Coastal Adaptation Study
for Alexandrina Council

GOOLWA BEACH

Cells SF3 and SF4

By Integrated Coasts: Western, Hesp, and Bourman (2019)

Report to be cited as: Western, M., Bourman, R., Hesp, P (2019) Coastal Adaptation Study for Alexandrina Council (Cell SF3-4 Goolwa Beach) prepared by Integrated Coasts, South Australia.

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Cover photograph: SA Coast Protection Board, 2008

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Introduction

This document is a partial output for the Coastal Adaptation Study for Alexandrina Council (Goolwa Beach/ Tokuremoar Cell SF3-4). This document also represents an output from the coastal adaptation assessment tool designed by Integrated Coast.

This document should be read in conjunction with the main report, *Coastal Adaptation Strategy for Alexandrina,* that explains more fully the underpinning methodology. Definition of terms within this work are adopted from www.coastadapt.com.au (Glossary).

ASSESSMENT FRAMEWORK

This coastal assessment tool adopts a simple and intuitive framework. Coastal hazards experienced along a section of a coastline can be categorised and assessed in three main ways:

- **Coastal fabric (geology)**

Intuitively we understand that if we are standing on an elevated coastline of granite that the coast is not easily erodible. Conversely, we understand if we are standing on a low sandy dune that erosion may indeed be a factor. It is the geology of the coast upon which our settlements are situated that determines one side of the hazard assessment in terms of elevation (height above sea level), and the nature of the fabric of the coasts (how resistant it is to erosion). This assessment tool categorises coastal geology in four main ways:

(1) Low erodibility
(2) Moderate erodibility
(3) High erodibility
(4) Very high erodibility

- **Coastal modifiers (human intervention)**

In some locations there are additional factors that modify this core relationship between fabric and exposure. For example, an extensive rock revetment has been installed from Brighton to Glenelg along the Adelaide coastline. This installation has modified the fabric of the coast from dunes to rock.

- **Coastal exposure (actions of the sea)**

If we find ourselves on the shore of a protected bay, or in the upper reaches of a gulf, we intuitively know that the impact from the ocean is likely to be limited. On the other hand, if we are standing on a beach on the Southern Ocean and listening to the roar of the waves, we understand that we are far more exposed. This assessment tool categorises coastal exposure in four main ways:

(1) Very sheltered
(2) Moderately sheltered
(3) Moderately exposed
(4) Very exposed

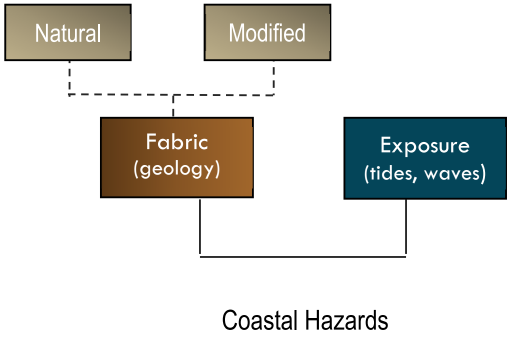
CHANGES IN THE RELATIONSHIP

Finally, in a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements.

Our sea levels have been quite stable for several thousand years. However, in recent times, the rate of sea level rise has escalated. Last century, sea levels rose at ~2-3mm per year. In this century, seas are rising on average at ~4-5mm per year in our region. The general consensus of the scientific community is that the rate of sea level rise will continue to escalate towards the end of this century (~10-15mm per year). These projections are based on sound physics, but the exact rate is uncertain.

What is certain is that if seas rise as projected then the relationship between fabric and exposure will change significantly in some coastal locations.

Figure 1: Conceptual assessment framework



What we aim to do in this project is to evaluate the relationship between the ***fabric*** of the coastline and its current ***exposure*** to actions of the sea and how this relationship may change over time. We conduct this evaluation within the regional setting of secondary coastal cell **Coorong** (CoastAdapt) and within tertiary cell **Southern Fleurieu 3 and 4** (Nature Maps).

Introduction

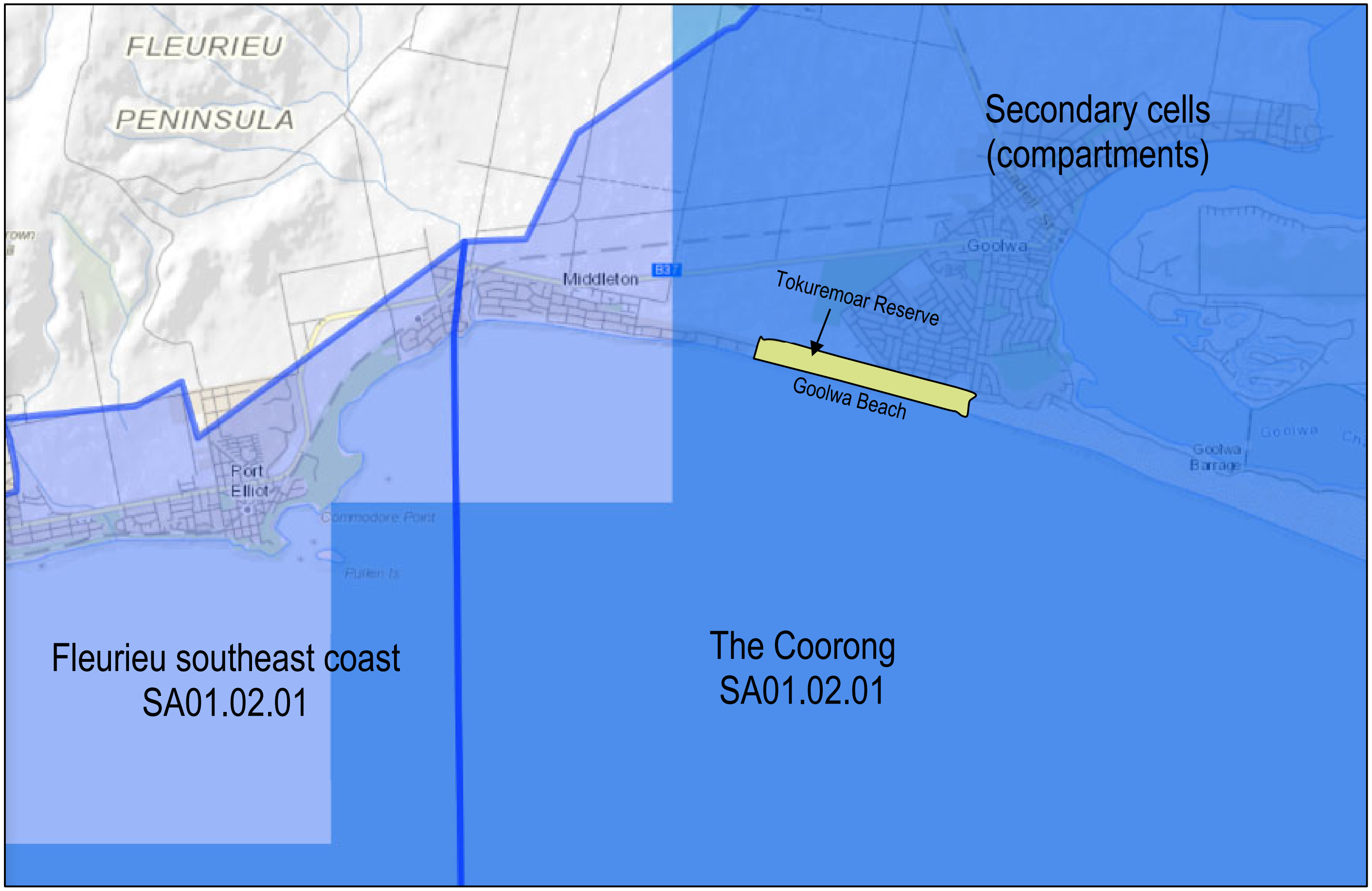
Overview

Map: SF3-4

Secondary Cell: COORONG

Tertiary Cells: Goolwa Beach and Tokuremoar Reserve

Secondary Cell



CoastAdapt provides the Australian regional setting

Cell: The Coorong (extends from Cape Jaffa to Middleton)

Geomorphology of the cell:
Sheltered to exposed, W-SW facing curving barrier, with beach-foredune ridges (Lacapede Bay) to massive dune transgression - onshore transport (mix of quartz & carbonate beach sand).

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The dominant regional processes influencing coastal geomorphology in this region are the Mediterranean to humid cool-temperate climate, micro-tides, high energy south-westerly swells, westerly seas, carbonate sediments with interrupted swell-driven longshore transport, and the Southern Annular Mode (driving dominant south-westerly swells and storms). Regional hazards or processes driving large scale rapid coastal changes include: mid-latitude cyclones (depressions), storm surges and shelf waves.

Source: https://coastadapt.com.au/sites/default/files/docs/sediment_compartments/SA01.02.01.pdf

Introduction

Overview

Map: SF3-4
Secondary Cell: COORONG
Tertiary Cells: Goolwa Beach and Tokuremoar Reserve
Tertiary Cell

SA regional setting

Conservation Cell: Southern Fleurieu 3, Goolwa Beach and Southern Fleurieu 4, Tokuremoar Reserve.

Cell extent

From Goolwa carpark to end Boult Street (edge of Tukuremoar Reserve)

Note: These two cells combined encompass what is known locally as Goolwa Beach.

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1. SETTLEMENT HISTORY

A historical review ensures that the circumstances in which the settlement was founded are understood and key documents and events are identified and reviewed. In this section we:

- Give a brief history of the settlement
- Review archives at Coastal Management Branch
- Identify key studies and plans
- Identify any key storm events (if known).

1. Settlement history

One purpose of this section is to identify the key factors of settlement history in the context of the coastal environment. It is not to provide a comprehensive historical account. In particular, we are interested in identifying any key ocean impacts or events, and past protection and management strategies.

A second purpose is to identify key studies so that we build appropriately upon previous work.

BRIEF HISTORY

Prior to European settlement the Goolwa Beach region was inhabited by the Ngarrindjeri people[1]. There is ample evidence in the dunes backing Goolwa Beach of Aboriginal occupation in the form of shell middens, comprised dominantly of the Goolwa cockle, *Donax deltoides*. Radiocarbon dates on similar middens on Sir Richard Peninsula fall in the range between about 200 and 3,500 years[2].

Early European explorers and settlers saw the potential for expansion along the fertile lower reaches of the River Murray. However, the mouth of the Murray River was completely unsuitable for navigation[3].

Goolwa was formally established in 1853 as Australia's first inland port, built to connect Goolwa to Port Elliot and later extended to Victor Harbor, allowing for goods and people to move from river boats to sea boats to avoid navigating the Murray Mouth.

The circumstances that saw Goolwa Beach established as a recreational area are not easily determined but it is likely that Goolwa Beach was accessed for recreation from the early times of settlement.

An account handed down to Dr Bob Bourman by the late Mr Arthur Neighbour of Goolwa, tells of a beach shelter that was constructed in 1914 at 100 m from the shoreline, but became permanently inundated, and by the mid-1950s only the upright posts remained.

Figure 2: Goolwa Beach on a windy day 1917. Pictured Averill Stow-Smith and Ray. SA State Library.

The 1949 aerial photograph below shows the long road from Goolwa that terminates in much the same place is it does currently.

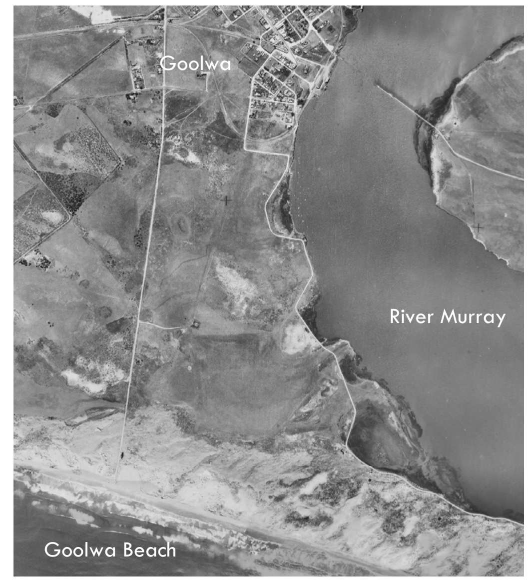

Figure 3: Aerial photograph of Goolwa Beach Road (1949), Department of Environment and Water.

KEY DOCUMENT

Port Elliot and Goolwa Heritage Study (1981) provides comprehensive history of the region and identifies key heritage sites. But this study is silent on Goolwa Beach.

[1] See the Ngarrindjeri Ratalang Cultural Heritage Management Plan.

[2] Dr Bob Bourman (contributor)

[3] History and Heritage of Coastal Engineering p.7

1. Settlement history

ARCHIVAL REVIEW

Records exist in hardcopy archives of Coastal Management Branch from 1974 to 1983. Scans are referenced within text according to date.

Erosion control

Most correspondence relates to control of sand movement and erosion (19740823, 19750424, 19750926, 19790525). A total of $30,400 was expended on erosion control measures from 1974 to 1983. Most of this work was concentrated on the sea side of the dunes but some work was undertaken on the rear side of the dunes after reports that 'sand was drifting into established subdivisions' (19800430).

Purchase of allotments by CPB

In 1978 Coast Protection Board purchased 17 allotments in the Boult Street region at a total cost of $50,000. Council contributed $10,000. The backstory as to how these allotments were approved within the dune system is not known (19780613)

Construction of kiosk

In 1981, Council referred a proposal for a kiosk to Coastal Management Branch for comment. There appears to have been another kiosk in existence at the time at 400m further north. One condition of approval was that 'the kiosk should be located a minimum of 60m from the seaward edge of the carpark.

SIGNIFICANT STORM EVENTS

A review of the archives did not identify any specific storm events at Goolwa Beach. Council staff report that the current main access way to the beach is very difficult to manage in terms of sand loss and gain.

STUDIES AND PLANS

Goolwa Beach Car Park and Surrounds Masterplan, Jensen Planning and Design (December 2016).

The prime review document for this section of work is *Goolwa Beach Car Park and Surrounds Masterplan* for two main reasons:

(1) The document includes a comprehensive literature review was conducted in the context of Goolwa Beach.
(2) The plan includes proposed upgrade to Goolwa Beach carpark area

In regard to the first, the following documents have been reviewed:

- Community Strategic Plan (2014-2023)

This Plan includes the priority to promote 'climate-ready communities' and in particular notes the requirements set out by Coast Protection Board to take into account sea level rise impact to 2050 and 2100.

- Environmental Action Plan (2014-2018)

This Plan notes that the Goolwa Dune System is one of the few remaining significant areas of remnant vegetation.

- Goolwa Dunes and Tokuremoar Reserve Action Plan 2015

Identifies the Goolwa Car Park as part of the Goolwa Dune System and notes the contribution made to the stabilisation and control of the dunes of various community organisations.

- Economic Development Strategy (2016-22)

The Strategy outlines nine objectives, one of which is to promote tourism and 'create memorable experiences'

KEY DOCUMENT

Goolwa Beach Car Park and Surrounds Masterplan sets out proposed works for Goolwa Beach car park but also includes a comprehensive literature review of relevant documents and studies.

1. Settlement history

Goolwa Beach Car Park and Surrounds Masterplan (continued)

Based on advice from Coast Protection Board the masterplan has adopted ~60m of shoreline retreat by 2100 (Figure 4).

2. GEOMORPHOLOGY

2. Geomorphological context

By Dr Robert Bourman
See full version in Part 1 of the report

COASTAL FORMATION

Today we live in an interglacial period, the most equitable time for human beings. The previous time in Earth history was about 125,000 years ago during what is called the Last Interglacial when locally it was warmer and wetter than at present with sea level being 2-5m higher than present.

Tectonic Movement

Relicts of the geological history of the area are preserved in places along the Alexandrina Coastline. Ancient metamorphic and granitic rocks at Middleton and Port Elliot bring stability to the shoreline at those locations. Permian glacial sediments and alluvium of the last interglacial age form the back shore of easily eroded coastlines, while offsets of limestones of various ages record the tectonic behaviour of the area. In particular, offsets of the last interglacial shoreline (125,000 years old), which originally stood at ~2m above present sea level confirm the ongoing tectonic uplift of the Mount Lofty Range and the South East Coastal Plain, with subsidence occurring in the Murray Estuary. Consequently, most of the study area is undergoing subsidence at an approximate rate of 0.02mm/yr.

Modern coastline

The modern coastline developed after sea level rose between 17,000 and 7000 years ago at a rate of ~10mm /year at the end of the Last Glacial Maximum. With sea level rise, large reserves of sand, including the last glacial maximum desert dunes on the exposed continental shelf, were carried landward, providing source material for the modern beaches and dunes. The coastline east of Middleton Creek is very dynamic, changing with variations in sea level, wind, storm waves and tidal conditions. A prominent feature of this section of coastline has been recent coastal erosion, which as been particularly marked in the softer rocks of the Middleton to Goolwa Section of the coastline.

KEY POINTS

- Land areas to the east of Watson Gap (including Cell 7) are subsiding, but at a very low rate of 0.02mm/ yr.
- The coastline from Middleton to Goolwa is very dynamic and has undergone significant erosion in times before the 1950s.

Figure: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

2. Geomorphological context

By Dr Robert Bourman
See full version in Part 1 of the report

COASTAL FORMATION

It is possible to map out the approximate location of the last interglacial shoreline (ie when the earth was last free of ice) which provides a useful indication of where sea level may rise to in the future due to naturally occurring changes plus the influence of human impacts (See Figure 3).

Goolwa Beach

Between Surfers Beach and Goolwa Beach the shoreline is backed by modern sand dunes.

A tea tree swamp area with marls and coxiella occurs in the interdune area between the old last interglacial calcareous dune in which the Goolwa Dump and Traeger's Sand Quarry have been established, and the modern coastal dune. The low-lying swamp continues to the west between the modern dunes and the 100,000-year old dune at Surfers Beach. This low-lying region is underlain by calcareous marl that may have formed in the freshwater swamp. On the northern side of the swamp in Traeger's Sand Quarry shells of the last interglacial shoreline occur at an elevation close to modern sea level, in contrast to their position at Watson Gap of ~10 m. This again demonstrates the tectonic sinking of the Goolwa area over the last 125,000 yrs

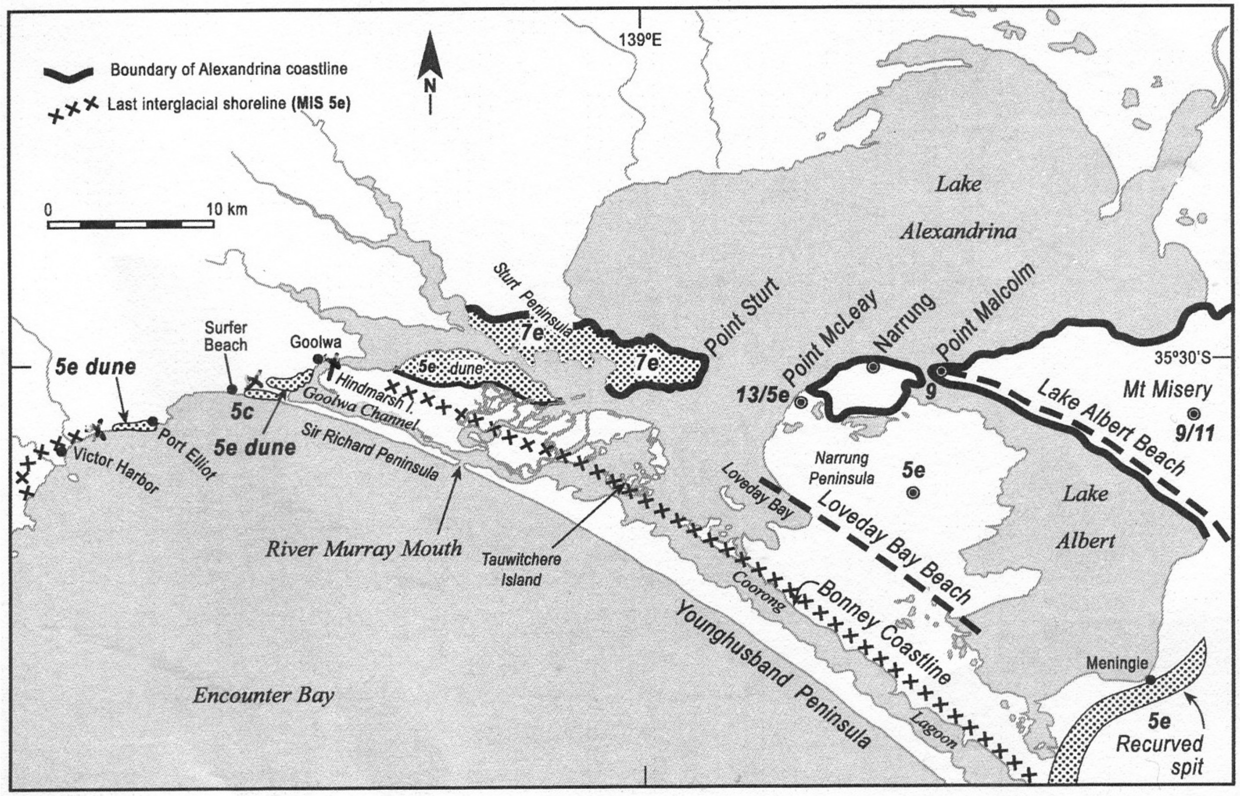

Figure 3: The location of the last interglacial (125,000 years old) shoreline, marked by crosses) originally at ~ 2 m above present sea level, now uplifted to ~6 m in the Victor Harbor area and depressed to near present sea level in the Goolwa area. The Chiton area is being uplifted while the remainder of the shoreline is sinking tectonically at an average rate of 0.02 mm/yr. The MIS 7e dune is about 250,0000 years old. The Alexandrina Coastline (dark black line) on this map was a name given to the much older sand dunes landward of the last interglacial shoreline.

KEY POINT

Every hundred thousand years (or so) sea level has been at present or higher levels and formed a coastal barrier.

2. Geomorphological context

COASTAL FORMATION

At Goolwa Beach patches of calcreted aeolianite are exposed on the vehicle access drive to the beach; occasionally coastal erosion exposes a calcrete surface below the beach sand on the beach face in front of the Car Park. These occurrences of calcreted aeolianite are probably the same age as the aeolianite at Surfers (~100,000 years) as they lie seawards of the last interglacial dune which underlies much of Goolwa Township, extending through Goolwa Beach and the Goolwa Dump area almost to Middleton, with the back edge of the fossil dune being easily visible from the main Goolwa-Middleton road.

Coastal erosion (longer term)

There is evidence of longer-term coastal erosion at this locality. Black organic deposits, which would have originally formed in a back-barrier lagoon setting behind the modern coastal dunes, have been sporadically exposed after storms on the modern beach from Goolwa Beach almost to the Murray Mouth. Skeletons of rodents, shells and tree stumps contained in the back-barrier deposits, have been radiocarbon dated between 7,000 to 4,500 years BP (Before Present). These sediments demonstrate that the dunes and the shoreline have moved landward at least 1 kilometre over the past 7,000 years at an average rate of 14 cm/yr.

Figure 4: Back-barrier lagoonal sediments containing skeletons of rodents, shells and tree stumps dated at 7,000 to 4,500 years Before Present exposed on the modern beach from Goolwa Beach almost to the Murray Mouth. These sediments demonstrate that the dunes and the shoreline have moved landward at least 1 kilometre over the past 7,000 years at an average rate of 14 cm/yr.

(R. Bourman)

GOOLWA BEACH

3. COASTAL FABRIC

In this section we evaluate coastal fabric in more detail:

- Overview of current coastal fabric
- Changes to shoreline over seventy years
- Changes to seafloor since 1977
- Human intervention

The current coastal fabric is a combination of natural geology and human intervention.

3. Coastal Fabric - natural

Overview

Map: SF3

Secondary Cell: Coorong
Tertiary Cell: Goolwa Beach

Form

Beach

Fine-medium sandy beach

Backshores

Backshore 1: Dunes 15-20m high and 200m wide on eastern end and 10-15 high and 80m wide on western end.

Backshore 2: Behind the dunes is a tea tree swamp at elevations less than 2m AHD. Behind the swamp land elevation is ~10m at distance of 500m inland from shore.

Bathymetry

Overall slope of ocean floor:
-10m /1km from beach (overall slope ratio 1:100).

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3. Coastal Fabric - natural

Overview

Map: SF3

Secondary Cell: Coorong

Tertiary Cells: Goolwa Beach

Geology

Geology

Beach and backshore 1:

Semaphore sand – unconsolidated white bioclastic quartz- carbonate sand of modern beaches and transgressive dune fields.

