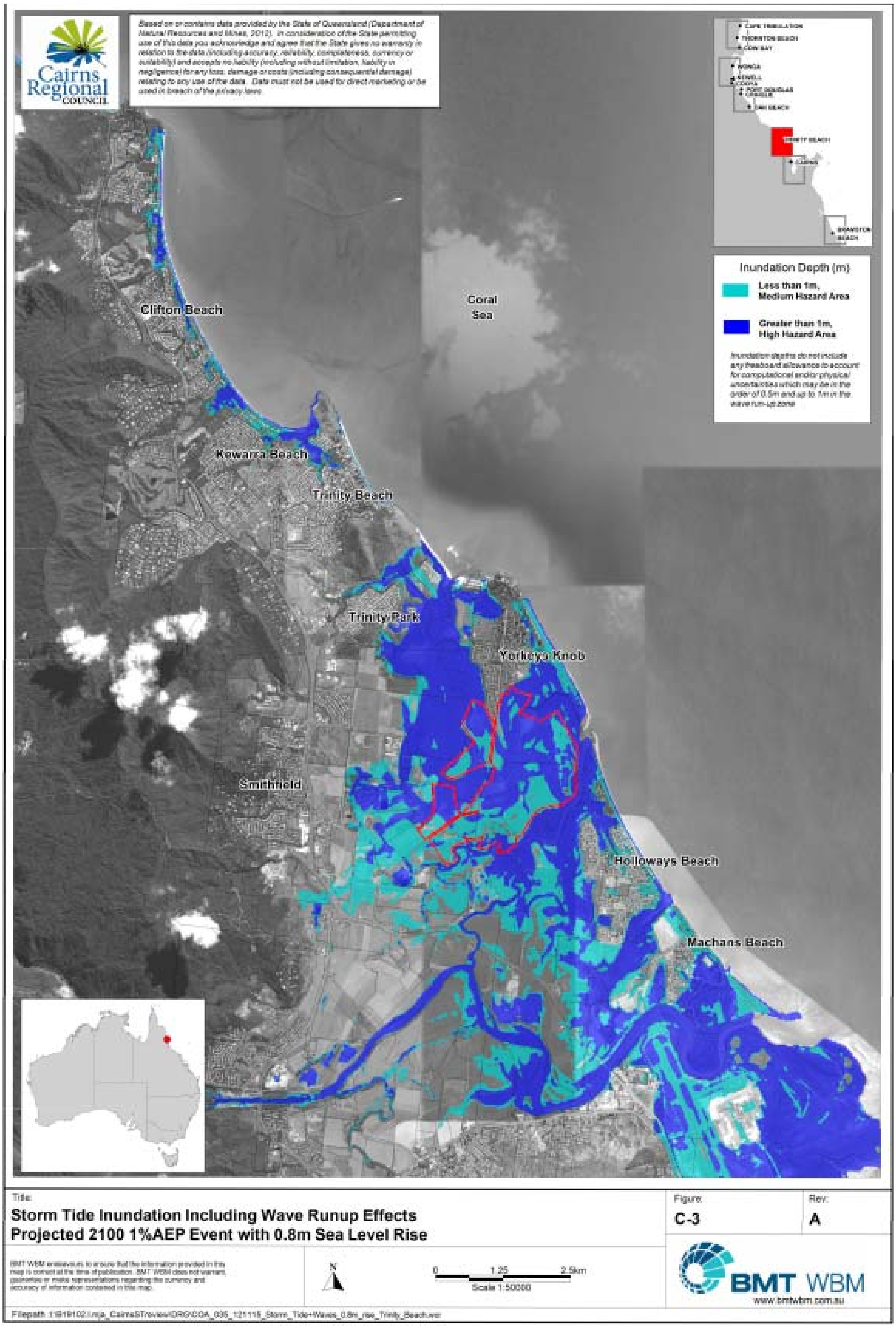

Figure 8-3 Storm tide inundation for a 1% AEP storm tide plus wave run up plus 0.8 m SLR.
Source: BMT WBM (M Andrews pers. comm. 9 December 2013).

The resort has been designed to 'pass' significantly greater flows of water during flood events without afflux, albeit in the reverse direction. The intention of hydrodynamic modelling of storm tide inundation is to establish depth versus velocity relationships to allow assessment of structural damage to buildings. In this case the ground levels of the development are designed to be above the 1% AEP flood level. This is substantially higher than an equivalent storm tide level and, as such, there is no potential for damage.

The effect of the development on storm tide beyond the site would be negligible, as the main mechanism for storm tide penetration is via Richters Creek in the area of the site, and this remains unchanged due to the development. In addition, storm tide at Holloways Beach arises directly from Trinity Bay and crosses the frontal dune which is 'upstream' of the Aquis Resort.

In summary, the adjacent communities will be impacted by ocean effects before Aquis Resort and, as such, will not be influenced by the proposed development. Because the resort is not expected to be impacted by storm surge and will have no impact on adjacent communities during storm tide events, storm tide propagation modelling has not been carried out.

The existing natural surface profile in front of the project site is variable with a general elevation of about 2.5 m AHD (varies from 1m AHD to 3 m AHD).

