“Where will our knowledge take you?”

DHA Stockton Rifle Range Stockton Beach Coastal Engineering Assessment

December 2016

Document Control Sheet

BMT WBM Pty Ltd 126 Belford Street Broadmeadow NSW 2292 Australia PO Box 266 Broadmeadow NSW 2292 Tel: +61 2 4940 8882 Fax: +61 2 4940 8887 ABN 54 010 830 421 www.bmtwbm.com.au	**Document:**	R.N20693.001.00.RifleRange.docx
	Title:	DHA Stockton Rifle Range Stockton Beach Coastal Engineering Assessment
	Project Manager:	Verity Rollason
	Author:	Verity Rollason
	Client:	Department of Housing Australia
	Client Contact:	Nigel Macdonald, Gully Coote
	Client Reference:	
Synopsis:	**This Coastal Hazard Assessment report outlines the potential for coastal erosion, wave overtopping, reduced foundation capacity of dunes, and sand drift to affect the Stockton Rifle Range Planning Proposal by 2100. Measures to mitigate or manage the identified risks by 2100 are also provided.**	

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Executive Summary

Defence Housing Australia (DHA) has recently purchased the Stockton Rifle Range site (Lot 5 DP233358) covering 111.35 ha on Stockton Beach within the Port Stephens local government area (LGA), see Figure 1. DHA seeks to rezone this site and develop it for a mix of housing for Australian Defence Force (Defence) personnel and the private market. DHA's planning proposal seeks to rezone the site for low density residential development (R2); and Public Recreation (RE1).

This report provides an assessment of coastal hazards by 2100 that may impact upon the Stockton Rifle Range site, proposed zoning and masterplan prepared by Architectus (refer to Figure 1). Where impacts may occur, this report provides recommended mitigation measures to reduce the risks. Key outcomes of the coastal hazard and mitigation assessment are summarised below.

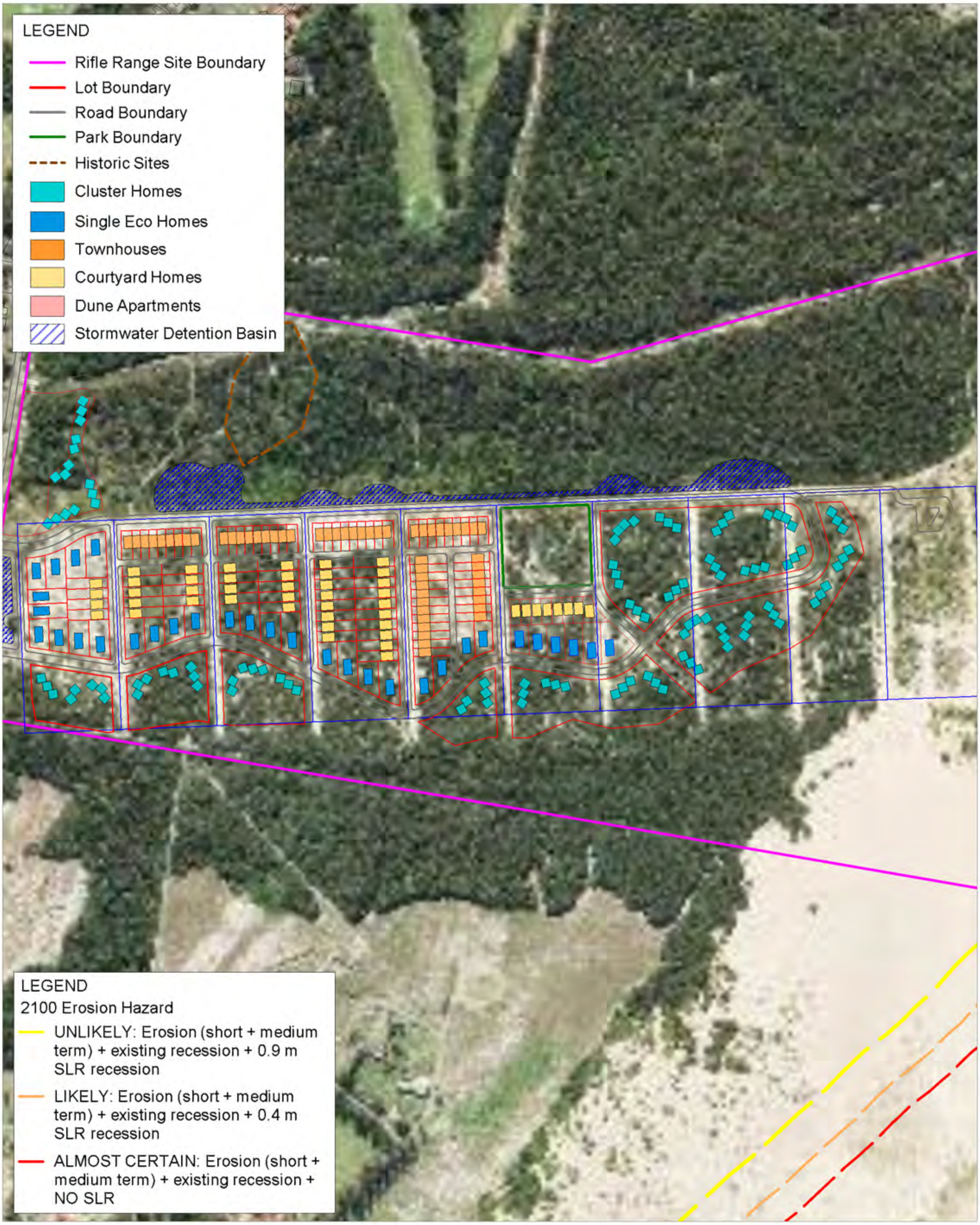
Risks from Erosion by 2100

Three scenarios for erosion by 2100 were investigated:

- an 'almost certain' erosion scenario including short and medium term erosion, ongoing recession (due to the Newcastle Harbour breakwaters), but excluding the impacts of sea level rise;
- a 'likely' erosion scenario including short and medium term erosion, ongoing recession, and future recession due to sea level rise of 0.4 m by 2100 (equivalent to the current rate of sea level rise); and
- an 'unlikely' erosion scenario including short and medium term erosion, ongoing recession, and future recession due to sea level rise of 0.9 m by 2100 (equivalent to highest emission scenario along which we are tracking). The 'unlikely' scenario is the typical conservative estimate used for planning purposes in NSW.

As shown in Figure 1, all land proposed for residential, purposes is located well landward of the 2100 'unlikely' erosion hazard. The Stockton Rifle Range footprint is at least 200 m from the 2100 'unlikely' coastal erosion hazard line, with habitable buildings within the residential zones even further landward, at least 350 m from this hazard line.

The coastal erosion risk to the proposed rezoning of the Stockton Rifle Range site (as per the Planning Proposal) is considered to be extremely low. No further mitigation of this risk is required.



Title:

2100 Erosion Hazards for the Stockton Rifle Range Masterplan

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Reduced Foundation Capacity Hazard

Immediately following a storm erosion event, a near vertical erosion escarpment of substantial height can be left in the dunes or beach ridge. At some time after the erosion event, the escarpment may slump and the slope adjust to a more stable angle. This slumping may occur suddenly and poses a risk to structures located immediately behind the dune escarpment within this zone of slope adjustment and reduced foundation capacity. The width of the reduced foundation capacity zone is directly dependent on the height of the dunes, with higher dunes resulting in a wider zone.

Caution is required in assessing and applying the dune instability hazard for 2100. The present day height of dunes/land in the region of the 2100 erosion hazard may not accurately represent the actual height of the dunes by that time. Activities including development for residential purposes, community uses, and even dune rehabilitation may lower or heighten the dunes over time. However, as the best proxy for the potential region of reduced foundation capacity that may affect the Stockton Rifle Range development, the average, maximum and minimum dune heights along the erosion hazard scenario lines (i.e. 'almost certain', 'likely' and 'unlikely', see Figure 1) were used to calculate the potential region of reduced foundation capacity.

Should the erosion escarpment reach the 'unlikely' hazard scenario line and dune heights remain at their current level by 2100, the zone of slope adjustment and reduced foundation capacity may average 9 m and range from 5 to 23 m width landward of the 'unlikely' erosion hazard scenario.

Being located at least 200 m from the 'unlikely' coastal erosion hazard line, residential zones given in the Planning Proposal are not expected to be at risk from reduced foundation capacity of the dunes by 2100.

Wave Overtopping Hazard

Detailed analysis of wave run up and the subsequent potential for wave overtopping of dune barriers during an extreme storm by 2100 was undertaken.