Age: Holocene

Backshore 2 (swamp and hill)

Bridgewater formation

Age: Pleistocene

Figure opposite sourced from www.sarig.gov.au

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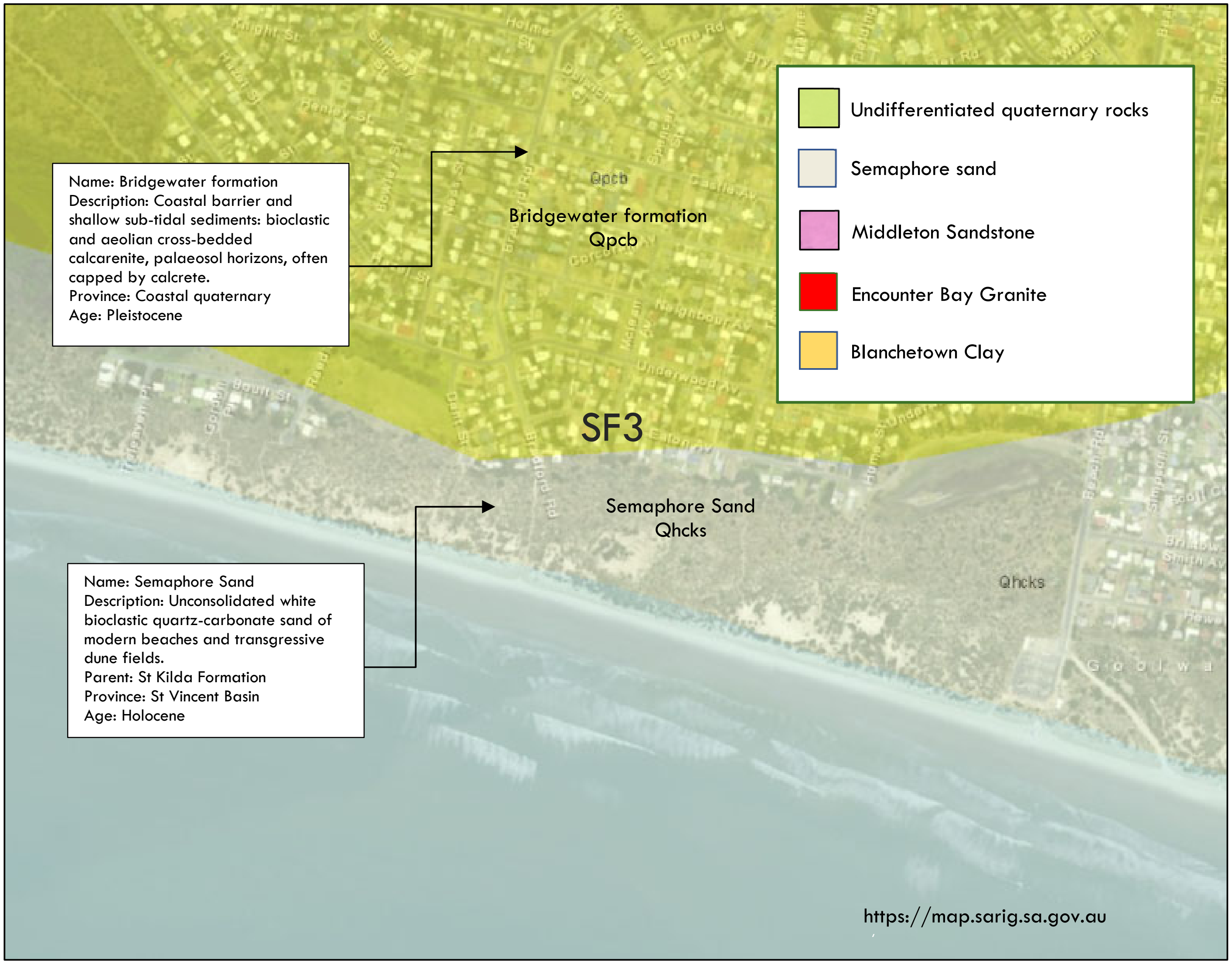

3. Coastal Fabric - natural

Overview

Map: SF3

Secondary Cell: Coorong

Tertiary Cell: Goolwa Beach

Benthic

Benthic

Wide, low gradient, fine sand, dissipative surfzone often with two or more shore parallel bars and troughs. Wave energy can be significant and the surfzone may be severql hundred metres wide during storms.

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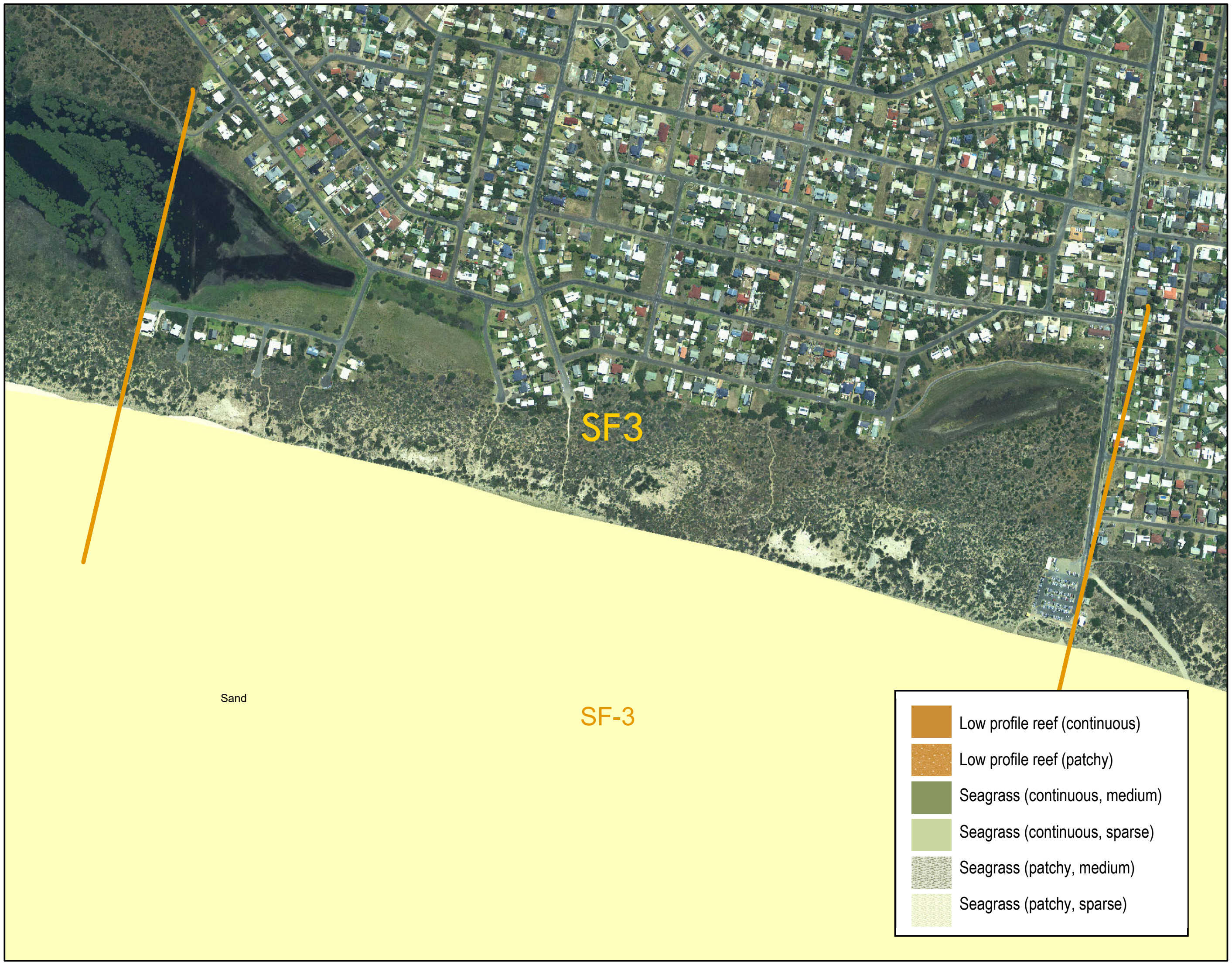

3. Coastal Fabric - natural

Overview

Map: SF3

Secondary Cell: Coorong
Tertiary Cell: Goolwa Beach

<u>Nature Maps</u>

Shoreline class

Dissipative Beach (see inset)

Sand rating
Fine sandy beach

Exposure:
Exposed

Wave:
High (2m average, Surfwatch)

Backshore 1:
Unstable dune (partially vegetated).

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Dissipative Beaches

Dissipative beaches only occur on parts of the high energy southern coast where waves regularly exceed 2.0m and where the beaches are composed of fine sand. These combine to maintain a low gradient surf zone up to 500m wide with usually two to occasionally three shore-parallel bars, separated by subdued troughs. Waves begin breaking several hundred metres offshore as spilling breakers on the outer bar, then reform in the outer trough to break again and again on the inner bar or bars. In this way they dissipate their energy across the wide surf zone. The beach has a wide, low gradient swash zone, with the high tide swash reaching to the back of the beach, often leaving no dry sand to sit on at high tide. The shoreline tends to be relatively straight and uniform alongshore with no rip currents. (OzCoasts, 2019)

3. Coastal Fabric - natural

MEDIUM TERM CHANGES

Recession between 1860 and 1950

The coastline at Goolwa Beach has also been affected by coastal erosion since European settlement, with previously existing sand dunes having been destroyed. The erosion of European structures such as beach shelters and surveyed roads demonstrates ample evidence of historical coastal changes.

Example 1:

For example, a beach shelter originally built on the upper part of the beach was removed after it became permanently inundated. According to the late Mr Arthur Neighbour of Goolwa, the upright post remnants of a beach shelter, originally constructed 100 m from the shoreline in 1914, became permanently inundated by the mid-1950s, and were removed for firewood.

Example 2:

In the 1860s usual practice was to make surveys to within 150 links (1.5 chains, 30m) from high water.

Assuming the practice was adhered to at Goolwa Beach then high water mark in the 1860s would have been 30m further to the south. We establish in the next section that there has been little erosion since 1950, and therefore any erosion calculation in this context is predominantly related to the period 1860 to 1950.

Therefore, in this location, ~40-45m of erosion occurred between 1860 and 1950 at approximately 0.5m per year.

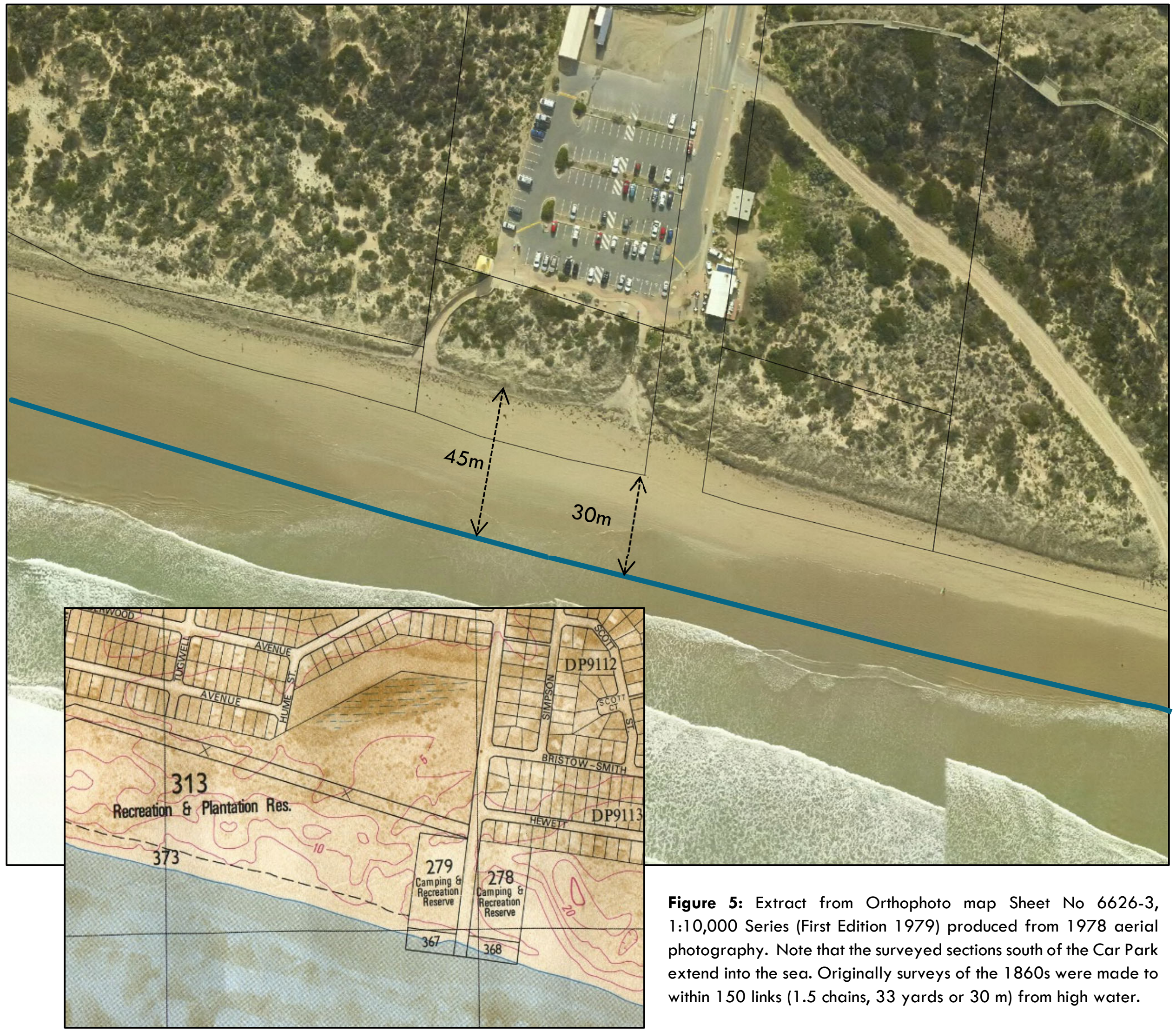


Figure 5: Extract from Orthophoto map Sheet No 6626-3, 1:10,000 Series (First Edition 1979) produced from 1978 aerial photography. Note that the surveyed sections south of the Car Park extend into the sea. Originally surveys of the 1860s were made to within 150 links (1.5 chains, 33 yards or 30 m) from high water.

3. Coastal Fabric - natural

By Dr Robert Bourman
See full version in Part 1 of the report

Recession between 1860 and 1950 (continued)

Example 3:

In the western section of Goolwa Beach a former road that is now designated 'closed road' on SA Nature Maps is situated ~50m from the current shoreline. Allowing for a further 30m in accordance with surveying practice at the time, then the shoreline has retreated 80m between 1860s and 1950. This equates to ~ 0.9m per year of recession.

Given this evidence of both long-term and short-term coastal erosion along this section of coastline under natural conditions highlights the vulnerability of this coast to erosion with a scenario of a possible future 1 m rise in sea level.

3. Coastal Fabric - natural

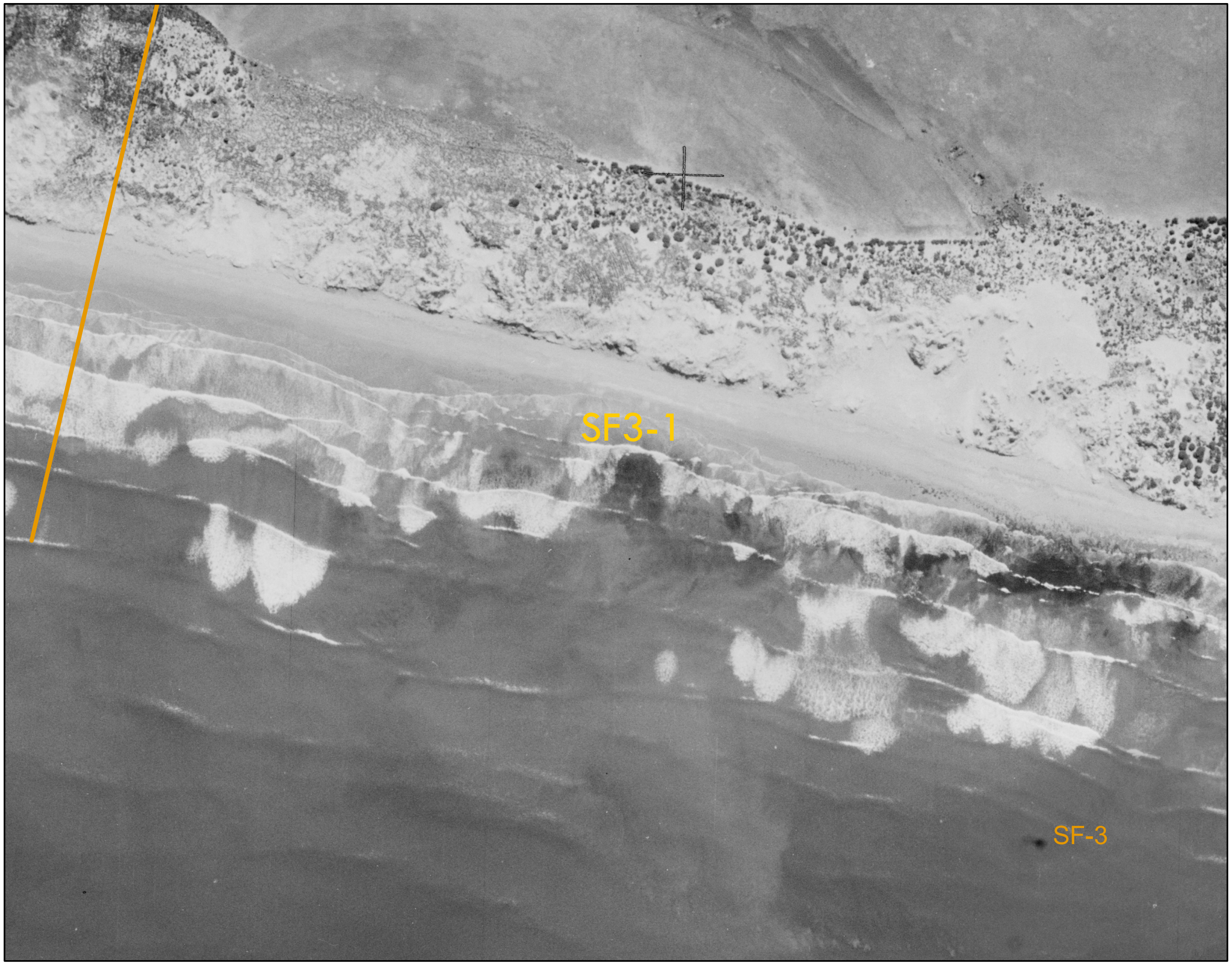
Medium Term Changes

Map SF3-1

Goolwa Beach

Historical comparison

1949



Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

The photograph on this page is to the west of the Goolwa Carpark.

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3. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium Term Changes

Map SF3-1

Goolwa Beach

Historical comparison

1949

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

The photograph on this page is to the west of the Goolwa Carpark.

The baseline escarpment position is depicted as a dotted line.

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Georeferencing

The 1949 aerial photograph has been checked against the 2016 aerial photograph at Middleton Hotel, Goolwa Barrage, and a house within Goolwa. The 1949 photograph aligns with the first two but not the house in Goolwa. The 1949 photography in this region may be 1m south of current photography. This will tend to lessen the appearance of erosion by ~1m

3. Coastal Fabric - natural

Medium Term Changes

Map SF3-1

Goolwa Beach

Historical comparison

1949 - 2006

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

In cell 3.1, a comparison between 1949 and 2006 demonstrates that in some sections minor erosion has occurred of ~5-6m recession

The word 'geomorphology' is formed from three ancient Greek words
Ge – earth
Morphe – form (change)
Logos – study(word)

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3. Coastal Fabric - natural

Medium Term Changes

Map SF3-1

Goolwa Beach

Historical comparison

1949 - 2016

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

In cell 3.1, a comparison between 2006 and 2016 suggests minor accretion of the dune.

Most of the dune line in 2016 is in the same position as 1949.

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3. Coastal Fabric - natural

Medium Term Changes

Map SF3-2

Goolwa Beach

Historical comparison

1949

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

The photograph on this page is the current day carpark. Goolwa Beach Road is in a similar position to the track in 1949.

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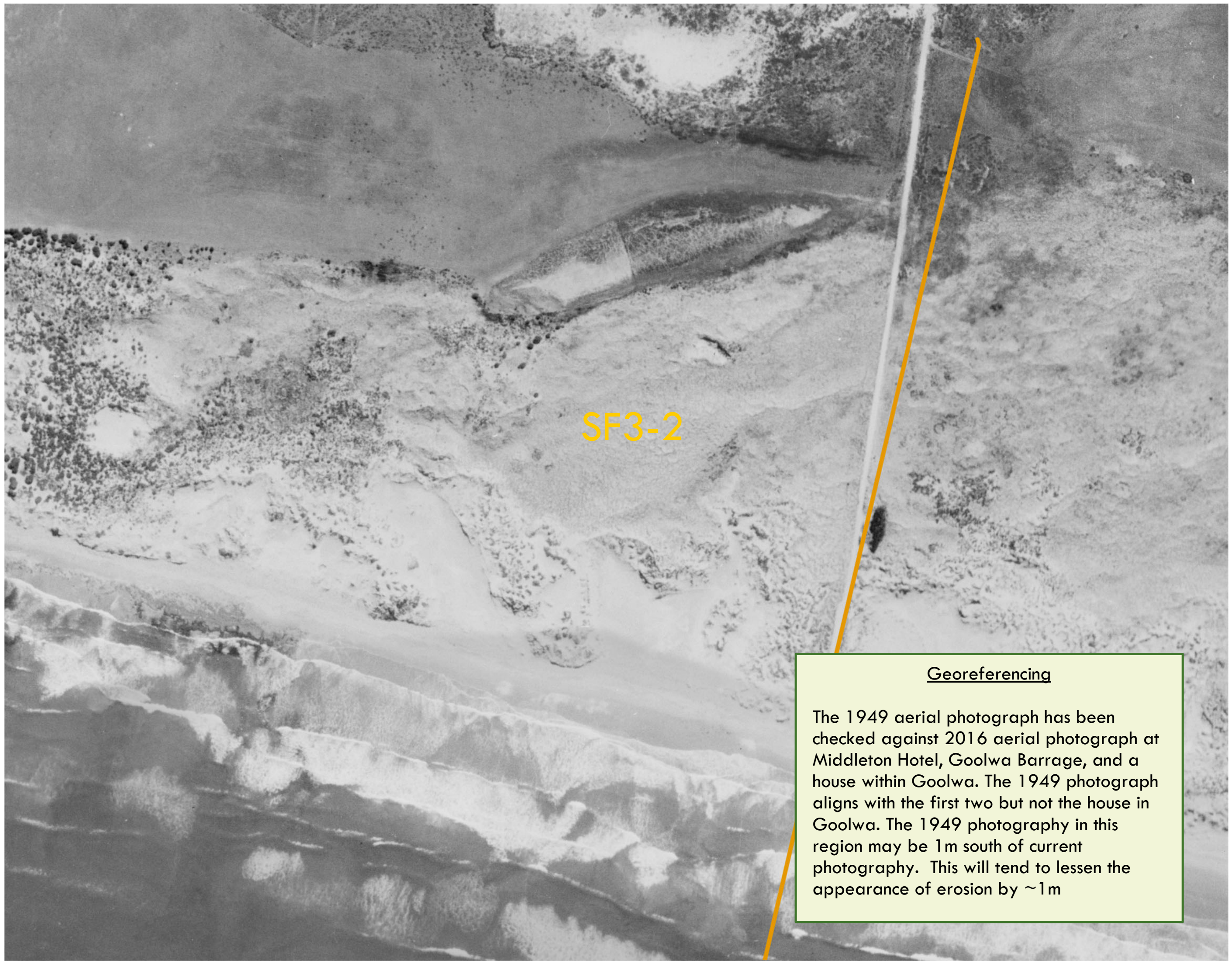

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3. Coastal Fabric - natural

Medium Term Changes

Map SF3-2

Goolwa Beach

Historical comparison

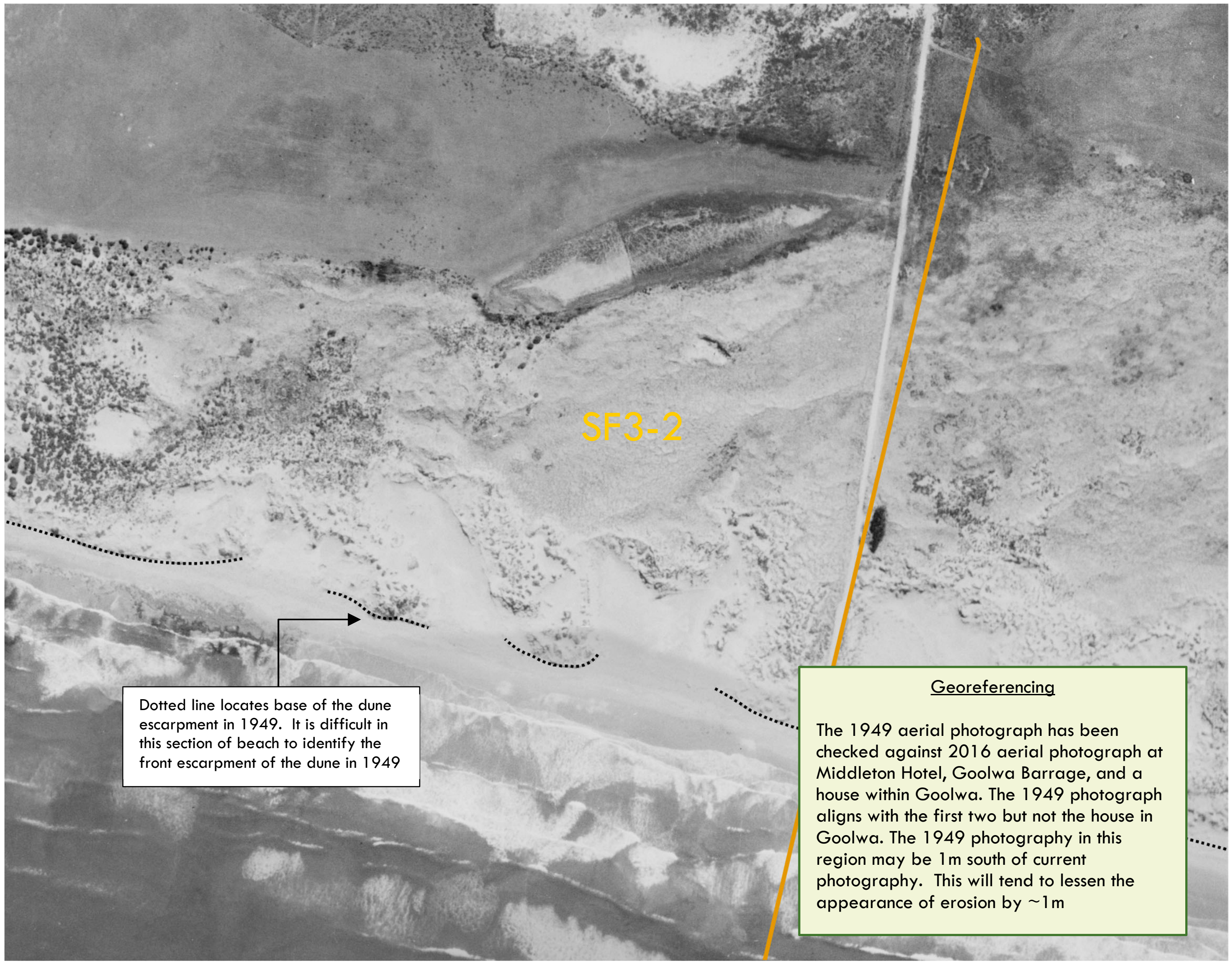
1949

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

The photograph on this page is of the Goolwa Beach carpark region.

