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Fox Beach Robe
Dune Erosion
Assessment Report

Civil & Environmental Solutions

Quality Information

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1. Background

The District Council of Robe (Council) has in the past 3 years noted accelerated erosion of the existing foredune at Fox Beach Robe resulting in damage to and subsequent removal of a treated pine beach access structure located at the western end of the Esplanade, undermining of existing fencing and restricted access to local residents and visitors.

The existing beach which is approximately 210m long and comprises limestone headlands at its western and eastern ends, is widely used by local residents and visitors however the existing erosion scar at the back of the beach is in excess of 1.5m high and with regular dune slippage occurring at the back of the beach, a public safety hazard has emerged.

Council has commissioned Civil & Environmental Solutions Pty Ltd to undertake a study of the problem comprising:

- An assessment of the likely causes of the erosion and coastal processes;
- Identifying long term erosion and inundation risk assessment under sea level rise;
- Identifying and evaluating potential adaptation options

The site is shown in Figure 1.

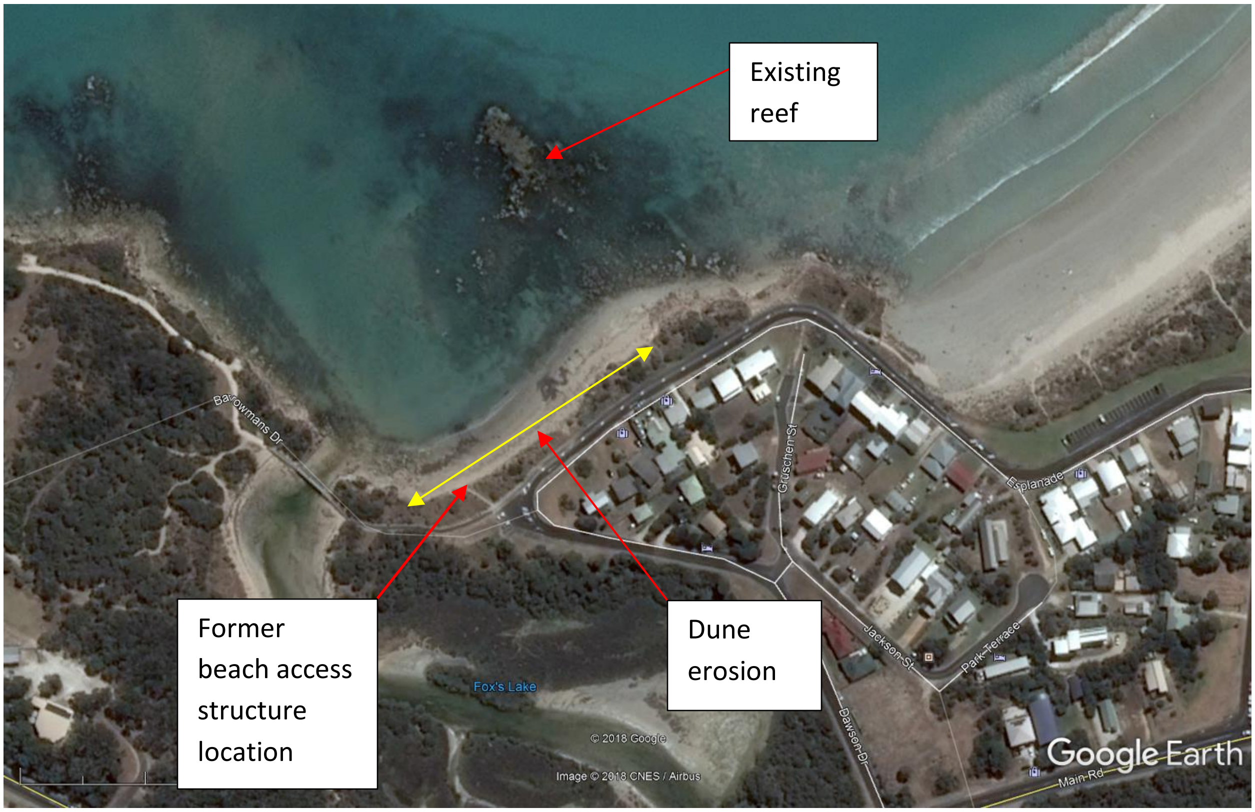


Figure 1-Study Locality Plan

Source: Google 2018 Imagery

The study provides the results of the assessment.

2. Assessment Methodology

The assessment involved the following tasks:

- Site visit and meeting with the Council CEO Mr Roger Sweetman to gain and appreciation of historical wave tidal and erosion events, observe existing erosion and wave breaking patterns, and obtain a sand sample for particle size distribution laboratory testing;
- Review of available data (BOM wind and tidal data, Department of Environment and Water (DEW) including Coastal profile surveys and 1% AEP Still Water levels wave set up and wave run up);
- Undertaking a detailed engineering survey of the section of beach down to the low water mark and dune foreshore and the Esplanade;

- Telephone and e-mail Liaison with DEW Coastal and River Murray Unit of Coast Protection Board to obtain critical current 2050 and 2100 wave climate information and historical coastal profiles and historical aerial photos;

- Calculate significant wave height for the critical north north-west fetch for the 1% AEP event;

- Undertake particle size sampling of the existing sand and S Beach modelling to calculate the estimated dune erosion from a 1%AEP storm surge event;

- Estimate the projected long term erosion including storm surge annual recession and recession under sea level rise using the Bruun rule.

- Undertake a desk top risk assessment of the potential erosion and inundation impacts including mapping hazard lines arising from a breach of the existing dune under existing and projected 1% AEP still water levels and under sea level rise;

- Identify potential dune protection options including access management options as well as a CAD sketch overlaid on the survey and aerial photography;

- Provide a draft and final report of the findings options and recommendations;

- Meeting with DEW staff in Adelaide to discuss draft report and options;

- Conduct an elected member briefing of the findings and options in Robe;

- Attend a public meeting organized by Council with abutting residents and land owners at Council's offices;

- Conduct a follow up engineering survey of the beach and back of the dune in October or November 2018 to assess any erosion in the ensuing Winter spring period;

- Provide a final report.

3 Site Inspection & Site Observations

Based on an inspection by Civil & Environmental Solutions on 31 May 2018 and discussions with Mr Roger Sweetman the following observations were made:

- The existing back of beach position is approximately 2.5-3m landward of where it was in 2015 and the erosion scar ranges from 1.5-2m in height which regular slippage cracking evident at the top of dune interface;
- The top of dune is vegetated with spinifex and other established coastal vegetation with evidence of recent revegetation;
- Waves appear to break approximately 130m offshore adjacent to the submerged reef;

- The sand size is very fine DN 50=0.20mm;
- There is evidence of 2 other informal pedestrian access tracks being formed north of the former access stairs location;
- There beach is exposed to long fetch waves from the north north-west.

View of western end of Fox Beach

View of eroded dune looking towards eastern end

View of dune at former access stair location

View of eroded dune at beach midpoint

4 Discussions with Key Stakeholders

4.1 *Client*

Discussions were held with Mr Roger Sweetman CEO DC Robe to gain an appreciation of past storm surge events and erosion and access management activities at the site and the following information was offered:

- The erosion began to accelerate approximately 3 years ago and the toe of the dune has receded inland by 2.5-3m since;
- The existing beach access steps were damaged in 2016 following storm surge events and subsequently repaired however they were subsequently removed due to further undermining of foundations
- Some people are beginning to access the beach further north over the existing dune fence which is also impacting on dune vegetation.

4.2 *DEW*

The Department of Environment and Water (DEW) had previously inspected the site and based on face to face discussions with DEW Coastal Management Branch staff on 21 August 2018, the Coastal Management Branch (CMB) agree that dune management measures are required at Fox Beach and suggest an erosion monitoring program be implemented to inform triggers for more long term solutions.

Beach nourishment was encouraged as a short term measure subject to availability of suitable quantities of coarser sand together with beach access management strategies.

Estimated current 1 in 100 year ARI (1%AEP) storm surge SWL for Robe is 1.50m AHD with wave set up and wave run up of 0.2m and 0.3m respectively so current design water level =2.00m AHD with site levels to make provision for 0.3m of sea level rise by 2050.

5 Coastal Processes

5.1 *Reference Document Review*

A number of reference documents comprising various past studies investigations and designs as provided by Council DEWNR and public sources were perused and are summarised below.

- Robe Airport historical Wind Roses 9am and 3pm (BOM);
- Cape Jaffa Robe and Beachport 2016 & 2018 Tide predictions (BOM);
- Victor Harbor Monthy Tide Gauge Sea level observations 1964-2016
- Tidal planes from (National Tidal Unit; BOM;

- DEW coastal profiles 2000-2018 for profile Numbers 735002 approximately 2km to the east at Long Beach and 7355004 located approximately 1.5km to the west of the site;
- Near Maps Robe Coastal Bathymetry;
- District Council of Robe Development Plan;
- Engineering survey of the site and surrounds Alexander Symons July 2018.