Assuming that existing dune heights along the 2100 'unlikely' erosion hazard scenario lines remain at the same height as at present, there is a substantial potential for wave overtopping particularly at very low lying sections of dune. However, even at the high overtopping rates identified, wave overtopping would not be expected to extend more than 50 m landward of the 'unlikely' erosion hazard line, and is expected to percolate quickly into the dune sands. As such, the proposed new zones, particularly residential zones, are not expected to be at risk from wave overtopping of coastal barriers by 2100.

Sand Drift and Dune Rehabilitation

The key coastal issue identified for the Stockton Rifle Range site is managing sand drift and dune rehabilitation in balance with maintaining the substantial region of active (unvegetated) dunes on the site in order to support the existing windborne sand transport system of Stockton Bight.

Windborne or Aeolian sediment transport allows the transfer of sand from the sub-aerial beach into the dunes behind. This sand drift is a natural phenomenon, however it can pose a hazard where coastal developments are being overwhelmed by windborne sediment, or significant volumes of sediment are being lost from the active beach system.

Windborne transport of sand can be an important component of the coastal sediment transport system. This is particularly the case on the Stockton Rifle Range site, which forms part of the active pathway for sand transport via the extensive transgressive dune system of Stockton Bight. The lack of vegetation within this dunal system is highly important for allowing the transgression of sand along Stockton Beach towards Birubi Point and beyond. This forms a significant portion of the natural northerly sand transport within the coastal system. As such, it is vital that this vast active system remains unvegetated, to avoid detrimental erosion impacts updrift. If the entire site were to be revegetated, this may cause erosion impacts on and updrift of the site, as the natural transport of sand by wind is impeded.

For the Stockton Rifle Range site, managing potential sand drift into the proposed development must be balanced with retaining the active dunal areas on the site. It is recommended that dune remediation be limited to the area of existing dune vegetation on the seaward boundary of the proposed development footprint (i.e., not the seaward boundary of the site). Extending dune revegetation activities seaward of this should be avoided, and careful maintenance of dune vegetation within this boundary is required. Provided that the full hierarchy of dune vegetation structure (i.e. a hierarchy of vegetation types and heights from primary species to secondary species then tertiary species that includes small trees) is used within this footprint, the sand drift issues should be effectively managed.

Risk Mitigation

The proposed rezoning and subdivision of the Stockton Rifle Range site is not expected to be at risk from coastal erosion, reduced dune foundation capacity or wave overtopping by 2100. As such, the Planning Proposal can be accepted with no further mitigation of these risks required.

As noted above, any works to rehabilitate dunal vegetation on site must be cautious of the active and unvegetated dune regions on the site, which are part of one of the largest transgressive dune systems in Australia.

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1 Introduction

1.1 Purpose of the Planning Proposal

Defence Housing Australia (DHA) has recently purchased two surplus Defence sites at Stockton with the objective of obtaining the necessary planning approvals and developing them for a mix of housing for Australian Defence Force (Defence) personnel and the private market. DHA has an ongoing requirement for additional housing in Newcastle, to cater for Newcastle based Defence members and their families and to replace existing DHA dwellings that do not meet current standards.

One of these sites is the Stockton Rifle Range site (Lot 5 DP233358) on Stockton Beach within the Port Stephens local government area (LGA). The site covers an area of 111.35 ha, and is currently zoned for E2 Environmental Conservation.

DHA are seeking to rezone this site to allow for:

- Low density residential development;
- Protection and management of areas of high-value vegetation or environmentally sensitive areas (RE2);

The Planning Proposal will amend the land use / zoning controls, height controls and lot size controls for the site.

This report provides an assessment of coastal hazards by 2100 that may impact upon the Stockton Rifle Range site and proposed rezoning in particular. Where impacts may occur, this report provides recommended mitigation measures to reduce the risks from coastal hazards to the Stockton Rifle Range rezoning proposal. The following coastal hazards are assessed in this report:

- **Erosion**, over the short and medium term, due to long term recession processes, and due to sea level rise in future;
- **Dune Stability and Reduced Foundation Capacity** for buildings in relation to erosion escarpments in dunes;
- **Wave Overtopping**, due to high tides, ocean water levels during storms, and in the future due to sea level rise; and
- **Sand Drift**, whereby natural windborne sand transport from active dunes engulfs nearby properties.

1.2 The Stockton Rifle Range Site

The Stockton Rifle Range site lies on Stockton Beach in NSW around 5.2 km north of Newcastle Harbour entrance, as shown in Figure 1-1. The site lies north of the existing residential development at Stockton, and adjacent to the Stockton Centre. The entire site extends to the shoreline of Stockton Beach, however the proposed development footprint will not extend onto the foredunes or beach.

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Locality Plan for Stockton Rifle Range

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2 Coastal Setting

2.1 Stockton Beach

Stockton Beach is located at the southern end of the larger embayed section of sandy coast known as Stockton Bight. The northern breakwater of the Hunter River entrance forms the southern end of the beach unit. The southern end of Stockton Beach faces east-north-east. Towards the north, the shoreline curves in a long arc, facing progressively more southwards to culminate at Birubi Point, Anna Bay some 32 km to the north.

The southern 5km or so of Stockton Beach experiences lower waves averaging around 1 m (Short, 2007), as it lies in the wave shadow created by the Newcastle Harbour entrance breakwaters. The surf zone at this end generally displays a single attached sand bar cut by rips, with the sand bar becoming detached towards the north.

Particularly north of Fort Wallace and the Stockton Centre, the beach becomes increasingly exposed to wave energy, as it extends beyond the wave shadow created by the Harbour breakwaters and arcs to face into the dominant southerly swell direction. The surf zone is described as high energy, with a well-developed double sand bar system, with both bars cut frequently by rips and separated by a deep wide trough (Short, 2007). In very big seas, the northern end of the beach (Birubi Point) will develop a third outer sand bar (Short, 2007).

In the nearshore zone off Stockton Bight, outcropping of rock reef is not evident in the surfzone, and the beach extends as a long, sandy embayment. The continental shelf is slightly wider through this region particularly out to the 40 m contour, which may have assisted in the onshore supply of sediment to the shoreline. Birubi Point forms a bedrock anchor that has repeatedly trapped northward littoral sediment transport to form Stockton Bight over previous interglacial periods.

2.1.1 Stockton Sand Dunes

The Stockton Sand Dunes are the largest and most active transverse dune system in NSW. The sand dunes extend some 25 km roughly from Fern Bay to Birubi Point in the north, and up to 3 km inland. Sands in some parts of the dune field are believed to pre-date the last two glacial periods (i.e. > 500,000 years old). A key aspect of these active dunes is that they are un-vegetated. This allows for sand to be blown into and northwards along the dunes, thus forming an important part of the coastal sediment transport system. That is, an important portion of the sediment transport occurring along Stockton Beach is actually above the water, on land via these active sand dunes.

2.1.2 The Rifle Range Site

The Rifle Range site includes beach frontage on Stockton Beach. The site's coastal frontage encompasses a considerable area of active transgressive dunes, which are naturally unvegetated. Closer to the shoreline, patchy vegetation is present. Fronting the site, the beach itself is fairly wide, and the surf zone typically displays a deep trough then single detached bar cut by rips. In the right conditions, the beach can provide decent surfing conditions.

The beach does not currently exhibit signs of erosion even after the recent June 2016 storms (see Figure 2-1). The June 2016 event arrived from a more north easterly direction, and so caused substantial damage to southern end of Stockton Beach. In general, the site does not presently appear to be greatly affected by ongoing recession due to the harbour breakwaters, unlike the southern part of Stockton Beach (see Section 2.1.4).

The dunes at Stockton Rifle Range vary considerably in height across the site. The foredune crest is typically 5 -6 m in height, but dune heights across the site may be as low as 1-2 m and as high as 20 m AHD. Dune vegetation is very patchy adjacent to the shoreline, then generally not absent, before becoming well established from around 500 m from the shoreline.

Figure 2-1 Beach appears accreted, historical recession not presently evident

2.1.3 History of Newcastle Harbour Construction

The history of construction of the breakwaters and dredging activities that have formed the Port of Newcastle entrance are as follows (Umwelt, 2002; DHI, 2006):

- Between 1812 and 1846, the Macquarie Pier was constructed between Newcastle mainland and Nobbys Island (now Nobbys Head);
- Dredging of the Newcastle Harbour entrance commenced in 1859, as the entrance was still hazardous for ships;
- In 1875 the extension of the southern breakwater from Nobbys commenced, and following several storms, was completed in 1891;
- Between 1898 and 1912, the northern breakwater was constructed, measuring nearly 1140 m;
- In 1961, depths across the harbour entrance were around -8 m. To enable safer passage, the harbour entrance was deepened to -11 m between 1962 and 1967;
- A further channel deepening project commenced between 1967 to 1976, to increase depths through the channel to -12.8 m;
- Channel deepening continued between 1977 and 1983 to further deepen the entrance in line with Port expansion activities that continue to the present; and

- At the present time, the navigation channel is maintained at a depth of -18 m, with dredged material typically placed at an offshore disposal site.