The baseline escarpment position is depicted as a dotted line.



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3. Coastal Fabric - natural

Medium Term Changes

Map SF3-2

Goolwa Beach

Historical recession

1949 - 2006

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

In cell 3.2, a comparison between 1949 and 2006 demonstrates that in some sections up to 6m erosion has occurred.

Possible erosion rate in this area is 10cm per year over 70 years. However, although dune fencing, vegetation planting and invasion has stabilised and formed a new foredune.

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3. Coastal Fabric - natural

Medium Term Changes

Map SF3-2

Goolwa Beach

Historical recession

1949 - 2016

Assessment

To provide greater resolution Cell SF3 has been divided into two minor cells (3:1 and 3:2).

In cell 3.2, a comparison between 1949 and 2016 demonstrates that in some sections minor erosion has occurred.

The dune line appears slightly forward of 2006 (accreting).

Possible erosion rate in this area is 10cm per year over 70 years.

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3. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium Term Change

Map SF3

Goolwa Beach

Sediment change

1977 - 2009

Assessment

Coastal Management Branch from Department of Water and Environment (DEW) has conducted profile survey (number 615005) of the ocean floor from 1977 to 2009.

The profile lines show general accretion from 1977, through to 2014, although this may contain periods of erosion which are part of the natural beach cycle. The accretion of the dune is likely to be related to vegetation and other erosion mitigation infrastructure (e.g. sand fencing).

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4. Coastal Fabric - modified

Evaluating how human intervention has modified the fabric of the coast

HUMAN INTERVENTION

Human intervention:

Currently no hard protection strategies are utilised at Goolwa Beach.

However, the carpark installed in the 1980s is a major installation within the Goolwa Dune System. The front edge of the carpark is 40m from the current shoreline, and the pedestrian section is 30m from the current shoreline.

The current café is also set back approximately 40m from the current shoreline.

Management strategies

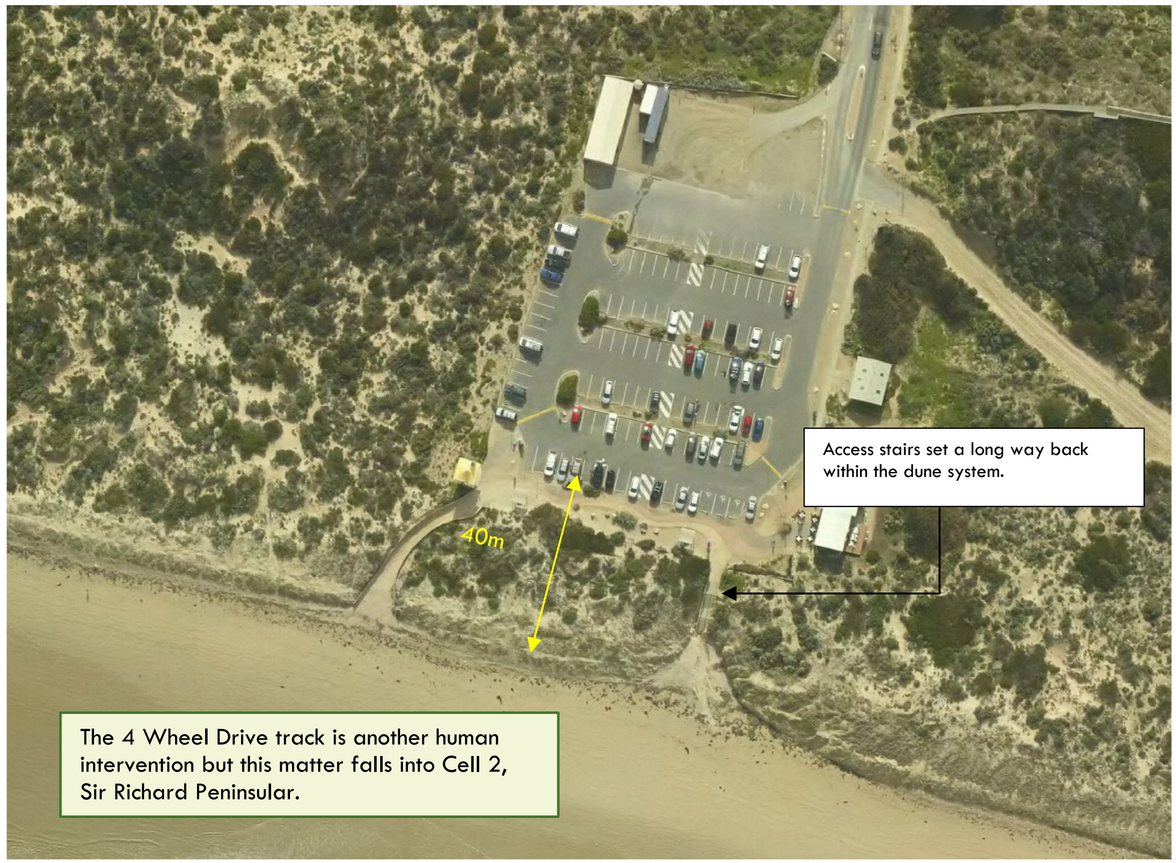
1. An active revegetation program was started in the 1980s (compare pp 19-20) and continues today with Coastcare and other community contributions.

Over a period of 40 years the dunes have increasing amounts of vegetation that assist in reducing wind and wave erosion.

2. There are two pedestrian access points to the beach. The main access is a set of stairs set well-back into the dune system. The second access is beach (sand) path to the beach on the western end of the carpark. This access point is fenced on either side.

3. No dune fencing has been installed to the front side of the dunes, but the dune escarpment is quite steep at the beach level. Inspections revealed very little pedestrian activity within the foredune system.

4. Dune fencing has been installed to carpark side of the dunes to the left of the accessway, and a retaining system has been installed to the right hand side of the accessway. Both of these measures are designed to control sand drifting into the carpark area.



4. Coastal Fabric - modified

Land use

Map: SF3

Secondary Cell: COORONG

Tertiary Cell: Goolwa Beach

Minor cell: NA

Land use

Land use: Council Reserve

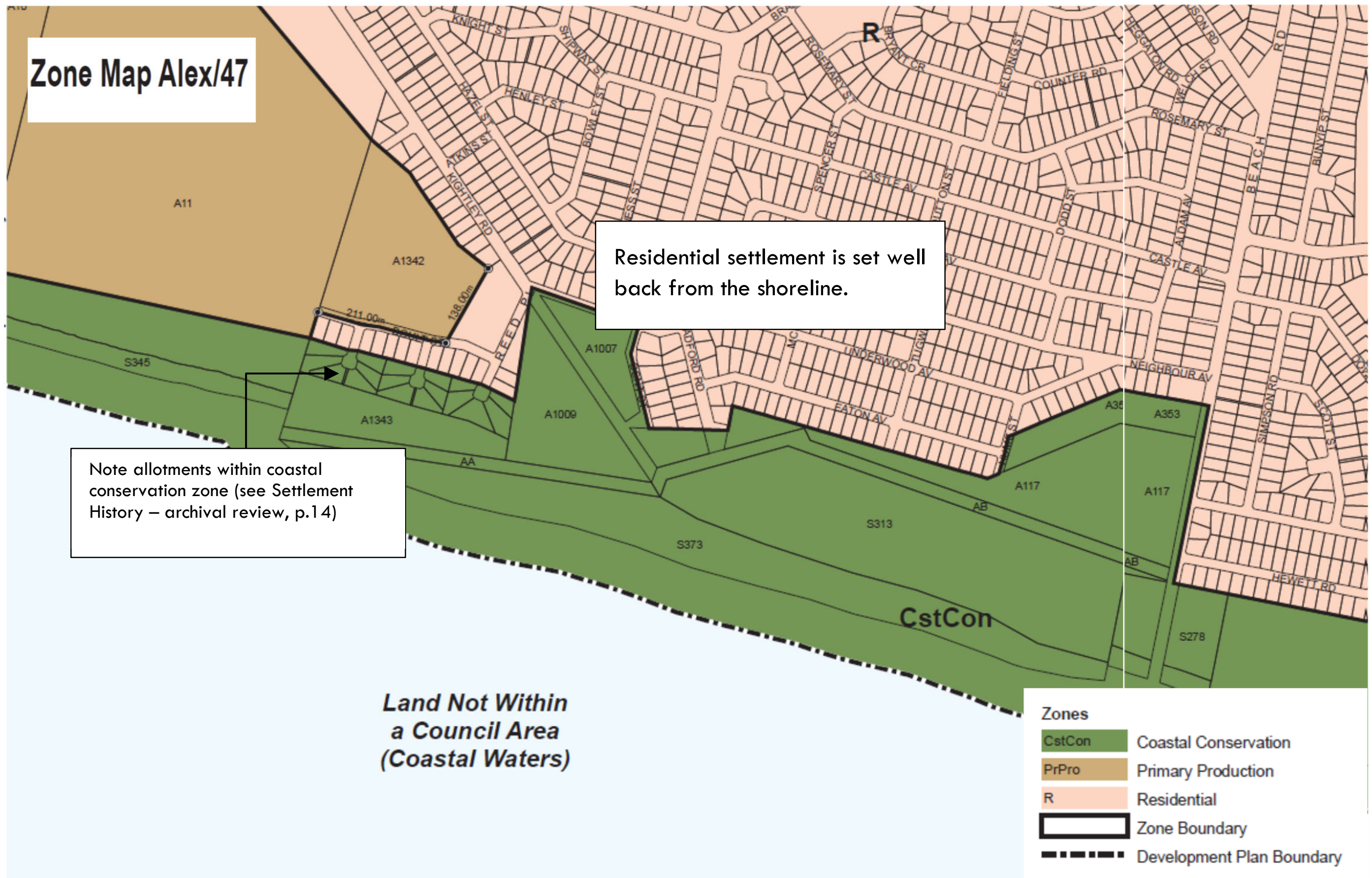
Zoning: Coastal Conservation (incorporates Council Reserve and foreshore). Zoning to the north of the reserves is predominantly Residential, with Primary Production in the western portion of the cell.

Policy Area: Southern Policy Area 11 is overlain the Residential section.

Precinct: Goolwa Beach Precinct 18 also applies to the residential area.

The Coastal Conservation zoning ensures that development is limited and any proposal must be referred to Coast Protection Board.

Increased density is not proposed for Precinct 18 because most of the area is not connected to the Community Waste Water Management Scheme.



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The 'Coastal Areas' section of the Development Plan (pp 23-27) has maintained standard South Australian planning policy library text apart from the insertion of PDC 11 (p. 24) that deals with the aim to limit the impact of private and public access to coastal areas.

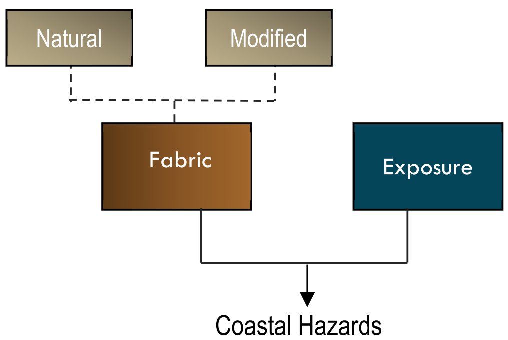
The 'flooding' section of 'Hazards' in the Development Plan (p. 38,39) has maintained standard South Australian planning policy library text apart from the insertion of PDC 7 that deals with development within the River Murray region (not relevant here).

COASTAL FABRIC

Summary and conclusions

Progress report:

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Goolwa Beach (Cell SF3) is situated between Tukuremoar Reserve and the line of Goolwa Beach Road (ie east side of the carpark).

Beach and backshore 1

The beach compartment is classified as a 'sandy beach'. Backshore 1 consists of sand dunes with lower areas of swamp (or former swamp) with some more elevated areas utilised for residential uses. Geological classification is Semaphore Sand.

The current beach and dune system have been formed over time by the way in which waves have interacted with the erodible sediments.

The dune stabilisation and vegetation program begun in the 1980s has substantially increased the stability of the dune system.

Backshore 2:

Landward of the dunes and lower swamp/residential areas the geology is classified as Bridgewater Formation, and rises ~10m AHD at 500m inland.

Benthic

In keeping with a classic dissipative beach, the intertidal and subtidal zones are dominated by sand.

Human intervention

Goolwa Beach Road provided access to Goolwa Beach from at least 1949. The beach was used essentially for recreational purposes. A carpark and café/kiosk and toilet facilities have been installed within the dune system.

Since the 1980s humans have employed management practices to contain human traffic and implemented planting to stablise dunes.

Residential settlement is set well back from the shoreline.

Analysis

Early evidence demonstrates that Goolwa Beach is likely to have eroded ~40m from 1860 to 1949.

A comparative analysis of photographs from 1949 to 2006 demonstrates that approximately 5-6m erosion occurred, but the dune is currently accreting so that much of the dune escarpment is in the same position as 1949.

Erodibility rating:

Backshore 1: High erodibility (3)

Backshore 2: High erodibility (3)

5. CURRENT EXPOSURE

Evaluating how actions of sea and other weather events currently impact the coastal fabric by:

- Analysing a current storm event
- Applying current 1 in 100 sea-flood risk scenario
- Analysing routine high tide impact.
- Analysing storm water runoff

5. Current exposure – overview

Overview

Map SF3-1

Goolwa Beach

Overview

SA Classification
The yellow line drawn in Nature Maps (Department of Environment and Water) signifies the following coastal characteristics:

Shoreline class
Dissipative Beach (see inset)

Sand rating
Fine sandy beach

Exposure:
Exposed

Wave:
High (2m average, Surfwatch)

Backshore 1:
Unstable dune (partially vegetated).

Dissipative Beaches

Dissipative beaches only occur on parts of the high energy southern coast where waves regularly exceed 2.5m and where the beaches are composed of fine sand. These combine to maintain a low gradient surf zone up to 500m wide with usually two to occasionally three shore-parallel bars, separated by subdued troughs. Waves begin breaking several hundred metres offshore as spilling breakers on the outer bar, then reform in the outer trough to break again and again on the inner bar or bars. In this way they dissipate their energy across the wide surf zone. The beach has a wide, low gradient swash zone, with the high tide swash reaching to the back of the beach, often leaving no dry sand to sit on at high tide. The shoreline tends to be relatively straight and uniform alongshore with no rip currents. (OzCoasts, 2019)

As the Alexandrina coast is open to the Southern Ocean, swell waves generated by storms 1000s of kms away, approach the coast independently of local winds and storms. Storm waves have greater waves heights and shorter wavelengths than swell waves. The resultant of onshore winds >28 km/hr, those winds which are capable of generating longshore transport, trends from the southwesterly quarter at a bearing of 227°, striking Goolwa Beach at an angle 60°. This causes longshore drift along Sir Richard Peninsula towards the Murray Mouth and the loss of beach sediment from the coast east of Middleton. As well as producing waves winds also transport sand. The weighted resultants of onshore winds capable of causing sand drift also approach from the southwesterly quarter and are responsible for building the dunes along the coastline. **Dr R. Bourman.**

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5. Current exposure – storm surge

Storm surge

Map SF3-1

Goolwa Beach

Current risk:

1 in 100-year risk

Assessment

The current 1 in 100-year ARI event risk set by Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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5. Current exposure – monthly high water

Monthly high water

Map SF3-1

Goolwa Beach

Current risk:

Monthly high water

Assessment

Extreme events are very rare and can have a significant impact. Routine tidal action may also have an impact on the stability of a dune system over time.

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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Routine tide

On dissipative beaches the high tide swash (ie wave runup) reaches the back of the beaches and the reach of these is associated with the line of dunes. . In other words, in high sandy environment on a dissipative beach, the base of the dunes is where it is because that's where regular wave runup is too.

5. Current exposure – storm surge

Storm surge

Map SF3-2

Goolwa Beach

Current risk :

1 in 100-year event risk

Assessment

The current 1 in 100-year ARI event risk set by Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	<u>0.50m</u>
Risk	2.25m AHD

Wave run-up is included at 1.2m

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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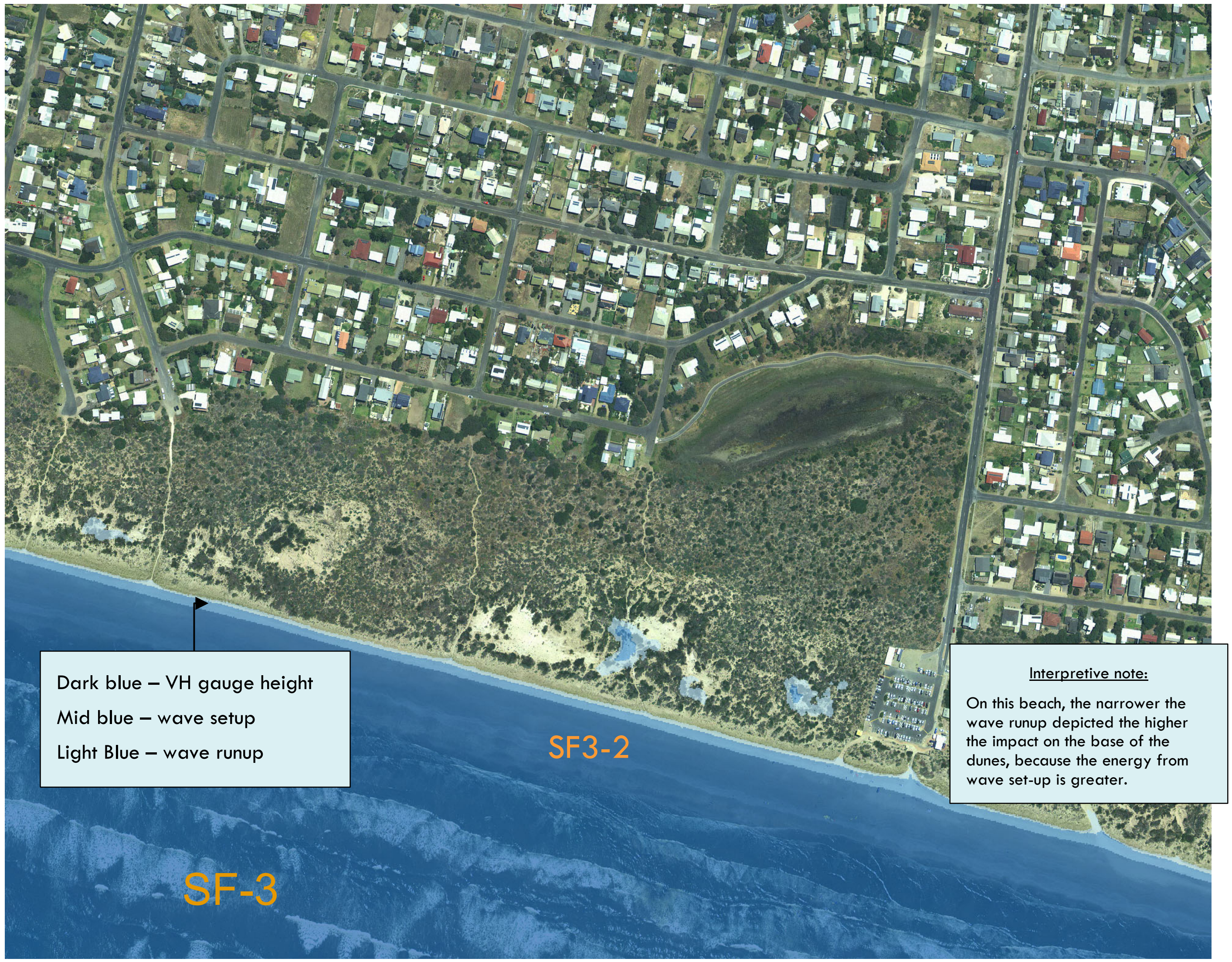

5. Current exposure – monthly high water

Monthly high water

Map SF3-2

Goolwa Beach

Current risk:

Monthly high water

Assessment

Extreme events (such as 1 in 100-year events) are very rare and can have a significant impact. Routine tidal action may also have an impact on the stability of a dune system over time.

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave set-up	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included. Current impact is likely to be very minor or nil.

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Routine tidal events

On dissipative beaches the high tide swash (ie wave runup) reaches the back of the beaches and generally the reach of these is also associated with the position of the dune escarpment. In other words, in high sandy environment on a dissipative beach, the base of the dunes is determined by the routine swash of the wave runup.

Interpretive note:

On this beach, the narrower the wave runup depicted the higher the impact on the base of the dunes, because the energy from wave set-up is greater.

Dark blue – VH gauge height

Mid blue – wave setup

Light Blue – wave runup

5. Current exposure – storm water

Storm water

Map SF3-1
Goolwa Beach

Current risk:

Storm water

Assessment

Storm water in SF3-1 drains into the swamp associated with Tukuremoar Reserve.

Storm water run-off from urban areas in SF3-1 is having no impact on dunes or foreshore.

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5. Current exposure – storm water

Storm water

Map SF3-2

Goolwa Beach

Current risk:

Storm water

Assessment

Storm water in SF3-2 drains into basin from the former swamp land.

Storm water run-off from urban areas in SF3-2 is having no impact on dunes or foreshore.

However, storm water is draining from the carpark area to the beach (see next page).

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5. Current exposure – storm water

Storm water

Map SF3-2

Goolwa Beach

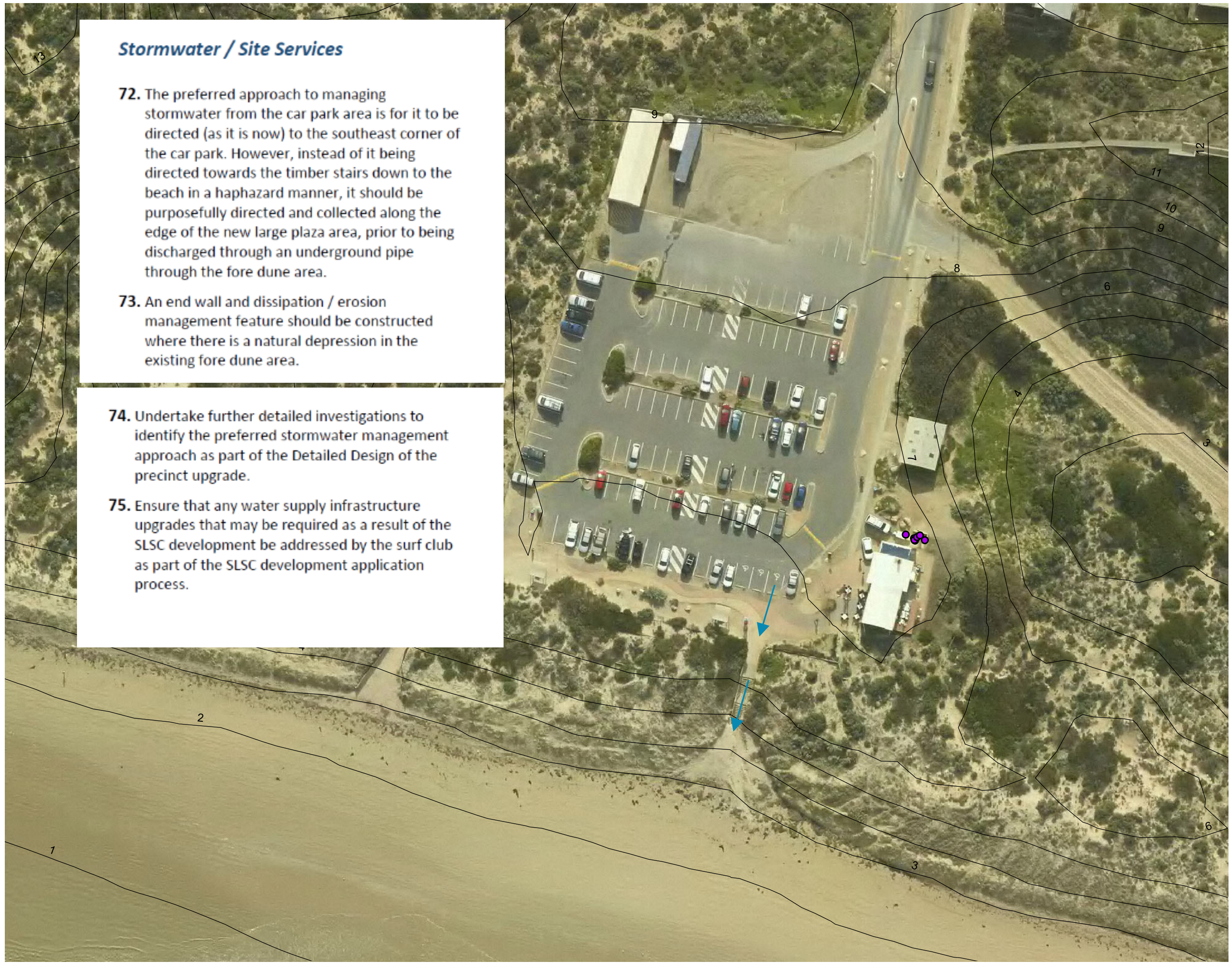
Current risk:

Storm water

Assessment

Goolwa Beach Carpark Masterplan notes that water is collecting from carpark catchment area and flows from south-east corner and through the stair area. It is not known if this is piped or free flowing.