At this level, a 0.2% AEP storm tide alone (2.50 m AHD) 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 off-shore waves with a significant height in the order of 3.5 m. The extreme elevated water level, assuming run-up will occur, is expected to be 3.75 m AHD at present or 3.91 m AHD in the year 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 to propagate across the foreshore and dunal area towards the site.

At 0.01% AEP storm tide level (3.44 m AHD), inundation and some depth-limited wave action are expected to extend across the foreshore and dunal area and inundate the lake. It is unlikely that wave setup or runup will occur in this scenario. The design of the inner lake edge will therefore require armouring against wave attack. The sizing or detail of this armour will be dependent on the details of infrastructure and the design return period used.

The proposed design measures are strictly internal and will not have any adverse impact on surrounding areas.

Tsunami

Similar to storm tide inundation, tsunami inundation from the ocean will be such that Aquis Resort is 'downstream' of existing coastal development at Holloways Beach and Yorkeys Knob. As for storm tide, flood flows are significantly greater than those arising from a tsunami and it is not expected that the proposed development will have any impact on adjacent communities during tsunami events.

8.1.3 Mitigation and Management

The major mitigation of elevated water levels is design-related and involves the elevation of the Resort Complex Precinct above the identified hazard level and the construction of the lake to mitigate afflux. A 'shelter in place' strategy in adequately-designed structures will ensure the safety of guests and staff during a cyclone and other similar natural emergencies.

The raising of Yorkeys Knob Road (see **Chapter 9** – Flooding) will provide a higher level of immunity for access after the event has passed and the Integrated Emergency Management Plan (see **Chapter 12** – Hazards) will provide the desired management response.

At this stage it is not considered that any further mitigation is required, although this will be addressed during detailed design.

8.1.4 Residual Impacts

It is considered that the design levels adopted provided for the Resort Complex Precinct are adequate to provide a very high level of safety in the event of extreme water levels. At 7.5 m AHD, this level:

- provides 2 m freeboard to the 0.01% AEP storm tide (allowing for 0.8 m sea level rise)
- is also well above the 6 m AHD refuge level set by CRC for tsunami
- provides adequate allowance to any conceivable extreme coastal event, even with sea level rise.

Structures will need to be designed for the loads induced by these events to guarantee the effectiveness of the adopted 'shelter in place' strategy and a range of emergency response measures will be required to be in place via the Integrated Emergency Management Plan.

The Aquis Resort response to this hazard will not have any adverse impact on the surrounding area.

8.2 COASTAL EROSION

8.2.1 Existing Situation

All of the sites other than Lot 2 RP745120 are within a Coastal Management District (CMD). Refer **Figure 3-4**. Hazards associated with locating buildings and structures within the coastal zone are well known and have been investigated in detail in **Appendix K** and **Appendix L**.

It is known from a number of studies that the Barron River has a history of switching channels and exhibiting other characteristics of a mobile delta. According to the Barron River Delta Investigation (Department of Harbours and Marine 1981) and the Mulgrave Shire Northern Beaches Report (Beach Protection Authority 1984), the evidence during the Holocene period (i.e. over the last 6,000 years) is that the major change has been near the river's entrance.

a) Historical Changes

The most recent change occurred in 1939 when the river formed a new entrance in its current location at Ellie Point near the airport (see **Figure 8-4**). 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 accreted to build the bar system at the new entrance.