2.1.4 History of Recession and Remediation on Stockton Beach

Stockton Beach is known to have experienced ongoing recession, overlain on the natural periods of erosion and accretion. A number of studies have been undertaken over time, confirming that Stockton Beach is experiencing ongoing recession as a result of the cessation of littoral drift past the Newcastle Harbour Breakwaters into the beach. Previous detailed investigations include:

- *Newcastle Coastline Hazards Definition Study* (WBM, 2000)
- *Shifting Sands at Stockton Beach* (Umwelt, 2002);
- *Stockton Beach Coastal Processes Study* (DHI 2006); and
- *Stockton Beach Coastal Processes Study Addendum – Revised Coastal Erosion Hazard Lines 2011* (DHI, 2011).

Northerly littoral drift of up to 30,000 m^3/year has been impeded from passing the Hunter River entrance and supplying Stockton Beach by the construction of the southern then northern breakwaters. Littoral drift past the entrance breakwaters has not been able to re-establish because the Harbour channel is regularly dredged to a depth of 18 m, to allow for the passage of coal and other container ships. Fluvial sand supply from the Hunter River that may also have assisted to supply Stockton Beach has also ceased due to entrance dredging. The result has been ongoing recession of Stockton Beach, occurring as erosion and steepening of the surfzone, reduced beach width and progressive erosion into the back beach dunes and more recently, development.

Recession has previously threatened development in the central section of the beach along Mitchell Street as well as facilities such as the Stockton Beach Surf Life Saving Club (SLSC) house and pavilion, at the southern end of the beach (see Figure 2-2). Four treatment ponds were constructed in the late 1960's on HWC’s Wastewater Treatment Works (adjacent to Fort Wallace). One pond has been lost to erosion and the next most seaward pond is now under threat.

In 1989 in response to the erosion threat, a substantial rock seawall was constructed between Pembroke Street and Stone Street to protect the adjacent section of Mitchell Street and residential properties (see Figure 2-3). A sandbag wall with a design life of 5 years was also constructed in November 1996 to provide interim protection for the Stockton SLSC. The sandbag wall was implemented as a short term solution, however, it is still present and functional some 20 years later today. In June 2011, the sandbag wall was extended at the base of the SLSC towards the north. The sandbag structure was recently exposed during storms in June 2016.

Stockton Beach – July 1999, looking south to SLSC, with clear evidence of recession

Stockton Beach – June 2011, looking south to SLSC, in relatively accreted state

Stockton Beach – July 2016, looking south to SLSC, with recession again evident following storms in June 2016.

Figure 2-2 Stockton Beach Key Area of Recession over time

Mitchell St Seawall – July 1999, with no sand in front of structure and severely affected beach access and amenity.

Mitchell St Seawall – June 2011, with sand naturally accreted onto structure, allowing beach access.

Mitchell St Seawall – July 2016, after recent storms is again eroded of sand, making beach access dangerous.

Figure 2-3 Stockton Beach Mitchell St Seawall and Recession over time

A dune system was formed between the northern breakwater and Pembroke Street, and north of the rock seawall to Meredith Street during the period 1988 to 1991. Severe erosion in the mid-1990s effectively removed these dune reconstruction works. In the late 1990s, a new dune system was constructed south from the SLSC and seaward of the Stockton Caravan Park. Between the SLSC and Mitchell St seawall, a dune system is absent and the general ground level is as low as 4.0m AHD in places (see Figure 2-2). This area was further eroded during the June 2016 storms.

Approximately 130,000 m^3 of sand was dredged from the Harbour entrance in August 2009 and placed off Stockton Beach. The placement event was generally agreed to be a success and represents the first documented nourishment event for Stockton Beach. Over recent years, some small volumes of suitable dredged material (~5,000 m^3 per episode) have been placed at Stockton Beach by the Port's maintenance dredger. While this is a valuable exercise, it has not fully replicated the lost regional sand supply of up to 30,000 m^3/year into Stockton Beach. As such, recession is expected to be ongoing.

2.2 Coastal Processes

The occurrence of coastal risks such as erosion and inundation occur due to the interaction of different coastal processes with the sediments and structure of a coastline, as described by its geology and geomorphology, outlined for Stockton Beach in Section 2.1.

Coastal drivers operating on coastlines such as Stockton Beach include:

- Waves
- Oceanic water levels
- Sea level rise

These drivers interact to generate:

- Cross-shore sediment transport,
- Longshore sediment transport, and
- Aeolian sediment transport within active dunes.

Depending on these interactions, coastal hazards such as erosion (short term, medium term, recession), wave overtopping and inundation, and sand drift may occur. A brief description of the coastal processes relevant to the hazard assessment of Stockton Beach is provided in Table 2-1.

Table 2-1 Summary of Coastal Processes Relevant to Stockton Beach

Coastal Process	Description	Measured parameter
Waves	**Significant Wave Height** Significant wave height (H_s) varies in response to the different wave generation sources that occur throughout the year, as well as larger scale climate cycles such as the El Nino Southern Oscillation. East coast low cyclones are known to generate the largest waves on the NSW coast.	Average H_s: 1.6 m 100 year Average Recurrence Interval (ARI) 6 hour duration H_s = 8.7 m (based on measured wave data from Sydney)
	Wave Direction Waves on the NSW coast are dominantly south east in origin. Wave direction occur in response to the different wave generation sources and their occurrence during the year, e.g. tropical cyclones occur to the north in summer; east coast low cyclones from May to July that can produce more northerly storms; and mid-latitude cyclones throughout the year that generate the predominant south easterly swell	Average Wave Direction: SE to S, with slight shift towards ESE in summer.
Water levels	**Astronomical Tide** NSW tides are micro-tidal (i.e. <2.0 m range) and semi diurnal (high and low occurs twice a day) with significant diurnal inequalities (the two high and two low tide levels are different in any one day).	Port of Newcastle Highest Astronomical Tide: 1.1 m AHD Lowest Astronomical Tide: -0.9 m AHD

Coastal Process	Description	Measured parameter
	Elevated water levels Elevated ocean water levels during storms occur due to a combination of: • Astronomical tide • Barometric pressure set up • Wind set up	100 year ARI ocean water level: 1.44 m AHD (DECCW, 2010)
	Wave Set Up Wave set up adds to the elevated water levels at the beach. Wave set up is generated by the breaking of waves, and increases to a maximum at the beach face. A typical measure of wave set up for hazard estimation is 15% of the offshore wave height. A 6 hour duration H_s is typically used, as this is likely to coincide with a high tide.	Wave set up: 1.3 m, (calculated as 15% of the100 year ARI 6 hr duration H_s of 8.7 m)
Sediment Transport	**Longshore Sediment Transport** Longshore sediment transport occurs when waves arrive obliquely to the shoreline, generating a current along shore. Depending on the wave direction, transport may be directed upcoast or downcoast. On the NSW coast, the net longshore sediment transport is northerly, due to the predominance of southeasterly waves. The volume of transport also tends to increase towards the north of NSW, as headlands are fewer (and so, there is less interruption of the sediment transport) and sand reserves greater.	Regional longshore sediment transport rate: up to 30,000 m^3/year (based on investigations by various authors including: WBM, 2000; Umwelt, 2002; DHI, 2006)
	Cross-shore sediment transport High waves during storms tend to generate offshore transport of sand eroded from the beach and nearshore. Rip currents are directed offshore, and contribute to beach erosion during storms. During calm conditions, lower waves tend to generate transport of sand back onshore, to help rebuild the beach.	N/A
	Aeolian (Windborne) Sediment transport Aeolian or windborne sediment transport originates from the dry sub-aerial upper beach face and berm and unvegetated incipient dunes and foredunes, supplying sediment to landward foredunes. Aeolian transport is the key builder of foredunes particularly where vegetation enables the windblown sediment to be captured and stabilised.	N/A
Sea Level Rise	**Sea level rise** Sea level rise is occurring at present, and the rate of rise is projected to increase in response to human-induced climate change.	Detailed discussion of sea level rise scenarios investigated for this report is given in Section 2.2.

2.3 Sea Level Rise

2.3.1 Sea Level Rise Measurements to Date

Global mean sea level rose about 1.6 mm/year on average during the 20th Century (CSIRO, 2016a). Since 1992, high quality measurements of sea level rise have been made by satellite altimeters. From 1992 to present, Global Mean Sea Level (GMSL) has risen at a rate of around 3.2 ± 0.4 mm/year (CSIRO, 2016b). The rate of sea level rise over the past 20 years is therefore about double that of the previous century. If the rate of sea level rise were to remain at its present level of 3.2 mm/year, sea level can be expected to be nearly 0.3 m higher than at present by 2100.