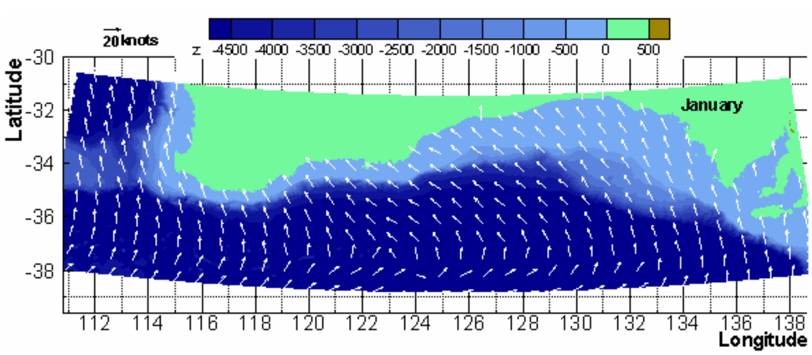
The key findings from the review were:

- Highest recorded tide level=+1.37mAHD
- Highest Astronomical Tide (HAT)=+0.6mAHD;
- Mean High High Water (MHHW)=+0.50 AHD;
- Mean sea level (MSL) =0m AHD);
- Mean Low Water Springs (MLWS)=-0.4m AHD
- Lowest Astronomical Tide (LAT)=-0.6mAHD
- I% AEP Storm Surge Still Water level=+1.50m AHD
- Council Development Plan Minimum site level-2mAHD

5.2 *Wind Patterns*

Winds generate currents and waves, which in turn are directly responsible for sand transport and erosion along the Coast. Wind data from the Bureau of Meteorology (BoM) at the Robe airport weather station has been analysed for annual and seasonal distributions.

The seasonal wind patterns in the Southern Ocean and lower south east coast have been examined and show a distinct seasonal pattern where the dominant winds are from the south, south-south-west, and south-east in summer and north and west in winter. The cold fronts in winter and spring are associated with mid-latitude low-pressure systems. The westerlies and south-westerlies generate storm surges of at half a meter in height following the passage of cold fronts (Government of South Australia, 2013).



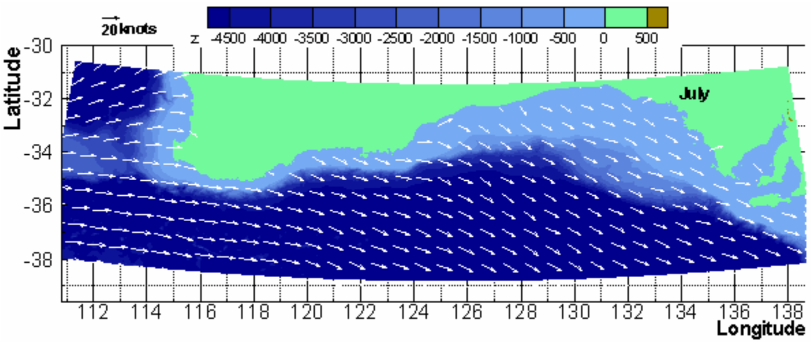


FIGURE 2 WIND PATTERNS IN SUMMER (UPPER) AND WINTER (LOWER).

The annual and winter wind distribution patterns at Robe are shown in Figures 3 & 4 where the 9 am winds blow from virtually all directions but the north west, west and south west are dominant at 3 pm with the winter winds being stronger.

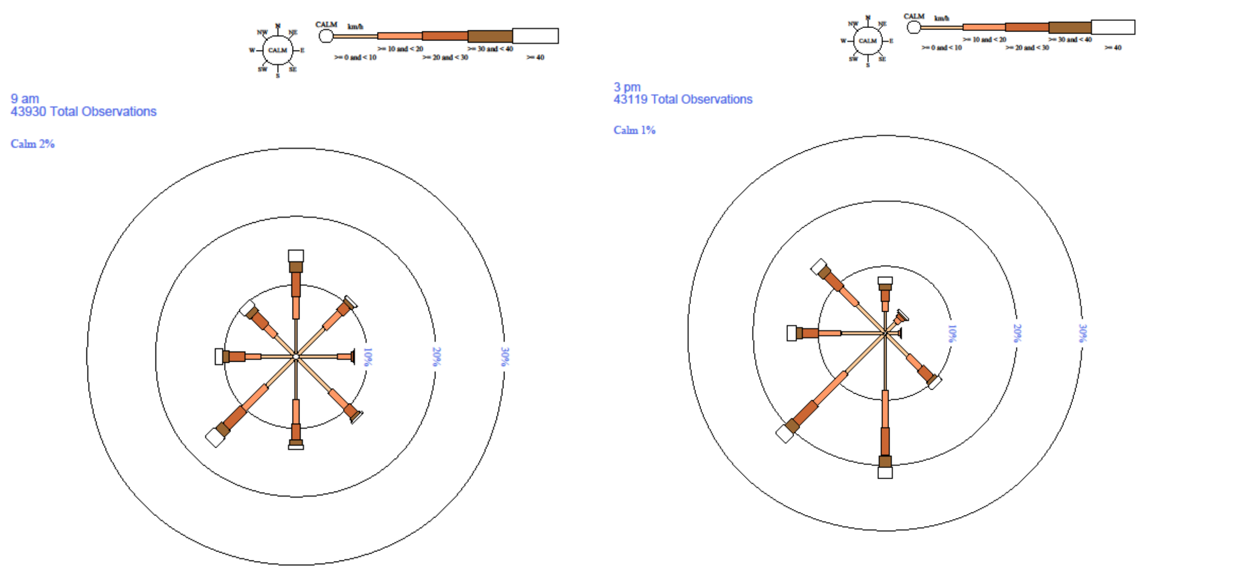


Figure 3 Annual wind roses at Robe Airport. Left panel shows winds (9 am) and the right panel shows winds at 3 pm (Source: Bureau of Meteorology).

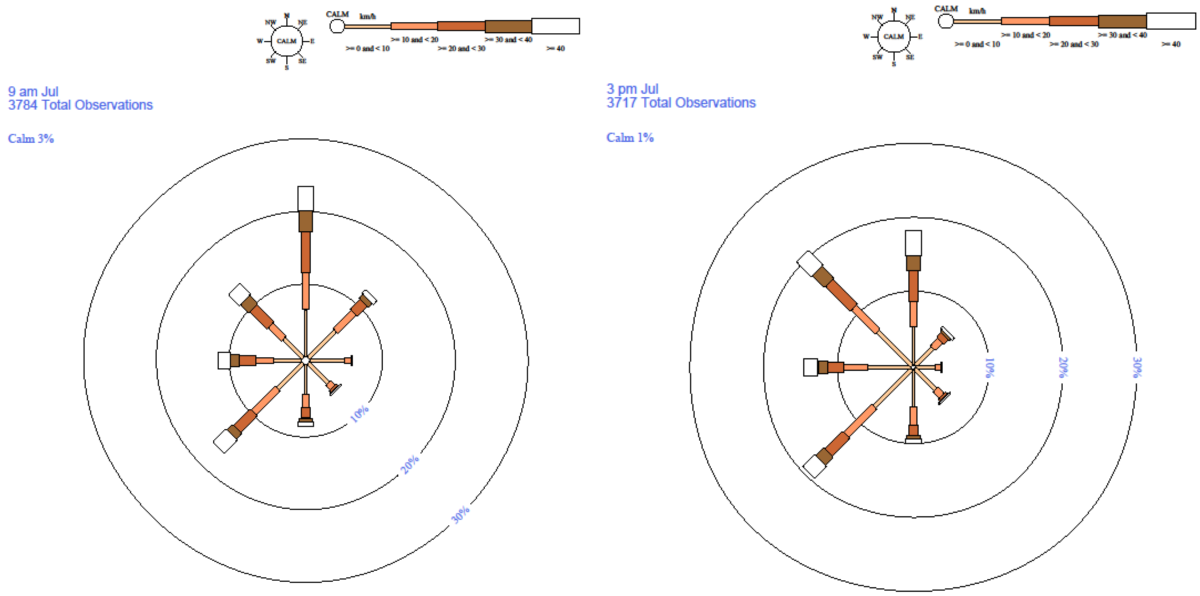


Figure 4 **Winter wind roses at Robe. Left panel shows winds (9 am) and the right panel shows winds at 3 pm (Source: Bureau of Meteorology).**

The above wind roses confirms a dominant north and north west wind in the winter period.

5.3 *Waves*

5.3.1 Swell Waves

The Southern Ocean is the most intense of all oceans. Large ocean swell waves from the Southern Ocean generated by winds blowing over the ocean in both the Southern and the Indian Oceans penetrate into the lower south east coast south of Cape Jaffa. Swells of up to 12m have been observed at the Cape De Couedic wave rider buoy south west of Kangaroo Island in the past three years(BOM.) and large swells have recently been observed in Guechin Bay.