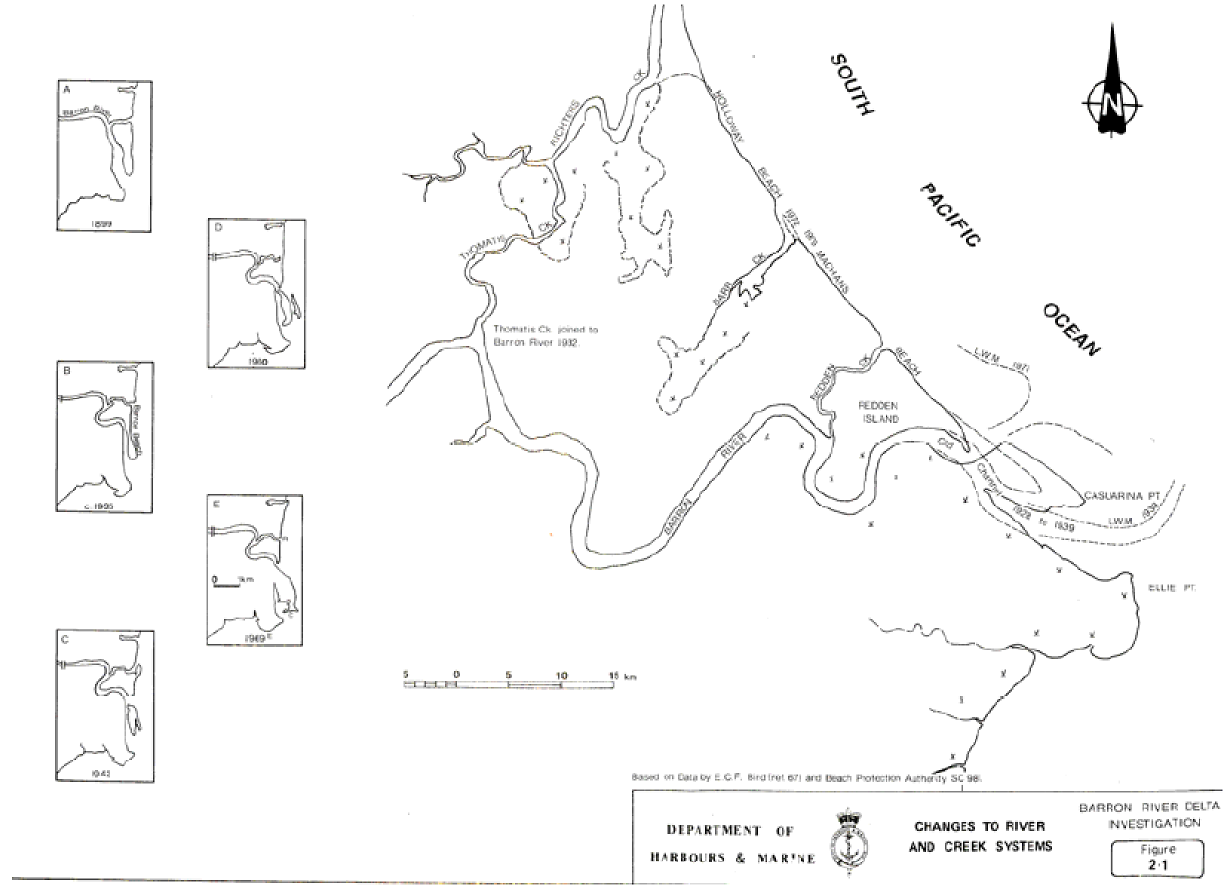

Figure 8-4 Historic changes to the mouth of the Barron River.

Source: Department of Harbours and Marine (1981).

Historic aerial photographs from the Mulgrave Shire Northern Beaches report (Beach Protection Authority 1984) reveal that the mouth of Richters Creek is also mobile as shown on as shown on **Figure 8-5** below.

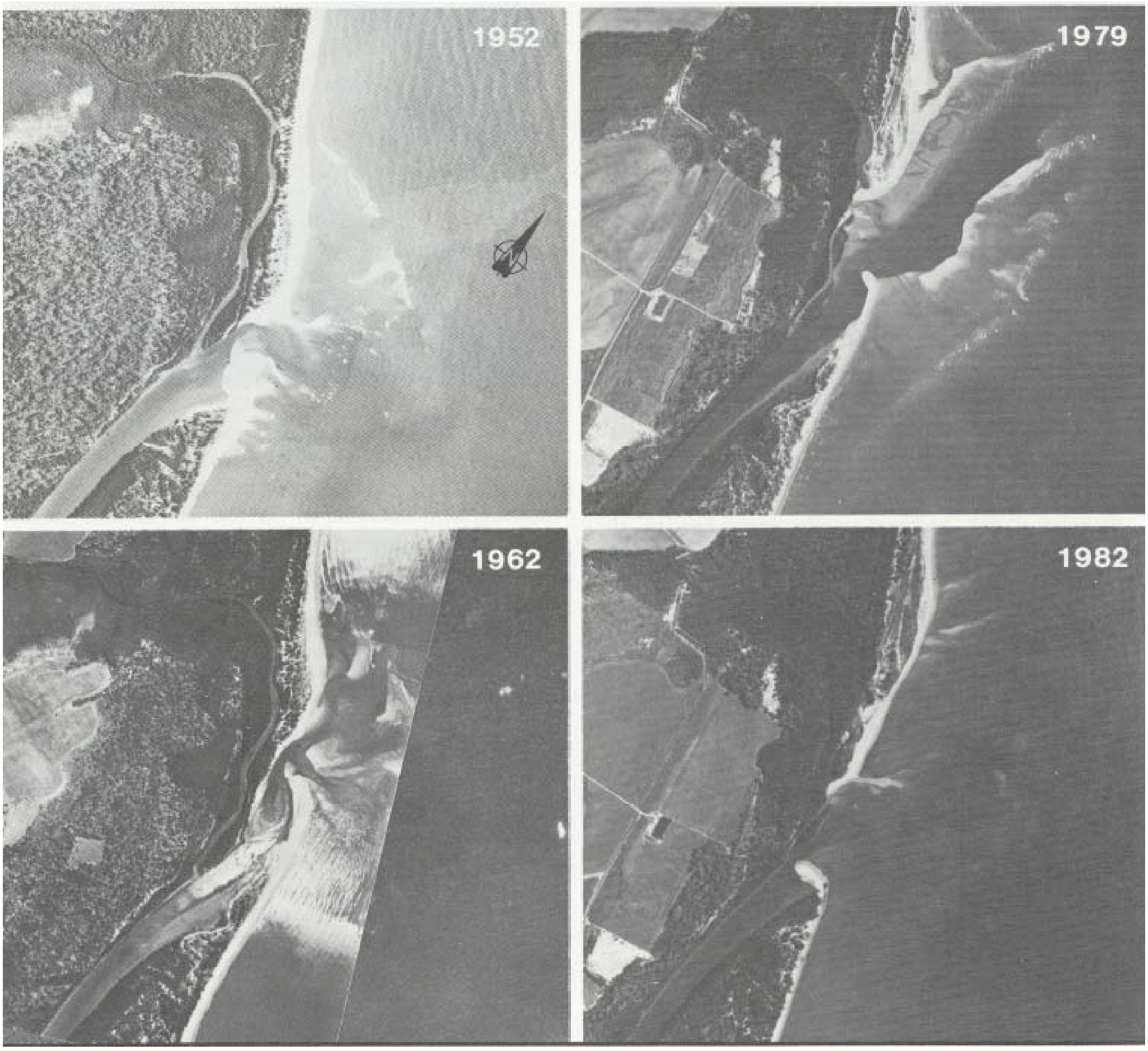

Figure 8-5 Historic aerial photos showing changes to the mouth of Richters Creek.

