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Technical note

Project	Sandhills Stormwater Management System		
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1 Background

This technical note provides an assessment of the potential impacts of coastal processes and coastal hazards, including potential impacts of sea level rise, on and arising from the proposed Sandhills Stormwater Management System, Byron Bay. It draws heavily from existing assessments of coastal processes and hazards, and considers the requirements of the NSW Coastal Management Framework.

2 Overview of Coastal Processes

The coastal processes that shape the coastline of Byron Shire have been the subject of numerous studies over the past twenty years. The 2013 assessment "Byron Shire Coastline Hazards Assessment Update" by BMT WBM is considered to be the most comprehensive of these and has subsequently formed the basis of several management and hazard mitigation plans.

The following summary of coastal processes (including tables) affecting the beaches of Byron Shire (and particularly Clarkes Beach) from BMT WBM (2013) is paraphrased in italics below:

> *Coastal processes (natural and human influenced) are the principal source of hazard in the coastal zone. Coastal processes and their interactions include:*

- *long term evolution and regional spatial behaviour of the coastal system*
- *waves and storms, and variability in the wave climate from large scale climatological patterns such as El Nino- La Nina over seasonal, inter-annual and decadal time scales*
- *elevated water levels, which includes tides, storm surge, wave set up and wave run-up*
- *longshore and cross-shore sediment transport driven by waves and currents*
- *projected sea level rise and climate change impacts and their interaction and impacts upon all of the coastal processes described above*

Waves

The regional wave climate is a dominant component of the local coastal processes. The deep-water wave climate of the northern NSW coast comprises a highly variable wind wave climate superimposed on a persistent long period moderate to high energy swell predominantly from the southeast to east direction sectors. Two types of storm wave generation, east coast low and tropical cyclone, are dominant in determining the prevailing extreme wave climate. Table 2.1 shows the extreme wave probabilities.

Table 2.1 Extreme significant wave height estimates[1]

Average Return Interval (years)	East Coast Lows Hs (m)	Tropical Cyclones Hs (m)	Combined Hs (Allen & Callaghan) (m)	Byron1 hr Hs Kulmar *et al* (2005) (m)
2	4.85	3.89	5.02	5.4
5	5.67	4.60	5.83	6.0
10	6.10	5.20	6.29	6.3
20	6.47	5.83	6.71	6.7
50	6.90	6.73	7.28	7.3
100	7.20	7.46	7.75	7.6

Water levels

Astronomical tide levels under the present climate are provided in Table 2.2. Increases to these levels under future climates for planning purposes provide for sea level rises of 0.4m and 0.9m at 2050 and 2100 respectively.

Table 2.2 Tidal statistics for Tweed-Byron region[2]

Tidal Plane	m AHD
Highest Astronomical Tide (HAT)	Approx. 1.0 – 1.1
Mean High Water Springs (MHWS)	0.66
Mean High Water Neaps (MHWN)	0.37
Mean Sea Level (MSL)	0.0
Mean Low Water Neaps (MLWN)	-0.37
Mean Low Water Springs (MLWS)	-0.66
Lowest Astronomical Tide (LAT)	-1.0

Derived from tidal constituents: Source Australian National Tide Tables

[1] Table 2-1 of BMT WBM (2013)
[2] Table 2-2 of BMT WBM (2013)

Byron Shire Council determined its own policy for the 100 year design elevated ocean levels at estuary mouths for flood planning scenarios with storm surge events and climate change, as set out in document #908785 adopted 12th November 2009 by resolution No. 09-968. These levels are shown in Table 2.3 and incorporate:

- *provisions for a design storm surge of 0.9m under 2013 conditions, increased to 1.1m and 1.2m by 2050 and 2100 respectively to allow for increased cyclone intensity*
- *addition of the storm surge to an adopted possible high tide level of 0.94m (AHD) under 2013 conditions, being the average of the higher of the two daily spring high tides*
- *wave setup of 0.45m, based on Council's adopted value of 6% of the 100 year ARI significant wave height of 1 hour duration*
- *sea level rise provisions of 0.4m and 0.9m at 2050 and 2100 respectively.*

Table 2.3 Adopted design ocean water levels for estuary inundation[3]

ARI (years)	2010 (m AHD)	2050 (m AHD)	2100 (m AHD)
100	2.29	2.89	3.49

Sediment transport and shoreline changes

Annual and medium-term variability in the wave climate is observed in the Byron wave climate. Other researchers have found reasonable correlation between the Australian east coast wave climate and the El Nino Southern Oscillation (ENSO). Generally, there is an increase in the occurrence of tropical cyclones and east coast low cyclones, with a shift to a more easterly mean wave direction during the La Nina phase, while the El Nino phase is associated with more southerly waves. Substantial natural variability in the wave climate is observed to occur over longer periods (years and decades).