The management plan calls for a solution.



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5. Current exposure - erosion

Erosion

Map SF3

Goolwa Beach

Current risk:

Erosion outlook

Assessment

A comparison of historical aerial photographs supports the view that the base of the dune escarpment has largely been in the same location since 1949. Recent comparisons from 2006 to 2018 demonstrate that the dune escarpment is moving slightly from year to year (expected).

Periodically wave action undermines and erodes the foredunes but over time these tend to reform.

The current position of the dunes on a dissipative sandy beach and backshore is dictated by the current sea level and wave climate.

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6. FUTURE EXPOSURE

Evaluating how future actions of sea and other weather events may impact the coastal fabric by:

- Reviewing 1 in 100 scenarios for 2050 and 2100
- Reviewing monthly high tide scenarios for 2050 and 2100
- Analysing erosion risk to 2100

6. Future exposure – storm surge (2050)

Storm surge

Map SF3-1

Goolwa Beach

2050 risk:

1 in 100-year risk

Assessment

The 1 in 100-year event ARI risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	<u>0.30</u>
	2.05m AHD
Wave set-up	<u>0.50</u>
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes. The impact of this event on the current dunes would be very high.

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6. Future exposure – storm surge (2100)

Storm surge

Map SF3-1

Goolwa Beach

2100 risk:

1 in 100-year risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe. Erosion extreme.

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6. Future exposure – monthly high water (2100)

Storm surge

Map SF3-1

Goolwa Beach

2100 risk:

Monthly high water

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of a dune system over time.

The event modelled:

Average high tide	1.50m
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.70m

Wave run-up of 0.8m has been included.

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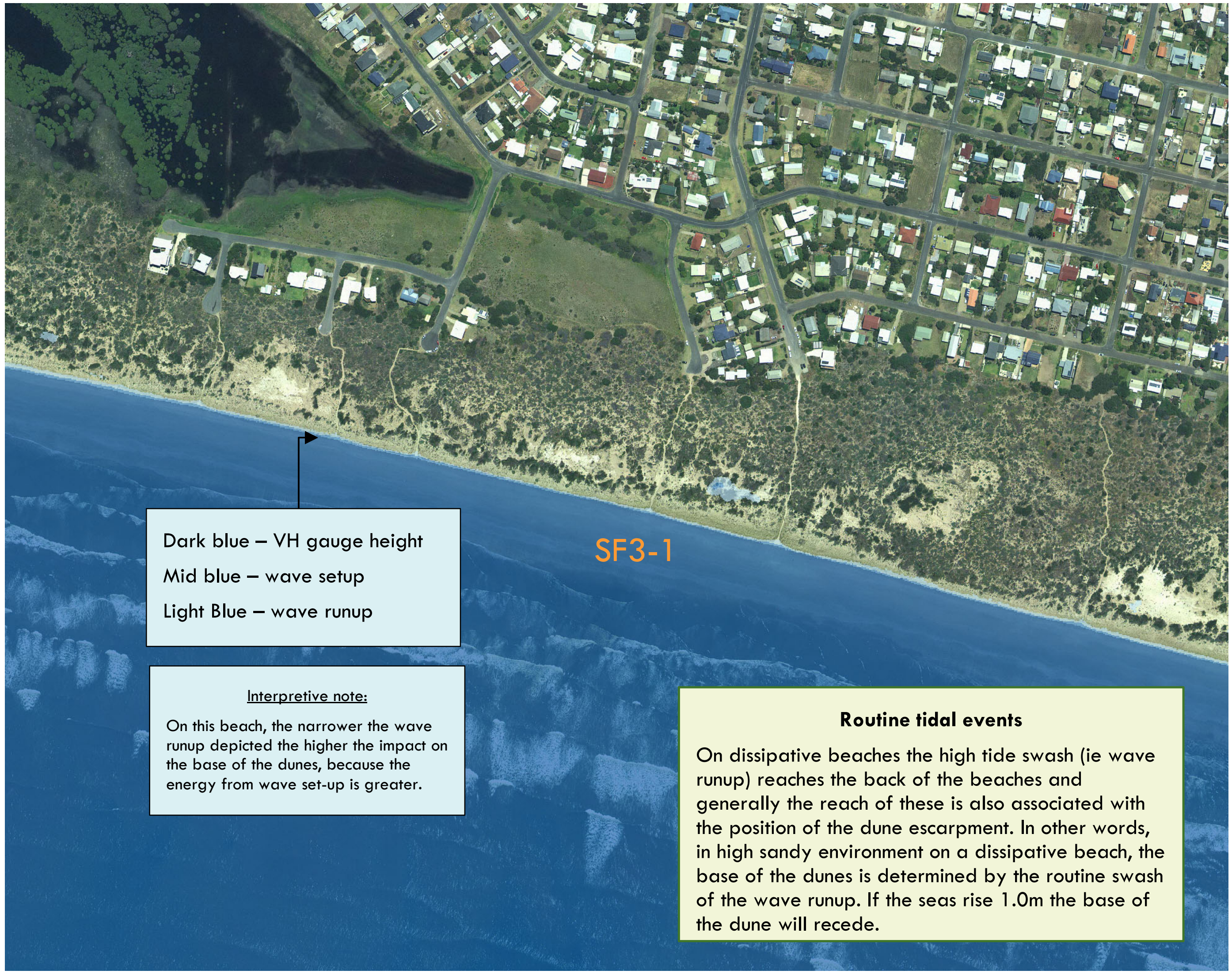

Dark blue – VH gauge height

Mid blue – wave setup

Light Blue – wave runup

Interpretive note:

On this beach, the narrower the wave runup depicted the higher the impact on the base of the dunes, because the energy from wave set-up is greater.

Routine tidal events

On dissipative beaches the high tide swash (ie wave runup) reaches the back of the beaches and generally the reach of these is also associated with the position of the dune escarpment. In other words, in high sandy environment on a dissipative beach, the base of the dunes is determined by the routine swash of the wave runup. If the seas rise 1.0m the base of the dune will recede.

6. Future exposure – storm surge (2050)

Storm surge

Map SF3-2

Goolwa Beach

2050 risk:

1 in 100-year event risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted in light blue.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes if this event occurred in current times. The impact of this event on the current dunes would be very high.

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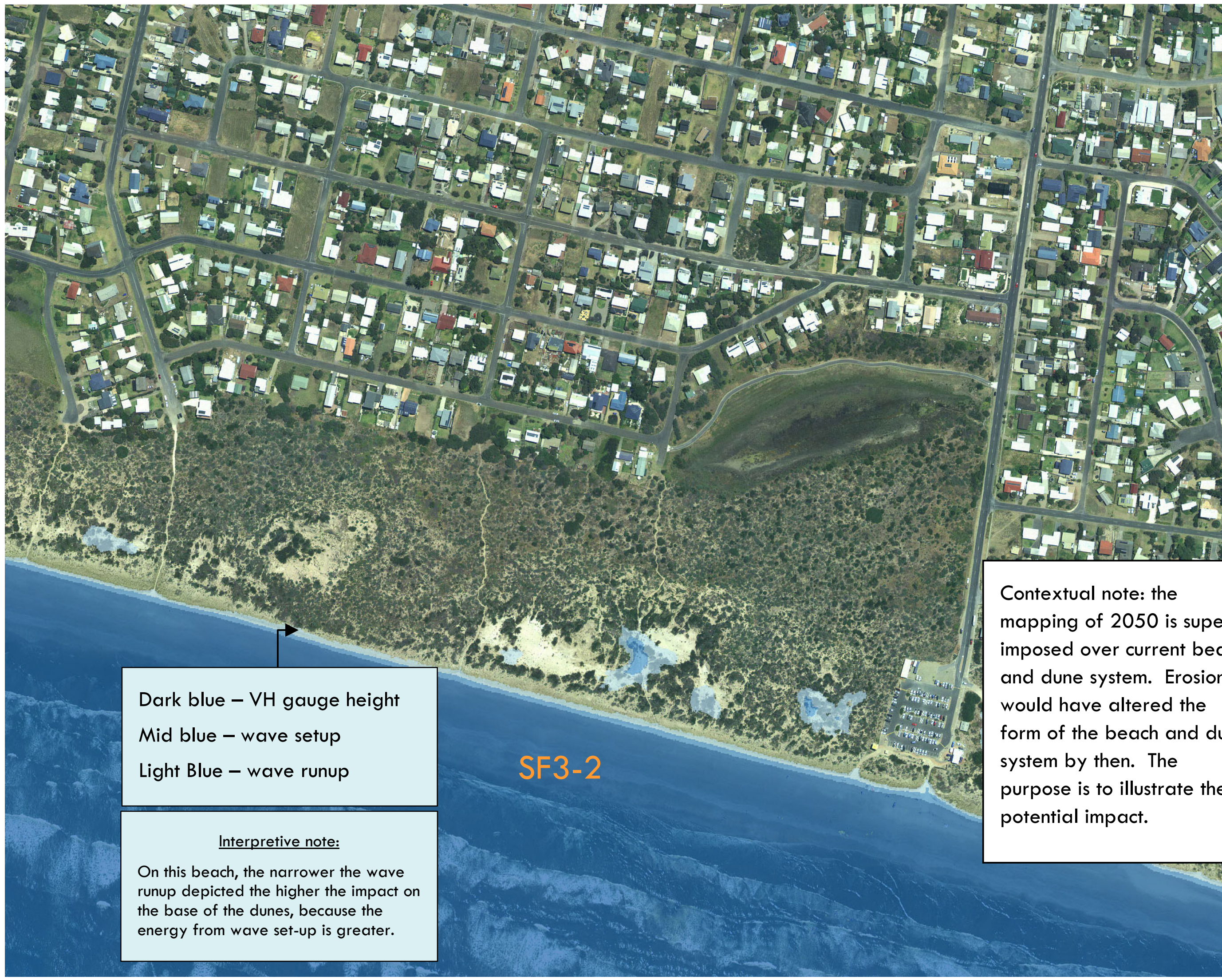

Dark blue – VH gauge height

Mid blue – wave setup

Light Blue – wave runup

Interpretive note:

On this beach, the narrower the wave runup depicted the higher the impact on the base of the dunes, because the energy from wave set-up is greater.

Contextual note: the mapping of 2050 is super-imposed over current beach and dune system. Erosion would have altered the form of the beach and dune system by then. The purpose is to illustrate the potential impact.

6. Future exposure – storm surge (2100)

Storm surge

Map SF3-2

Goolwa Beach

2100 risk:

1 in 100-year event risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe. Erosion extreme.

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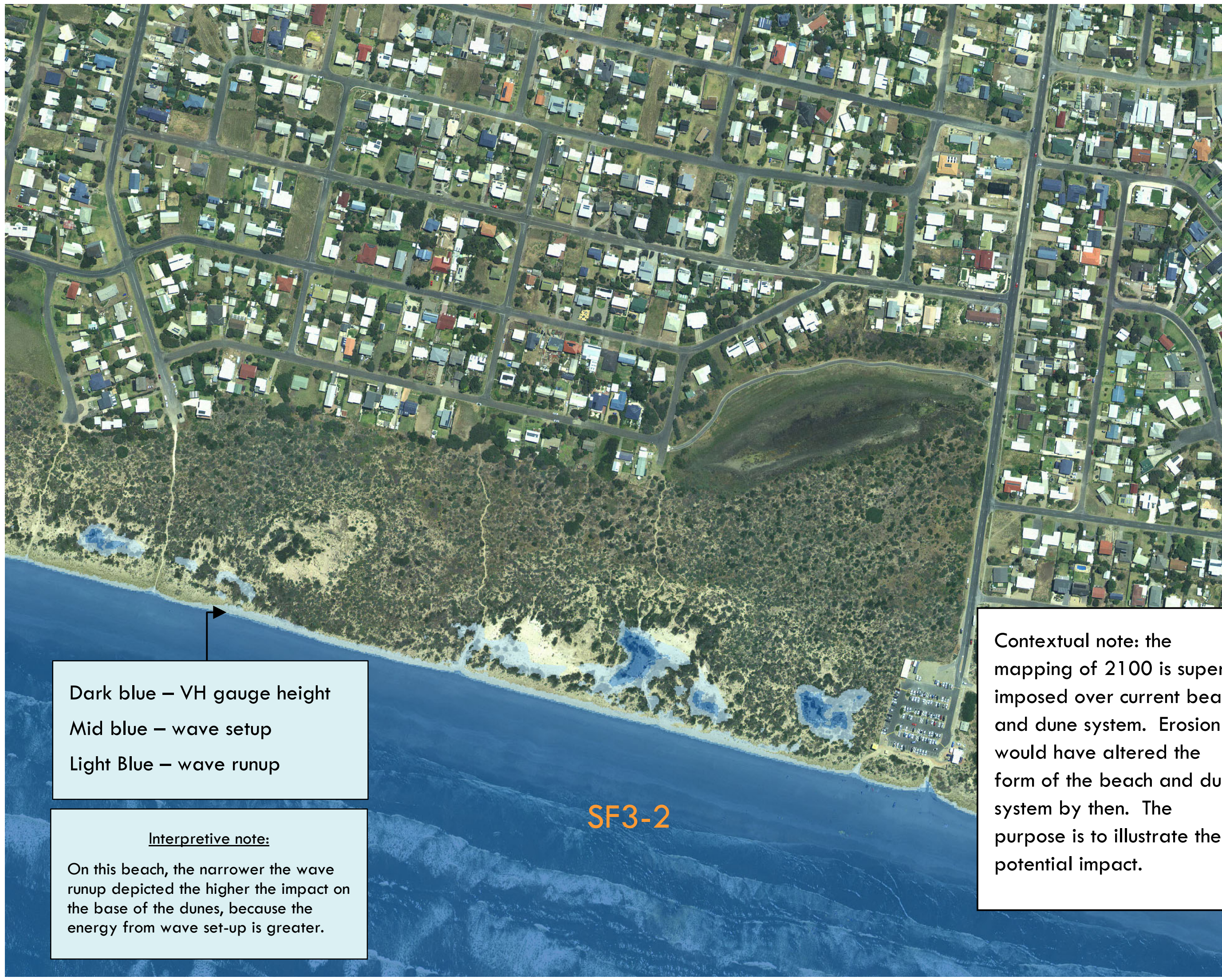

Dark blue – VH gauge height

Mid blue – wave setup

Light Blue – wave runup

Interpretive note:

On this beach, the narrower the wave runup depicted the higher the impact on the base of the dunes, because the energy from wave set-up is greater.

Contextual note: the mapping of 2100 is super-imposed over current beach and dune system. Erosion would have altered the form of the beach and dune system by then. The purpose is to illustrate the potential impact.

6. Future exposure – monthly high water (2100)

Storm surge

Map SF3-2

Goolwa Beach

2100 risk:

Monthly high water

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of a dune system over time.

The event modelled:

Average high tide	1.50m
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

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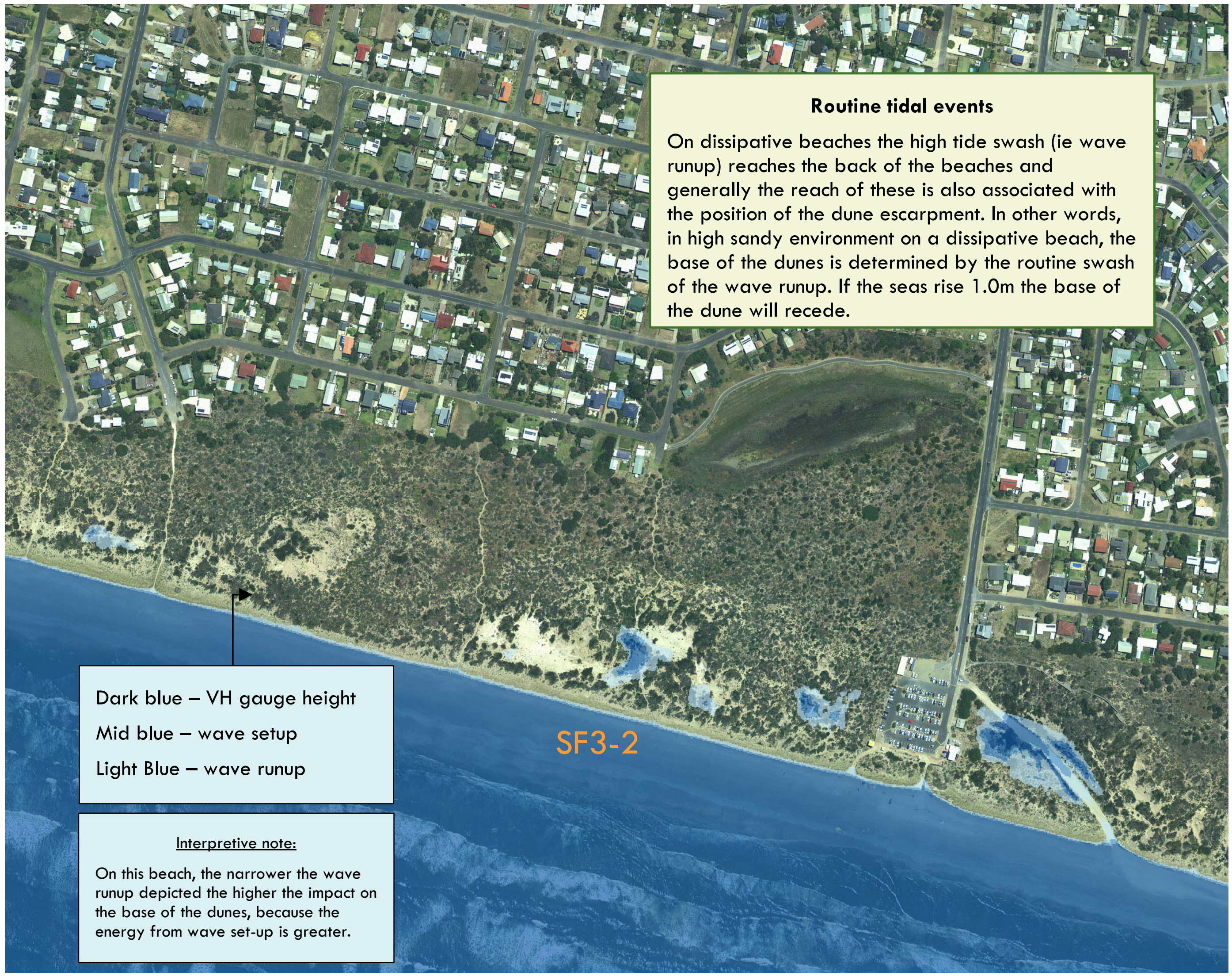


Routine tidal events

On dissipative beaches the high tide swash (ie wave runup) reaches the back of the beaches and generally the reach of these is also associated with the position of the dune escarpment. In other words, in high sandy environment on a dissipative beach, the base of the dunes is determined by the routine swash of the wave runup. If the seas rise 1.0m the base of the dune will recede.

Interpretive note:

On this beach, the narrower the wave runup depicted the higher the impact on the base of the dunes, because the energy from wave set-up is greater.

6. Future exposure – erosion (SF3-1)

By Dr Patrick Hesp

See full version in Part 1 of the report

Shoreline recession due to sea level rise

In the following, we attempt to estimate shoreline retreat in the Goolwa Beach West sector due to sea level rise. This is achieved by two methods, one, utilising the Bruun Rule, which is the standard method to estimate shoreline retreat, but which has several implicit assumptions, and ignores the possibility of dune translation. The second is a method which assumes the beach and dune system can translate upwards and landwards as sea level rises, and estimates shoreline change based on assumptions that the coastal system can actually do this, and that there is sufficient sediment in the system for this to occur.

Shoreline Change indicated by the Bruun Rule

The Bruun Rule is an equation developed by Per Bruun (1962). While it has subsequently been modified (e.g. Dean and Houston, 2016), the modified equations require more data than available for this coast. The original equation is the most widely used method for determining shoreline response to sea level rise.

$$S = -Sp\,(W/dc + B) \qquad (1)$$

Where

- *S* is Erosion due to sea level rise
- *Sp* is Sea level rise projection
- *W* is Width of the beach profile
- *dc* is Depth of closure
- *B* is Foreshore/Dune crest height

The depth of closure is estimated from equation *(2)* where *h* is the closure depth in the inner portion of the surfzone-nearshore, and *Hs* is mean annual significant wave height following Hallermeier (1981) as modified by Houston (1995):

$$h = 8.9\overline{Hs} \qquad (2)$$

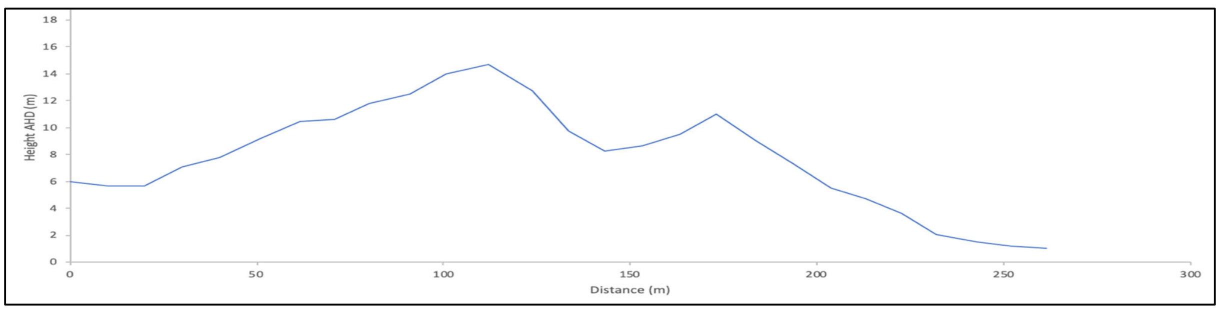
Equation (1) applies to the upper shoreface (Cowell et al., 2003a). It assumes that the upper shoreface keeps the same profile and translates seaward or landward depending on the sediment budget, and ignoring alongshore and across-shore changes in sediment supply (Le Cozannet et al. (2016). Obviously this is a huge assumption in the case of many coastal tracts in South Australia.

Figure. Topographic profile of dune near the Western boundary of cell SF3-1 (Source: Integrated Coasts)

West Goolwa Beach (SF3-1)

There is extremely limited information available aong this section of beach to determine alongshore and acrosshore sediment exchanges. These are the contributions of other processes causing losses or gains of sediments in the active beach profile. However, as Le Cozannet et al. (2016) note, there is currently no better model or "rule" to use. Recent results regarding the global impact of sea-level rise on shoreline change are largely based on the Bruun rule and it is commonly utilised to provide at least a rough estimate of shoreline migration in relation to sea level rise. Alternative approaches exist, but they are more complex and they require more data. Thus, for the purposes of obtaining some estimate of shoreline change driven by sea level rise, the Bruun Rule is first utilised.

An estimate of shoreline retreat due to a sea level rise of 1m by 2100 has been carried out for one topographic profile at this location (see Figure).



6. Future exposure – erosion (SF3-1)

By Dr Patrick Hesp

See full version in Part 1 of the report

Future Exposure Erosion (SF3-1) Continued

For a sea level rise of 1.0 metre, depth of closure (*dc*) of 13.35 (assumes a significant wave height $[\overline{Hs}]$of 1.5m), and beach profile width (*W in eqn 1)* of 2000m, the Bruun Rule indicates a shoreline recession of 70.5m by 2100. For 2050 the shoreline erosion is estimated at 21m.

This number essentially indicates recession resulting in a cliffed dune (if the dune still exists!) and lee slope. The vertical face or scarp of a dune is inherently unstable, and will collapse and slide to a stable angle of ~ 25° resulting in a zone of slope adjustment.

This will produce further landward retreat of the dune crest in addition to that estimated by the Bruun Rule erosion.

