Coastal Adaptation Study
for Alexandria Council

MIDDLETON CREEK

Cell SF6

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

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Front 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 (Cell: Middleton Creek). 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 (eg 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

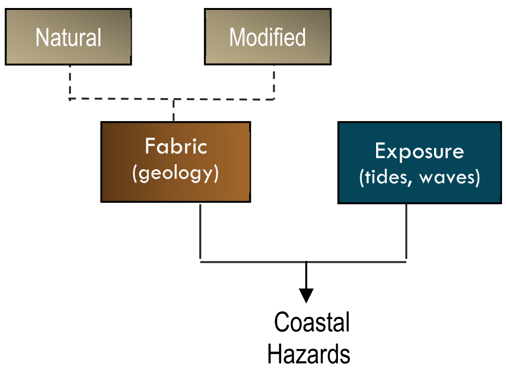
Finally, in a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements.

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 **Fleurieu southeast coast** (CoastAdapt) and within tertiary cell **Southern Fleurieu 6** (Nature Maps). These cells are depicted on the following pages.

Introduction

Regional setting

Map: SF6

Secondary Cell: Fleurieu *and* Coorong

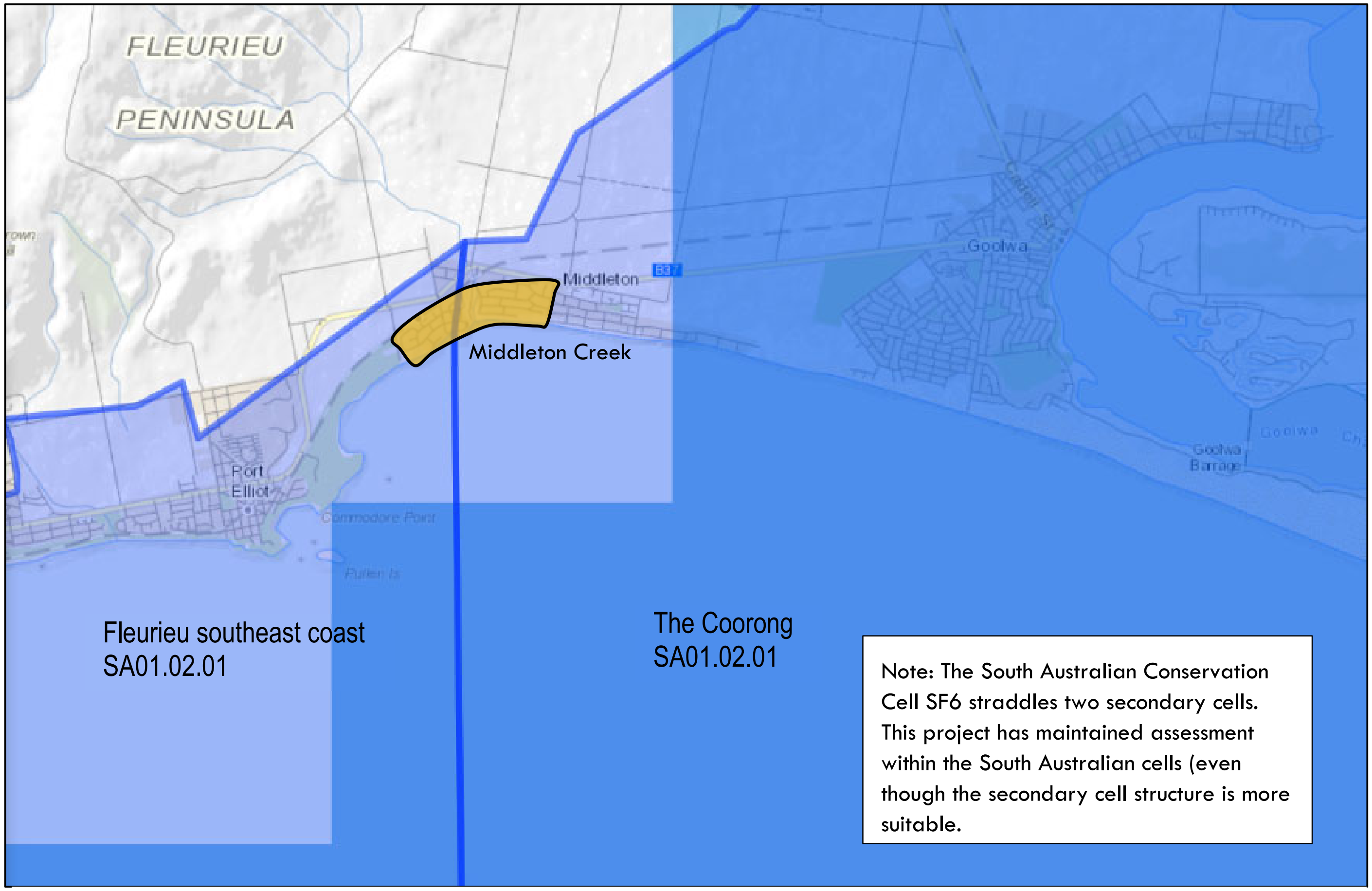
Tertiary Cell: Southern Fleurieu 6

Secondary Cell

Australian regional setting
The SA tertiary cell straddles two secondary cells: Fleurieu - southeast coast and the Coorong.

Geomorphology of the Fleurieu southeast coast cell:
Exposed, south facing, bedrock dominated, moderate-high energy coast with some embayed wave dominated beaches.

Geomorphology of the Coorong 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/SA01.03.01.pdf (See also Coorong Cell)

Introduction

Regional setting

Map: SF6

Secondary Cell: Fleurieu/ Coorong

Tertiary Cell: Southern Fleurieu 6

Minor cell: SF6:1 and SF6:2

Tertiary Cell

Shoreline class

The yellow shoreline by Nature Maps designates:

Sandy Beach (but Middleton east has hard sandstone outcrops)

Low tide terrace and Traverse Bar and Rip (west of the creek)
Dissipative (east of the creek)

Sand rating
Fine sandy beach

Exposure:
Moderate (west of the creek)
High (east of the creek)

Wave energy:
Moderate (west of the creek)
High (east of Creek but moderates downward towards the creek)

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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

The first 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, 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 Middleton Beach region was inhabited by the Ngarrindjeri people.