An examination of SWAN wave modelling for the Cape Jaffa Anchorage EIS estimates swell waves of up 4m entering Guechin Bay but due to the relatively shallow and sheltered nature of Guechen Bay, the flat relatively shallow bathymetry (depth range 6-10m) and the presence of emergent reefs in the near shore zone adjacent to the site and at Boatswain Point, some of the swell wave energy would be dissipated before reaching Fox Beach.

5.3.2 Wind waves

The critical onshore wind wave climate at Fox Beach will be governed by local winds generated from the north north-west of Cape Jaffa where the fetch exceeds 60km, however some wave refraction and reflection may occur around the Cape Jaffa headland where the water depth reduces from 30m offshore to 5m nearshore over 14Km, accordingly a 45km fetch and an average water depth ranging from of 6-9m assuming depth limited conditions are considered representative for estimating Fox Beach wind waves.

Refer Figures 5 & 6

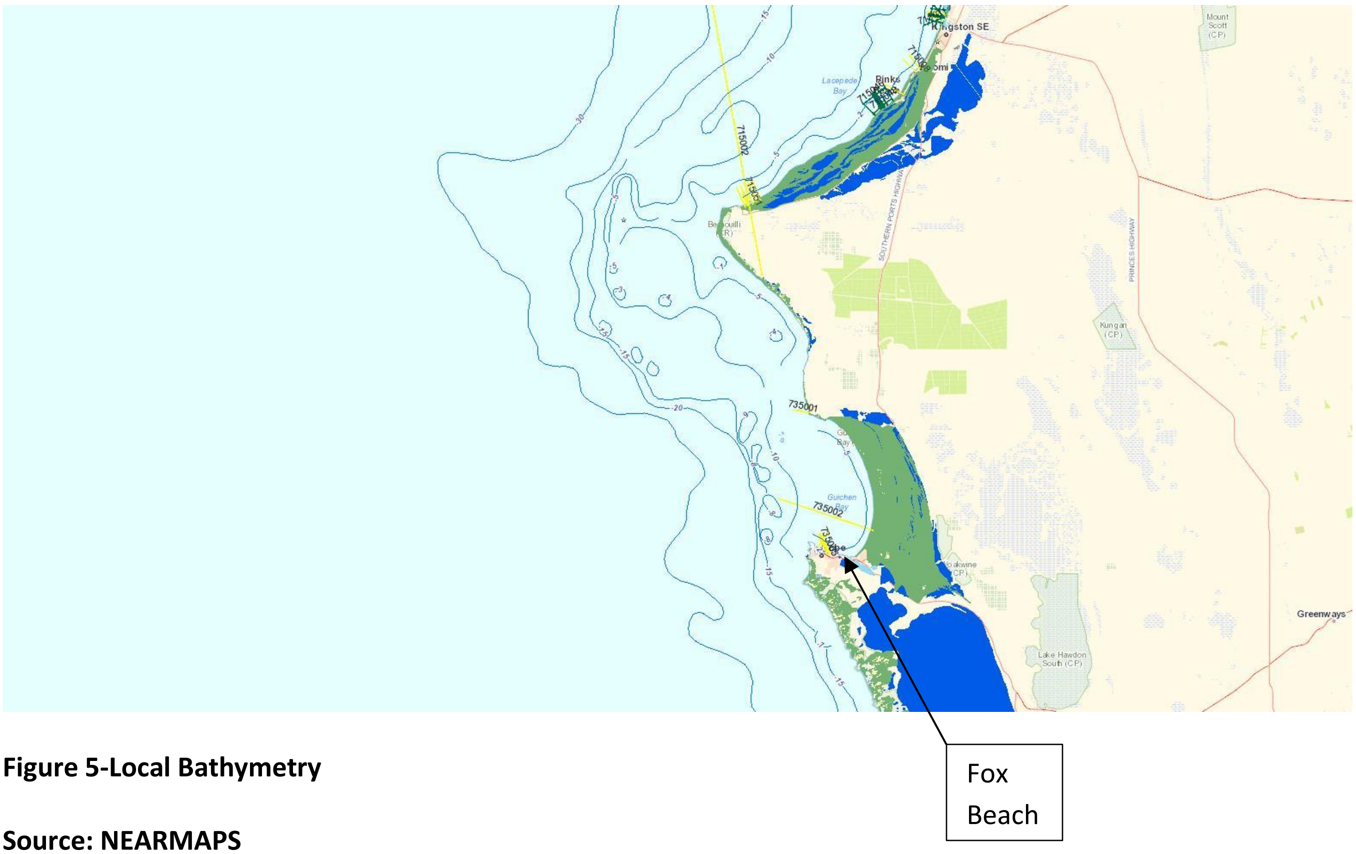


Figure 5-Local Bathymetry

Source: NEARMAPS

Figure 6-Fox Beach North-North-West Fetch

Source: GOOGLE EARTH

Using the fetch above and the extreme wind speeds from the Australian Standard AS1170.2 wind code, the wind-waves generated by 1% (100 year) winds for 6m, 7.5m and 9m average water depths have been calculated. In this report, we will henceforth `refer to extreme events using the AEP or the annual exceedance probability instead of the average recurrence interval (ARI).

The simple wind-growth functions (Coastal Engineering Manual) were employed to compute the wind-waves. The 3-s gust from AS1170.2 was converted to a mean-hourly wind speed at 10m elevation required for wave generation. Directional factors were applied to the wind speed. Table 1 presents the results of the wind-wave analysis.

TABLE 1: WIND-WAVE PARAMETERS AT FOX BEACH NNW WIND 1% AEP STORM EVENT

Average Water Depth(m)	Mean hourly wind speed (m/s)	Hs (m)	T (s)
6.0	36.2	1.8	7.0
7.5	36.2	2.3	7.4
9.0	36.2	2.6	7.8

It should be noted that this method assumes that the wind is constant across the fetch and the waves are coincident with the winds. It does not take into account the complex bathymetry. This may result in overestimation of wave heights. Long-term wave measurements at the site or a numerical wave model set-up with representative bathymetry and realistic boundary conditions would provide an accurate estimate of wave parameters at the site.

The presence of the partially submerged limestone reef immediately to the northeast of the existing beach may cause some wave shoaling and refraction of extreme waves prior to reaching the existing beach and the 15m wide Foxes' Lake outlet channel and adjacent limestone cliffs may cause a localised elevation of water levels at the western end of the beach.

For the purpose of wave overtopping and S Beach modelling for short term storm surge erosion, an offshore significant wave height for the 1% AEP event of 2.3 m has been adopted with a corresponding wave period of 7.4s.

5.4 *Sea levels including storm surge and sea level rise*

5.4.1 Existing Climatic Conditions

The shape and bathymetry of the bay would lead to a low to moderate tidal range within the bay with an estimated average daily tidal range of 0.7-1.2m.

Extreme sea levels are caused by a combination of astronomical tides and storm surge (high wind stress and low atmospheric pressure), and wave setup. Extreme sea levels cause flooding and also facilitate wave damage by raising the base level for run up and overtopping, by allowing increased depth-limited wave heights, and by shifting the zone of wave attack further shoreward such that waves can damage coastal structures. Recorded sea level data from the Port Lincoln tide station provided by Flinders Ports and wind data from MOM have been analysed for frequency of occurrences of various tidal levels and estimation of extreme water levels for various storm return period intervals.

The tide observations from Table 4.12 of the Cape Jaffa EIS reported at Robe are shown in Table 2.

Table 2: Estimated Tidal Planes at Robe Main Beach (Cape Jaffa EIS 2005).

Tidal Planes	m AHD	m CD
Highest recorded tide (source: Ports Corp Flinders Ports)	1.37*	1.97*
HAT	0.6	1.2
MHWS	0.5	1.1
MSL	0.0	0.60
MLWS	-0.4	0.2
LAT	-0.6	0.0

* Based on 1952 observation by Ports Corp. NB Tides on 9 May 2016 were highest on record so would have been exceeded.

It should be noted that up to 90mm of sea level rise had been recorded at the former Port Stanvac tide gauge over a twenty year period prior to its decommissioning so present tide levels may be up to 90-100mm higher that shown in Table 2.

South Australia is not deemed a tropical cyclone risk area with a low probability of occurrence, however coastal areas can still potentially be affected by storm surge. The South Australia planning guidance for coastal development refer to the 100-year Average Recurrence Interval (ARI) sea level rather than a storm surge level.

5.4.2 Future Climatic Conditions

All coastal infrastructure needs to incorporate allowances for future rises in sea level. Such provisions for a long term rise in sea levels will need to consider both the projected sea level rise and associated increases in storm surge. The sea level has been projected to rise by 1.0 m by 2100. However recent observations of faster than predicted melting of ice in the polar caps have led to increased sea level rise projections by 2100 to 1.1 - 1.4 m. For this study, following recommendations of DEW, sea level rise of 0.3 m to 2050 and 1.0 m to 2100 has been adopted.