Source: Beach Protection Authority (1984) – included in **Appendix L** as Figure 6-3.

These photos reveal that the mouth of Richters Creek has periodically moved and sometimes become quite restricted at times.

According to WBM (2005), as the bar was developing following changes in the distribution of flow in the Barron River at this time, Yorkeys Knob Beach was starved of sand supply and this lead to the historical erosion. It appears that the bar at Richters Creek has now filled to a natural level and currently releases sand to the beach system and longshore transport carries this to the north. This sand has effectively replenished Yorkeys Knob Beach and consequently it is currently in a well-nourished state with the groyne holding a significant quantity of sand.

Photo 8-1 Yorkeys Beach in 2005 showing substantial accretion.

Source: WBM (2005).

An inspection of aerial photography over the last decade or more shows increasing amounts of sand in the coastal zone (as shown on **Figure 8-5** extracted from WBM (2005) and included in **Appendix L**) and hence lead to the conclusion that the storm bite will move progressively seaward i.e. away from the site over time. It should be noted that the 'storm bite' shown below takes into account the foredune profile from the 2012 LiDAR data and also SLR to the year 2100 of 0.8 m.

b) EHP Erosion Prone Areas

Erosion prone areas have been declared under the *Coastal Protection and Management Act 1995* (Qld) (CPM Act) over land adjacent to all tidal water in Queensland. These areas include three components as described below:

- extent of current HAT + 40 m (plan offset)
- calculated shoreline erosion based a formula developed by EHP
- HAT + 0.8m to take into account future SLR to the year 2100.

These extents have been mapped by EHP (refer **Figure 8-6** and **Figure 8-7**).

Shoreline 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 SLR associated with the climate change. 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 site lies within the HAT + 0.8m (2.66 m AHD) contour but is generally outside the shoreline erosion prone area which just covers the eastern boundary (refer to **Figure 8-7**).

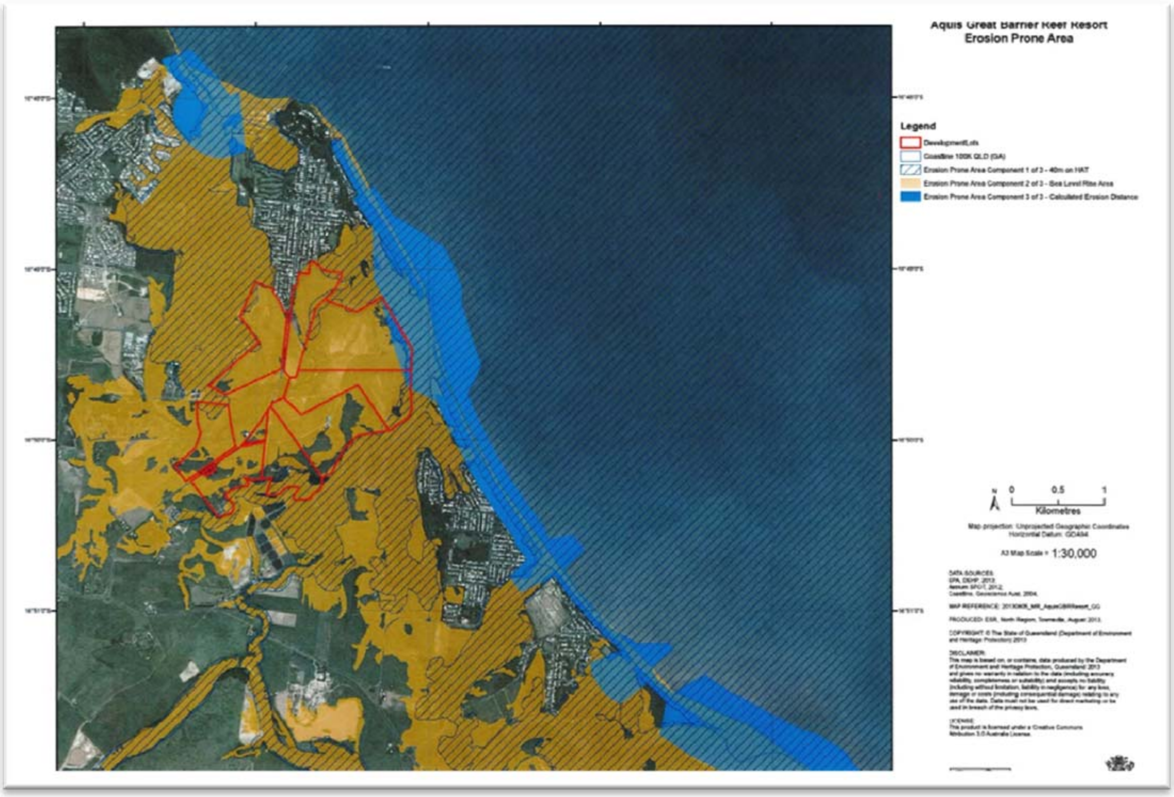

Figure 8-6 Extract from EHP's declared erosion prone area for Cairns Regional LGA.