Middleton's history as township was directly related to changes in railways. The first siding was established in 1854, and for a time Middleton's population was equal to Goolwa's population. Middleton's significance as a railway centre ended soon after 1885 when the railway was diverted, and the original town has remained large the same since.

Goolwa, Port Elliot and Middleton became, with Victor Harbor, major resort centres, amongst the earliest outside Adelaide.

Middleton west (of Middleton Creek) was established first in the 1950s and 1960s.

Middleton East (surfers subdivision) was implemented in mid 1970s (19771200).

KEY STUDIES AND PLANS

Middleton Foreshore Plan (19771200)

The main focus of this plan prepared by Neill Wallman for the foreshore was carparks and access points. Carparks were installed at: Surf Street, Middleton Point and Middleton Creek, Padman Crescent, Middleton East carpark. Coast Protection Board contributed 50% towards a budget cost of ~$50,000 to develop the foreshore (19780613, 19780622).

In relation to coastal erosion the report noted:

> (5) The cliff face at Middleton East was 'rapidly eroding' due to: access by pedestrians, undercutting by the sea during storms, increased surface water run-off from the subdivision (the latter specifically identifies the construction period),
>
> (6) The cliff face at Middleton Point was eroding at lesser rate due to pedestrian access only.

Proposals to deal with the erosion were to:

- Restrict pedestrian access using fencing
- Conduct a planting program
- Carry out engineering studies to determine appropriate measures for protection (in particular, consider beach replenishment)
- Construct a low height retaining wall along cliff top from Mindacowie Road to Dover Road.

Coast Management Study – Port Elliot to Middleton (19830928)

This management study prepared by Doug Wallace and Associates in 1983 reviewed the coastal environs from Green Bay (Port Elliot) to Chapman Road (Middleton), dividing the coast into 6 units. Units 5 and 6 of this study are contained within Cell SF6.