2050 Projections

The 2050 projected sea level at Fox Beach for the 1% AEP storm event is computed as 2.3m AHD. It includes the astronomical tide, storm surge, wave set-up, wave run-up, and sea level rise as shown in Table 3.

2100 Projections

The 2100 projected sea level at the beach for the 1% AEP storm event is computed as 3.0 m AHD. It includes the astronomical tide, storm surge, wave set-up, wave run-up, and sea level rise as shown in Table 3.

Whilst the changes in wind intensities and directions are not considered robust, CSIRO has undertaken studies that predict that extreme wind speeds will decrease in most parts of South Australia in summer and winter while these would increase in autumn in the north of the state (Government of South Australia, 2013).

The frequency of winter time low pressure systems is projected to decrease by about 20% in the vicinity of South Australia based on current water levels, however research by DEWR and others indicates that 0.3m of sea level rise would equate to a 1%AEP storm occurring at 5 yearly intervals.

The information on sea levels provided by DEWNR is provided in Table 3.

TABLE 3 ESTIMATES OF SEA LEVEL COMPONENTS PROVIDED BY DEW.

Sea level components	m
Current 1% AEP (100 year ARI) sea level (tide plus storm surge)	1.50 m AHD
Wave set-up	0.2 m
Wave run-up	0.3 m
Current sea level for planning	2.0m AHD
Future Sea level to 2050 for planning	2.3m AHD
Future Sea level rise to 2100 for planning	3.0 m AHD

5.5 *Erosion*

5.5.1 Coastal Erosion and Recession

Coastal erosion refers to the erosion of beaches and cliffs due to waves, tides and storm surge while shoreline recession is the long-term change in shoreline position due to waves, sea levels and sediment transport patterns. Both affect the safety of assets and the people living and working within the risk areas.

Coastal erosion can have both long and short term impacts. These include the loss of land as well as short term damage due to storm erosion.

Coastal erosion can be caused by three different mechanisms:

1) Short-term storm erosion

It is the combination of vertical erosion of the beach profile and the horizontal recession of the coastline that occurs during a storm event. During a large storm event, sand can be moved from the beach, to deeper water. Over time, the beach profile generally returns to the original configuration as sand is redistributed.

2) Long-term coastal erosion

Long term coastal erosion refers to historical changes in the shoreline position where the shoreline is receding landward over time due to various natural and man-made processes. It includes longshore transport, the movement of sand parallel to the shore, induced by waves or currents running parallel to the coast line. This can be either erosion or deposition of sand from coastal processes such as tides, waves or currents.

For Fox Beach longshore transport would be limited due to the presence of the rock headlands at each end and would also be influenced by tidal flows and currents in and from the Fox's lake channel Drain L.

3) Recession due to sea-level rise

Increases in sea level can lead to erosion of unconsolidated sands. Bruun hypothesized that a beach assumes a profile that is in equilibrium with the incoming wave energy (Bruun, 1954) (Bruun, 1962) (Bruun, 1983), therefore, a rise in sea level would cause the profile to adjust.

Bruun's rule is defined as follows.

$$R = \frac{S}{(h_c + B)/L}$$

Where:

R = Shoreline recession due to sea level rise

S = Sea level rise

B = Berm height

hc = Depth of closure

L = Length of active zone

Utilising the Bruun Rule, it is possible to determine the potential erosion due to sea level rise. This takes into consideration the magnitude of the sea level rise and the profile of the beach. Application of the Bruun Rule is subject to certain assumptions and limitations, which include presence of unconsolidated sands, equilibrium profile and cross-shore transport only.

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Short-term Storm Erosion

Morphological response of the shoreline due to storm wave conditions occurs over relatively short periods of time (hours to days). This response primarily involves the erosion of the sub aerial beach face or storm cut through offshore transport and deposition near the storm wave break point to form an offshore bar. It is referred to as cross-shore or onshore-offshore transport. During a large storm event, sand can be moved from the beach, to deeper water. Over time, the beach profile generally returns to the original configuration as sand is redistributed.

Short term storm based erosion from a single 1% AEP storm tide based on a 2.3m significant wave height has been assessed using the S Beach program as part of this study and the results are shown in Figure 9 based on the DN 50=0.2mm sand grain size determined from the laboratory Particle size distribution and the surveyed beach and dune profile.

It is noted that the back of beach above RL 1.2m AHD has a 12% slope which would contribute to higher wave run up whereas in the normal intertidal zone range, the beach has a 7.4% profile flattening to 2.1% in the near shore zone.

The estimated erosion in a 1% AEP storm surge at the top of the dune is 8m as shown in Figure 7.

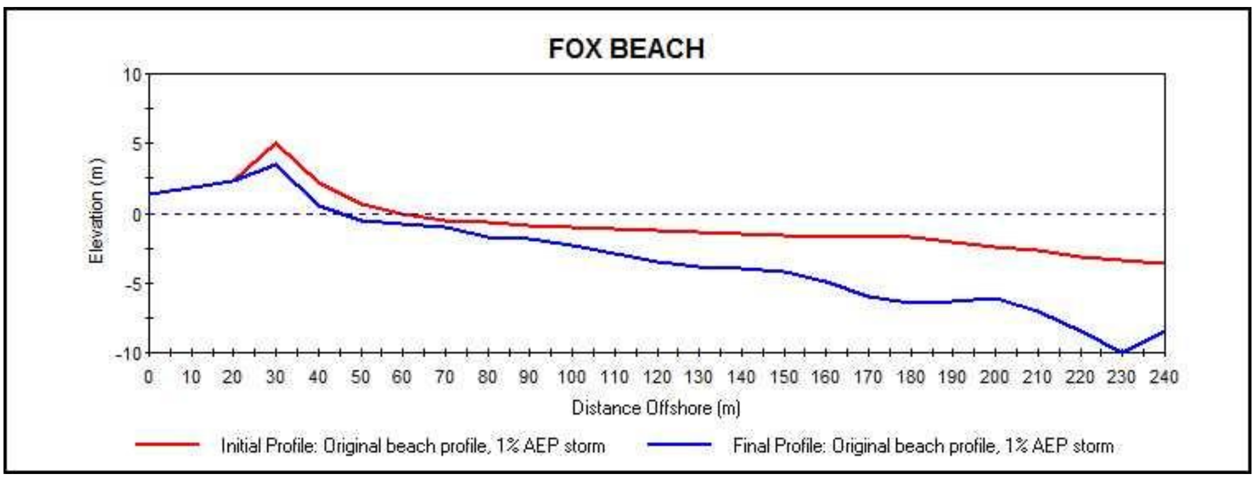


Figure 7-Estimated erosion in a 1% AEP storm surge event

The estimated volume of sand eroded from the front and back of the beach in such a storm over the 120m beach length is 11,300m3 as well as considerable sand loss in the nearshore zone.

This compares to an estimated eroded volume of 2000m3 since 2016.

5.5.2 Long Term Recession

Long term landward recession of the coastline can vary significantly along sandy coastlines ranging from 0.25m/pa to more than 1m/pa and would be expected to be greater on unprotected sections of coastline.

An examination of DEW Profile Number 735002 located at Long Beach 2km to the east of Fox Beach shown in Figure 8 and Profile 735004 located 1.5km to the west at the caravan park in Figure 9 indicates that between 2014 and 2018 the beach profile has been modified as shown in Table 4.

Table 4: Estimated Historical Changes in Beach Profile

Location	Recession (m)
Profile 735002 Back of beach (2.0m AHD) 2010-2018	+1
Profile 735002 Back of beach (1.0m AHD) 2010-2018	-1
Profile 735002 Front of beach (0.0m AHD) 2010-2018	-15
Profile 735002 Nearshore Zone (-1.0m AHD) 2010-2018	-25
Profile 735002 Nearshore Zone (-2m AHD) 2010-2018	+10
Profile 735004 Back of Beach (2m AHD) 2013-2018	0
Profile 735004 Back of Beach (1.0m AHD) 2013-2018	+1
Profile 735004 front of beach (0mAHD) 2013-2018	-2
Profile 735004 Nearshore Zone (-1m AHD) 2013-2018	-3*
Profile 735004 Nearshore Zone (-2m AHD) 2013-2018	-5*