Projections for sea level rise of about 0.9 m by 2100 (above 1990 sea level), as given by CSIRO (2015) and IPCC (2014), are based on the rate of sea level rise more than doubling from its present rate of 3.2 mm/year. This is not unreasonable given that the rate of sea level rise has already doubled over the last 20 years. The current rate of rise is also tracking along the rate expected under the highest carbon emission scenario modelled by CSIRO (2015) and IPCC (2014).

2.3.2 Sea Level Rise Projections used in this Assessment

The CSIRO released new regional projections for Australia in 2015, which are the most relevant to this coastal hazard assessment. The CSIRO (2015) suggest a 'likely' range for sea level rise of 0.45 to 0.88m by 2090 for the highest emission scenario (along which sea level rise is currently tracking, see Section 2.3.1).

The 2015 CSIRO projections are almost identical to the former *NSW Sea Level Rise Policy Statement 2009* benchmarks of 0.4 m and 0.9 m rise above 1990 mean sea level by 2050 and 2100 respectively. These benchmarks were used by Newcastle City Council in deriving hazard estimates for Stockton Beach (as per the DHI (2011) study). The former benchmarks were based upon the latest reports by the IPCC (2007) and CSIRO (2007) available at that time. The recent IPCC report in 2014 also provides very similar projections to the 2007 IPCC report.

For this study three sea level rise scenarios were considered as shown in Table 2-2, representing:

- no further sea level rise occurs in the future;
- sea level rise remains at its current rate of ~ 3.2 mm/yr to the end of the century; and
- the rate of sea level rise increases as projected for the highest emission scenario by CSIRO (2015), and along which sea level rise has been tracking to date (i.e. the rate of rise doubles over the remainder of this century).

Because the projections from 2007 and 2014/2015 are so similar, the sea level rise scenarios applied are consistent with the projections used by DHI (2011) and Council.

It should be noted that small differences of 1 to 5 cm between exact projections are likely to make no appreciable difference in the position of a hazard line, or level of inundation, particularly at the scale of interest to this study.

Table 2-2 Sea Level Rise Projections used for this Assessment

Scenario	SLR Value Adopted	Rational and Reference
No SLR	**0.0 m**	A "no sea level rise" scenario provides a benchmark of coastal risk that is expected to occur regardless of the rate and impact of sea level rise.
SLR at current rate (~3.2 mm/year)	**0.4 m** (above 1990 levels)	This scenario represents current rate of sea level rise of 3.2 mm/year ± 0.4 mm (CSIRO 2016b) prevailing to the end of the century. However, this scenario also represents the lower value estimate given by CSIRO (2015) for the highest emission scenario, of 0.45m by 2090.
SLR at projected rate	**0.9 m** (above 1990 levels)	This scenario represents the upper value given by CSIRO (2015) for the highest emission scenario, of 0.88 m by 2090. As a demonstration of the similarities between previous and current scientific projections, this SLR value is also consistent with the benchmarks previously prescribed by the NSW Government for studies of this kind, including DHI (2011).

3 Coastal Hazard Assessment

3.1 General Provisions

Application of 2100 Timeframe for this Coastal Hazards Assessment

Given the proposed development at Stockton Rifle Range represents a new subdivision, it is typical for local councils (including Newcastle City Council) to apply a 100 year design life to such developments. Therefore, the risk to the subdivision from coastal hazards by 2100 has been investigated. The application of the 2100 hazard extent is particularly important given that Stockton is experiencing ongoing recession (not related to sea level rise).

Use of Existing Hazard Calculations

The coastal hazard definition given in this assessment has relied on existing information in the DHI (2006, 2011) reports because this is the information currently approved and being used by Newcastle City Council for coastal planning purposes.

3.2 Beach Erosion Hazard

3.2.1 Definitions

The following modes of erosion have been included in the definition of the 2100 erosion hazard for the Stockton Rifle Range site on Stockton Beach:

- **Short term erosion**, during a severe storm or storms in close succession (hours to days). Storms involve increased wave heights and ocean water levels (tide, barometric pressure set up, wind set up, wave set up) resulting in waves attacking the beach berm and dunes. The storm waves and water levels generate cross shore (offshore) and longshore sand transport simultaneously, resulting in erosion of the beach, berm and foredune. For example, storms on June 6, 2016 generated significant erosion of the beach and back beach area particularly at the southern end of Stockton Beach (see Figure 2-2).
- **Medium term erosion**, relating to 5-10 year cycles in the wave and water level climates, which are related to large scale climate cycles such as the El Nino Southern Oscillation. For example, there has recently been a shift from El Nino conditions (typically associated with lower storminess and a more dominant southerly wave direction) to La Nina conditions (typically associated with greater storminess and a slight shift in average wave direction towards the east/north). The direction of longshore sediment transport is directly related to the incoming wave direction, and so, slight shifts in wave direction over 5-10 year cycles can have a significant effect on longshore sediment transport direction and volume, and therefore, sand reserves within a beach system.
- **Long term recession**, (ongoing recession) being the long term, permanent loss of sediment from a beach system, resulting in an ongoing loss of beach and dune width. Stockton Beach has been experiencing recession over the last 100 years or so in relation to the construction of the Newcastle Harbour Breakwaters (commencing in the early 1800s to present, refer Section 3.2.2.2). Beaches such as Stockton that are experiencing long term recession are characterised

by a prominent back beach escarpment which moves landward over time after storm events, rather than recovering fully to the pre-storm position.

- **Future recession due to sea level rise**, where the beach and dune shift upward and landward in response to the rise in sea level. This is commonly represented by the Bruun Rule (Bruun, 1962), as in Figure 3-1 below. The coastline structure in terms of headlands, reefs and artificial structures such as breakwaters and seawalls will also control how recession due to sea level rise occurs, due to the structures' control on longshore sediment transport. While newer modelling techniques are available to assess recession due to sea level rise (e.g. Patterson, 2013, Cowell et al 1992, 1995), it remains accepted industry practise to apply the Bruun Rule (1962) to determine the extent of recession due to sea level rise.

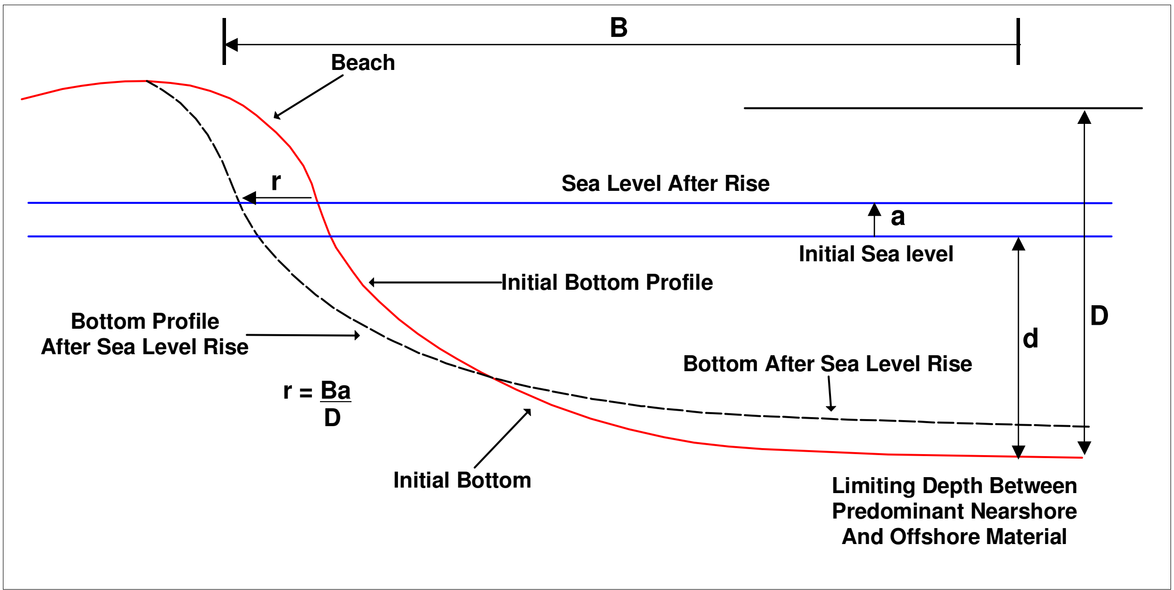


Figure 3-1 Bruun (1962) Concept of Recession due to Sea Level Rise

3.2.2 Calculations

3.2.2.1 Short and Medium Term Erosion

Potential short term erosion for Stockton Beach was analysed by DHI (2006) using a dune erosion model and application of storm conditions from May & June 1974, as well as June 1999 that arrived from the east to east-south-east and so more directly impacted the southern end of Stockton Beach. While the design storm approach can be problematic, Stockton Beach is experiencing long term recession and therefore it is difficult to separate short term events from the long term recession signal in beach survey and photogrammetric data. The maximum erosion estimates adopted by DHI (2006) ranged from 5 m at Stockton Tourist Park to 17 m at Meredith Street, 22 m at Fort Wallace and 24.5 m at the LGA Boundary, as in Table 3-1. The increase in the extent of storm erosion towards the north reflects the increased exposure of the beach to the pre-dominant south easterly waves experienced on the NSW coast.