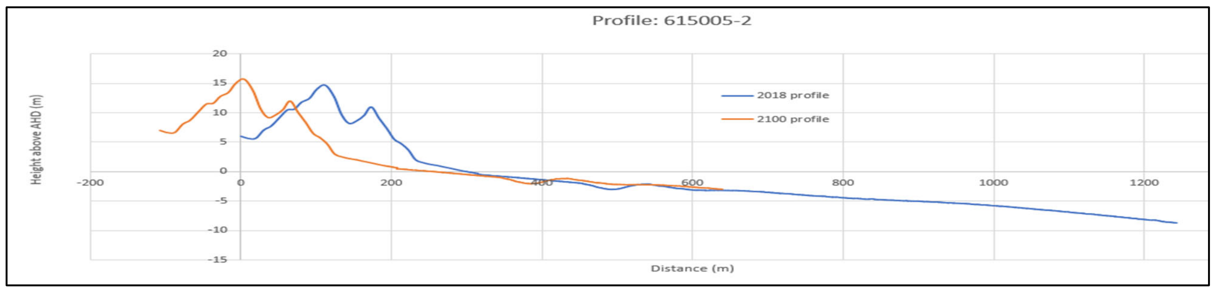
The figures show two dune profiles and calculated landward translation for the SF3-1 region. The topographic profiles were surveyed in 2019 and have had the below sea level (bathymetric) profile of the CPB 615005 (Goolwa carpark) appended as this is likely to be very similar.

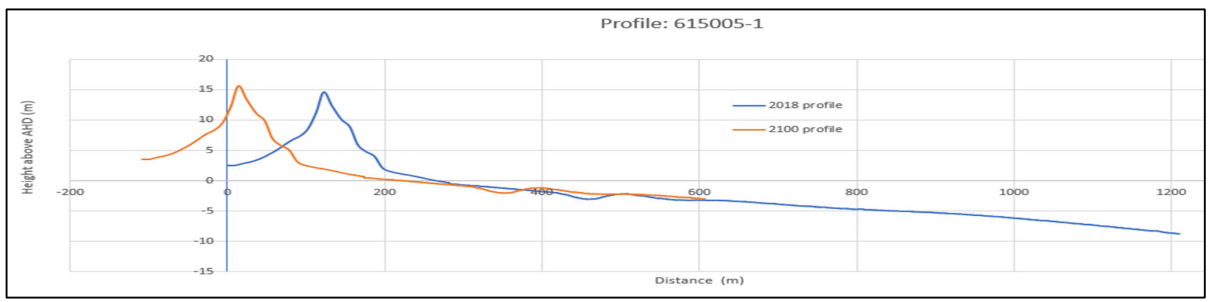
Shoreface-Beach and Dune Translation Model

The utility of the Bruun Rule has been the subject of debate over the last decades, because the "rule" takes no account of longshore sediment transport, the possibility that the foredune or dunes existing behind the beach can translate upwards and landwards with sea level rise, and it is not supposed to be utilised where surfzone-nearshore reefs exist.

It is now a known fact that beaches and dunes can easily translate upwards and landwards as either shoreline erosion occurs or sea level rises (Davidson-Arnott, 2005). Therefore, another way to estimate the degree of shoreline retreat due to a given sea level rise is to take the latest topographic profile of the

Figures. Topographic profiles and appended bathymetric profile for the region (Coast Protection Board).





6. Future exposure – erosion SF3-1 (2100)

Future Exposure

Map SF3-1

Goolwa Beach

2100 risk:

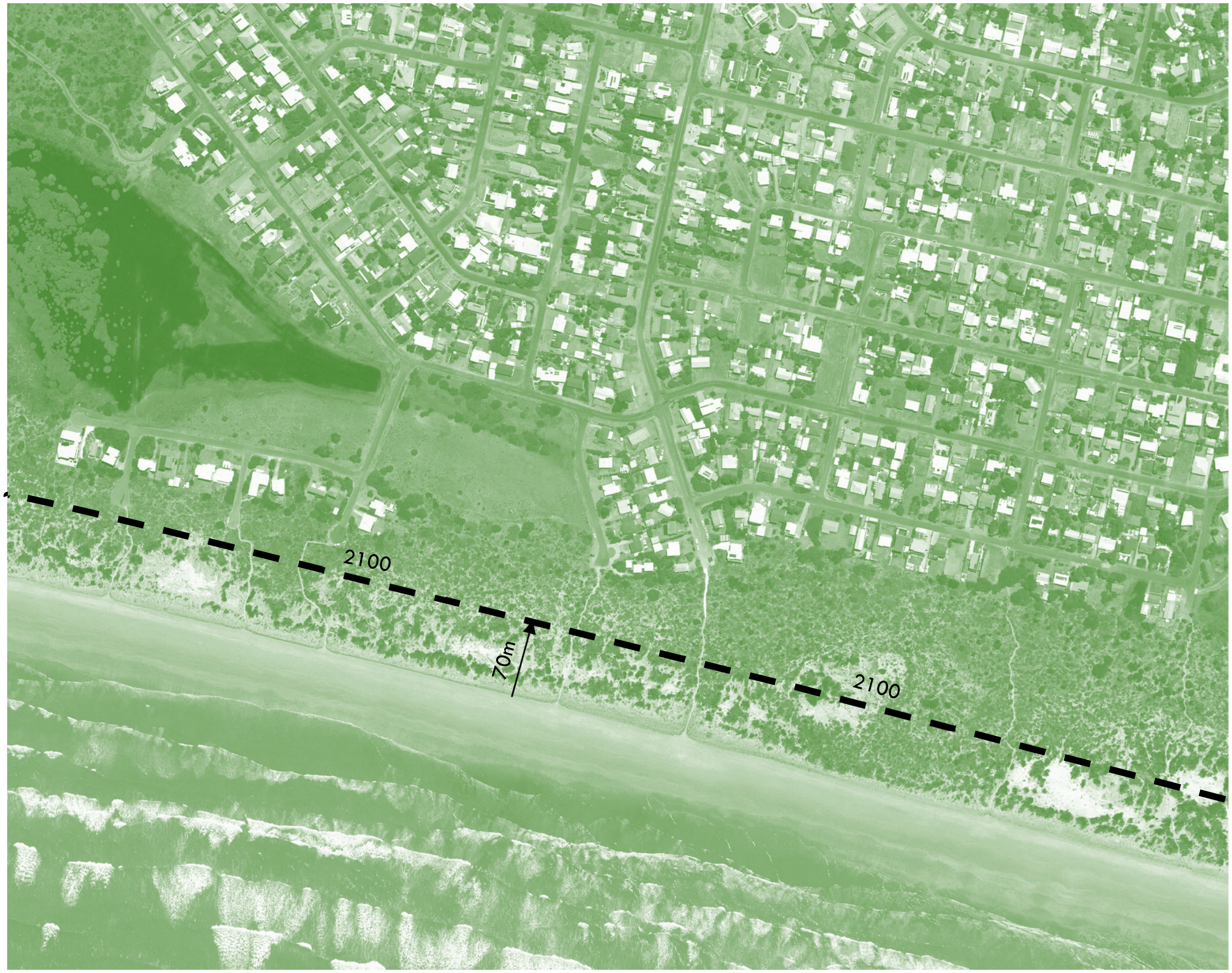
Erosion outlook

Assessment

A number of evaluation methods have been utilised to provide the basis for an estimate of shoreline recession.

Sea-flood and routine high tide modelling indicates increased impact on dunes. Certainly 2100 scenarios indicate impact of the sea in alignment with the former shoreline.

Erosion assessment is difficult and estimates of shoreline recession is around 70m by 2100.



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6. Future exposure – erosion (SF3-2)

By Dr Patrick Hesp

See full version in Part 1 of the report

Shoreline recession due to sea level rise

In the following, we attempt to estimate shoreline retreat in the Goolwa Beach East (main carpark) sector due to sea level rise. This is achieved by two methods, one, utilising the Bruun Rule, which is the standard method to estimate shoreline retreat, but which has several implicit assumptions, and ignores the possibility of dune translation. The second is a method which assumes the beach and dune system can translate upwards and landwards as sea level rises, and estimates shoreline change based on assumptions that the coastal system can actually do this, and that there is sufficient sediment in the system for this to occur.

Shoreline Change indicated by the Bruun Rule

The Bruun Rule is an equation developed by Per Bruun (1962). While it has subsequently been modified (e.g. Dean and Houston, 2016), the modified equations require more data than available for this coast. The original equation is the most widely used method for determining shoreline response to sea level rise.

$$S = -Sp\,(W/dc + B) \qquad (1)$$

Where

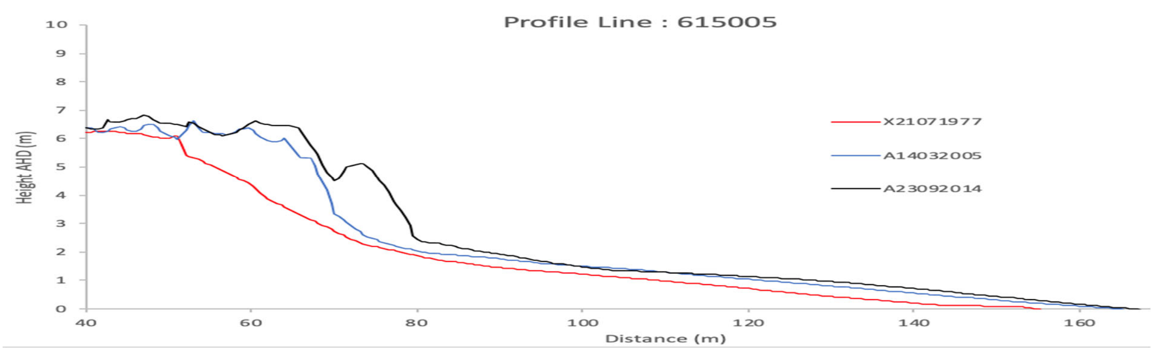
- *S* is Erosion due to sea level rise
- *Sp* is Sea level rise projection
- *W* is Width of the beach profile
- *dc* is Depth of closure
- *B* is Foreshore/Dune crest height

The depth of closure is estimated from equation *(2)* where *h* is the closure depth in the inner portion of the surfzone-nearshore, and *Hs* is mean annual significant wave height following Hallermeier (1981) as modified by Houston (1995):

$$h = 8.9\overline{Hs} \qquad (2)$$

Equation (1) applies to the upper shoreface (Cowell et al., 2003a). It assumes that the upper shoreface keeps the same profile and translates seaward or landward depending on the sediment budget, and ignoring alongshore and across-shore changes in sediment supply (Le Cozannet et al. (2016). Obviously this is a huge assumption in the case of many coastal tracts in South Australia.

Figure. Topographic profile, CPB 61005, at Goolwa carpark, showing general accretion from 1977 to 2014.



East Goolwa Beach (SF3-2)

There is extremely limited information available along this section of beach to determine alongshore and acrosshore sediment exchanges. These are the contributions of other processes causing losses or gains of sediments in the active beach profile. However, as Le Cozannet et al. (2016) note, there is currently no better model or "rule" to use. Recent results regarding the global impact of sea-level rise on shoreline change are largely based on the Bruun rule and it is commonly utilised to provide at least a rough estimate of shoreline migration in relation to sea level rise. Alternative approaches exist, but they are more complex and they require more data. Thus, for the purposes of obtaining some estimate of shoreline change driven by sea level rise, the Bruun Rule is first utilised.

An estimate of shoreline retreat due to a sea level rise of 1m by 2100 has been carried out for one topographic profile at this location (see Figure).

6. Future exposure – erosion (SF3-2)

By Dr Patrick Hesp

See full version in Part 1 of the report

Future Exposure Erosion (SF3-2) Continued

For a sea level rise of 1.0 metre, depth of closure (*dc*) of 13.35 (assumes a significant wave height [$\overline{Hs}$]of 1.5m), and beach profile width (*W in eqn 1)* of 2000m, the Bruun Rule indicates a shoreline recession of 96.7m by 2100. For 2050 the shoreline erosion is estimated at 29m.

This number essentially indicates recession resulting in a cliffed dune (if the dune still exists!) and lee slope. The vertical face or scarp of a dune is inherently unstable, and will collapse and slide to a stable angle of ~ 25° resulting in a zone of slope adjustment.

This will produce further landward retreat of the dune crest in addition to that estimated by the Bruun Rule erosion.

The figures show two dune profiles and calculated landward translation for the SF3-1 region. The topographic profiles were surveyed in 2019 and have had the below sea level (bathymetric) profile of the CPB 615005 (Goolwa carpark) appended as this is likely to be very similar.

Shoreface-Beach and Dune Translation Model

The utility of the Bruun Rule has been the subject of debate over the last decades, because the "rule" takes no account of longshore sediment transport, the possibility that the foredune or dunes existing behind the beach can translate upwards and landwards with sea level rise, and it is not supposed to be utilised where surfzone-nearshore reefs exist.

It is now a known fact that beaches and dunes can easily translate upwards and landwards as either shoreline erosion occurs or sea level rises (Davidson-Arnott, 2005). Therefore, another way to estimate the degree of shoreline retreat due to a given sea level rise is to take the latest topographic profile of the nearshore-beach-dune system and merely translate it entirely upwards and landwards by a given amount of sea level rise (in this case 1.0 m by 2100).

The distance that the profile is translated horizontally is determined by maintaining the distance between two topographic points (i.e. the slope of the beach-backshore) on the original profile in the projected future translated profile. For example, if the distance between zero m or AHD on the current profile and the foredune toe is, say, 15m, then that distance between those two points is maintained in the translated 2100 profile.

The figure indicates detail of the beach-dune system segment of the latest available topographic profile (CPB 615005) from a 2014 survey which has been used for calculation of likely shoreward translation.

The calculations result in a theoretical shoreward translation of the foredune system at approximately 105 metres by 2100. Note that this assumes there is enough sediment in the system to allow this to occur, which is certainly NOT the case in the region of the carpark. It also assumes that the foredune is maintained as the shoreline retreats and sea level rises and has not been destroyed, in part or fully, due to increased storminess and/or significant jumps in sea level due to meltwater pulses (very rapid rises in sea level due to massive ice retreat or ice shelf collapse) occurring in the next ~80 years.

6. Future exposure – erosion SF3-2 (2100)

Future Exposure

Map SF3-2

Goolwa Beach

2100 risk:

Erosion outlook

Assessment

A number of evaluation methods have been utilised to provide the basis for an estimate of shoreline recession.

Sea-flood and routine high tide modelling indicates increased impact on dunes. Certainly 2100 scenarios indicate impact of the sea in alignment with the former shoreline.

Erosion assessment is difficult and estimates of shoreline recession is around 97m by 2100. Coast Protection Branch calculated recession of 60m by 2100.

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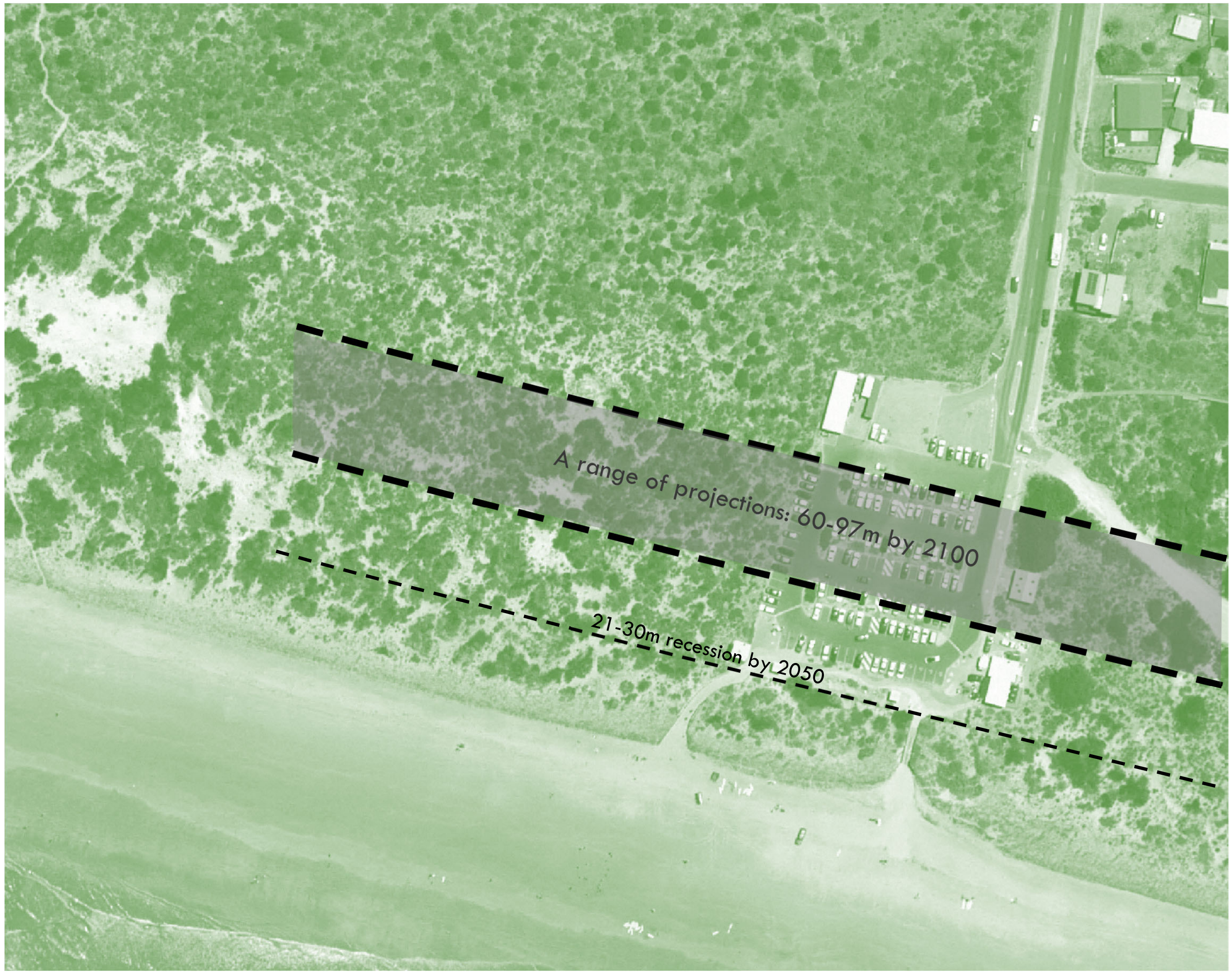
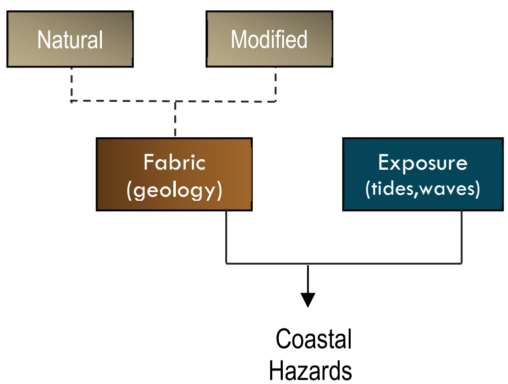


COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell. In the last section we also analysed current and future exposure.



Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Goolwa Beach. (It is recommended that one or two more events are analysed in the future). Total wave effects in SF3 totalled 1.70m.

However, while this storm produced significant wave effects the tide at the gauge was not exceptionally high (less ~0.20m than record of 9 May 2016).

Storm surge

Coast Protection Board has set 1 in 100 ARI event at 1.75m AHD (ie at the tide Victor Harbor tide gauge).

If this event was to occur, mapping shows that the impact upon the dunes would be severe.

Monthly high water

Extreme events such as a 1 in 100 ARI event can cause considerable damage but these are rare events. Routine tidal action is more likely to break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event in 2050 would significantly impact the dunes.

Monthly high water

High tides in the context of sea level rise would erode the foredune so that it receded. Generally, the dune is substantial in this cell. However, in the vicinity of the carpark there is no room for the dune to recede.

Future exposure (indicatively by 2100)

Storm surge and high tides

The 1 in 100 ARI storm event would significantly impact the beach and dunes. High tides 1m greater than today would also routinely impact the dunes.

Erosion assessment

Various methods and various personnel have estimated the potential rate of erosion for the Goolwa Beach carpark area. These range from 21-30m by 2050 and 60 to 97m by 2100. Rates of erosion are slower to the west of the carpark where the dunes are substantially higher. Rates of erosion in this area are estimated at 50 to 70m by 2100.

Exposure rating: Very exposed (4)

Contextual note

Mapping of 2050 and 2100 scenarios is super-imposed over the current beach and dune system. It is understood that the layout of the beach and dune system will have changed, especially by 2100. However, this mapping does give an indication of the likely extent of recession, and where impacts will be 'felt' the most.

7. Inherent hazard risk assessment

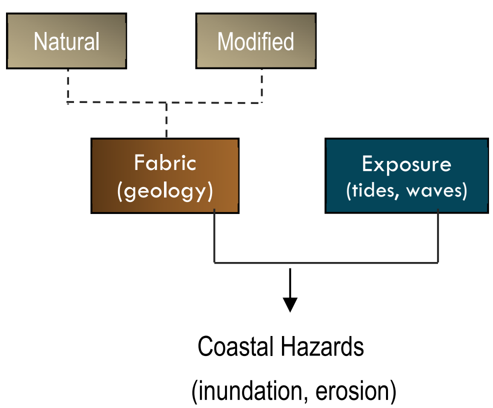
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk.

This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is *inherently* more at risk from flooding whereas an elevated coast is inherently not at risk from flooding.

The assessment of the erosion hazard is far more complex, but it is still the relationship of *fabric* to *exposure* that determines whether a coast is *inherently* more at risk from erosion or less at risk.



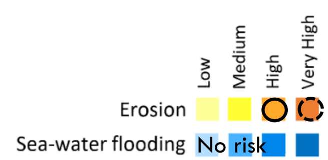
Inundation hazard risk

Due to the slope and elevation of backshore 1, there is no inundation hazard risk for Goolwa Beach

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main report)	Sandy beach, backshore 1: dune backshore , backshore 2: semaphore sand (dunes)	High
Should this rating be amended due to human intervention such as a protection item? If so, how?	No, human intervention is limited to dune fencing.	High
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'exposed' (means very exposed).	Very high
Assess any impact on backshore 1	Due to the nature of this beach, the location of the dune escarpment relates to the routine actions of wave run-up (monthly high water).	Very High
Assess any influence from Benthic	Offshore is dominated by unconsolidated sand	Very high
Assess the sediment balance	Over the last 70 years Goolwa Beach has been stable (and accreting in previous 10 years)	High-very high
Assess any other factors that may warrant a change of inherent hazard risk.	Nil	High-very high

Inherent Hazard Risk – Goolwa Beach



8. HAZARD IMPACTS

In this section we identify and describe the potential hazard impacts within four main receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

8a. Assets at risk

In the shorter time frame to 2050, public assets at risk are confined to beach access ways, dune fencing and other beach structures.

In the longer term, erosion estimates suggest that the carpark, walkways and other structures in the carpark are likely to come under threat. However, it is worth noting that the erosion estimates do not take into account any attempt to slow erosion through human intervention of dune fencing, planting, nourishment and other methods utilised to slow erosion.

In particular Council reports that the main beach stairs are often impacted by actions of the sea.

Review: Goolwa Beach Car Park and Surrounds Masterplan

The masterplan for the Goolwa Beach Car Park and Surrounds acknowledges the projection for a 60m recession of the coastline, and also notes that there is currently a 40m buffer between the dune escarpment and the carpark. The problem with this approach is that over time the existing dune buffer will reduce to zero, and in time actions of the sea will be interacting with the hard edge of the carpark. A review by coastal geomorphologists associated with this project (Dr Bourman and Professor Hesp) recommend that an increased buffer be provided to the dune of approximately 20m. This will provide 60m of dune to cater for the natural erosion and accretion cycles the beach may go through, but also for increased flexibility dealing with recession associated with sea level rise over the course of this century.

On a related point, Council reports that sand is constantly drifting into the carpark area. An increased buffer will allow the dune to be managed more naturally and the dune is likely to naturally increase in width and height.

8b. Assets at risk (private)

Private assets are unlikely to be at risk over the course of the current century.

8c. Safety of people

Sea level rise and associated erosion is unlikely to increase risk to the safety of people above that risk which is normally incurred by people at the beach.

8d. Ecology at risk

In this cell the dunes are likely to remain intact until the end of the century. This means that large scale threat to the ecology behind the dunes is unlikely.

9. RISK ASSESSMENT

In this section we conduct a formal risk assessment of hazard impacts upon the four receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

This risk assessment utilises the risk framework of Alexandrina Council.

9. RISK ASSESSMENT

Inherent hazard rating

Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to two main hazards:

- Sea-water flooding
- Erosion

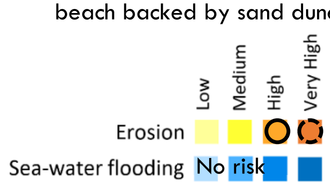
The application of an inherent risk rating does not suggest that areas rated as low are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location using a process that will also benchmark the locality in the context of all of South Australia.

The visual output from the inherent risk assessment process is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs.

Inherent hazard rating: Goolwa Beach

Inherent Hazard Rating

Sandy dissipative high energy beach backed by sand dunes



Specific Risk Assessment

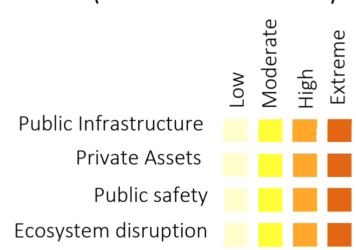
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

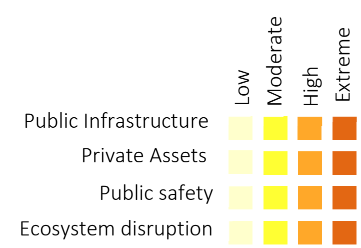
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

The specific risk assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The specific pass risk assessment utilises the risk assessment of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion (See next page).

Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Yet to be assigned

9. Risk Assessment

Erosion assessment

Goolwa Beach (SF3)

Risk identification: Erosion is currently, or may in the future, cause the dune system to recede and assets placed at risk.

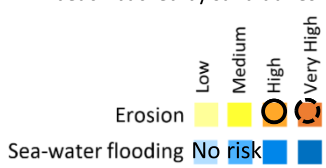
Coastal processes	Goolwa Beach is situated on a dissipative high energy beach facing the Southern Ocean. Over seventy years the coast has remained relatively stable while going through its natural cycles of accretion and erosion. Over the last ten years the Middleton – Goolwa coastline has been undergoing accretion.

Are any strategies employed to mitigate the risk? Dune fencing and planting assist in limiting the rate of erosion.

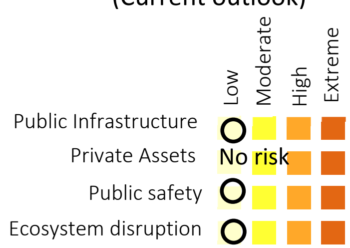
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carpark, walking pathways and tracks, beach access stairs, Surf Life Saving Club, and café, beach foreshore furniture. Currently the beach is in an accretion cycle.	current	*Unlikely*	*Minor*	low
		2100	*Likely*	*Significant*	high
Private assets	Private assets are not located in the vicinity of Goolwa Beach.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk
Safety of people	This assessment does not relate to general beach safety of pedestrians or swimmers. It relates only to how the safety of people may be exacerbated due to increased sea level (and associated impacts)	current	*Rare*	*Minor*	low
		2100	*Rare*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. The dune system is not expected to break down over the course of the century and therefore major ecological disruption is unlikely.	current	*Rare*	*Minor*	low
		2100	*Unlikely*	*Minor*	low

Inherent Hazard Rating

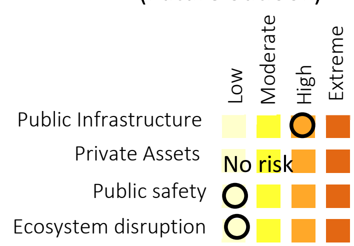
Sandy dissipative high energy beach backed by sand dunes



Erosion Hazard Rating
(Current outlook)



Erosion Hazard Rating
(Future outlook)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment

Summary	Currently Goolwa Beach is in an accretion cycle, and it is expected that the beach will return to an erosion cycle at some stage. Should the seas rise as projected, then the dunes will be impacted and recede accordingly. Over time the current buffer between the dune escarpment and the carpark will be lost, and actions of the sea will impact the carpark and associated infrastructure.

10. ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

CoastAdapt notes that there are generally six categories of adaptation responses to climate change in the coastal zone:

- Avoidance
- Hold the line (protect)
- Accommodation (or limited intervention)
- Managed retreat
- Defer and monitor
- Loss acceptance

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. Thus, land that Is projected to become more prone to flooding in future can be scheduled as suitable only for development such as light industry or warehouses, and unsuitable for housing or critical infrastructure.

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. These approaches differ from other types of approaches in that they require significant commitments of financial resources and create a physical asset.

Environmental management

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support continued growth of habitat such as seagrasses or reefs.

It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

ADAPTATION APPROACHES

There are two broad ways in which adaptation can occur in relation to timing:

- Incremental approach

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change.

- Transformative approach

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant tat they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

GOOLWA BEACH

The modelling and assessment indicate that Goolwa Beach undergoes normal periods of accretion and recession over time periods measured in decades.

An incremental adaptation approach is recommended.

The overall strategy is for **managed retreat**. The main adaptation issue is the location of the existing carpark, and proposed foreshore redevelopment. Storm water drains under the main beach access point. To protect this public infrastructure over time, a **hold the line** methodology is recommended.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore.

Further reading and resources

This section of work adopts the framework and understanding of adaptation options from CoastAdapt. Further reading at:

https://coastadapt.com.au/understand-adaptation
https://coastadapt.com.au/adaptation options

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Managed retreat

Map SF3

Goolwa Beach

Adaptation proposal

(General)

The key to managing Goolwa Beach over time is to understand what the normal parameters of the beach are, and what impacts may be attributed to sea level rise.

Monitor

The beach and base of the escarpment should be regularly monitored. The purpose of the monitoring is to understand how the beach operates over time. The second purpose is to monitor the impact of storm events.

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Managed Retreat

The nature of the Southern Ocean in the context of a dissipative beach means that protection options are unlikely to succeed. If sea levels rise as projected, then the dunes can be expected to retreat ~70-100 (depending on nature and slope of backshore). The preferred option is to allow the coastline to retreat, while at the same time using various cost-effective methods to slow the rate and manage the impact.

Adaptation proposals

Managed retreat

Map SF3

Goolwa Beach

Adaptation proposal

(Specific)

Two main proposals:

1. Increase the buffer to the Goolwa Carpark and Surrounds proposal by 20m.

2. Reinstate the dunes to the main access point and install a ramp over the dunes with an exit to the beach. It is recommended that the end be buried down below current sand levels so that if the coast returns to an erosion mode that the infrastructure will not be left stranded by falling sand levels.

Note, the area in front of the current access stairs is low due to pedestrian traffic, and wave runup tends to penetrate further up the beach at this location. Reinstating the dunes in this location will increase protection when the erosion cycle returns, or seas rise and erosion increases.

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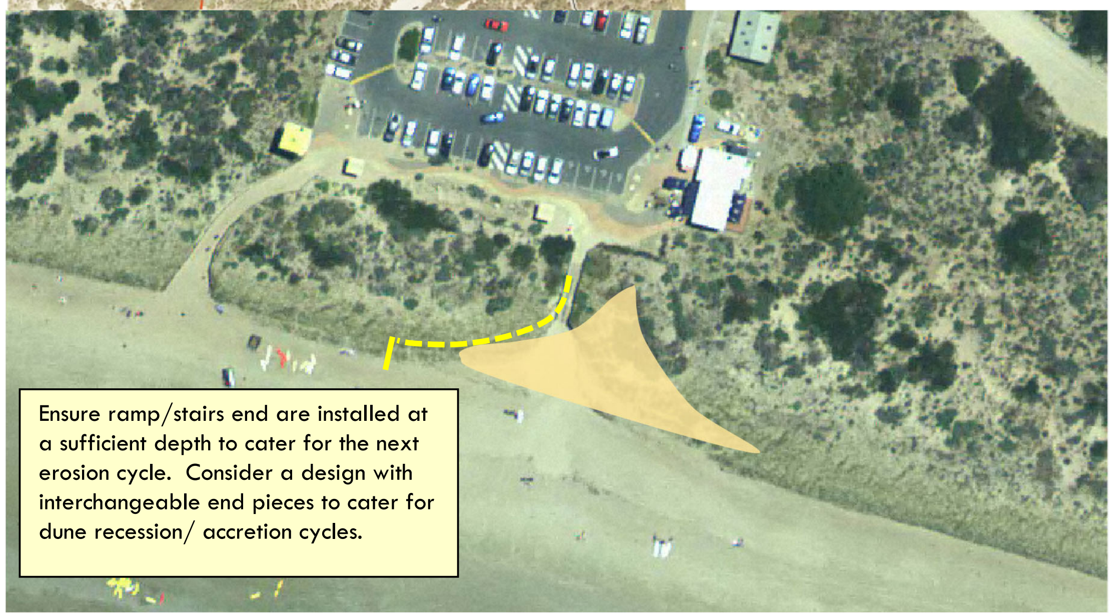
Consider amending the masterplan to increase the dune buffer to the front of the carpark.

Recommendation to reinstate the dune system and reconfigure the access way as a ramp, culminating in smaller number of stairs that are buried into the sand to cater for expected erosion cycle. It may be possible to take this a ramp all the way to the beach.



Ensure ramp/stairs end are installed at a sufficient depth to cater for the next erosion cycle. Consider a design with interchangeable end pieces to cater for dune recession/ accretion cycles.

Monitoring strategies

The purpose here is not to provide a design for a detailed monitoring program as this will be completed as a separate project. The purpose here is to provide a context for understanding why monitoring is necessary and broadly, what type of monitoring actions are likely to be adopted.

In most areas of Alexandrina coastline, this study has recommended an 'incremental approach' to adaptation (see page above). The main reason to adopt this approach is that most of the coastline is not currently at risk from erosion or inundation. In fact, large sections of the coastline have shown to be accreting over the last ten years.

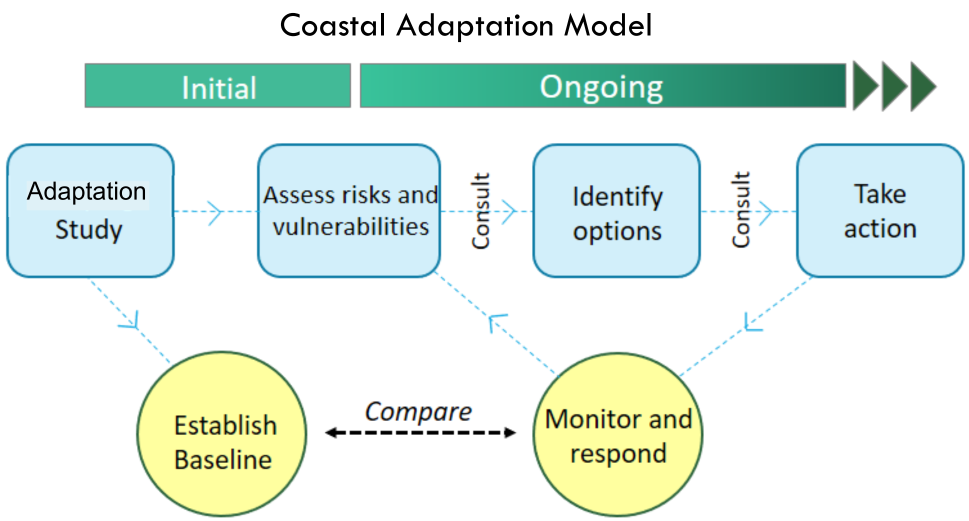
Prime response – 'monitor and respond'

Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

We have established a baseline in two ways: First, the capturing of the digital elevation model in 2018 provides a point in time baseline of the current form of the coast. In 5- or 10-years' time (depending whether the coast is accreting or eroding), another digital elevation model could be captured, and comparisons made between the two digital models (Figure).

The second way in which this study has formed a baseline is by analysing coastal change over time. We have compared the position of the shoreline from 1949 to 2018 and identified areas of erosion and accretion. Overall, the coastline in most places appears to have been stable for 70 years. In some places it has eroded. This understanding of how a coast operates over time also forms part of the baseline understanding. In the future, we can use newly acquired aerial photographs to compare shoreline position in the future and use various techniques to monitor sand volumes (see also Main Report).

Figure: In a digital environment, software tools can be utilised to compare coastal change (Source: Aerometrex)

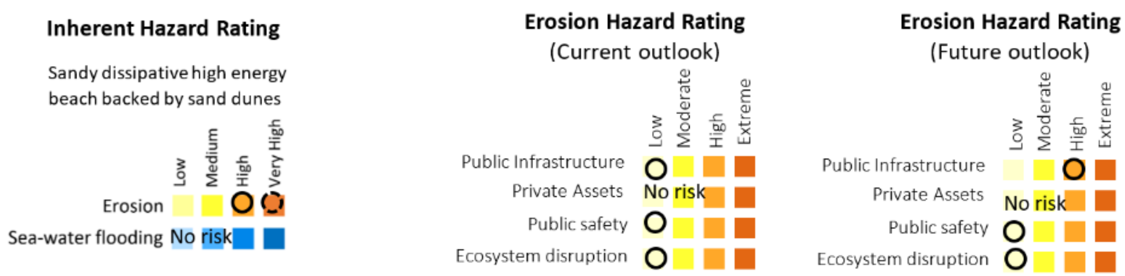


Integrated Coasts (2017)

Adaptation strategy: Goolwa Beach (Cell SF3)

Coastal processes	Goolwa Beach is situated on a dissipative high energy beach facing the Southern Ocean. Over seventy years the coast has remained relatively stable while going through its natural cycles of accretion and erosion. Over the last ten years the Middleton – Goolwa coastline has been undergoing accretion.

Risk outlook



Adaptation overview:

The over-all long-term strategy for Goolwa Beach is to allow the dunes to retreat. Soft options such as dune fencing and planting will slow the rate of erosion. For the Goolwa Carpark area, the recommendation is to increase the dune buffer from 20m to 40m and reorientate the access stairs (ie review and amend Master Plan for Goolwa Beach carpark area. If the dunes erode at a later time in this location then a 'hold the line' strategy is likely to be employed to protect the carpark area or alternatively, accept loss.

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Goolwa Beach Cell SF3	Incremental (monitor and respond)	Monitor [no immediate works are likely to be required]	Monitor [protection may be required by 2050, or the latter part of this century]	Overall strategy: Allow retreat of dunes. The exception is the carpark area which may need protection later in this century.	Environmental: Increase dune field at the carpark. Continue use of dune fencing and planting. Engineering: Reorientate beach access point.	Shoreline position Sand volumes Storm impacts on backshore

TOKUREMOAR RESERVE

(GOOLWA BEACH)

3. COASTAL FABRIC

In this section we evaluate coastal fabric in more detail:

- Overview of current coastal fabric
- Changes to shoreline over seventy years
- Changes to seafloor since 1977
- Human intervention

3. Coastal Fabric - natural

Overview

Map: SF4

Secondary Cell: Coorong

Tertiary Cell: Tokuremoar

Form

Beach

Fine sandy beach

Backshores

Backshore 1: Low foredunes 6-8 m high, 40 to 80m wide.

Backshore 2: Behind the dunes is a tea tree swamp at elevations less than 2m AHD that extends landwards further than 500m.

Bathymetry

Overall slope of ocean floor: -10m ~1km from beach (overall slope ratio 1:100).

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3. Coastal Fabric - natural

Overview

Map: SF4

Secondary Cell: Coorong

Tertiary Cell: Tokuremoar

Geology

Geology

Beach and backshore 1:

Semaphore sand – unconsolidated white bioclastic quartz- carbonate sand of modern beaches and transgressive dune fields.

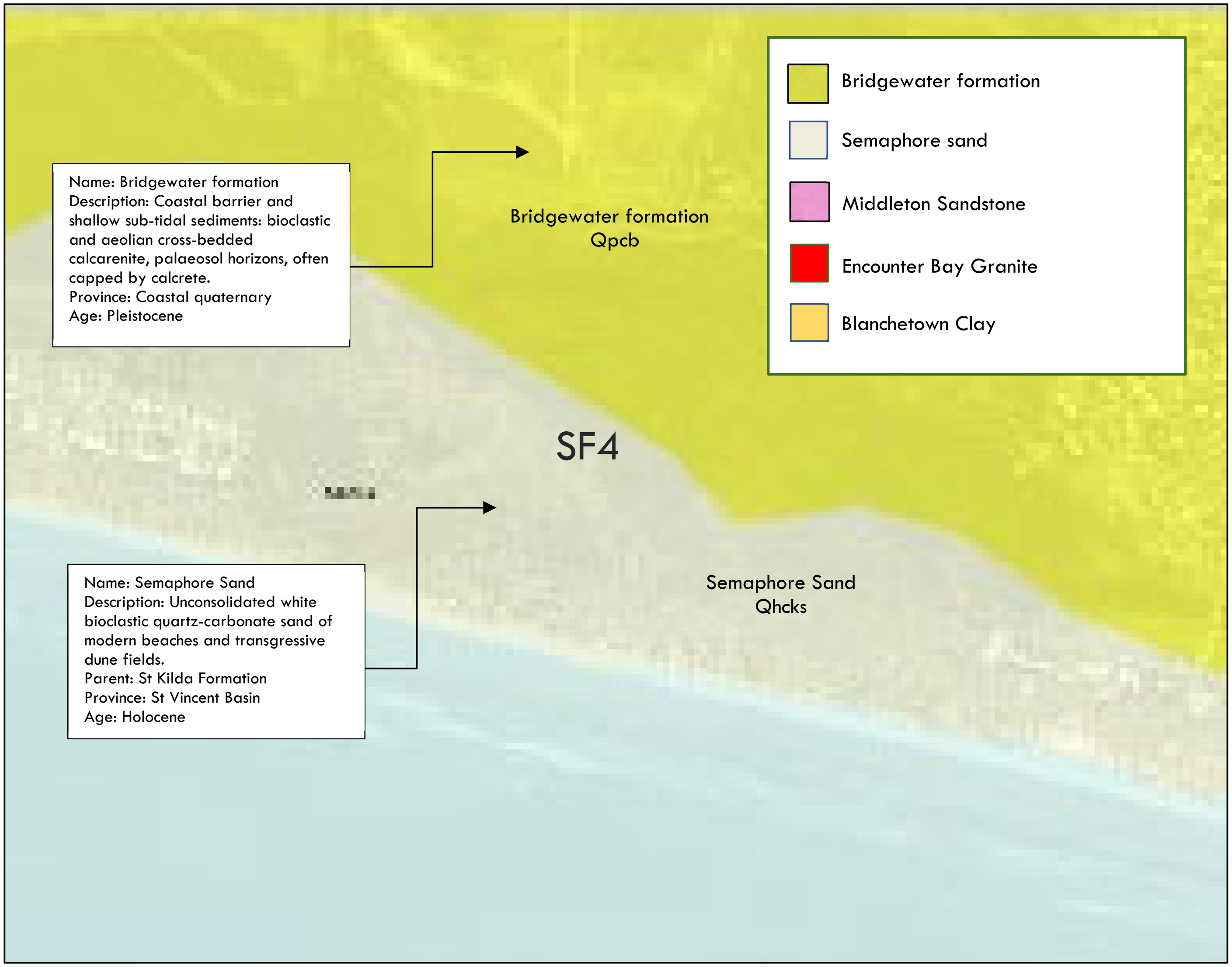
Age: Holocene

Backshore 2 (swamp and hill)

Bridgewater formation

Age: Pleistocene

Figure opposite sourced from www.sarig.gov.au



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3. Coastal Fabric - natural

Overview

Map: SF4

Secondary Cell: Coorong
Tertiary Cell: Tokuremoar

Benthic

Benthic

Wide, low gradient, fine sand, dissipative surfzone often with two or more shore parallel bars and troughs. Wave energy can be significant and the surfzone may be several hundred metres wide during storms.

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3. Coastal Fabric - natural

Overview

Map: SF4

Secondary Cell: Coorong
Tertiary Cell: Tokuremoar

Nature Maps

Yellow line in Nature Maps represents the following characteristics:

Shoreline class

Dissipative Beach (see inset)

Sand rating
Fine sandy beach

Exposure:
Exposed

Wave:
High (2m average, Surfwatch)

Backshore 1:
Unstable dune (partially vegetated).

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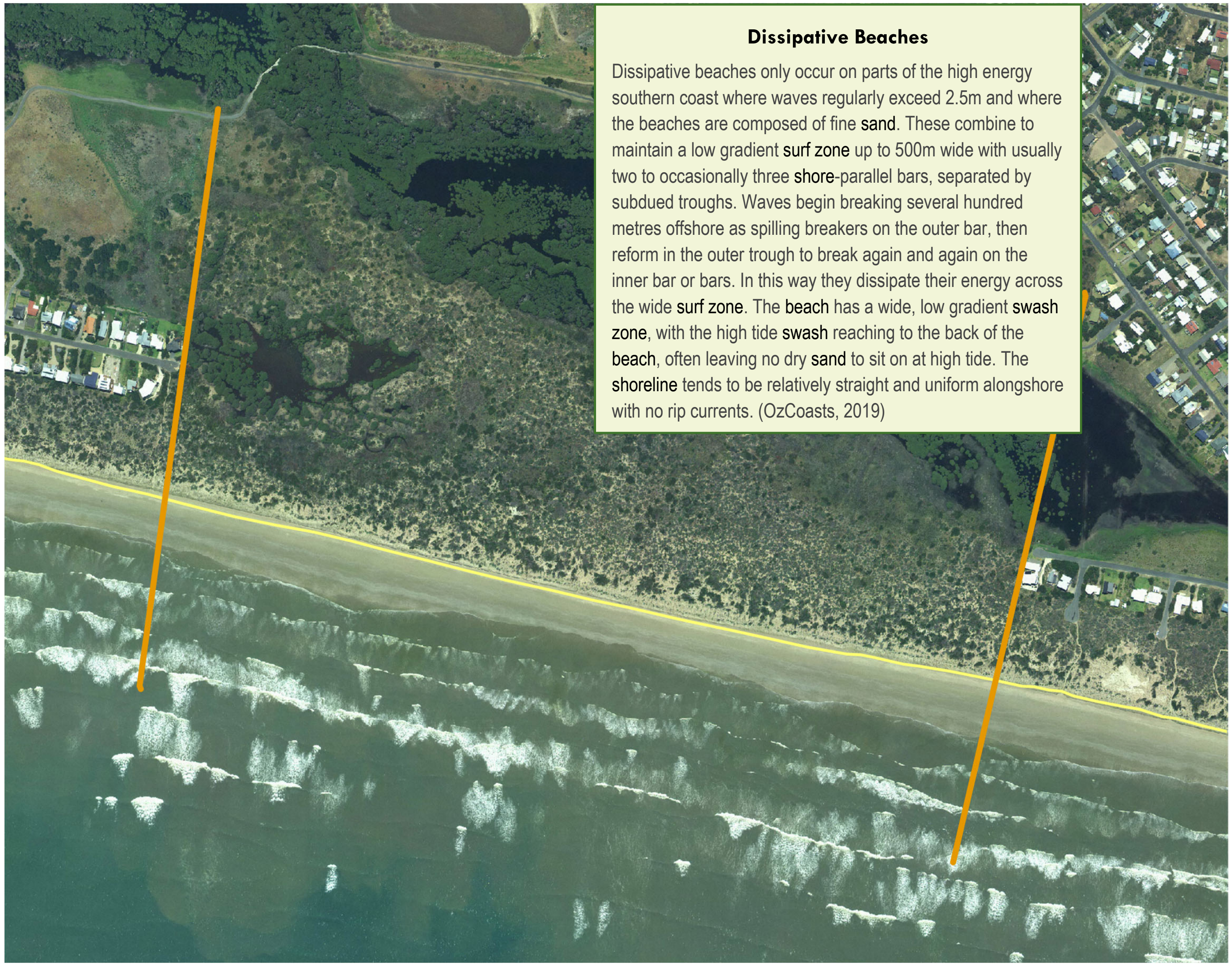

Dissipative Beaches

Dissipative beaches only occur on parts of the high energy southern coast where waves regularly exceed 2.5m and where the beaches are composed of fine sand. These combine to maintain a low gradient surf zone up to 500m wide with usually two to occasionally three shore-parallel bars, separated by subdued troughs. Waves begin breaking several hundred metres offshore as spilling breakers on the outer bar, then reform in the outer trough to break again and again on the inner bar or bars. In this way they dissipate their energy across the wide surf zone. The beach has a wide, low gradient swash zone, with the high tide swash reaching to the back of the beach, often leaving no dry sand to sit on at high tide. The shoreline tends to be relatively straight and uniform alongshore with no rip currents. (OzCoasts, 2019)

3. Coastal Fabric - natural

Medium Term Changes

Map SF4

Tukuremoar Reserve

Historical comparison

1949

Assessment

1949 baseline map. The maps on the following pages compare the location of the base of the dune escarpment.

<u>Georeferencing</u>

The 1949 aerial photograph has been checked against 2016 aerial photograph at Basham Homestead, Middleton Hotel, House in Goolwa, and Goolwa Barrage. The north-south alignments were all close (less than 1m). The north-south alignment is the key alignment when assessing beach movement. East-west alignment found that the 1949 photograph was 1-2m to the west of 2016. There are no landmarks near the coast at Goolwa to check in the immediate vicinity.

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3. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium Term Changes

Map SF4
Tukuremoar Reserve

Historical comparison

1949

Assessment

The baseline escarpment position in 1949 is depicted as a dotted line.

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3. Coastal Fabric - natural

Medium Term Changes

Map SF4
Tukuremoar Reserve

Historical comparison

1949 - 2006

Assessment

The line of the dune escarpment is located in the same position as 1949.

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3. Coastal Fabric - natural

Medium Term Changes

Map SF4
Tukuremoar Reserve

Historical comparison

1949 - 2016

Assessment

The line of the dune escarpment is located in the same position as 1949. In some sections the line of the escarpment has accreted since 1949 by as much as 4m but this is likely related to natural variability rather than a trend.

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4. Coastal Fabric - modified

HUMAN INTERVENTION

There have been no protection items or other infrastructure installed into the Tokuremoar cell.

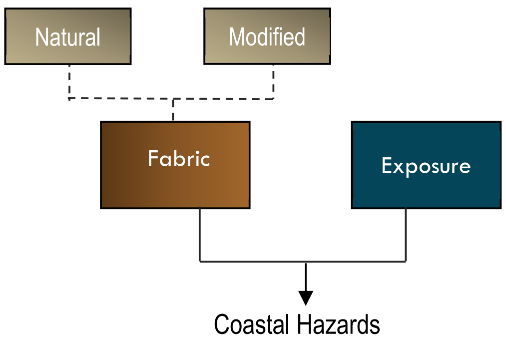
No urban settlements exist within the cell.