Source: Appendix L (Figure 3-13).

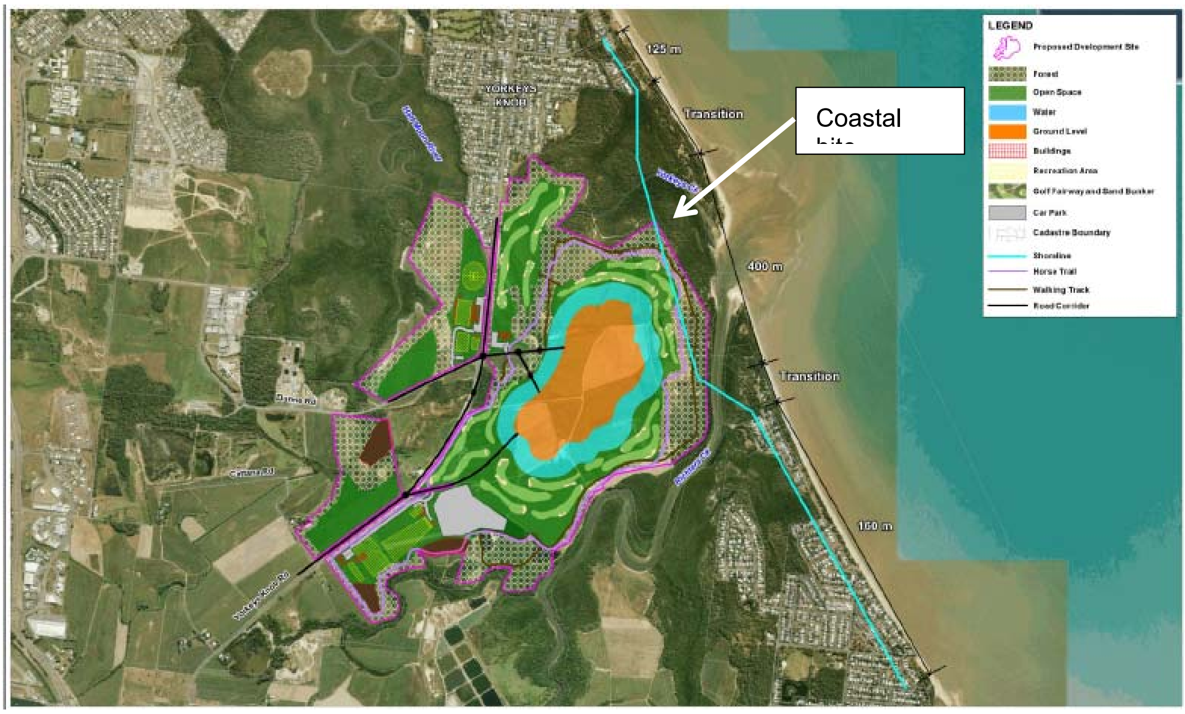

Figure 8-7 Erosion Prone Area ('coastal bite').

Source: Appendix L (Figure 3-14).

c) *Long Term Changes*

Over geological timescales, the beaches adjacent to the Barron River delta have been accreting, although local disturbances such as interruptions to the fluvial supply from rivers such as the Barron River have caused large scale disturbances. These fluctuations pre-date the arrival of Europeans and are a natural rather than anthropogenic (human-induced) occurrence. The Barron River delta is the largest source of sediment to Cairns' northern beaches and supplies about 23,000 m^3 annually.

Over the last 6,000 years, the eastern shore of Trinity Inlet has accreted due to sediment supply from the Barron River as shown on **Figure 8-8** where the site is superimposed on a figure from the Mulgrave Shire Northern Beaches report (BPA 1984).