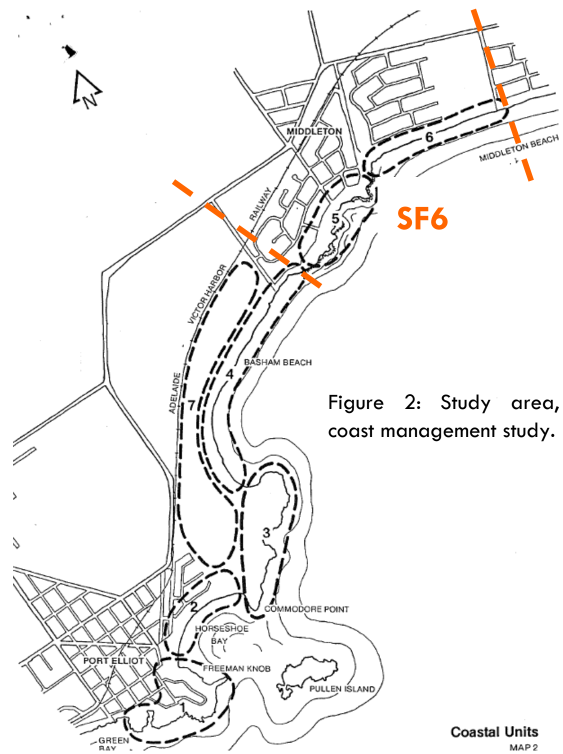


Figure 2: Study area, coast management study.

1. Settlement history

Coast Management Study (cont)…

<u>Coastal Unit 5 (Cell SF6-1)</u>

The study notes that, 'this part of the coast is suffering from coastal erosion processes that need to be carefully monitored' (see circle inset). There is also a proposal to monitor the rate of erosion of the cliffs in this location.

The report notes that the foreshore road reserve is not formed between Surf Street and Mindacowie Rd and nor should it be in the future. The proposal for improving access was only adopted on the eastern end.

Other proposals included relocating the toilets (not completed), and formalisation of carparking.

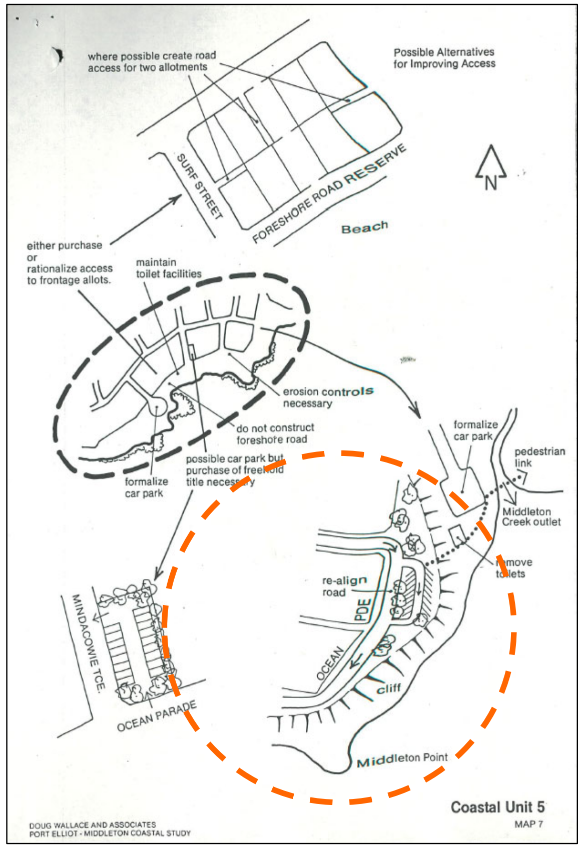
<u>Coastal Unit 6 (Cell SF6-2)</u>

The study identifies the cliffs on the eastern side of Middleton Creek as soft clay cliffs susceptible to rapid erosion (but this is in the context of human traffic).

The study recommends the formalisation of carparks, accessways, and fencing (completed).

The original toilets in Middleton Creek carpark area were removed and new toilets constructed at the base of the escarpment.

The study recommends installing a road over Middleton Creek to join Middleton East with Middleton West (not completed).