COASTAL FABRIC

Summary and conclusions

Progress report:

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell.



Summary:

Tukuremoar Reserve (Cell 4) is situated between the Middleton Suburb border and Boult Street area in Goolwa Beach.

<u>Beach and backshore 1</u>

The beach compartment is classified as a 'sandy beach'. Backshore 1 consists of low and narrow sand dunes with a former marsh situated behind. Geological classification is Semaphore Sand. Age: Holocene.

The current beach and dune system were formed after the last glacial maximum when sea levels rose, and large reserves of sand were carried landward.

<u>Backshore 2:</u>

In this location the marsh extends ~600m behind the dune system. Behind the marsh is an older dune from the Pleistocene age. Geological classification is Bridgewater formation, often capped with calcrete.

<u>Benthic</u>

In keeping with a high energy dissipative beach the intertidal and subtidal zones are dominated by fine sand.

<u>Human intervention</u>

No human intervention within Cell 4.

<u>Analysis</u>

Some evidence exists for shoreline recession from 1860s to 1949. The dune system will likely erode by 2100 with 1m of sea level rise and the swamp behind will be inundated. Impact is limited to approximately 600m inland where backshore 2 rises above sea level.

A comparative study of historical photographs from 1949, 2006, and 2016 demonstrates that the line of the dune escarpment is in the same position (with some minor accretion likely related to natural variability).

Thus, little change has apparently occurred in shoreline position since ~1949.

Erosion rating: Highly erodible (4)

5. CURRENT EXPOSURE

Evaluating how actions of sea and other weather events currently impact the coastal fabric by:

- Analysing a current storm event
- Applying current 1 in 100 sea-flood risk scenario
- Analysing routine high tide impact.
- Analysing storm water runoff

5. Current exposure – overview

Overview

Map SF4

Tokuremoar Reserve

Overview

Assessment

SA Classification
Nature Maps uses yellow coastal line to classify this coast as:

Shoreline class
Dissipative Beach (see inset)

Sand rating
Fine sandy beach

Exposure:
Exposed

Wave:
High (2m average, Surfwatch)

Backshore 1:
Unstable dune (partially vegetated).

Dissipative Beaches

Dissipative beaches only occur on parts of the high energy southern coast where waves regularly exceed 2.5m and where the beaches are composed of fine sand. These combine to maintain a low gradient surf zone up to 500m wide with usually two to occasionally three shore-parallel bars, separated by subdued troughs. Waves begin breaking several hundred metres offshore as spilling breakers on the outer bar, then reform in the outer trough to break again and again on the inner bar or bars. In this way they dissipate their energy across the wide surf zone. The beach has a wide, low gradient swash zone, with the high tide swash reaching to the back of the beach, often leaving no dry sand to sit on at high tide. The shoreline tends to be relatively straight and uniform alongshore with no rip currents. (OzCoasts, 2019)

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As the Alexandrina coast is open to the Southern Ocean, swell waves generated by storms 1000s of kms away, approach the coast independently of local winds and storms. Storm waves have greater waves heights and shorter wavelengths than swell waves. The resultant of onshore winds >28 km/hr, those winds which are capable of generating longshore transport, trends from the southwesterly quarter at a bearing of 227º, striking Goolwa Beach at an angle 60º. This causes longshore drift along Sir Richard Peninsula towards the Murray Mouth and the loss of beach sediment from the coast east of Middleton. As well as producing waves winds also transport sand. The weighted resultants of onshore winds capable of causing sand drift also approach from the southwesterly quarter and are responsible for building the dunes along the coastline. **Dr R. Bourman.**

5. Current exposure- storm event

Storm event

Map SF4

Tokuremoar Reserve

Event:

21-22 Nov 2018

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF3-4 of seaweed strands and other markers post event demonstrated wave effects were ~1.70m above tide gauge level. Wave set-up 0.5, wave runup 1.2. The modelling effectively replicates the event (see also separate report).

The impact in Cell 4 was minor (some minor scarping of dunes).

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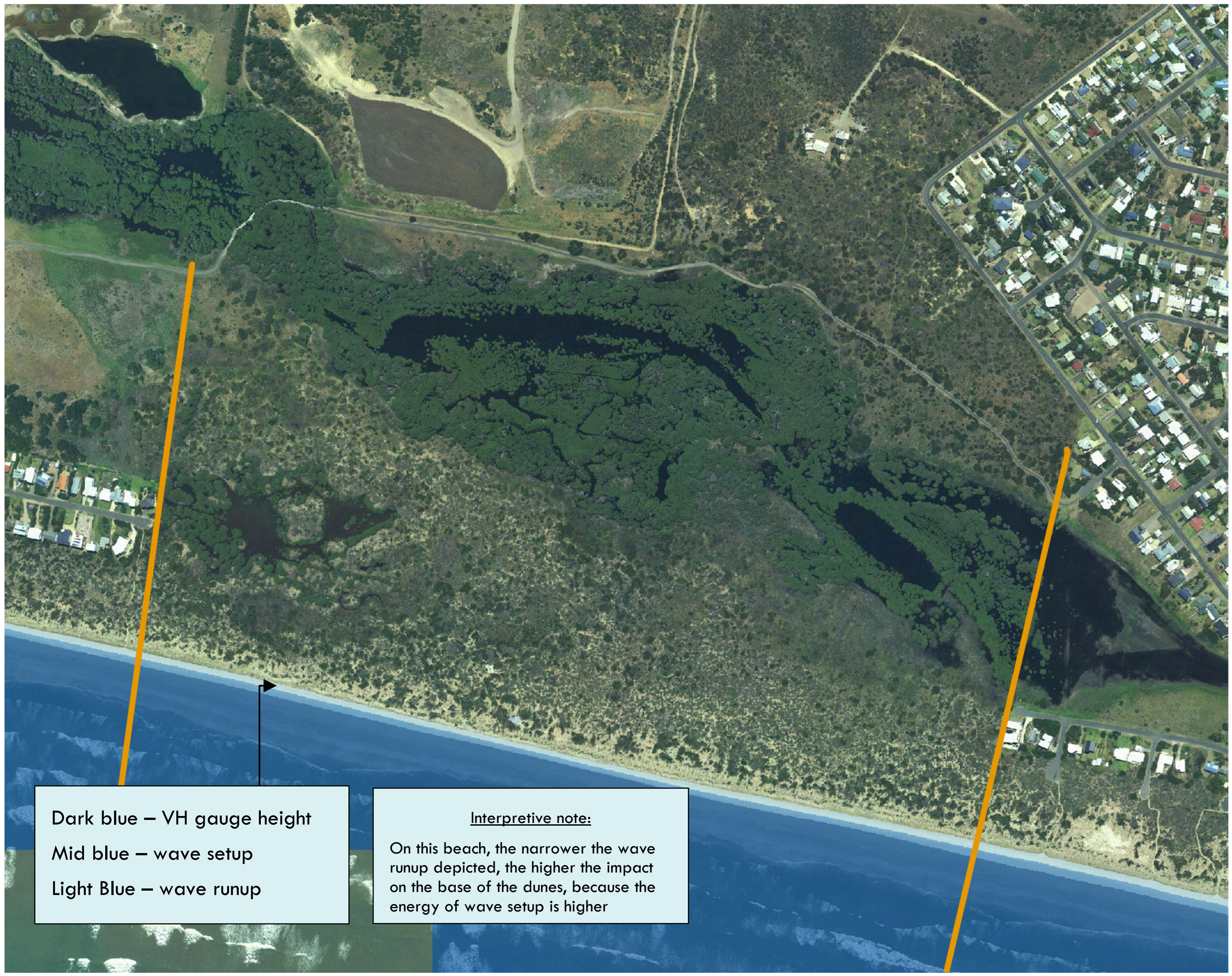

5. Current exposure – storm surge

Storm surge

Map SF4

Tokuremoar Reserve

Current risk:

1 in 100-year event risk

Assessment

The current 1 in 100-year ARI event risk set by Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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5. Current exposure – monthly high water

Monthly high water

Map SF4

Tokuremoar Reserve

Current risk:

Monthly high water

Assessment

Extreme events (such as 1 in 100-year events) are very rare and can have a significant impact. Routine tidal action may also have an impact on the stability of a dune system over time.

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is shown as light blue shading.

The current impact on beach and backshore is low.

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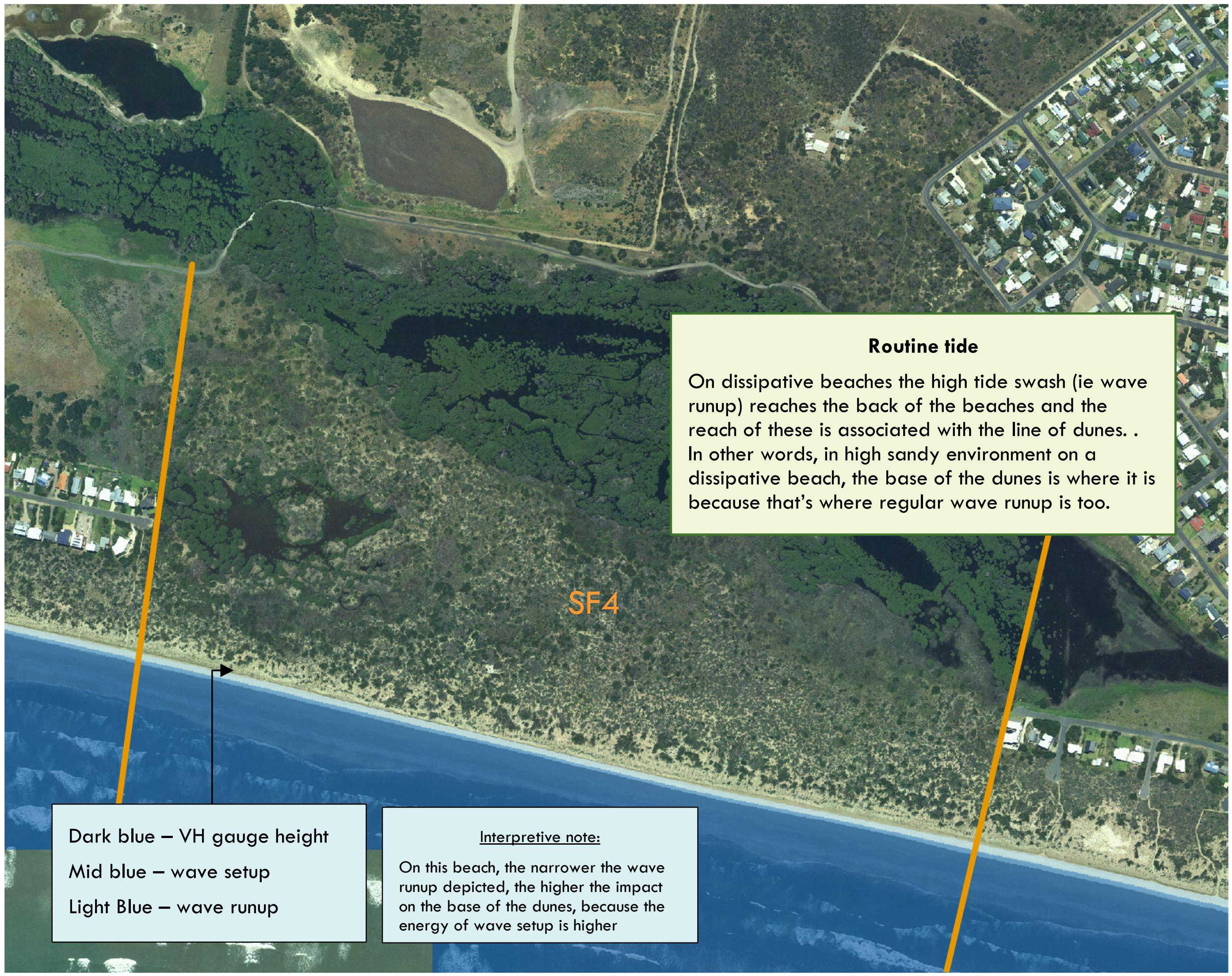

5. Current exposure – storm water

Storm water

Map SF4

Tokuremoar Reserve

Current risk:

Storm Water

Assessment

Storm water in SF4 drains into the swamp associated with Tokuremoar Reserve.

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5. Current exposure - erosion

Erosion

Map SF4

Tokuremoar Reserve

Current risk:

Erosion outlook

Assessment

A comparison of historical aerial photographs supports the view that the base of the dune escarpment has largely been in the same location since 1949 (with perhaps some slight recession).

Periodically wave action undermines and erodes the foredune but over time these tend to reform.

The current position of the dunes on a dissipative sandy beach and backshore is dictated by the current wave climate.

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6. FUTURE EXPOSURE

Evaluating how future actions of sea and other weather events may impact the coastal fabric by:

- Reviewing 1 in 100 scenarios for 2050 and 2100
- Reviewing monthly high tide scenarios for 2050 and 2100
- Analysing erosion risk to 2100

6. Future exposure – storm surge (2050)

Storm surge

Map SF4

Tokuremoar Reserve

2050 risk:

1 in 100-year event risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes. The impact of this event on the current dunes would be very high.

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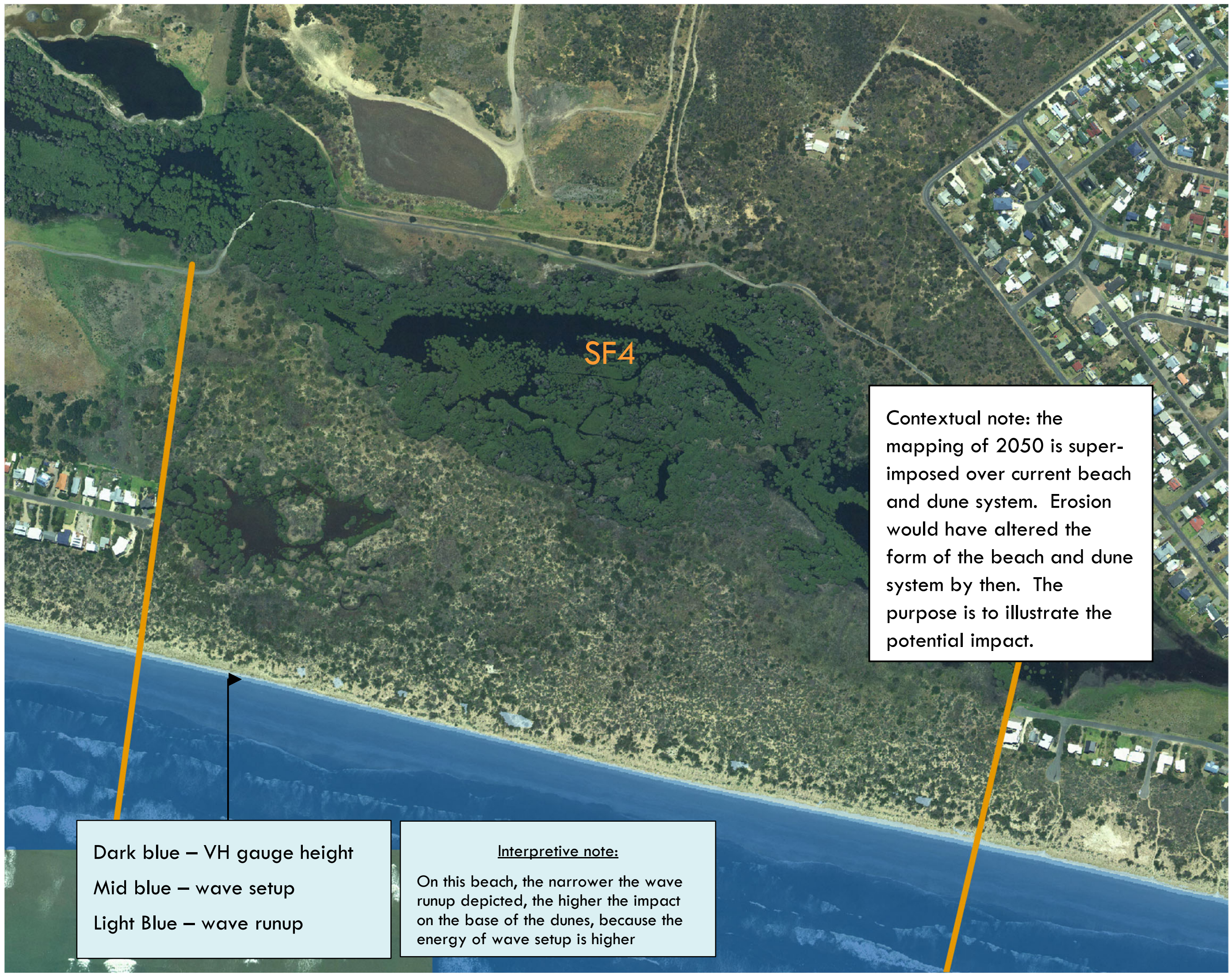

6. Future exposure – storm surge (2100)

Storm Surge

Map SF4

Tokuremoar Reserve

2100 risk:

1 in 100-year event risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe.

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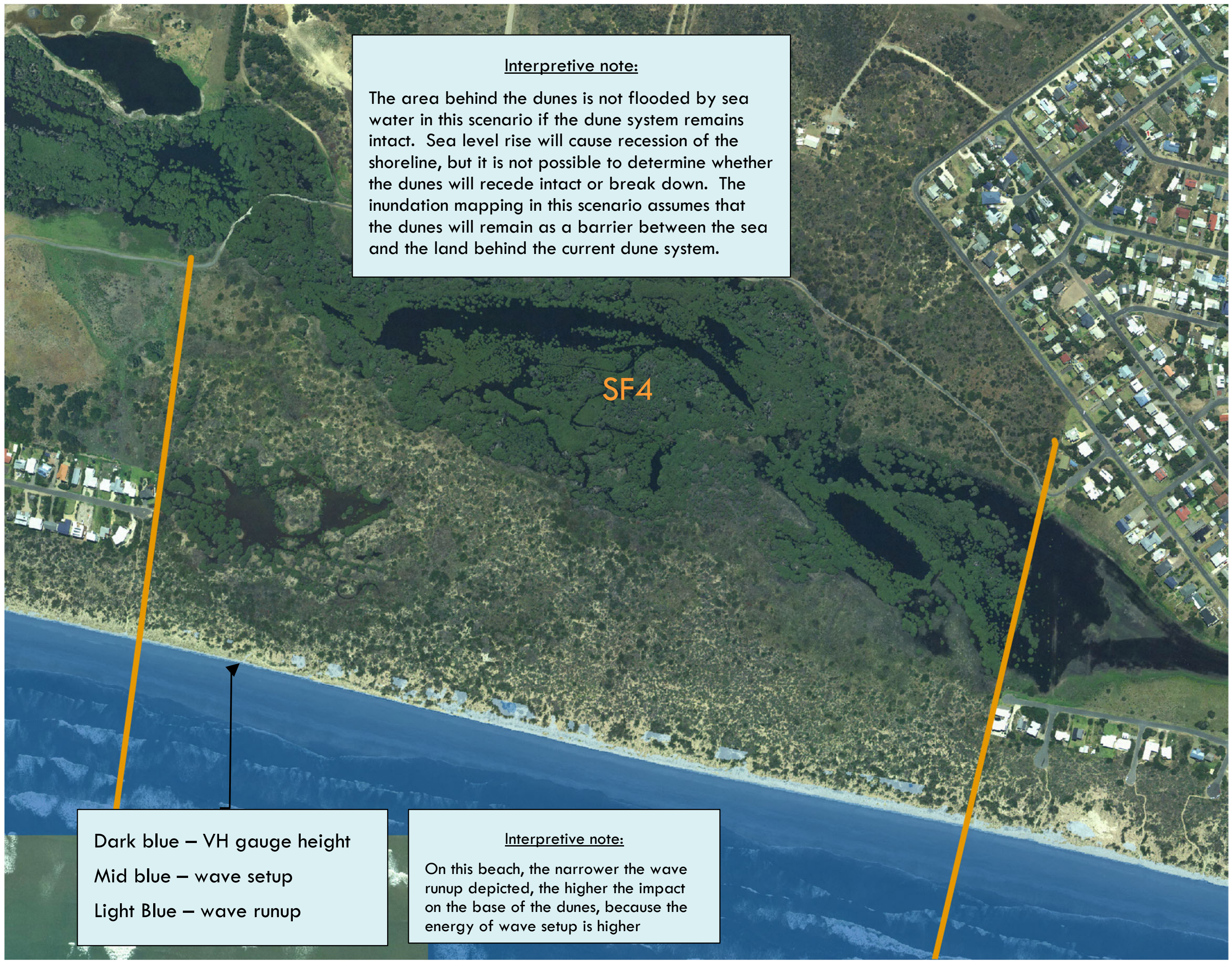

6. Future exposure – storm surge (2100)

Storm Surge

Map SF4

Tokuremoar Reserve

2100 risk:

1 in 100-year event risk

Assessment

The 1 in 100-year ARI event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD

In this scenario wave setup of 0.5m and wave run up of 1.2m has not been drawn/

Scenario modelling of future actions of the sea upon the current position of the shoreline demonstrates that wave setup would be impacting the base of the dunes. However, in reality, if seas rise as projected then the shoreline would retreat. It is also possible that the dune system would break down.

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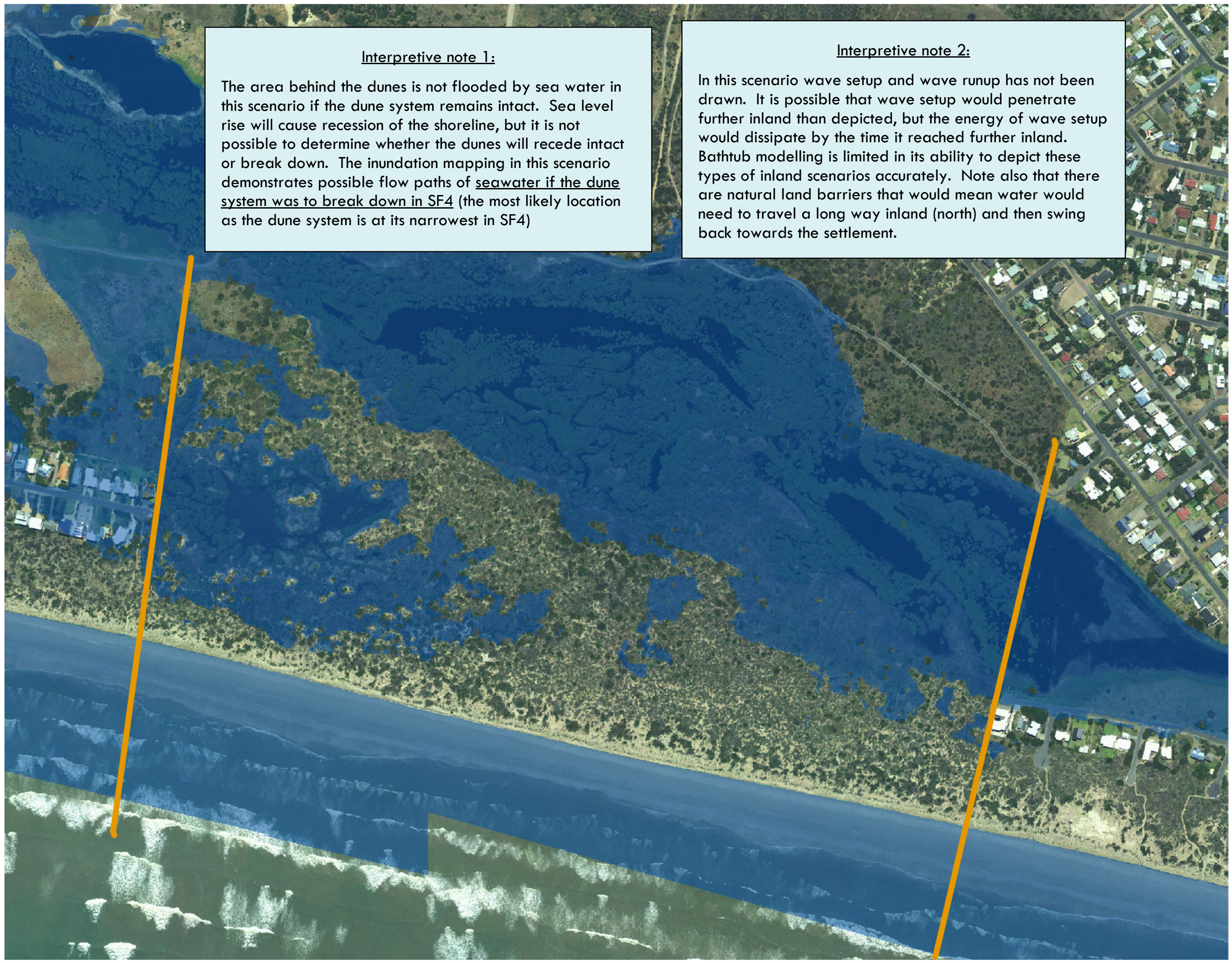

6. Future exposure – monthly high water (2100)

Monthly high water

Map SF4

Tokuremoar Reserve

2100 risk:

Monthly high water

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of a dune system over time.

The event modelled:

Average high tide	1.50m
Plus sea level rise	1.00
	2.50m

Wave set up 0.30m and wave runup of 0.80m has not been modelled.