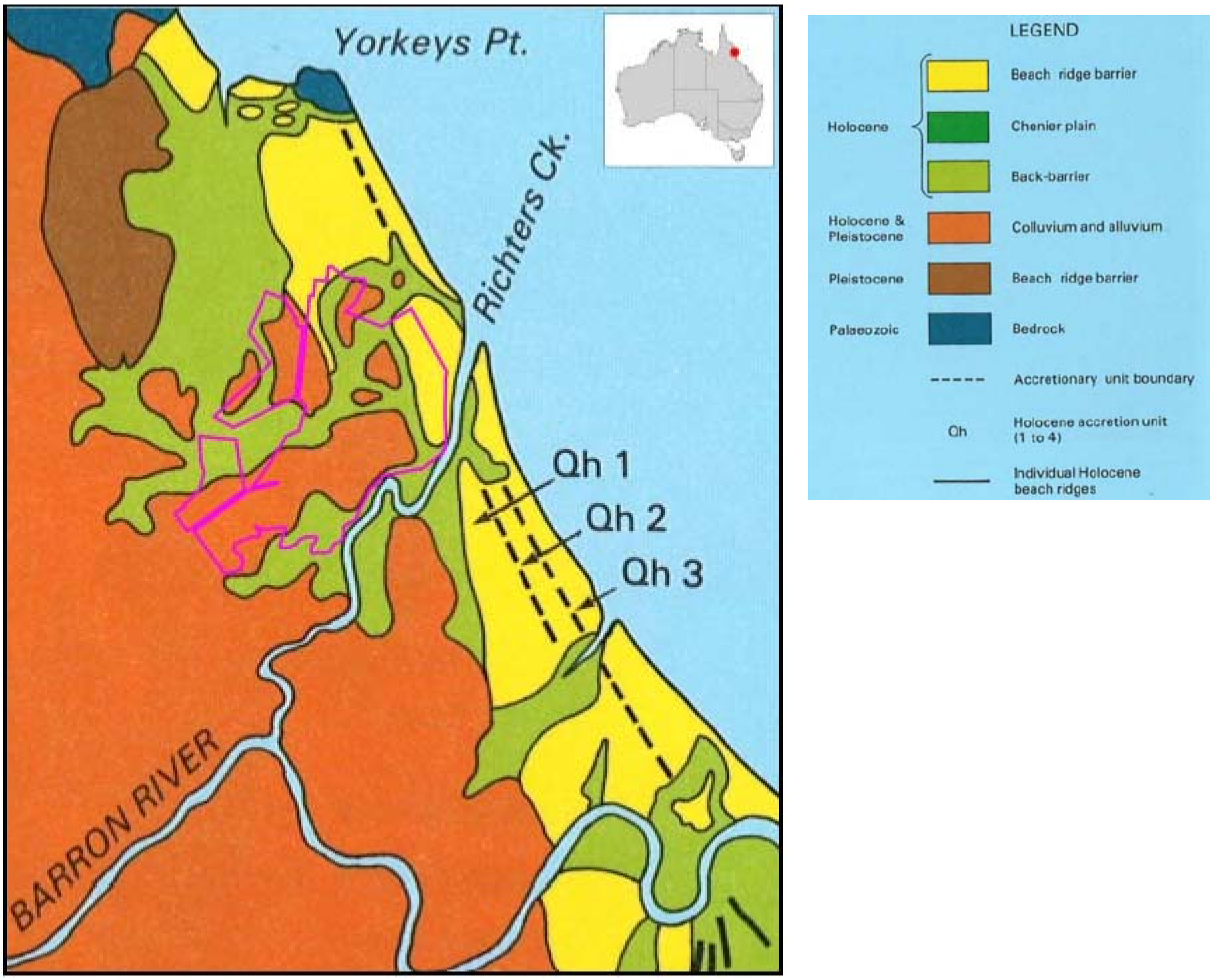

Figure 8-8 Aquis Resort site superimposed on historical accretion map.

Source: Appendix L (Figure 3-1) based on BPA (1984).

It can be seen that the site is located landward of the Qh 3 line (Qh 3 = Holocene accretion unit 3). The geological studies did not indicate the age of this unit except to say that Qh 1 to 4 occurred in the last 6,000 years. However, some dating of sediment was carried out and indicated that the average accretion rate for Yorkeys Beach over that time was 29 m every 100 years.

8.2.2 Impacts

The development of the project concept design has been based on the following:

- No major permanent structures east of the predicted shoreline erosion line.
- Consider need for armouring site against possible coastal bite and Richters Creek erosion.

The main design rule is to ensure adequate setback for major infrastructure (i.e. 400 m).

Consideration was given to the need for armouring against river migration by the construction of a buried rock wall within the site to act as a 'last line of defence'. This concluded that this is unnecessary and that the preferred approach involves:

- ensuring that the lake and Resort Complex Precinct are structurally secure against erosion
- stockpiling suitable rock on-site to be used for emergency stabilisation works in the event of serious erosion.

The project infrastructure is located approximately 600 m landward of the current shoreline and is outside of the calculated shoreline erosion prone area (maximum 400 m) and at the western extent of the Holocene accretion zone which is the result of continued accretion over the last 6,000 years due to sediment discharge from the Barron River.

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.

No measures proposed to be taken to mitigate the effect of coastal erosion on the Aquis Resort site will have an adverse impact on surrounding land.

The Aquis Resort is set approximately 400 m landward of the current shoreline and as such is located well behind current coastal dunes and associated sand transport processes. However, due to the low lying nature of the site, the predicted year 2100 HAT + SLR water level is located approximately 3.5 km to 4 km inland and therefore landward of the development. The coastal processes that would be involved in shoreline migration from its current position to a new year 2100 location as a result of SLR is impossible to predict, given the complex array of tidal creeks in the Barron River delta and beyond. However, it is likely that structural works will be constructed at the communities of Holloways Beach and Yorkeys Beach to protect these areas from such changes at an early stage, due to their proximity to the sea. This protection will interrupt coastal processes in the region and, in this circumstance, it is unlikely that the Aquis Resort will further impact coastal processes at any time. This situation is impossible to predict as it involves vagaries of climate change, community values, and government policy.

8.2.3 Mitigation and Management

The measures specified above for extreme event erosion apply equally to the more gradual coastal erosion process. However, in the latter case the changes (if any) are likely to be gradual and arise from discrete events spread over time. Under these circumstances, any minor damage can be repaired quickly and the property secured.

As post-event repairs may be necessary, a stockpile of suitable rock will be established on-site to be used for emergency stabilisation works in the event of serious erosion.