Using the photogrammetric data, DHI (2006) also estimated erosion relating to medium term wave climate variability, such as enhanced storminess or more easterly wave direction over a sustained period. DHI (2006) provided a best estimate for medium term erosion of 18 m north of the Mitchell St seawall, which is applicable to the study site, as given in Table 3-1.

Table 3-1 Short and Medium Term Erosion Estimates (adapted from DHI, 2006)

Location	Short term erosion[1]	Medium term erosion
Fort Wallace	22	18
Stockton Centre	24	18
Newcastle/Port Stephens LGA Boundary (Stockton Rifle Range)	25	18

[1] *Erosion has been rounded to the nearest metre, to reflect the uncertainty in erosion estimates (refer Section 3.2.4 also).*

3.2.2.2 Long term Recession

It is well documented that Stockton Beach is experience ongoing recession due to the Newcastle Harbour entrance breakwaters (e.g. WBM, 2000, Umwelt 2002, DHI 2006). The breakwaters have cut off the supply of sediment from the southern beaches across the river mouth and into Stockton Beach. The erosion of beaches updrift of river entrance training walls is a well known phenomenon on the NSW coast (e.g. has occurred at Coffs Harbour, Richmond River, Tweed River and others).

Unlike most other places on the NSW coast, the Hunter River entrance and Stockton beach system has not been able to adjust to the construction of the Harbour Breakwaters. Bypassing of the southern breakwater is very likely to be occurring, however, the marine sand is removed by dredging to retain the entrance depth at 18 m to facilitate the passage of coal ships into the Port of Newcastle. Any sediment that in not dredged remains in water depths at or greater than 18 m, which is too deep for significant wave driven currents to form to transport the sediment back onto Stockton Beach (DHI, 2006). Therefore, the loss of up to 30,000 m^3/year of sand into Stockton Beach is, and will continue to be, ongoing.

The pattern of recession varies along Stockton Beach. The northern breakwater acts to shadow the southern end of Stockton Beach from south easterly swells, and a complex pattern of sediment transport is generated towards the south and then captured against the northern breakwater (DHI, 2006). Both the WBM (2000) and Umwelt (2002) studies also identified a slight accretionary trend at the southern end of Stockton Beach. North of this, the recession starts at low rates increasing to its peak of 1.3 m/year loss at the former Sewage Treatment Ponds, before reducing again to around 0.8 m/year loss at Fort Wallace and extending to the LGA Boundary at Stockton Rifle Range (DHI, 2006).

DHI (2006, 2011) used model results to determine best estimates of shoreline retreat along Stockton Beach, which are reproduced for the study site in Table 3-2. These rates were found to be in good agreement with historical recession rates of 1 to 1.3 m/year along the beach (DHI, 2006).

Periodically, dredged marine sand from the Harbour entrance is placed on Stockton Beach (around 5,000 m^3 per episode, once or twice a year). However, this is insufficient to fully replace the yearly loss to the beach. As such, the recession rates provided by DHI (2006, 2011) have been applied for this assessment.

Table 3-2 Ongoing Recession Rate at Stockton Beach from DHI (2011)

Location	Recession (m/year)
Fort Wallace / Stockton Centre	-0.8
Newcastle/Port Stephens LGA Boundary (Stockton Rifle Range)	-0.8

3.2.2.3 Future Recession due to Sea Level Rise

DHI (2011) calculated recession due to sea level rise using the standard Bruun Rule (1962). Long sandy shorelines such as the central portion of Stockton Beach, can reasonably be expected to respond in the uniform, two-dimensional manner described by Bruun (1962), because headlands and reefs are not present and so, sea level rise cannot reduce longshore sediment transport past these structures. However, the southern portion of Stockton Beach is also expected to behave in accordance with the Bruun Rule (1962). The longshore supply into the southern end of Stockton Beach has already been interrupted by the harbour breakwaters (and without recovery due to the ongoing dredging). Sea level rise cannot further reduce longshore transport past the harbour breakwaters. In this case, assessment of recession due to sea level rise with the Bruun Rule (1962) is suitable at Stockton Beach.

DHI (2011) estimated 28 m recession due to a sea level rise of 0.4 m (above 1990 levels) and 68 m for a sea level rise of 0.9 m, as given in Table 3-3 below.

Table 3-3 Future Recession Due to Sea Level Rise (from DHI, 2011)

Sea level rise (above 1990 level)	**Recession**
0.4 m	28 m
0.9 m	68 m

3.2.3 Potential Impacts

In order to understand the profile of risk to the Stockton Rifle Range site, three scenarios for the erosion hazard by 2100 were investigated, as follows:

- ‘Almost certain’ erosion by 2100, comprising the addition of short term erosion, medium term erosion, ongoing recession, but no recession due to sea level rise (i.e. a 0.0 m sea level rise was adopted, see Section 2.3.2);
- ‘Likely’ erosion by 2100, being the addition of short term erosion, medium term erosion, ongoing recession, and recession due to sea level rise of 0.4 m (equivalent to the current rate of sea level rise, see Section 2.3.2) ; and
- ‘Unlikely’ erosion by 2100 being the addition of short and medium term erosion, ongoing recession, and future recession due to sea level rise of 0.9 m by 2100 (equivalent to highest emission scenario along which we are tracking, see Section 2.3.2).

The 'unlikely' scenario represents the conservative hazard estimate that is typically used for planning purposes in NSW. The combination of calculations into the probable erosion extents described above is provided in Table 3-4. The definition of the erosion hazard scenarios in terms of 'likelihood' or a descriptive probability has been used by BMT WBM in numerous other coastal hazard assessments (for example, see BMT WBM, 2015), and is provided in Table 3-5 below.

The erosion hazard scenarios for 2100 have been mapped for the Stockton Rifle Range planning proposal zoning (and indicative masterplan layout) in Figure 3-2.

From Figure 3-2, it is evident that the Stockton Rifle Range footprint is at least 200 m from the 2100 'unlikely' coastal erosion hazard line, with habitable buildings within the residential zones even further landward, at least 350 m from this hazard line.

The coastal erosion risk to the proposed rezoning of the Stockton Rifle Range site (as per the Planning Proposal) is considered to be extremely low. No further mitigation of this risk is required.

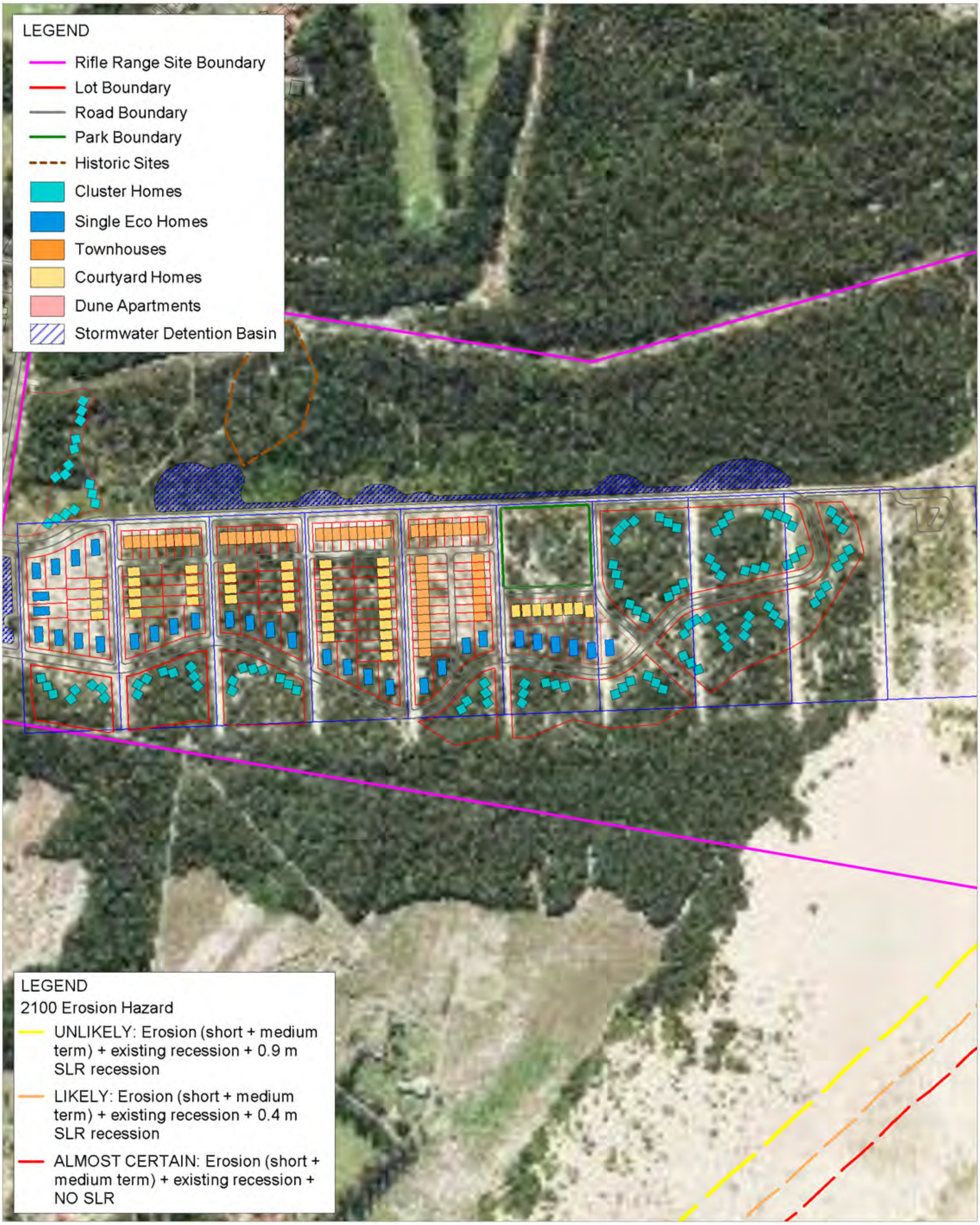
Table 3-4 2100 Erosion Hazard for the Stockton Rifle Range Site