Variability in wave height and direction that persists for years to decades may result in alternate cycles of erosion and accretion and potential rotation of the shoreline due to variability in the alongshore sediment movement and the direction of intense storm waves. The data suggests an extended La Nina pattern prior to 1977 followed by predominantly El Nino through to about 2009. There have been several La Nina years both within that time and strongly so during 2010-12.

Cyclone erosion events in the region have been recorded in the surveys at the Gold Coast and also are indicated in the photogrammetry data for Byron and Tweed Shires. The surveys indicate typical profile modification and bar formation limited to water depths of about 10m and up to about 13m in more extreme events. This corresponds well to the Hallermeier (1977) predicted depth of profile change in storm events. Storm bite volumes up to 250m^3/m have been identified but are more typically around 150-200m^3/m. The larger volume losses may occur during multiple storm events or where there is significant alongshore net sand loss in addition to the removal of sand to nearshore.

[3] Table 2-5 of BMT WBM (2013)

Studies show that there is a gradient in the net longshore sand transport rate from about 150,000-200,000m^3/yr at the Clarence River to about 550,000m^3/yr at the Gold Coast. Additionally, research shows that there is a net shoreward sand supply into the shore-face from the inner continental shelf of about 0.5-1.0m^3/m/year, offsetting shoreline recession that would otherwise result from the longshore transport gradient.

The positive gradient in the longshore transport northward from the Clarence River to Point Danger of about 350,000-400,000m^3/year along 150km of coastline corresponds to an average loss of about 2.3-2.7m^3/m/yr, which would potentially lead to average shoreline recession for an active vertical zone of about 0.15-0.18m/yr. However, it is likely that this is partially offset by a continuing shoreward sand supply to the beach system of at least 1m^3/m/year, reducing the average recession to less than 0.1m/yr. Further, the recession is not uniform along the coastline, being less immediately updrift (south) of headlands and greater downdrift (north).

3 Key Coastal Hazards

The *Coastal Protection Act 2016* defines "coastal hazard" as any of the following:

a. beach erosion

b. shoreline recession

c. coastal lake or watercourse entrance instability

d. coastal inundation

e. coastal cliff or slope instability

f. tidal inundation

g. erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

The following italicised summary of coastal hazards has been paraphrased from BMT WBM (2013) and edited to focus on the hazards affecting Clarkes Beach.

Coastal hazards arise where coastal processes interact with our use and development of coastal land and assets, or where human development has impeded natural coastal processes. The major coastal hazards of note in the vicinity of Clarkes Beach *comprise:*

- *Beach erosion, relating to periods of intense storminess over seasons to years, and associated dune slope instability*
- *Long-term recession, relating to a long-term sediment deficit (e.g. at the Byron Bay Embayment), and due to both prevailing sediment deficits and sea level rise in the future*
- *Coastal inundation associated with high tides combined with storms, wave run-up and sea level rise that may overtop coastal barriers*

Erosion hazards, including coastal recession

BMT WBM (2013) undertook an assessment of erosion hazards along Clarkes Beach.

The beaches … experience considerable fluctuation associated with storm erosion and variability due to changes in the prevailing wave conditions. As well, previous studies … have established that there is a general regional trend of long-term shoreline recession … the 'immediate' erosion hazard extent represents the zone that could be affected by erosion in the immediate near future (e.g. over the next few years) in the event of one or more major storm events while the 2050 and 2100 extents incorporate a landward shift in the immediate hazard line in response to the shoreline recession.

The erosion hazard extent … takes account of the combined factors of:

- *storm bite extent*
- *natural short to medium-term variability of the shoreline*
- *projection to the future, with hazard definition at years 2050 and 2100, of:*
  - any presently prevailing long term shoreline recession, and
  - shoreline recession caused directly by the effects of projected future climate change induced sea level rise.

Identification of prevailing long-term trends may be difficult where variability is significant, if not dominant. … The erosion hazards are thus determined and presented in terms of:

- *the immediate erosion hazard which includes provision for the design storm bite with provision for the effects of wave climate variability over the next few years*
- *future erosion hazards for which the immediate erosion hazard extent is projected to 2050 and 2100 respectively by incorporating the effects of underlying recession trends and sea level rise, with provision for uncertainties about those processes leading to hazard extent ranges from 'minimum' through 'best estimate' to 'maximum'.*

BMT WBM (2013) provides details on the methods and data used to define the erosion hazard extents. Uncertainties are accommodated through:

- *assessment of the immediate erosion hazard on the basis of the design storm bite provision in the context of the present erosion-accretion state of the beach and dune, in consideration also of variability patterns determined … on the basis of analysis of the photogrammetry data*
- *assessment of the best estimate, as well as upper and lower limits of the prevailing underlying long term recession rates. For this assessment, these have been determined for each location on the basis of analysis of the photogrammetry data and consideration of regional trends, with generally ±20% adopted for the 'maximum' and 'minimum' recession distances except where local processes indicate other factors are more appropriate*
- *adoption of modelled shoreline recession responses to sea level rise as the best estimate values, which are shown to correlate well with the Bruun Rule approach where effects of coastal headlands and structures are minor, with generally ±20% provisions applied to those best estimate distances to represent reasonable upper and lower limits, except where local circumstances indicate other factors are more appropriate, based on best practice engineering opinion as informed by the available evidence.*

Historically a sand mining site, aerial imagery from the 1960's does not indicate the presence of any watercourses discharging to the dune system. Presently, the only "watercourses" reaching the beach and penetrating the dune system are piped stormwater outlets. While these outlets are unable to meander, stormwater jetting from the outlets can result in occasional localised scour of the dune system through ponding and/or meandering of the discharged flow along the upper beach. This local scour has been captured in the erosion assessment above through the photogrammetric analysis of the natural short to medium-term variability of the shoreline.

The extent of the erosion hazards in the vicinity of the Clarkes Beach and the Sandhills Stormwater Management System site (referred to herein as the Sandhills site) are provided in Figure 3.1, based on the position of the dune toe in 2010. The "best estimate" erosion recession is 43m at 2050 and 91m at 2100. The Sandhills site is located landward of the dune system of Clarkes Beach, and based on imagery captured in July 2022, was more than 100m inland of the dune toe.

Overall, coastal erosion hazards are not expected to impact on the Sandhills site to the year 2100.

Inundation hazards

To reach the Sandhills site, coastal inundation would need to either overtop the coastal dune or penetrate via the local drainage system. The NSW Beach profile database indicates that in 2021, the dunes in the vicinity of Clarkes Beach had a crest height in excess of 7m AHD, and elevations inland of the dune at Clarkes Beach are in the order of 6m AHD.

Under sea level rise scenarios to 2100 (0.8m sea level rise), overtopping of the dune by astronomical tides is improbable, with the future projected HAT level being approximately 2.0m AHD.

An analysis of wave runup under storm tide conditions by WBM BMT (2013) indicated that in the Clarkes Beach to Main Beach area, under the existing climate there was "no potential for overtopping along Main Beach where dune heights are in excess of 6m (AHD), significantly higher than potential runup levels". Under future scenarios, breaching of the dune in the vicinity of Clarkes Beach is still not expected, however "in the event of substantial wave overtopping that would most probably accompany shoreline recession to the hind-dune areas, dune sand would be carried landward and infill the low-lying land ... Eventually, a new dune would form at a more landward position." (BMT WBM, 2013). In addition, any wave overtopping of the dune would be temporary in nature and would need to penetrate tens of metres inland before reaching the Sandhills site.

At this stage it is not expected that overtopping of the dune would reach the Sandhills site.

The existing stormwater pipe extending along Cowper Street discharges directly onto Clarkes Beach. As identified in the discussion on erosion hazards, a localised scour pocket has formed around this outlet. The invert level of the existing outlet pipe where it discharges to the beach has not been provided, but at the location where the most downstream stormwater management cell (Cell 3) connects to the pipe the Cowper Street stormwater pipe invert level is 1.13m. At a basic level, this indicates that under the present climate, highest astronomical tide (HAT) inundation does not penetrate this far up the Cowper Street stormwater pipe (present climate HAT is 1.0-1.1m AHD).

The design invert level for the outlet pipe from stormwater management Cell 3 is 1.83m AHD. This height differential provides capacity to accommodate an increase in sea levels of 0.7 to 0.8m, which for astronomical tides is projected to occur around the year 2100. As identified in Table 2.3, the present climate 1%AEP storm tide level already exceeds this level, indicating that temporary inundation of the stormwater management cell could occur via penetration of the stormwater network.

Figure 3.1 Erosion hazards, Clarkes Beach (BMT WBM, 2013)

Influence of Future Proposed Development

There are a number of works proposed in the vicinity of the Sandhills site that may influence the local coastal processes.

To the east of Cowper Street, along Clarkes Beach, coastal erosion has necessitated construction of two seawalls to protect threatened infrastructure close to the Reflections Holiday Park and the café (refer Figure 3.2). An analysis of shoreline movements following construction of the seawalls did not identify any notable end scour effects associated with either seawall that may have accelerated erosion as far downdrift as Cowper Street (BMT, 2021), acknowledging that broader erosion processes in the embayment dominated.

Seawall works proposed at Jonson Street (BSC, 2022) (west of Cowper Street) are not expected to impact on the eastern end of the embayment due to the dominant longshore transport direction along this section of coast being from the east towards the west.