8.2.4 Residual Impacts

The major mitigation of the effects of extreme event erosion and waves is design-related and involves the provision of a large setback of Aquis Resort infrastructure and the recommended armouring of the lake and especially the inner edge that supports the Resort Complex Precinct.

At this stage it is not considered that any further mitigation is required, although this will be addressed during detailed design.

As for the more extreme situation, a small risk remains that the 'coastal bite' could affect Aquis Resort infrastructure. As noted, this is a gradual process and any minor damage can be repaired quickly and the property secured.

The Aquis Resort response to this hazard will not have any adverse impact on the surrounding area.

8.3 RIVER MIGRATION

8.3.1 Existing Situation

a) The Barron River / Thomatis Creek Bifurcation

As noted in more detail in **Chapter 12** (Water Resources) some of the Barron River flow is carried by the Thomatis / Richters Creek distributary. The point at which the flow splits into the main channel of the Barron River and the Thomatis / Richters Creek distributary is located just upstream of the Captain Cook Highway and some 9.2 km upstream from the mouth of the Barron River at what is referred to as the 'Thomatis Creek bifurcation'. This is some 2.2 km upstream of the Aquis Resort site. During the 1970s, there was concern over increasing flows in Thomatis / Richters Creek (then estimated at 35% of Barron River discharge) and the effect that this could have on the stability of the bifurcation. Erosion mitigation works were recommended at that location. Some of these options have since been implemented and the creek currently appears stable for most of its full length, with significant mangrove populations in the lower sections.

b) Richters Creek

One exception is at the bend adjacent to the site on Lot 2 RP8000898 where riparian vegetation has been lost and bank erosion is occurring (see **Photo 8-2**).

Photo 8-2 Richters Creek looking downstream from Lot 2 RP800898.

This is one of a very few areas on Richters Creek where riparian vegetation is absent and has been selected as the site for a lake overflow structure, erosion protection, and extensive restoration. See **Chapter 11** (Water Quality).

Although extreme events can possibly cause significant changes in a delta in a short time, the available studies indicate that the major changes in recent times have been in the lower estuary below the Thomatis Creek bifurcation. These changes are:

- river mouth changes (including the effect of this on sand supply for beach nourishment)
- longshore sand transport and beach erosion and accretion
- short-term storm erosion potential
- longer term shore erosion, including the effects of sea level rise.

The best estimate of shoreline erosion over a 50-year planning period adjacent to the site is 400 m. Significant existing residential developments both to the north and south of the proposed development are located closer than this to the shoreline.

As shown on **Figure 8-9**, the entrance to Thomatis / Richters Creek at the bifurcation has become more constrained due to the stabilisation works which have been constructed and that have resulted in an increase in sediment build-up and subsequent vegetation growth. The stabilisation works are essentially restricting the bifurcation's movement to the east under pressure from the spit growth on the eastern bank due to sediment deposition. The increasing growth of mangroves along the shorelines of Thomatis / Richters Creek is indicative of increasing sediment accretion which is in turn indicative of decreasing tidal flows. It is also noted that while the distance to the ocean is shorter via Thomatis / Richters Creek than via the Barron River and hence the gradient is greater, the size of the relevant channels and their resulting conveyance potential still hydraulically favours the Barron River as the preferred channel.