Erosion Likelihood for 2100	Erosion modes included	Calculations[1] for 2100	**Total recession distance** (fr. 4m AHD beach contour)
Almost Certain	Short term erosion Medium term erosion Ongoing recession NO recession due to sea level rise	25 m 18 m 0.8 m/yr 0 m	115 m
Likely	Short term erosion Medium term erosion Ongoing recession Recession due to 0.4 m sea level rise	25 m 18 m 0.8 m/yr 28 m	143 m
Unlikely	Short term erosion Medium term erosion Ongoing recession Recession due to 0.9 m sea level rise	25 m 18 m 0.8 m/yr 68 m	183 m

1 All calculations sourced from DHI (2006), except recession due to sea level rise sourced from DHI (2011).

Table 3-5 Risk Likelihood for Coastal Hazards (100 year timeframe)

Likelihood	Description
Almost Certain	There is a high possibility the event will occur as there is a history of frequent occurrence
Likely	It is likely the event will occur as there is a history of casual occurrence
Unlikely	There is a low possibility that the event will occur, however, there is a history of infrequent and isolated occurrence



Title:
2100 Erosion Hazards for the Stockton Rifle Range Masterplan

Figure: 3-2

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20693 Stockton Coastal Engineering Assessment\MapInfo\Workspaces\DRG_004_Erosion_RifleRange_002.wor

3.2.4 Uncertainties in Erosion Hazard estimates

Uncertainty in defining coastal erosion hazards particularly over long timeframes (50 years +) is an inherent feature of all coastal assessments. Uncertainty in coastal hazard estimation arises due to:

- the complexity of the coastal system, and limitations of our understanding of the interactions within this complex system;
- due to this complexity, the requirement for assumptions when replicating the coastal system via modelling or other techniques,
- the uncertainties associated with climate change, particularly the rate and extent of sea level rise over long timeframes; and
- the uncertainties of how the coastal system will respond to sea level rise, particularly as this will be combined with existing recession at Stockton Beach.

With such uncertainties in mind, three scenarios for the occurrence of coastal erosion to the 2100 timeframe were investigated (being 'almost certain', 'likely' and 'unlikely', as noted above), to provide more transparency regarding how erosion estimates are derived and combined.

The key areas of uncertainty in the erosion hazard estimate relating to Stockton Beach are listed then explained below:

- the extent of ongoing recession;
- the response of the shoreline to sea level rise, and
- the potential for mitigation measures such as beach nourishment being implemented on Stockton Beach before 2100 (e.g. by State/Local government to manage the existing risks downdrift of Stockton Rifle Range).

It could be argued that the rate of ongoing recession occurring at the Stockton Rifle Range site is overestimated. The current state of the beach and dunes at the Stockton Rifle Range site are stable to accreted, and is not typical for a receding beach. By comparison, the southern end of Stockton Beach did experience a period of relative accretion as shown in Figure 2-2, however the dunes and beach were not as accreted as is currently evident at Stockton Rifle Range.

The height and width of the sand dunes on the Stockton Rifle Range site actually represent a substantial store of sand. When the beach recedes into these dunes, the sand will be liberated and can supply the coastal system. The existing substantial stores of sand in the dunes in front of the proposed subdivision may assist to reduce the rate of future recession, but have not been taken into account when deriving the erosion hazard estimates. Modelling techniques available to determine future recession either due to historical influences (as in DHI, 2006); or due to sea level rise with the Bruun Rule (as calculated by DHI, 2011), are not currently able to include such sand reserves in their calculation.

The Bruun Rule (1962) that was used to estimate recession due to sea level rise is known to have significant limitations (for example, refer Ranasinghe *et al*, 2007). Any one of these limitations may present an error in the sea level rise recession extent used in this coastal hazard assessment. For example, recession calculated with the Bruun Rule (1962) is entirely dependent upon the offshore slope applied. If the bathymetric data is of poor quality or is analysed differently, then a difference in the calculated extent of recession could occur. While the NSW Government has supplied guidance on this matter, selecting the distance/depth offshore from which to measure this slope (called the depth of closure), is an ongoing source of argument and discussion within the coastal science community.

Lastly, Stockton Beach has been subject to many and ongoing investigations by the state and local government regarding methods to ameliorate the existing recession issue. The most recent such study was the Stockton Beach Sand Scoping and Funding Feasibility Study (WorleyParsons, 2011). The WorleyParsons (2011) report identified suitable sediment sources for use as beach nourishment on Stockton Beach. The report recommended: episodic trucking of sand from further north on Stockton Beach to the southern areas affected by recession; continued episodic use of dredged marine sand from Newcastle Harbour on the beach; lobbying of developments within the Port of Newcastle to access marine sand reserves that are liberated during site works; and, while it is currently not politically viable, the dredging and use of sand from offshore (i.e. > 30-40 m water depth) remains a technically and financially viable option.

Given the feasibility of beach nourishment activities described above, it is very possible that both small and large scale nourishment programs may commence on Stockton Beach well before the 2100 timeframe for coastal risks for which this development has been designed for. Such programs will invariably reduce the potential for erosion impacts to the Stockton Rifle Range site.

3.3 Dune Stability and Reduced Foundation Capacity Hazard

3.3.1 Definition

Immediately following a storm erosion event, a near vertical erosion escarpment of substantial height can be left in the dune or beach ridge. At some time after the erosion event, the escarpment may slump, and the slope may adjust to a more stable angle. This slumping may occur suddenly, and poses a risk to structures located immediately behind the dune escarpment.

The schema of Nielsen *et al.* (1992) is the accepted method for determining the zone behind a dune escarpment that remains unstable, as follows (see Figure 3-3):

- *Zone of Slope Adjustment:* the area landward of the vertical erosion escarpment crest that may be expected to collapse after the storm event; and
- *Zone of Reduced Foundation Capacity:* the area landward of the zone of slope adjustment that is unstable being in proximity to the storm erosion and dune slumping.

As shown in Figure 3-3, these zones are shaped as a wedge, and so, stable foundation can be reached below the zones. Developments in the immediate vicinity of beaches with the potential to be affected by the zone of reduced foundation capacity may require foundation piles that penetrate to the stable foundation zone (see Figure 3-4).