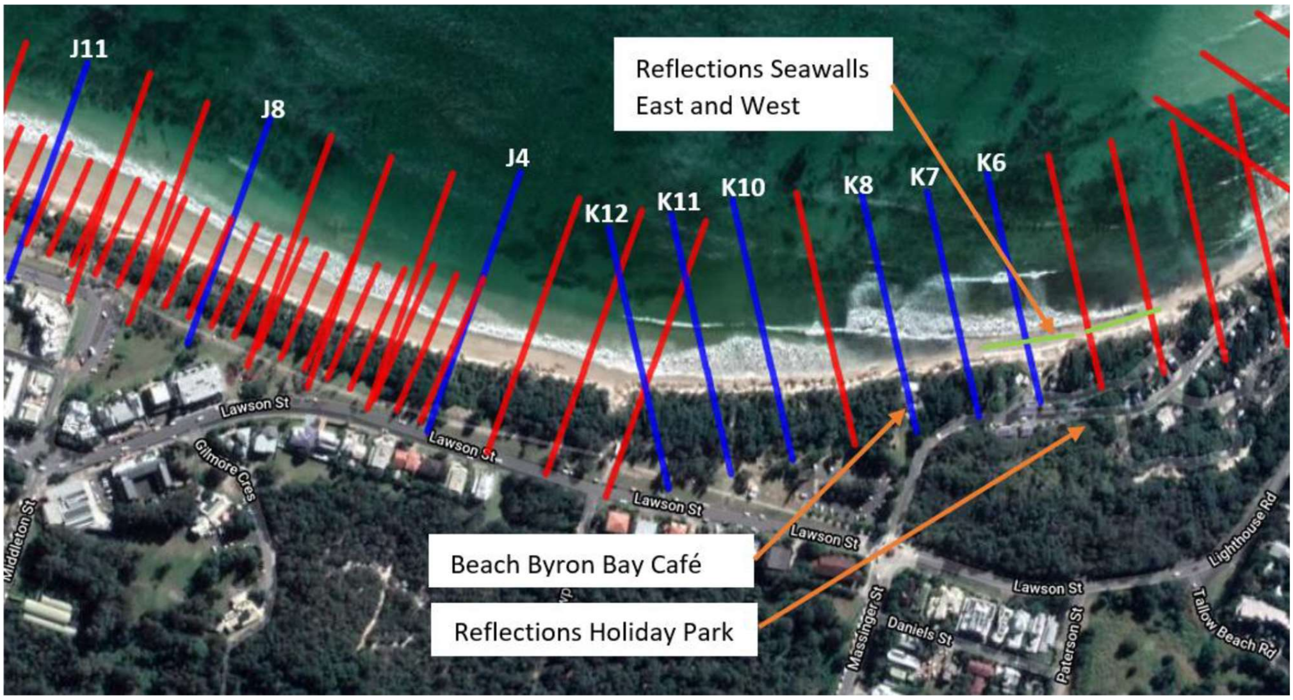

Figure 3.2 Location of Geotextile Seawall, Clarkes Beach

4 Risk Assessment and Recommendations for Risk Mitigation

The discussion of coastal hazards presented in the previous sections indicates that the Sandhills site is currently exposed to storm tide inundation hazards reaching the proposed Stormwater Management System via the existing Cowper Street stormwater pipe.

The impact of temporary saline inundation on the Stormwater Management System would not be expected to be severe. There may be some localised die-back of highly salt-sensitive species. It is worth noting that the site was heavily modified by historical sand mining and the current species represent regrowth. It is also important to consider that most storm tide events occurring in northern NSW are associated with East Coast Lows or ex-tropical cyclones, which invariably coincide with high rainfall. This rainfall would be expected to dilute any saline inundation.

On the basis of the BMT WBM (2013) hazard assessment, an audit of coastal assets identified that the Cowper Street stormwater outlet was "at risk from coastal erosion and projected long-term recession to 2050", as documented in the Draft Coastal Zone Management Plan for the Eastern Precincts of the Byron Bay Embayment (BSC, 2018). This plan recommended an upgrade to the stormwater outlet, particularly to respond to risks associated with impacts on beach access points and to improve water quality and amenity issues. The construction of the Sandhills Stormwater Management System is an important measure to achieve this improvement in local water quality and is also reinforced as a key measure in the Byron Bay Town Centre Masterplan (McGregor Coxall, 2016).

Although any works would be outside of the scope of the Sandhills Stormwater Management System project, to mitigate the risk associated with storm tide penetration up the Cowper Street stormwater pipe and into the Sandhills site, the detailed design of the stormwater outlet on the beach or at the Stormwater Management System connection could include provision of a device such as an inline check valve, that permits flow in one direction only (i.e. stormwater can flow out to the ocean but ocean water cannot flow in).

5 References

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