*Possibly influenced by nearshore reef

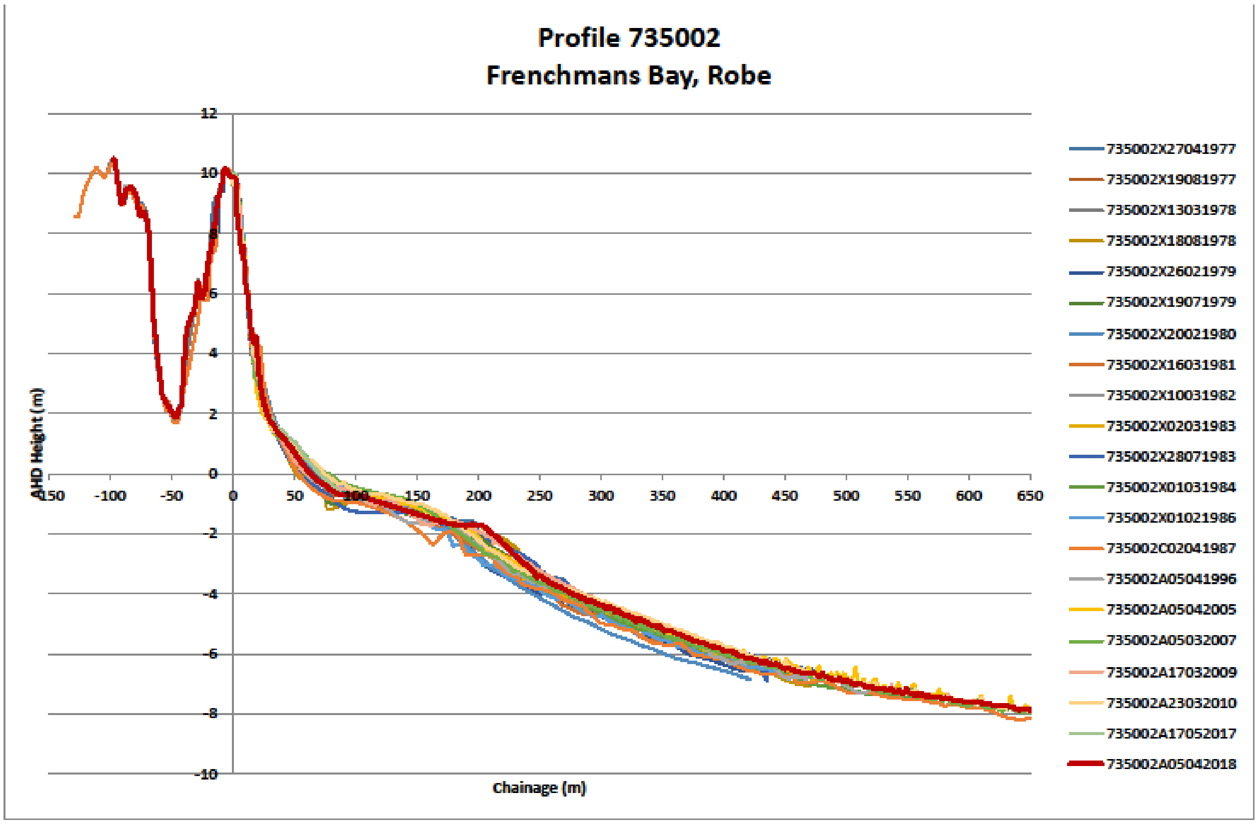


Figure 8-DEW Profile 735002

Source: DEW

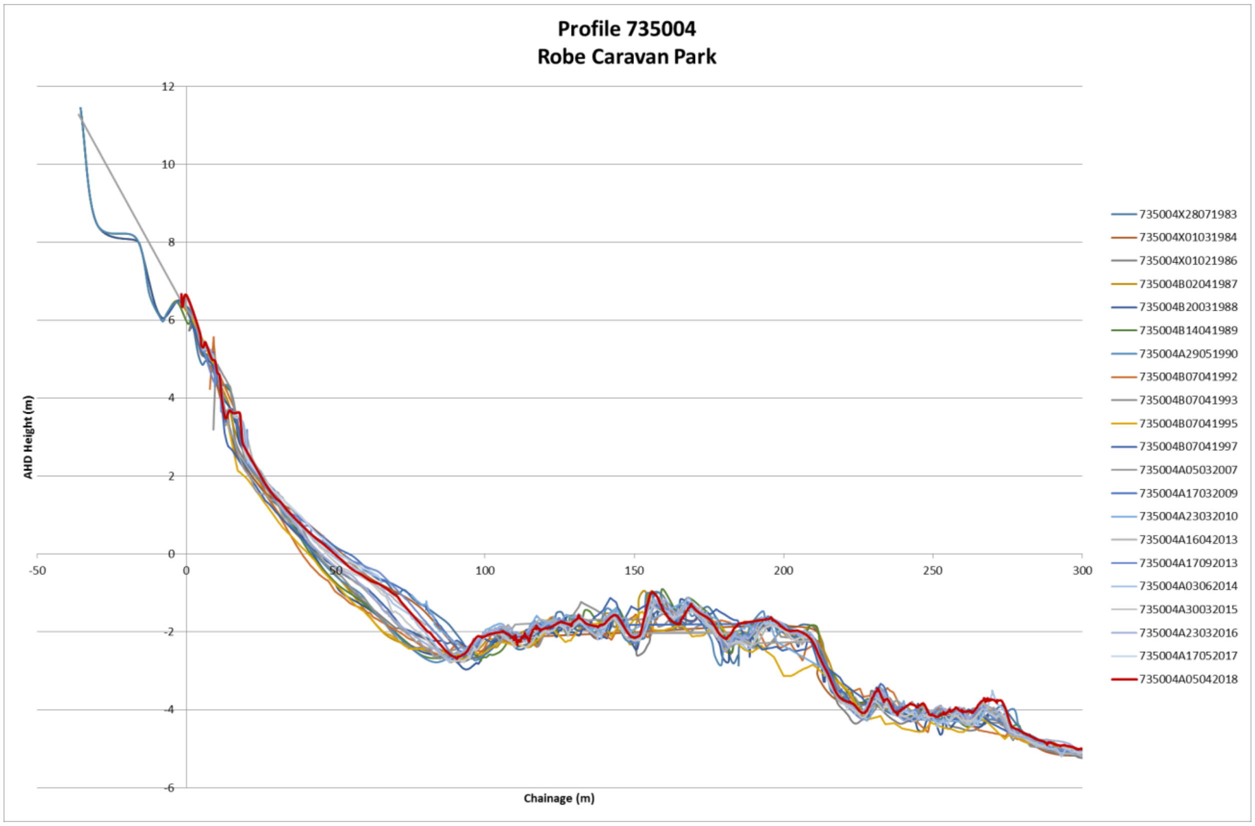


Fig 9-DEW Profile 735004

Source-DEW

This indicates between 2010-2018 significant erosion has occurred at the front of the beach and intertidal near shore zone with minimal erosion above 1m AHD at the existing sandy beaches east and west of the Fox Beach site and an average annual recession rate of 0.2m pa at the back of the beach may be an appropriate estimate of long term recession for Fox Beach.

An examination of the August 2018 engineering survey of Fox beach, indicates the current back of the beach/toe of dune level ranges from 1.90m AHD to 2.4m AHD in the main dune section and rises to 2.5m AHD at the northern rocky outcrop.

This confirms the current toe of dune in the main beach section is currently at or above the 1% AEP Storm tide planning level of 2m AHD.

It is noted that the back of beach above RL 1.2m AHD has a 12% slope which would contribute to higher wave run up whereas in the normal intertidal zone range, the beach has a 7.4% profile flattening to 2.1%

in the near shore zone. This compares closely with the intertidal profile measured at Profile 735002 in 2018.

It should be noted that although the profile data does show a loss in recent times, the erosion currently experienced is still within historic levels.

Long term variability in beach levels indicates that this current erosion trend may be cyclic, with a current trend towards loss. The close proximity of the Fox lake Drain L outfall channel and strong tidal currents during tide recession periods is also likely to contribute to sand loss in the near shore zone potentially impacting on the ability of the system to naturally recover which in turn may impact on the timing of any long term hard engineering options.

View of strong tidal outflows from Drain L outlet

It is also noted that the recent dune erosion based on Council observations has been most notable in the back of beach zone above 1.5m AHD where the beach slope is 12 %.

The dune crest abutting the main beach has an elevation ranging from 3.79m AHD at it's lowest point to 5.3m AHD at its highest point, with the dune adjacent to the northern rocky outcrop having an elevation up to 7m AHD.

The coastal path west of the carpark has an elevation ranging from 1.7m AHD at the footbridge to 2.6m AHD at the carpark.

5.5.3 Recession due to Sea Level Rise (future climate)

The application of the Bruun Rule requires the presence of unconsolidated sand and an equilibrium profile as described above. The requirements of the Bruun rule are considered to be satisfied for this section of beach.

The berm height (4.5m), depth of closure (depth beyond which there is minimal sediment movement) of 3.5m (from 0 to -4.2 m AHD), and the active length of the profile (250 m) have been taken from the profile 735002 shown in Figure 7.

The recession due to sea level rise for future climate projections is computed as shown in Table 5

TABLE 5 RECESSION DUE TO SEA LEVEL RISE ON FOX BEACH ASSUMING NO PROTECTION FROM A SEA WALL.

Recession due to sea level rise (m) – Bruun Rule		
	2050 (0.3m SLR)	2100 (1m SLR)
L = 250	8.6	28.7

There are large uncertainties associated with the estimates in Table 5 therefore these estimates should be treated with caution.