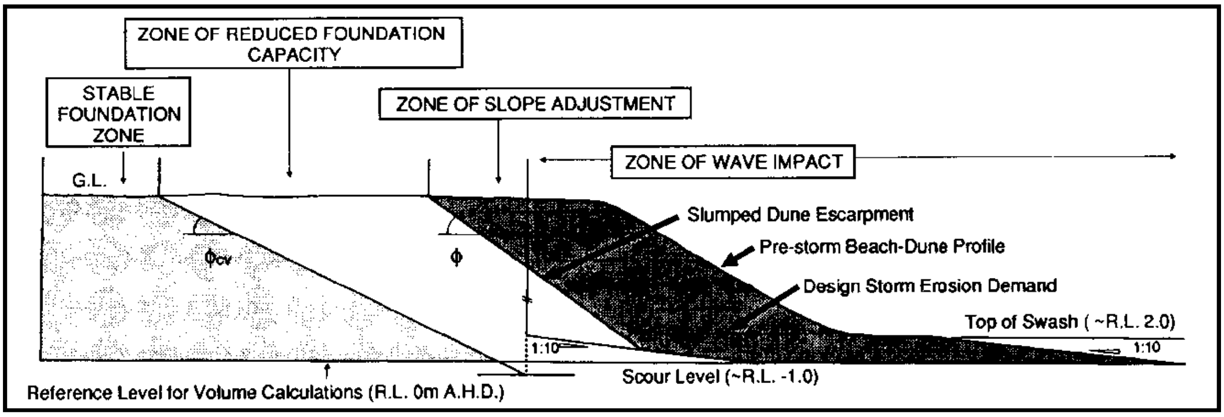


Figure 3-3 Zones of instability after Storm Erosion (From Nielsen *et al.,* (1992)

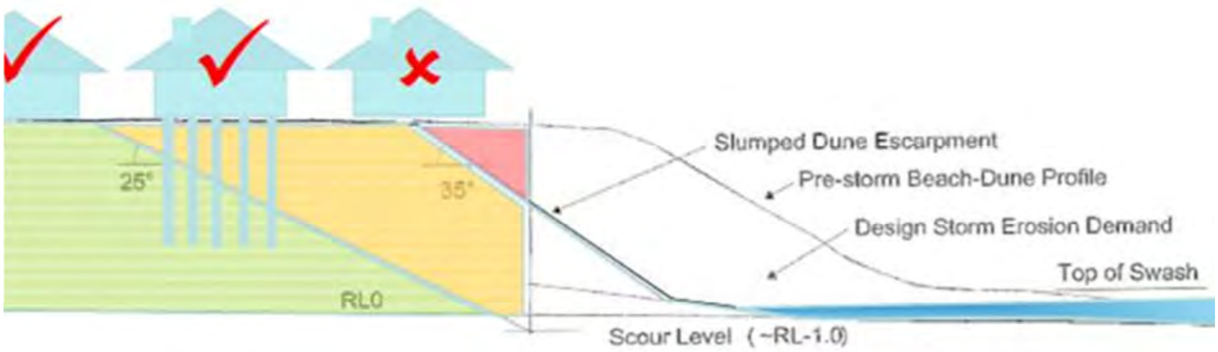


Figure 3-4 Using Foundation Piles to access the Stable Foundation Zone

3.3.2 Calculation

For the purpose of applying the Nielsen *et al.* (1992) schema to beach-scale assessments, it is accepted to assume that the entire dunal system comprises homogeneous sand, which allows an angle of repose of 35° to be applied in the calculation. This is very likely to be a suitable assumption for Stockton Beach given the long geologic history of sand accumulation in Stockton Bight. However, expert geotechnical engineering assessment is required to properly establish the zone and foundation requirements on an individual development basis.

The width of the zone of reduced foundation capacity is also directly dependent upon the height of the dunes. This is problematic where calculations must be made for the presumed position of the erosion escarpment in 2100. The present day height of dunes/land in the region of the 2100 erosion hazard may not accurately represent the actual height of the dunes by that time. Activities including development for residential purposes, community uses, and even dune rehabilitation may lower or heighten the dunes over time.

To provide an indication of the potential zone of reduced foundation capacity behind the 2100 erosion hazard zones, the existing topographic information for dune height has had to be used. Table 3-6 provides the average, maximum and minimum height of dunes along each of the erosion hazard lines fronting the masterplan lot boundary. These dune values have been used to calculate the average and range for the zone of slope adjustment plus zone of reduced foundation capacity that may exist landward of the erosion hazard lines.

The zone of reduced foundation capacity has not been mapped, because, in addition to these zones being based on present day, not future dune heights, the dunes themselves vary considerably in height.

The assessment of risk has considered the distance of proposed buildings in the masterplan layout from the erosion hazard lines, to determine where properties may potentially be at risk of dune instability, should erosion progress to the estimated level by 2100.

Table 3-6 Indicative Zone of Reduced Foundation Capacity Landward of Erosion Hazard Scenarios

Erosion Scenario		Dune Height (m AHD)[1]	Zone of Slope Adjustment [2]	Zone of Reduced Foundation Capacity [2]	Total for both zones [3]
'Almost certain' erosion hazard	Average	3.5	1.1	8.6	10
	Maximum	6	2.9	12.1	15
	Minimum	2	0.0	6.4	6
'Likely' erosion hazard	Average	3	0.7	7.9	9
	Maximum	7.5	3.9	14.3	18
	Minimum	1.5	-0.4	5.7	5
'Unlikely' erosion hazard	Average	3	0.7	7.9	9
	Maximum	9.5	5.4	17.1	23
	Minimum	1.5	-0.4	5.7	5

1 *Calculation assumes that surface of dunal system is approximately level (see Figure 3-3).*
2 *Calculated as per Nielsen et al 1992, in Figure 3-3.*
3 *Values rounded to nearest m, to reflect uncertainty and assumptions that affect accuracy of calculation.*

3.3.3 Potential Impacts

The zone of reduced foundation capacity that may be present by 2100 has not been mapped, to avoid presenting a false certainty to these calculations that are derived for a somewhat unknown future scenario.

At most, the zone of slope adjustment and reduced foundation capacity behind 2100 'unlikely' erosion hazard scenario may extend to 23 m (see Table 3-6). Even at this maximum width, it is not expected that reduced foundation capacity hazards will affected the proposed development, which lies at least 200 m from the 'unlikely' erosion hazard line.

3.4 Wave Overtopping

3.4.1 Definition

The coastal inundation hazard comprises:

- Elevated ocean water levels, comprising the addition of astronomical tide, barometric pressure set up, wind set up, and wave set up at the shoreline, which may inundate rivers, creeks, lagoons etc. hydraulically connected to the ocean; and
- Wave run up and overtopping of the shoreline, where waves overwash coastal barriers such as dunes and seawalls.

Wave overtopping is the inundation hazard of interest to this assessment, to determine the potential for the overtopping of frontal dunes during storms. The actual height of wave run up does not present a hazard unless the run-up is overtopping coastal barriers at a rate or volume that would cause a significant impact to pedestrians or land and assets behind.

There are no hydraulic connections to the ocean whereby oceanic waters may penetrate to inundate low lying areas on the Stockton Rifle Range site, and so coastal inundation from elevated ocean water levels alone (and which are lower than the wave run up level) were not considered further.

Sea level rise will contribute to elevated ocean water levels and wave run up in the future, and is therefore included in the wave overtopping assessment for 2100.

3.4.2 Calculations

For a coastal protection structure, including a natural dune barrier, wave run-up and subsequent overtopping depends, amongst other things, on:

- hydraulic parameters such as: ocean water level, wave height, wave period, wave direction, water depth; and
- structural parameters such as: the seawall roughness and porosity (random rock armour or smooth concrete surface); slope (sloping, composite, vertical, stepped); and crest levels. Dune sand barriers are considered equivalent to smooth concrete surfaces.

<u>Run-up on a Sandy Beach</u>

The 2% run-up level ($R_{2\%}$) has been derived based on the findings of Nielsen and Hanslow (1991), who indicate:

$$R_{2\%} = 0.58 \times \tan\beta \times \sqrt{H_{0_{RMS}} \times L_{0_{TZ}}} \times \sqrt{ln(50)}$$

Where
$\beta = \text{slope of the beach face (assumed to be 0.10)};$
$H_{0_{RMS}} = \text{deepwater RMS wave height} \approx \mathrm{H}_s/\sqrt{2};$
$L_{0_{TZ}} = \text{deepwater wavelength corresponding to zero crossing wave period};$
$x = \text{exceedence level}$

The run-up level derived from the above equation is added to the still water level (i.e. the addition of tide, water level anomaly caused by barometric pressure set up and wind set up, plus wave set up), plus sea level rise for 2100 of 0.0 m (almost certain); 0.4 m (likely); and 0.9 m (unlikely).

Wave run up levels for the 2100 are listed in Table 3-7.

Table 3-7 2100 Wave Run Up Hazard, Stockton Beach

Stockton Beach	2100 Wave Run Up Hazard
Almost Certain (no SLR)	5.4 m
Likely (0.4 m SLR)	5.8 m
Unlikely (0.9 m)	6.3 m

<u>Overtopping Rate for a Rock Armoured or Stepped Slope</u>

The present standard for engineering calculation of wave overtopping of various structures is provided by *EurOtop Wave Overtopping of Sea Defences and Related Structures: Assessment Manual* (Pullen *et al,*. 2007) ('the Eurotop Manual').