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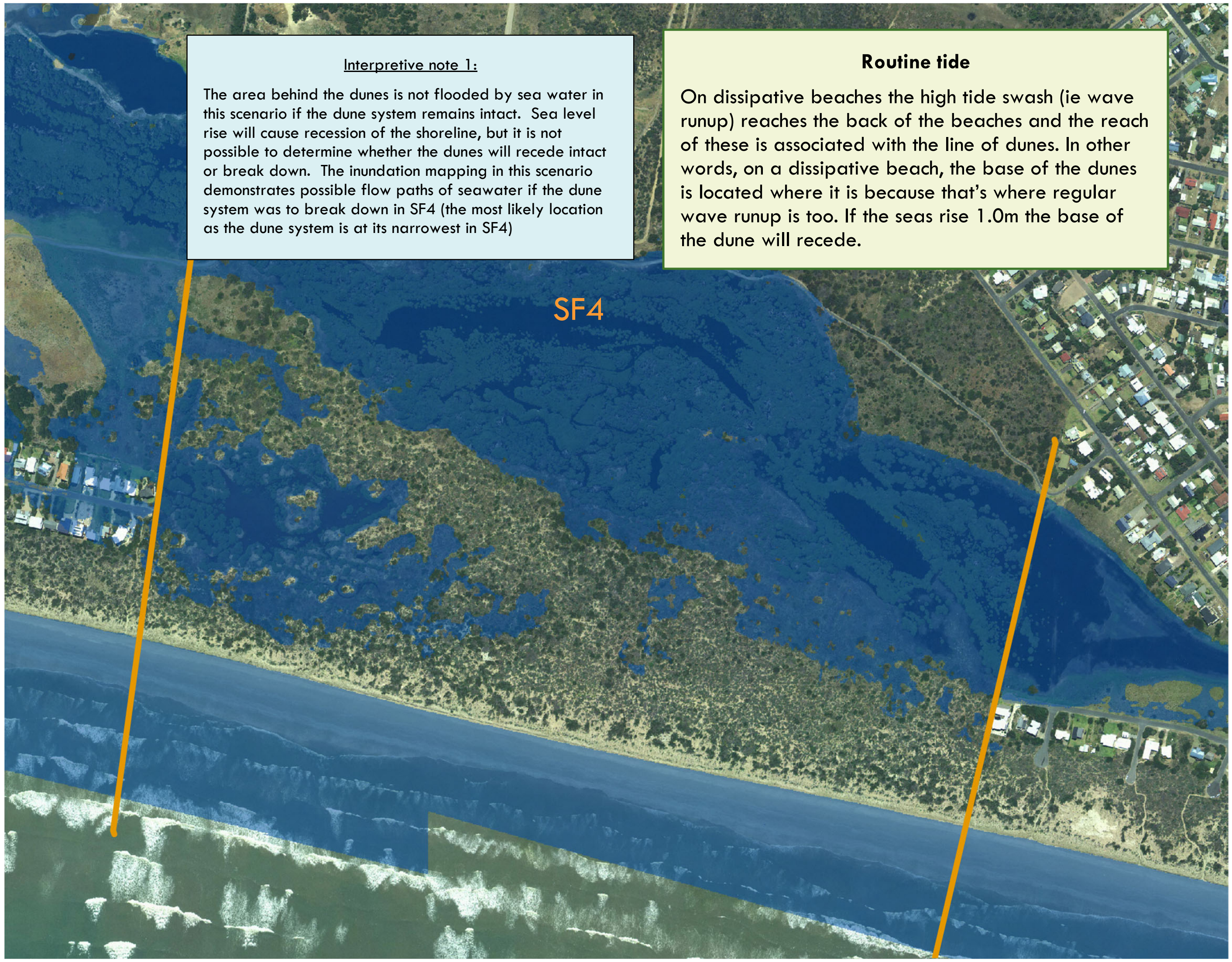


6. Future exposure - erosion

By Dr Patrick Hesp

See full version in Part 1 of the report

Shoreline recession due to sea level rise

In the following, we attempt to estimate shoreline retreat along the Tokuremoar Reserve region due to sea level rise.

Tokuremoar Reserve Beach

There is extremely limited information available at Tokuremoar Reserve Beach to determine alongshore and acrosshore sediment exchanges, these are the contributions of other processes causing losses or gains of sediments in the active beach profile.

An estimate of shoreline retreat due to a sea level rise of 1m by 2100 has been carried out for Goolwa, see cell SF3-1, which borders this cell to the East.Since similar conditions exist for erosion potential on the shoreface in these adjoining cells, and lacking a topotgraphic profile specific to this cell, the erosion estimate is derived from SF3-1.

From SF3-1… "for a sea level rise of 1.0 metre, depth of closure (*dc*) of 13.35 (assumes a significant wave height [$\overline{Hs}$]of 1.5m), and beach profile width (*W in eqn 1*) of 2000m, the Bruun Rule indicates a shoreline recession of 70.5m by 2100. For 2050 the shoreline erosion is estimated at 21m."

This number essentially indicates recession resulting in a cliffed dune (if the dune still exists!) and lee slope. The vertical face or scarp of a dune is inherently unstable, and will collapse and slide to a stable angle of ~ 25° resulting in a zone of slope adjustment.

This will produce further landward retreat of the dune crest in addition to that estimated by the Bruun Rule.

Shoreface-Beach and Dune Translation Model

Again, using calculations based on the adjoining cell SF3-1, we can expect similar behaviour in regard to landward shoreline translation. From SF3-1…

'The utility of the Bruun Rule has been the subject of debate over the last decades, because the "rule" takes no account of longshore sediment transport, the possibility that the foredune or dunes existing behind the beach can translate upwards and landwards with sea level rise, and it is not supposed to be utilised where surfzone-nearshore reefs exist'.

It is now a known fact that beaches and dunes can easily translate upwards and landwards as either shoreline erosion occurs or sea level rises (Davidson-Arnott, 2005). Therefore, another way to estimate the degree of shoreline retreat due to a given sea level rise is to take the latest topographic profile of the nearshore-beach-dune system and merely translate it entirely upwards and landwards by a given amount of sea level rise (in this case 1.0 m by 2100).

The distance that the profile is translated horizontally is determined by maintaining the distance between two topographic points (i.e. the slope of the beach-backshore) on the original profile in the projected future translated profile. For example, if the distance between zero m or AHD on the current profile and the foredune toe is, say, 15m, then that distance between those two points is maintained in the translated 2100 profile.

It may be seen that the beach-foredune system will translate approximately 108metres by 2100 in the case of both profiles.

Note that this assumes there is enough sediment in the system to allow this to occur (a large assumption), and that the nearshore profile can translate adequately given all the reefs present. It also assumes that the foredune is maintained as the shoreline retreats and sea level rises and has not changed its profile form (which is highly likely), and has not been destroyed, in part or fully, due to increased storminess and/or significant jumps in sea level due to meltwater pulses (very rapid rises in sea level due to massive ice retreat or ice shelf collapse) occurring in the next ~80 years.

The dunes in this location are relatively low (at around 6-8m) and range in width landward between 40m and 80m. The land behind the dunes is at low elevation (around 2m) and forms part of Tee Tree swamp.

With the existing predictions of coastline recession at 70 to 100m, it is obvious that the narrow sections of dune are at high risk of erosion and marine transgression.

Sea water inundation and potential flow around and behind remaining dunes through low lying land presents a risk and may accelerate the rate of erosion.

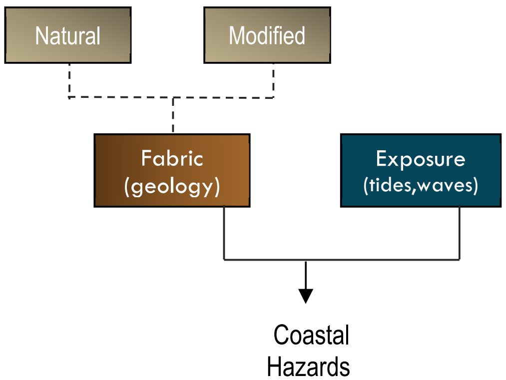
This type of incursion will change the ecology of parts of Tokuremoar Reserve, and while there are no settlements in the immediate vicinity, may pose additional threat to the adjoining cells to the West (SF5) and to a lesser degree East (SF3-1).

COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell. In the last section we also analysed current and future exposure (27-49).



Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Goolwa Beach. (It is recommended that one or two more events are analysed in the future). Total wave effects in SF4 totalled 1.70m.

However, while this storm produced significant wave effects the tide at the gauge was not exceptionally high (less ~0.20m than record of 9 May 2016).

Storm surge

Coast Protection Board has set 1 in 100 ARI event at 1.75m AHD (ie at the tide Victor Harbor tide gauge).

If this event was to occur, mapping shows that the impact on the dunes would be severe. It is unlikely that seawater would overtop the dunes or break through to the swamp area, but the dunes on the western end of the cell (immediately adjacent Surfers subdivision) are low and narrow in this location.

Monthly high water

Extreme events such as a 1 in 100 ARI event can cause considerable damage but these are rare events. Routine tidal action is more likely to break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era as routine tides dictate to a certain extent the position of the dune escarpment.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the dunes. Storm action is likely to threaten the stability of the dunes in the western section of this cell, and sea water may break through in this location.

Monthly high water

High tides with 0.3m sea level rise indicatively by 2050 would likely cause some recession of the dune escarpment.

Future exposure (indicatively by 2100)

Storm surge and routine high water

The 1 in 100 ARI storm event would significantly impact the beach and dune. High tides 1m greater than today would also routinely impact the dunes, and recession is the likely result.

Outcomes:

There are two Without intervention, the dune system would recede and likely break down on western end (adjacent subdivision) and sea water flow behind the settlement. If this were to occur human settlement would be threatened and the ecology of the Reserve changed irreversibly.

Exposure rating: Very exposed (4)

Contextual note

Mapping of 2050 and 2100 scenarios is super-imposed over the current beach and dune system. It is understood that the layout of the beach and dune system will have changed, especially by 2100. However, this mapping does give an indication of the likely extent of recession, and where impacts will be 'felt' the most.

7. Inherent hazard risk assessment

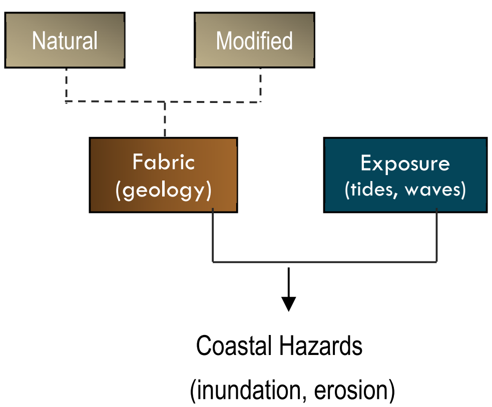
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk.

This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is *inherently* more at risk from flooding whereas an elevated coast is inherently not at risk from flooding.

The assessment of the erosion hazard is far more complex, but it is still the relationship of *fabric* to *exposure* that determines whether a coast is *inherently* more at risk from erosion or less at risk.



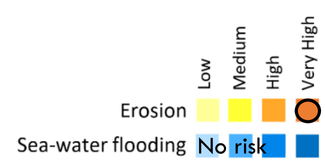
Inundation hazard risk

Due to the presence of sand dunes in the backshore there is no inundation risk to the marsh behind. However, if these dunes were to erode away then inundation of Backshore 2 (distal) is possible.

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main report)	Sandy beach, backshore 1: dune backshore , backshore 2: marsh	Very High
Should this rating be amended due to human intervention such as a protection item? If so, how?	No, human intervention is limited to dune fencing.	Very High
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'exposed' (means very exposed).	Very high
Assess any impact on backshore 1	Due to the nature of this beach, the location of the dune escarpment relates to the routine actions of wave run-up (monthly high water).	Very High
Assess any influence from Benthic	Offshore is dominated by unconsolidated sand	Very high
Assess the sediment balance	Over the last 70 years Goolwa Beach has been stable (and accreting in previous 10 years)	High-very high
Assess any other factors that may warrant a change of inherent hazard risk.	Due to marsh being the low lying backshore 2 (distal), 'very high' is the appropriate rating	Very high

Inherent Hazard Risk – Tokuremoar Reserve



8. HAZARD IMPACTS

In this section we identify and describe the potential hazard impacts within four main receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

8a. Assets at risk (public)

The land use of this cell is primarily 'reserve' and therefore very few (if any) public assets are located within it.

However, if the dunes were to break down and erode away, it is conceivable that road infrastructure could be impacted in the neighbouring cells. This potential threat could easily be managed with low height levees.

8b. Assets at risk (private)

The land use of this cell is primarily 'reserve' and therefore no assets are located within it.

However, if the dunes were to break down and erode away, it is conceivable that private infrastructure could be impacted in the neighbouring cells. This potential threat could easily be managed with low height levees.

8c. Safety of people

There is no perceived increase threat to the safety of people due to increasing sea levels and erosion apart from the normal safety issues related to the public accessing coastal areas.

8d. Ecology at risk

Without intervention, the dune system would recede and likely break down on western end (adjacent subdivision) and sea water flow behind the settlement. If this were to occur the ecology of the Reserve would change irreversibly.

9. RISK ASSESSMENT

In this section we conduct a formal risk assessment of hazard impacts upon the four receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

This risk assessment utilises the risk framework of Alexandrina Council.

9. RISK ASSESSMENT

Inherent hazard rating

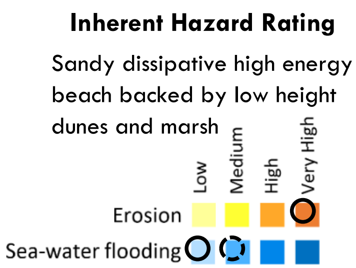
Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to four main hazards:

- Sea-water flooding
- Erosion

The application of an inherent risk rating does not suggest that areas rated as low are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location using a process that will also benchmark the locality in the context of all of South Australia.

The visual output from the inherent risk assessment process is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs.

Inherent hazard rating: Tokuremoar Reserve



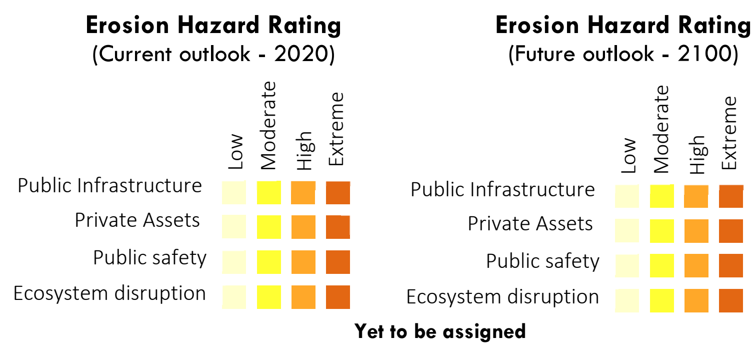
Specific Risk Assessment

Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Ecosystem

The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

The specific risk assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The specific risk assessment utilises the risk assessment of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding, gradual inundation, erosion, and eco-system disruption (See next pages).



9. Risk Assessment

Erosion assessment

Tokuremoar Reserve (SF4)

Risk identification: Erosion is currently, or may in the future, cause the dune system to recede and assets and ecology placed at risk

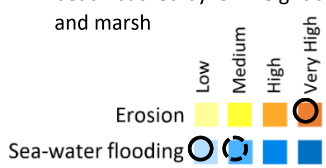
Coastal processes	Goolwa Beach is situated on a dissipative high energy beach facing the Southern Ocean. Over seventy years the coast has remained relatively stable while going through its natural cycles of accretion and erosion. Over the last ten years the Middleton – Goolwa coastline has been undergoing accretion.

Are any strategies employed to mitigate the risk? Nil. It may be likely that dune restoration was completed in the late 1970s

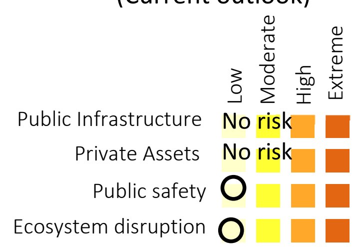
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Nil public infrastructure. However public infrastructure exists in neighbouring cells that could be impacted if the dune system eroded away.	current	*Unlikely*	*Minor*	No risk
		2100	*Likely*	*Significant*	low
Private assets	Private assets are not located within Cell 4. Private assets are located in neighbouring cells that could conceivably be impacted if the dunes eroded away.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk
Safety of people	This assessment does not relate to general beach safety of pedestrians or swimmers. It relates only to how the safety of people may be exacerbated due to increased sea level (and associated impacts)	current	*Rare*	*Minor*	low
		2100	*Rare*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. If seas rise as projected then the dune system is likely to react in one of two ways – retreat intact or break down and erode away (if the latter occurs, then seawater is likely to flow into areas of land behind the existing dune field and change the ecology).	current	*Rare*	*Minor*	low
		2100	*Likely*	*Significant*	high

Inherent Hazard Rating

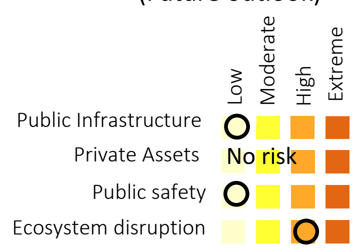
Sandy dissipative high energy beach backed by low height dunes and marsh



Erosion Hazard Rating
(Current outlook)



Erosion Hazard Rating
(Future outlook)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment

Summary	Currently Goolwa Beach is in an accretion cycle, and it is expected that the beach will return to an erosion cycle at some stage. Should the seas rise as projected, then the dunes will be impacted and recede accordingly. The dunes in this cell are of lower height and width and are likely to retreat and/or erode away. If the dunes erode away allowing seawater to flow through the dune system the ecology of the reserve would alter irreversibly.

10. ADAPTATION PPROPOSALS

Adaptation options

ADAPTATION OPTIONS

CoastAdapt notes that there are generally six categories of adaptation responses to climate change in the coastal zone:

- Avoidance
- Hold the line (protect)
- Accommodation (or limited intervention)
- Managed retreat
- Defer and monitor
- Loss acceptance

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. Thus, land that Is projected to become more prone to flooding in future can be scheduled as suitable only for development such as light industry or warehouses, and unsuitable for housing or critical infrastructure.

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. These approaches differ from other types of approaches in that they require significant commitments of financial resources and create a physical asset.

Environmental management

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support continued growth of habitat such as seagrasses or reefs.

It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

ADAPTATION APPROACHES

There are two broad ways in which adaptation can occur in relation to timing:

- Incremental approach

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change.

- Transformative approach

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant tat they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

TUKUREMOAR RESERVE

The modelling and assessment indicate that Goolwa Beach undergoes normal periods of accretion and recession over time periods likely to be measured in decades. Currently the dune system in front of the marsh is not under threat from actions of the sea. However, if seas rise as projected then in the latter part of this century the dune system could be under threat. Should sea water flow through the dunes, then the ecology of the marsh will become irreversibly changed.

An **incremental adaptation** approach is recommended. To protect the ecology, an initial **hold the line** methodology is recommended.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore.

Further reading and resources

This section of work adopts the framework and understanding of adaptation options from CoastAdapt. Further reading at:

https://coastadapt.com.au/understand-adaptation
https://coastadapt.com.au/adaptation options

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Managed retreat

Map SF4

Tokuremoar Reserve

Adaptation proposal

(General)

The key to managing Goolwa Beach over time is to understand what the normal parameters of the beach are, and what impacts may be attributed to sea level rise.

Monitor

The beach and base of the escarpment should be regularly monitored. The purpose of the monitoring is to understand how the beach operates over time. The second purpose is to monitor the impact of storm events.

Initially, hold the line

Where monitoring observed that the dunes were in danger of breaking down, remedial action should be undertaken such as dune fencing, planting, and dune nourishment.

Integrated Coasts

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Managed Retreat (including possible protection option)

The nature of the Southern Ocean in the context of a dissipative beach means that protection options may not succeed. The preferred option is to allow the coastline to retreat, while at the same time using various cost-effective methods to slow the rate and manage the impact. Low height levees could be installed behind the dunes to protect the ecology and infrastructure in this cell.

Monitoring strategies

The purpose here is not to provide a design for a detailed monitoring program as this will be completed as a separate project. The purpose here is to provide a context for understanding why monitoring is necessary and broadly, what type of monitoring actions are likely to be adopted.

In most areas of Alexandrina coastline, this study has recommended an 'incremental approach' to adaptation (see page above). The main reason to adopt this approach is that most of the coastline is not currently at risk from erosion or inundation. In fact, large sections of the coastline have shown to be accreting over the last ten years.

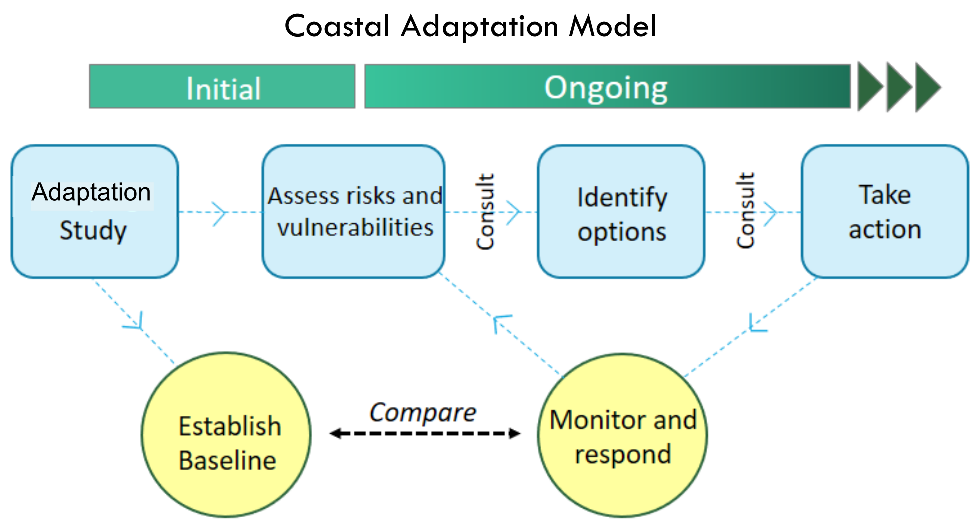
Prime response – 'monitor and respond'

Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

We have established a baseline in two ways: First, the capturing of the digital elevation model in 2018 provides a point in time baseline of the current form of the coast. In 5- or 10-years' time (depending whether the coast is accreting or eroding), another digital elevation model could be captured, and comparisons made between the two digital models (Figure).

The second way in which this study has formed a baseline is by analysing coastal change over time. We have compared the position of the shoreline from 1949 to 2018 and identified areas of erosion and accretion. Overall, the coastline in most places appears to have been stable for 70 years. In some places it has eroded. This understanding of how a coast operates over time also forms part of the baseline understanding. In the future, we can use newly acquired aerial photographs to compare shoreline position in the future and use various techniques to monitor sand volumes (see also Main Report).

Figure: In a digital environment, software tools can be utilised to compare coastal change (Source: Aerometrex)

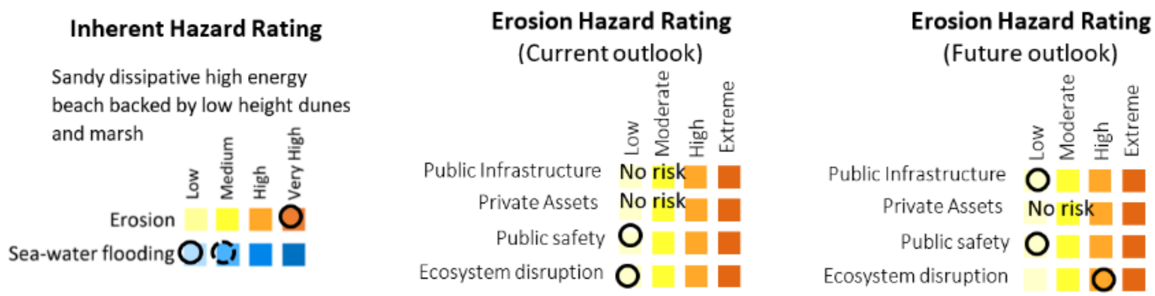


Integrated Coasts (2017)

Adaptation strategy: Tokuremoar Reserve (Cell SF4)

Coastal processes	Tokuremoar Reserve is situated behind low set dunes on Goolwa Beach. Goolwa Beach is situated on a dissipative high energy beach facing the Southern Ocean. Over seventy years the coast has remained relatively stable while going through its natural cycles of accretion and erosion. Over the last ten years the Middleton – Goolwa coastline has been undergoing accretion.

Risk outlook



Adaptation overview:

Initially, the main strategy for Tokuremoar Reserve is to monitor the dunes and provide soft engineering options to maintain dune width and height. However, as seas rises as projected, then this strategy may not succeed in the longer term, but how the coast will actually react to sea level rise is not clear. If protection was required to infrastructure and ecology behind the current dunes, low height levees could be employed further back from the coastline to prevent seawater from flowing inland.

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Tokuremoar Reserve Cell SF4	Incremental (monitor and respond)	Monitor [hold the line: remediate dunes at points they become vulnerable]	Monitor [hold the line: remediate dunes at points they become vulnerable]	Managed Retreat: if hold the line becomes unviable, provide low height levees inland to prevent the inland flow of seawater.	Environmental: Use soft options such as dune fill, sandbags, fencing and planting. Engineering: Longer term may require low height levees set inland.	Shoreline position Sand volumes (dunes) Storm impacts on backshore