5.5.4 Total estimated coastal recession

The total estimated coastal recession in 2050 & 2100 allowing for short term erosion, long term recession and erosion from sea level rise is estimated at 23m and 53.1m respectively as shown in Figure 10.

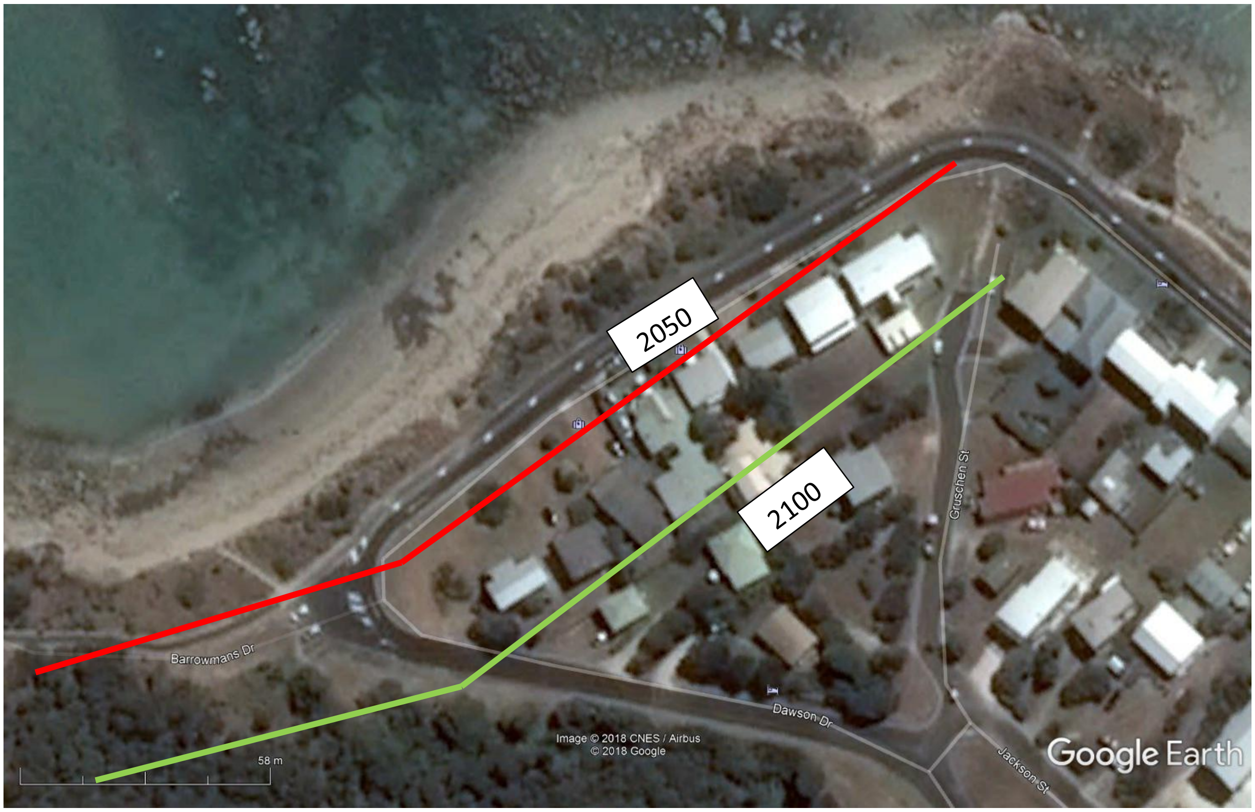


Figure 10-Projected long term recession line

5.5.5 Causes of Current Dune Erosion

The recent accelerated erosion and damage to the beach access steps experienced at Fox beach is considered to be a result of the following factors:

- Large storm surge events in 2016 in conjunction with record tide levels forcing waves directly onto coastal dunes and structures with high wave run up eroding the toe of the dune and access structure foundations as well as large swells;
- The resultant storm cut and wave run up erosion and fine sand grain size causing the dune to become unstable and collapse;
- Very large swells and storm surge events in July-September 2018 which resulted in additional sand loss since August 2018 however based on a November 2018 re-survey of the beach some 450m3 of sand has re-established at the front of the beach since the storms have abated.

Additional top of dune erosion is also occurring from uncontrolled pedestrian access at two locations north of the former timber access stairs location and long term undercut erosion is also evident at the rocky headland at the east end of the beach.

6 Coastal Hazards Risk Assessment

6.1 *Coastal Hazards*

6.1.1 Current Hazards & Risks (0-10 years)

The current hazards and risks at Fox Beach are:

- Personal injury risk to pedestrians due to dune or undercut rocky headland collapse;
- Collapse of dune fencing due to wave erosion undermining;
- Loss of dune vegetation and sand drift due to wave erosion and uncontrolled pedestrian access
- Loss of dune crest from extreme and large storm surge and large swell events and potential for wave overtopping onto the Esplanade

6.1.2 Future Hazards & Risk (Beyond 10 years)

The key future coastal hazards and risks at Fox Beach are:

- Increased frequency of extreme storm events and short-term storm induced dune erosion due to raised water levels sea level rise;
- Erosion damage to parts of the Esplanade and associated infrastructure and dune fencing by 2050 arising from coastal recession under storm surge and under 0.3m of sea level rise;
- Erosion damage to all of the Esplanade, coastal path, carpark and to up to 9 houses by 2100 arising from coastal recession dune erosion under storm surge and under 1.0m of sea level rise;
- Potential short duration coastal inundation of low point in property at the corner of the Esplanade and Dawson Drive arising from loss of coastal dune crest due to storm surge and under sea level rise;

6.1.3 Likelihood Consequence & Risk Rating

The likelihood consequence and risk rating of the above risk factors without mitigation measures prior to 2050 are summarized in Table 6 below.

TABLE 6 RISK MATRIX ASSUMING DO NOTHING.

Risk factor	Likelihood	Consequence	Risk rating	Control Measures
Personal Injury or death from dune collapse onto beach	Likely	Major/catastrophic	High/extreme	Protect/stabilize batter Restrict/control beach access Warning signs
Erosion of Esplanade &	Possible	Moderate	Moderate	Protect dune-hard or soft

associated Infrastructure				engineering structures
Erosion damage to houses	Unlikely	Low	Moderate	Monitor
Inundation to houses	Unlikely	Low	Moderate	
Inundation to private land	Possible	Low	Moderate	Raise dune crest & revegetate

7 Potential Management Options

Whilst Fox Beach is located in a relatively low wave energy environment it does receive up to one to two significant storm surge events annually and some swell and in 2016 received large events which have accelerated the rate of erosion of the front and back of the beach and with sea level rise such events will occur more frequently.

Uncontrolled foot traffic over the dune also has the potential to destabilize the foredune and beach which could contribute to further erosion and sand drift.

However longshore drift and natural sand supply is also contained by virtue of the existing rocky headlands at each end of the beach and tidal outflows from Drain J hence any end scour impacts arising from use of hard engineering options would be minimal compared to an unconfined beach.

Given the above, short and long term measures that provide both protection of the back of the beach and foredune for storm surge conditions in conjunction with revegetation of the top and back of the dune and other management measures that control public access, are considered appropriate for Fox Beach.

7.1 *Short Term Management Options*

Short term management options to address public safety dune stability and sand drift onto the Esplanade and vegetation and public access damage include:

- Erection of fencing and warning signs at the back of the dune and at entrances to the rocky headland undercut zones;
- Erection of an engineered fenced boardwalk pedestrian beach access structure either at the northern (accessed off the Esplanade) or southern end of the beach (accessed from the coastal path) adjacent to the rocky headlands

- The development and implementation of a detailed monitoring program including methodology and trigger levels in consultation with CMB which could include installation of sand movement monitoring galvanised or marine grade stainless steel poles at the toe of dune and front of beach at forty metre intervals along the beach to annually survey changes in beach level and toe position and inform triggers for longer term management options;
- Initial sand nourishment program involving importation of (3000m3) of coarser (Dn 50=0.5mm) similar coloured sand at the back of the beach to restore the dune and reduce rate of erosion subject to availability of suitable local sand possibly mixed with imported seagrass wrack from nearby beaches subject to availability and costs coupled with continued re-vegetation of the top and back face of the dune

7.2 *Long Term Management Options*

Long term coastal measures that provide both protection of the back of the beach and foredune for storm surge conditions in conjunction with increased revegetation of the top and back of the dune, are considered appropriate for Fox Beach.

Possible long term options are summarized below.