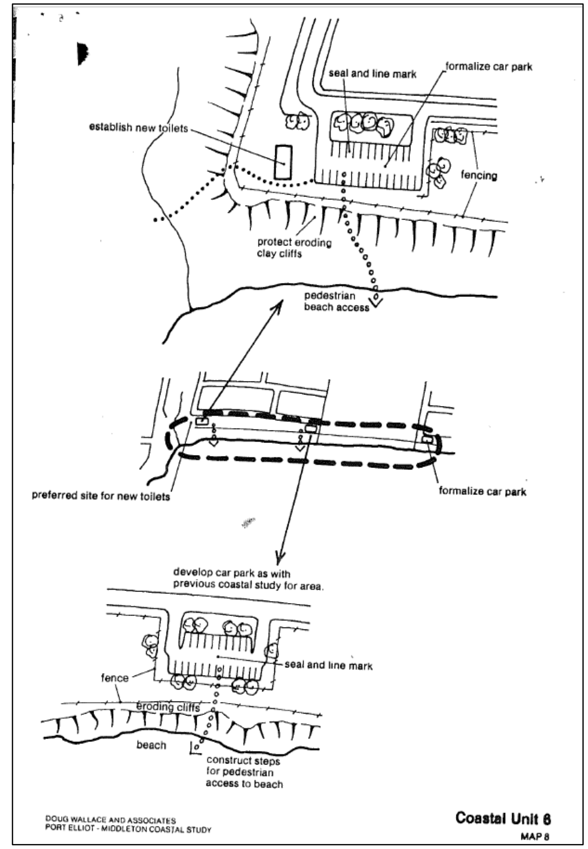


Figure 3: Middleton West - Coastal Unit 5 (SF6-1)

Figure 4: Middleton West - Coastal Unit 6 (SF6-2)

KEY DOCUMENT

Coast Management Study – Port Elliot to Middleton (Doug Wallace and Ass, 1983) provides assessment of coastal conditions of the time and proposals that form the basis for the existing layout of this area in current times.

1. Settlement history

ARCHIVAL REVIEW

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

Middleton Foreshore Development

Archives contain a budget of ~$50,000 for recommendations in Coast Management Study (1983) of which Coast Protection Board contributed half (19780613, 19780622).

Access issues at Ocean Parade

An existing road reserve on the foreshore between Surf Street and Mindacowie Road was created as part of an 'old subdivision' (19850419). Questions were raised about rights of access to existing houses. This issue was also dealt with in Doug Wallace report (see above). The proposal was to build a narrow rubble road to limit impact on the dunes and the archive states that 'the impact in the dunes was minimal and these would recover with the onset of winter'.

One person lodged a complaint in 1990 noting that increased vehicle and pedestrian traffic had damaged the dunes further (19900122).

COASTAL IMPACTS

Historical perspective

The late Mr Arthur Neighbour of Goolwa (pers. comm. 1970) claimed that the sea had advanced some 400 m since 1897. According to Mr Basham of Port Elliot (pers. comm. 1970), high seas and gale force winds destroyed a beach shelter made of railway sleepers shortly before 1920 and washed away the sandhills east of Middleton Creek.

Photographs taken of the beach in the late 19th century confirm that it was of extensive width, being used for gymkhanas. Today there are no extensive sand dunes backing the beach and over the years the sea storms sporadically eroded a line of alluvial cliffs. But the commonly held view that the coastline has eroded by as much as 400 m since 1897 **is not wholly supported by independent evidence.**

NOTE

The main contributor to this section of work is Dr Bob Bourman (project partner).

Figure 5: Early photograph of camp on dunes at Middleton Beach (the inference is that these dunes are in front of cliffs?)

Figure 6: View of Middleton Beach in 1890s showing its broad extent. The people in the photograph are those of the Basham family. Photo kindly provided by Miss P. Basham.

1. Settlement history

Nevertheless, aerial photographs taken in 1949 and 1972 clearly indicate that erosion of terrestrial alluvial deposits has formed a cliff line up to 8 m high and that there was a coastal retreat of many metres in this 23-year period.