The mean overtopping discharge is calculated from the relationship provided in Chapter 6 of the Eurotop manual (Pullen *et al*., 2007).

$$\frac{q}{\sqrt{g \times H_{m0}^3}} = 0.2 \times e^{-2.3 \times \frac{R_C}{H_{m0} \times \gamma_f \times \gamma_\beta}}$$

Where

$q =$ mean overtopping discharge rate (l/s);

$H_{m0} =$ Depth limited spectral significant wave height (m)

$R_c =$ distance of freeboard crest above still water level (m);

$\gamma_f =$ factor for effect of roughness elements (set to 0.60);

$\gamma_\beta =$ factor for effect of roughness elements (set to 1.00, assuming orthogonal wave approach)

The following values were applied in these equations:

- 100 year ARI 6 hour duration wave height (Hs) of 8.7 m;
- 100 year ARI elevated ocean water level of 1.44 m AHD;
- Dune crest height, as measured along the position of the 2100 erosion hazard scenarios (as per Section 3.3.2 also);
- Wave set up calculated from spectral wave modelling (SWAN) at Stockton Beach (using model results from other studies completed by BMT WBM in the Newcastle region, i.e. BMT WBM 2014); and
- Sea level rise of 0.0 m (almost certain); 0.4 m (likely); and 0.9 m (unlikely);

- A nearshore slope out to the 20 m depth contour calculated as -0.008, used in the transformation of waves from offshore to shore.
- The depth limited spectral significant wave height (H_{mo}), which describes the transformation of waves through the breaker zone, was calculated using a graphical method utilising charts derived from the findings of Van der Meer (1990), as recommended in the Eurotop manual; and
- Roughness elements of 1, as natural dune barriers are assumed to behave like smooth concrete for the purpose of the wave overtopping calculation.

Table 3-8 Potential Overtopping Rates for the 2100 Hazard Scenarios

Erosion Scenario	Dune Height	Dune Height	Wave Run Up	Overtopping Rate (l/m/s)
'Almost certain' erosion hazard	Average	3.5	5.4 m	147.0
	Maximum	6		0.0
	Minimum	2		936.3
'Likely' erosion hazard	Average[4]	3	5.8 m	532.8
	Maximum	7.5		0.0
	Minimum	1.5		2,861.3
'Unlikely' erosion hazard	Average	3	6.3 m	1,190.2
	Maximum	9.5		0.0
	Minimum	1.5		5,268.8

Table 3-9 Average wave overtopping volume limits resulting in damage (Eurotop, 2007)

At Risk	Average permissible overtopping (l/s/m)
Pedestrian[1]	0.10 to 10
Motor vehicles[2]	0.01 to 50
Damage to paving (landward of the crest)	200
Damage to grasses/turf (landward of the crest)	50
Seawall structure (crest)[3]	200
Buildings and assets[4]	1

Notes:
[1] Assumes that pedestrians have a clear view of the sea and able to tolerate getting wet through to trained staff expecting to get wet. All limits assume non violent, low velocity overtopping.
[2] Lower limits apply to high speed vehicles while upper limits apply to low speed vehicles, pulsating flows at low depths.
[3] Limit for no damage to a well protected crest
[4] Limit for damage, discharge measured at the building or asset

3.4.3 Potential Impacts

The average dune heights currently present along each of the 2100 erosion hazard lines are of sufficient height to protect the proposed development from wave overtopping. For the minimum dune height measured along the 'likely' and 'unlikely' hazard lines, there is potential for wave overtopping, should the dunes be eroded to these hazard lines in the future.

Wave overtopping rates in Table 3-8 have been compared to the guideline overtopping rates given in the Eurotop Manual in Table 3-9. For the minimum dune heights, wave overtopping rates may potentially damage structures and pose a risk to pedestrians or vehicles, should they be located on or immediately adjacent to the dune crest at the time that such overtopping occurs. Given the site is dominantly composed of sand, it can be expected that wave overtopping will be quickly absorbed into the porous sand, rather than continue to flow further landward to create an inundation issue on the site.

Based on the above, and the limited extent of low-lying dunes, the potential for overtopping to cause adverse impact to the proposed development is considered very low. Furthermore, continued maintenance of dune heights at or above 6 m AHD over time, which can generally be achieved through maintenance of appropriate vegetation, will adequately mitigate the potential for overtopping during extreme storm conditions in future.

3.5 Sand Drift

Windborne or Aeolian sediment transport allows the transfer of sand from the sub-aerial beach into the dunes behind. This sand drift is a natural phenomenon, however it can pose a hazard where coastal developments are being overwhelmed by windborne sediment, or significant volumes of sediment are being lost from the active beach system. For example, windblown sand can bury roads, stormwater drains and property located immediately behind an active or poorly vegetated dune system. Sand drift posing a hazard can be initiated by the degeneration or destruction of dune vegetation.

Dune vegetation plays an important role in minimising the detrimental effects of sand drift by acting to trap windblown sand, helping to build up the dune and keep the sand within the active beach system. In fact, the adequate maintenance of dune vegetation also assists to ameliorate other coastal hazards. Dune systems act as reservoirs to supply sand to the active beach during periods of erosion. If sand is lost inland through windborne transport, the volume of sand available to supply the erosion demand is less and therefore the erosion extent will be greater. Similarly, properly functioning dunal vegetation complexes also assist to ameliorate coastal inundation, as the capture of windblown sand helps to build dunes to greater heights, reducing the potential for wave overtopping.

Windborne transport of sand can be an important component of the coastal sediment transport system. This is particularly the case on the Stockton Rifle Range site, which contains a substantial area of active (naturally unvegetated) dune. The Stockton Bight beach system extends some 32 kilometres to the north east. Aeolian processes are significant within this highly active and vast transgressive dune system. The lack of dune vegetation within this dunal system is highly important for allowing the transgression of sand along Stockton Beach towards Birubi Point and beyond. In this case, a significant portion of the natural northerly sand transport is via the land-based portion of the coastal system. As such, it is vital that this vast active system is and should remain naturally unvegetated.

For the Stockton Rifle Range site, it is important that managing potential sand drift into the proposed development is balanced with retaining the natural values of the site. It is highly important that dune remediation be limited to areas with existing dune vegetation, and be avoided (and restricted from) on the active, unvegetated dune regions. If the entire site were to be revegetated, this may cause erosion impacts on and updrift of the site, as the natural transport of sand by wind is impeded.

4 Risk Mitigation

4.1 Summary of Potential Coastal Risks by 2100

Based upon the coastal hazard assessment detailed in Chapter 3, the key risk identified for the Stockton Rifle Range site is managing sand drift while maintaining the active, unvegetated region of dunes on the site.

Development allowed by the planning proposal as shown in the Master Plan (see Figure 3-2) is not expected to be affected by coastal erosion, wave overtopping or reduced foundation capacity by 2100. No further mitigation of these risks is required.

4.2 Risk Mitigation Measures

4.2.1 Dune Rehabilitation and Maintenance

The natural occurrence of Aeolian transport within the substantial area of active dunes on the Stockton Rifle Range site is an important element of the entire Stockton Bight coastal system.

Windborne sand transport may however pose a risk to development, such as proposed on the Stockton Rifle Range site.

In order to mitigate the potential for sand ingress into the proposed development, and maintain the active Aeolian sand transport system on the site, it is recommended that dune rehabilitation is limited to the area of existing (but in areas patchy) dune vegetation immediately adjacent (seaward) on the Stockton Rifle Range site. Extending dune revegetation activities seaward of this should be avoided, and careful maintenance of dune vegetation within this boundary is required. Provided that the full hierarchy of dune vegetation structure (i.e. a hierarchy of vegetation types and heights from primary species to secondary species then tertiary species that includes small trees) is used within this footprint, sand drift issues shall be effectively managed.

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BMT WBM Bangalow
6/20 Byron Street, Bangalow 2479
Tel +61 2 6687 0466 Fax +61 2 66870422
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Brisbane
Level 8, 200 Creek Street, Brisbane 4000
PO Box 203, Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, #B120
Centennial, Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com

BMT WBM London
International House, 1st Floor
St Katharine's Way, London E1W 1AY
Email london@bmtwbm.co.uk
Web www.bmtwbm.com

BMT WBM Mackay
PO Box 4447, Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street, Melbourne 3000
PO Box 604, Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street, Broadmeadow 2292
PO Box 266, Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Level 3, 20 Parkland Road, Osborne, WA 6017
PO Box 1027, Innaloo WA 6918
Tel +61 8 9328 2029 Fax +61 8 9486 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Suite G2, 13-15 Smail Street, Ultimo, Sydney 2007
Tel +61 2 8960 7755 Fax +61 2 8960 7745
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
Suite 401, 611 Alexander Street
Vancouver British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com