7.2.1 Soft Engineering Options

- **Option 1**-Annual beach nourishment program (3000m3pa) of coarser imported (Dn 50=0.5mm) similar coloured sand to restore the dune and reduce rate of erosion subject to availability of suitable local sand possibly mixed with imported seagrass wrack from nearby beaches subject to availability and costs coupled with extensive re-vegetation of the top and back face of the dune-**low capital cost but moderate whole of life cost**;
- **Option 2-**Construction of a shore parallel geotextile bag sea wall along the coastal edge of the existing dune coastal face (Elcorock or equivalent) up to the dune crest or 3.5m AHD and extensive re-vegetation of the top and back face of the dune coupled with annual beach nourishment -E**xpensive whole of life cost bags <25 year life**;
- **Option 3**-Construction of a shore parallel geotextile sand sock container revetment (25m long x 0.5m diameter sand sausage) at the back of the beach up to 3.5m AHD (6 stacked bags /m) in conjunction with beach nourishment to cover sand socks and extensive re-vegetation of the top and back face of the dune-**Lower capital cost < 25 year life**;
- **Option 4**-Construction of Geoweb (Plastic honeycomb sand filled vegetated panels) or Defence Cell (geotextile cover) on coastal and landward face of dune and extensive re-vegetation- application in a coastal environment and durability not adequately tested -**Moderate cost**

7.2.2 Hard Engineering Options

- **Option 5**-Construction of 1T-2.5T local limestone or igneous rock 3m thick two- layer armor revetment wall along the coastal edge of the existing dune face initially up to 3.5m AHD and extensive re-vegetation of the top and back face of the dune in conjunction with annual beach nourishment **High capital cost but low Whole of life cost > 100 years life**

- **Option 6-**Construction of 1m3 random placed concrete cube revetment wall up to 3.5m AHD in conjunction with annual beach nourishment **Low to moderate capital cost low whole of life cost > 50 years life**
- **Option 7-** Construction of 1.6-2.4 T buried interlocking concrete blocks laid in terraced pattern up to 3.5m AHD covered with sand on coastal side-used in trail applications only over past 3-4 years **Low to moderate capital cost low whole of life cost > 50 years life**

A multi-criteria comparison of options is summarized in Table 7 below.

TABLE 7: POTENTIAL LONG TERM COASTAL MANAGEMENT OPTIONS COMPARISON

Treatment Option	Indicative Capex $/m	Benefits	Dis-benefits	Staging Potential
Option 1-Sand Nourishment 3,000m3pa - imported sand and imported sea wrack bund wall to 3.0m AHD in front of dune and additional sand on the beach	120*	Sand would require replacement annually and seasonally to balance loss from storm surge erosion and nourishment volumes would increase as sea level rises. Lowest capital cost option. No loss of beach width. High social benefit	Short life maintenance only solution. Still long term erosion from sea level rise Increase in annual cost High whole of life costs.	Good
Option 2-Elcolrock sea wall 0.75m3 bags (1V:1.5H) crest height 3.5m AHD	2500*	Reduces potential for dune toe undercutting in wave run up zone Reasonably effective for higher waves with SLR Crest height can be increased in the future. Effective in reducing storm surge erosion and long term recession Matches natural sand colour. Potentially encourages natural revegetation in accreted sand	Higher wave run up and overtopping due to steep slope and hard surface Some storm erosion damage potential and moderate maintenance. Bags may need to be replaced every 15-20 years Very High capital and whole of life costs Potential negative impacts on natural sand supply at the ends and in front of the	Good

Treatment Option	Indicative Capex $/m	Benefits	Dis-benefits	Staging Potential
			structure so nourishment required. Some loss of beach width so potential social impacts	
Option 3- Longitudinal geotextile bag sand sausage in front of dune 6 x 0.5m diameter 2 wide x 3 high) between RL 0.9m AHD and RL 2.4m AHD with beach nourishment above and in front Medium life solution 8-10 years	413*	Stronger potential to reduce collapse of dune toe under wave run up and marginal reduction in sand loss in spring tides. Moderate capital cost. Could encourage natural sand accretion and natural vegetation propagation in front of and behind the structure	Containers may need replacement every 10 years Some sand in front of containers would require replacement annually and seasonally. High whole of life costs. Used in limited application eg Victor Harbor	Good
Option 4-Sand bund in front of dune to 3.5m AHD with Geoweb or Defence cell and planting over bund and dune	290*	Reduced frequency of sand replacement. Assists in reducing long term recession Helps control dune stability and wind blown sand drift if vegetated. Moderate capital cost	Short –medium life option. Untested locally in coastal applications High whole of life costs.	Good
Option 5-1-2.4 Tonne limestone rock armour sea wall with crest height at 3.5m AHD (two layers)	3000-3500*	Most effective in reducing storm surge erosion of dune. Crest height can be increased in the future. Low annual maintenance cost and lowest whole of life cost overall. Structure could last > 100 years	High capital cost. Dependant on availability of affordable adequate volume of suitable local rock Potential for further erosion on beach at front of wall and at wall ends so annul nourishment required as well.	Good

Treatment Option	Indicative Capex $/m	Benefits	Dis-benefits	Staging Potential
			Loss of beach width and potential social impacts Poor Aesthetics.	
Option 6- Randomly placed 1m3 concrete cube revetment wall with crest height at 3.5m AHD (two layers)	1700*	Very effective in reducing storm surge erosion of dune. Crest height can be increased in the future. Low annual maintenance cost and low whole of life cost. Structure could last > 50 years Concrete blocks could be manufactured locally	High capital cost Aesthetics Some concrete blocks may crack Potential for further erosion on beach at front of wall and at wall ends so annual sand nourishment required as well. Loss of beach width and potential social impacts Not used in SA but used on NSW coast	Good
Option 7- Terraced sand covered concrete block wall	800*	Potentially effective in reducing storm surge erosion of dune. Crest height can be increased in the future. Low annual maintenance cost and low whole of life cost. Structure could last > 50 years Concrete blocks could potentially be manufactured locally Moderate capital cost.	Moderate capital cost Some concrete blocks may crack Potential for further erosion on beach at front of wall and at wall ends so annual sand nourishment required as well. Loss of beach width and potential social impacts Treatment has only been used as a trial at Victor Harbor since January 2015 with no displacement since. Not a standard coastal; treatment and	Good

Treatment Option	Indicative Capex $/m	Benefits	Dis-benefits	Staging Potential
			long term performance yet to be proven.	

*All costing assumes the use of local labour plant & equipment and materials without the need for accommodation and per diem allowances and excludes construction contingencies design and project management costs and costs of re-vegetation and dune protection fencing assumed to be funded by NRM grant and volunteer labour.

Option 1 assumes sand nourishment at $10/m3 and importation of sea wrack from Kingstone at $10/m3.

8 Development Plan Provisions

The site is located in the Coastal Open Space Zone and coastal protection or management works are considered complying development.

The minimum site levels for this zone are set at 2m AHD however the crest level for any protection structures would need to be set above this level to ensure adequate freeboard and protection from wave overtopping dune erosion damage in a 1% AEP storm surge event.

All the identified long term management options would require development approval and sand extraction for any nourishment may also trigger an EPA Dredging Licence.

9 Council and Community Briefing

A briefing on the causes of the erosion and the above potential short term and long term coastal management options was provided to elected members on 4 September and the Robe Community on 30 September 2018.

The then Council acknowledged that coastal management measures were required and was supportive of the management options identified in Section 7 of this report.

The community briefing on 30 September was attended by 27 residents and property owners who also acknowledged that coastal management measures were required and attendees were supportive of the short term management options identified in Section 7 of this report with stronger support for Long Term Options 1 and Option 7 given the shortage of rock and aesthetics.

Questions and answers raised at the community briefing are attached in Appendix B.

10 Conclusions

Based on the study outcomes the following conclusions can be drawn:

- The recent accelerated erosion experienced at Fox Beach is considered to be a result of the following factors:
    - Large storm surge events in 2016 in conjunction with record tide levels forcing waves directly onto coastal dunes with high wave run up eroding the toe of the dune causing dune collapse;
    - Large swells in the past few weeks in Guichen Bay generated from abnormally large swells in the Southern Ocean;
    - The resultant storm cut and wave run up erosion and fine sand grain size causing the dune along the 120m beach length to become unstable and collapse.
    - Additional top of dune erosion from existing uncontrolled pedestrian access.
- The total estimated coastal recession in 2050 & 2100 allowing for short term erosion, long term recession and erosion from sea level rise is estimated at 23m and 53.1m respectively.
- The estimated volume of sand eroded from the front and back of the beach in a 1%AEP storm over the 120m beach length is 11,300m3.
- The current hazards and risks at Fox Beach are:
    - Personal injury risk to pedestrians due to dune or undercut rocky headland zones collapse;
    - Loss of dune vegetation and sand drift due to wave erosion and uncontrolled pedestrian access;
    - Collapse of dune fencing due to wave erosion undermining;
    - Loss of dune crest from extreme and large storm surge and large swell events and potential for wave overtopping onto the Esplanade
- The key future coastal hazards and risks at Fox Beach are:
    - Higher water levels and higher waves during extreme storm events causing accelerated erosion due to sea level rise;
    - Further Loss of dune vegetation and sand drift due to wave erosion and uncontrolled pedestrian access;
    - Collapse of rocky headland undercut zones;
    - Erosion damage to parts of the Esplanade and associated infrastructure and dune fencing by 2050 arising from coastal recession under storm surge and under 0.3m of sea level rise if no long term management measures are implemented;
    - Erosion damage to all of the Esplanade, coastal path, carpark and to up to 9 houses by 2100 arising from coastal recession dune erosion under storm surge and under 1.0m of sea level rise if no long term management measures are implemented;

  - Potential short duration coastal inundation of low point in property at the corner of the Esplanade and Dawson Drive arising from loss of coastal dune crest due to storm surge and under sea level rise.
- Management measures are required to reduce the rate of coastal erosion at Fox Beach and protect infrastructure from erosion damage in the longer term and the local community are supportive of the short term and long term management options identified in Section 7 of this report.