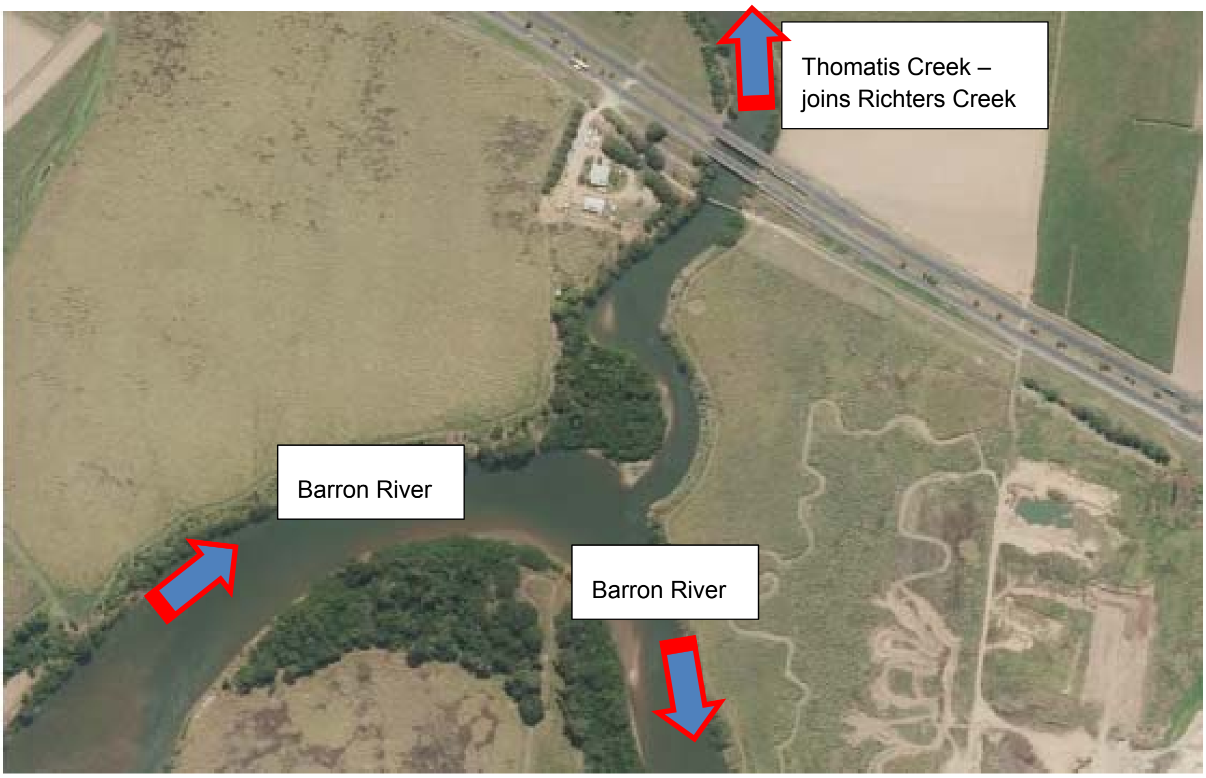

Figure 8-9 Thomatis Creek entrance (the 'bifurcation') in 2011.

Source: **Appendix L** (Figure 6-2) with labels added. The Aquis Resort site is approximately 2.2 km downstream of this point (i.e. via Thomatis Creek / Richters Creek).

In terms of improving tidal conveyance of the Barron River, recent geological evidence suggests that a breakout in the lower estuary on the main Barron River channel is more likely than changes at the bifurcation. In this area the low lying region around Redden Creek is a possible breakout point as the 'Airport Bend' is a significant inefficiency at this location in the estuary.

Further discussion of erosion prone areas and river migration is included in **Chapter 12** (Hazards). This reveals that there is some risk that river migration could occur (specifically Richters Creek but also the Barron River itself) if there were changes in the Barron / Thomatis Creek flow share due to erosion etc. at the bifurcation. While this has been assessed as having *Low* risk (**Table 12-3**), if it did occur it would be catastrophic to the project if unprotected. It would also be catastrophic for the communities of Yorkeys Knob and Holloways Beach in the short-term (flooding, erosion) and for beaches in these areas together with Machans Beach in the long term (reduced sediment inflow of beach nourishment leading to major shoreline erosion).

In addition, there is evidence of erosion on the banks of Richters Creek just opposite Lot 2 RP8000898. As this point is quite close to the abandoned aquaculture ponds, the ponds could make the area vulnerable to river erosion to the detriment of safety and project infrastructure.

8.3.2 Impacts

The development of the project concept design has been based on the following:

- Consider the need for armouring against river migration by the construction of a buried rock wall within the site to act as a 'last line of defence' (similar to that considered for coastal erosion).
- Consider need for armouring site against Richters Creek erosion.

The assessment concludes that the Richters Creek erosion works are necessary but that the buried rock wall is not needed. The preferred approach involves:

- ensuring that the lake and Resort Complex Precinct are structurally secure against erosion
- provision of rock protection of the banks of Richters Creek just opposite Lot 2 RP8000898 – this is to be integrated with erosion protection works associated with the lake overflow at that location
- draining and filling the disused aquaculture ponds to reduce the risk of river migration along this 'line of weakness'
- stockpiling suitable rock on-site to be used for emergency stabilisation works in the event of serious erosion
- making a sinking fund contribution or providing a bond or bank guarantee to fund additional armour works to stabilise the bifurcation of Thomatis Creek and the Barron River, and for armour to protect from erosion existing river banks of Thomatis / Richters Creek.

It is considered that there is a very low likelihood of river migration of a scale that could affect the Aquis Resort. Should this occur, it will not be a sudden occurrence and there will be adequate time to develop a detailed response. Such a response will need to be coordinated with actions involving Machans Beach, Holloways Beach and Yorkeys Knob at the very least by and is likely to involve major public and private infrastructure.

For lesser events, impacts will be limited to possible small areas of erosion on the banks of Richters Creek. These could mean a loss of some land and will require repair and restoration.

Referring to the principles of risk assessment (**Section 12.1.2**), it should be noted that although the presence of the Aquis Resort will increase the *consequence* of river migration (by creating valuable private infrastructure that could be damaged), it does not increase the *likelihood* of the event occurring. The presence of the Aquis Resort will not have any effect on current river migration processes and will not affect any damage that could occur to the Yorkeys Knob and Holloways Beach communities should the Barron River change its course.

Any protection work on the eroding bank of Richters Creek will simply preserve the status quo and will have no effect on external properties.

8.3.3 Mitigation and Management

It is not considered necessary or feasible to attempt to mitigate large scale river migration. The two design-related initiatives (protection of the eroding bank of Richters Creek and draining and filling the disused aquaculture ponds) are considered sufficient mitigation.

As described above, it is recommended that a stockpile of suitable rock is established on-site to be used for emergency stabilisation works in the event of serious erosion.

At this stage it is not considered that any further mitigation is required, although this will be addressed during detailed design.

8.3.4 Residual Impacts

The very unlikely event of major river migration is not proposed to be mitigated as this requires works beyond the Aquis Resort site.

There may be merit in considering protection works at that the bifurcation to reduce the likelihood of river migration arising from erosion at that location. This would benefit both the Aquis Resort and the Yorkeys Knob and Holloways Beach communities.