11 Recommendations

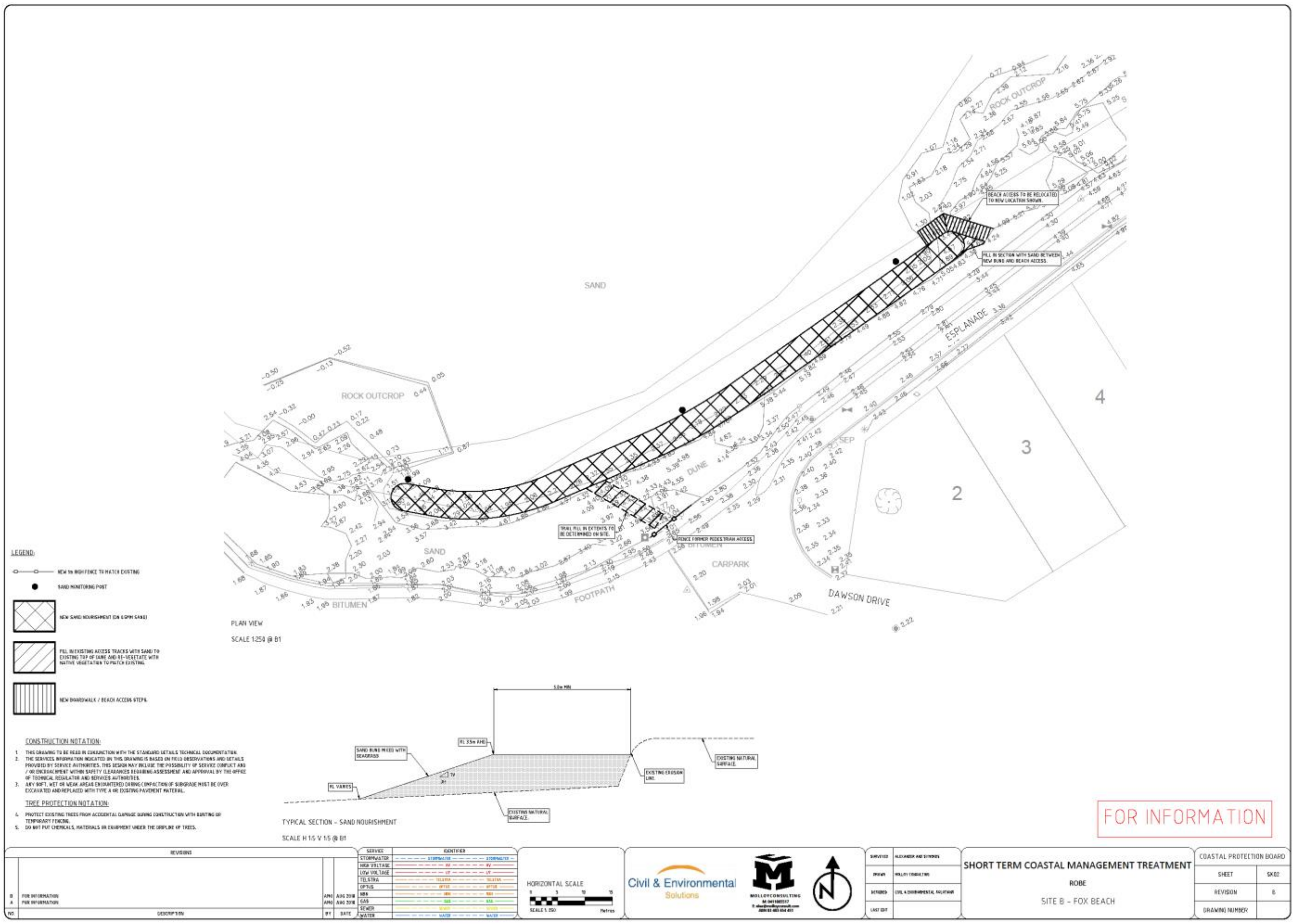
Based on the above assessment it is recommended that Council:

- Undertake an assessment of potential nearby sand borrow areas with a Dn 50=0.50mm grain size of similar colour and a quantity in excess of 40,000m3 including Particle Size distribution samples to confirm grain size;
- Undertake discussions with neighboring Councils eg Kingstone DC & Wattle Range Council to see if sea grass wrack can be obtained economically for any sand nourishment mixing;
- Erect fencing and unstable cliffs warning signs at the back of the dune and at entrances to rocky headland undercut zones;
- Develop and implement a detailed monitoring program including methodology and trigger levels in consultation with CMB which could include installation of sand movement monitoring galvanised or marine grade stainless steel poles at the toe of dune and front of beach at sixty metre intervals along the beach to annually survey changes in beach level and toe position and inform triggers for longer term management options;
- Undertake initial sand nourishment involving importation of (3000m3) of coarser (Dn 50=0.5mm) similar coloured sand to restore the dune and reduce rate of erosion subject to availability of suitable local sand possibly mixed with imported seagrass wrack from nearby beaches subject to availability and costs coupled with extensive re-vegetation of the top and back face of the dune and obtain all required Development approvals and licences as shown in Figure SK02 Appendix A ;
- Undertake an annual sand nourishment involving importation of (3000m3pa) of coarser (Dn 50=0.5mm) similar coloured sand to restore the dune and reduce rate of erosion subject to availability of suitable local sand possibly mixed with imported seagrass wrack from nearby beaches subject to availability and costs coupled with extensive re-vegetation of the top and back face of the dune and obtain all required Development approvals and licences;
- Should the top of dune erosion line get closer than 2m from to the northern edge of seal of the Esplanade or northern edge of coastal path, then consider installation one of the long term management options identified above;

- That any long term management measures be undertaken concurrently with rocky headland void restoration works and be extended around past the bend in the Esplanade to the beach to the east.

Appendix A

Figure SK02


SHORT TERM COASTAL MANAGEMENT TREATMENT
ROBE
SITE B - FOX BEACH
COASTAL PROTECTION BOARD
FOR INFORMATION
PLAN VIEW
TYPICAL SECTION - SAND NOURISHMENT
LEGEND:
CONSTRUCTION NOTATION:
TREE PROTECTION NOTATION:
SAND
ROCK OUTCROP
ESPLANADE
DAWSON DRIVE
CARPARK
FOOTPATH
BITUMEN
DUNE
HORIZONTAL SCALE

Appendix B

Summary of community briefing questions and answers

Coastal Erosion Information Session | Sunday 30 September 2018

Questions brought forward

Question	Response
Is the fence proposed at Hooper's Beach going in front of every property?	It is only a proposal at this point in time, and yes, if it were constructed it would be placed along the entire length of the coastal dunes at Hooper's Beach.
Will the plan involve financial modelling of all the options presented and who will do this work?	The report in its current form only presents options, once an option has been agreed upon and if that option involves considerable expense then the whole of life financial impact of the option would be ascertained. Who would actually do this financial modelling has not been considered.
Will council continue to undertake sand replenishment?	Yes, Council will remove the sand from the buildup of sand at Karatta Beach and replenish the beaches east of the breakwater.
Does the groyne at the eastern end of Main Beach work in holding back the sand?	Yes.
Does the groyne at the eastern end of Main Beach affect the sand levels at Hooper's and Fox Beach's?	Without sand movement modelling our understanding of the movement of sand along Guichen Bay would suggest that it has a level of impact. What that level of impact is not known.
Is the sand that Council places on Main Beach enough to replenish the sand that is lost?	From the impact on the beach and dunes it would appear that the sand carted by Council is not enough to replenish sand loss.
What are council's short term plans for Fox Beach?	Council will need to consider closing the beach, installing appropriate signs, or undertaking sand replenishment at the beach as soon as possible. It is unlikely that Fox Beach will be able to be in a safe condition for the upcoming summer.
Could Council consider a concrete access to Fox Beach as the concrete ramp has not eroded at Hooper's Beach?	Any constructed access at Fox Beach will be engineered, requires Coastal Management Branch approval and must be regarded as sacrificial.
Council must engage the community in an education process to inform them of the value of the dunes?	Agreed and work will be done over the holiday period.