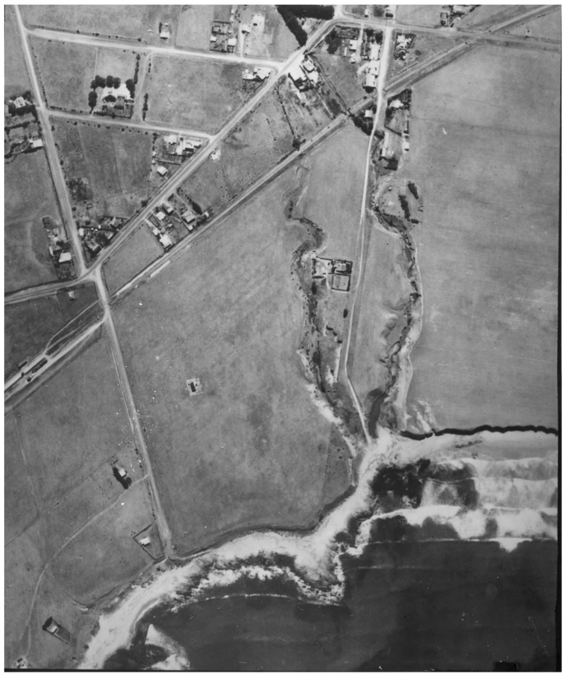


Figure 7: Middleton coast in 1949. Hard rocks of the Middleton Sandstone protect the shoreline to the left of the outlet of Middleton Creek. To the right of the creek mouth the crenulated nature of the cliff top indicates that active erosion is still occurring at this time. The hard rock outcrop bends the waves, focusing erosion on the alluvial cliffs.

Eyewitness accounts of dramatic coastal erosion at Middleton have been documented reporting that the coastline east of Middleton Township has suffered considerable erosion since the turn of the century.

For example, Hodge (1932) wrote:

> "Up to about 20 years ago Middleton was noted for its wonderful beach. At low tide it was probably nearly a quarter of a mile (400 m) wide from sandhill to sea, and so firm that vehicles could be driven for miles along its reaches in an easterly direction. But the sea encroached quite suddenly and there is now comparatively but little beach and ordinary high tides practically reach the sand hills."

The oldest accurate map of the area was prepared in the 1860s when surveys were made to within 150 links (29.7 m) of high-water level. Measurements from a fixed point in September 1974, 106 years after the first survey revealed that the cliff line had eroded by as much as 45 m, equivalent to a rate of 0.4 m/yr.

(There is an assumption here that the surveys were done on site (in Marino these were done in London)

Landowners in the affected area provide evidence of the truncation of fence lines at a rate of 0.3 m/yr over the period 1944-1974, erosion of the same order of magnitude as that determined by resurveying. However, even greater erosion has occurred to the west of the resurveyed line. Comparison of the original map with aerial photos suggests that near the mouth of Middleton Creek some 200 m of erosion had occurred, an average rate of 1.9 m/yr for the 106-year period.

Greater erosion at the western end of Middleton Beach may be related to the impact of the hard rocks on the headland at Middleton. These rocks by bending or refracting the waves focus wave attack on the western end of Middleton Beach.

SETTLEMENT HISTORY
Key points

Middleton Beach was first developed on the west side of Middleton Creek in the 1950s and 1960s.

The east side of Middleton Creek was developed first in mid 1970s (and then?)

Two key plans formed the basis for the foreshore in its current layout (Middleton Foreshore Plan 1977, Coast Management Plan - Port Elliot to Middleton Beach, 1983)

Coastal erosion was noted as impact for Middleton Cliffs (east of creek).

Human induced erosion was noted for cliffs on both sides of the creek. However, there seems to have been an additional erosion problem on western side (perhaps storm water run-off?)

Significant anecdotal evidence (ie passed down) and some based on old plans (check) seem to support that rapid erosion occurred of Middleton Beach at about the turn of the century. It is possible the cause was an off-shore earthquake.

MIDDLETON CREEK (WEST)

2.COASTAL FABRIC

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

In this section we evaluate coastal fabric in more detail:

- Ancient coastal formation
- Changes to shoreline over seventy years
- Human intervention

2. Coastal Fabric - natural

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

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.

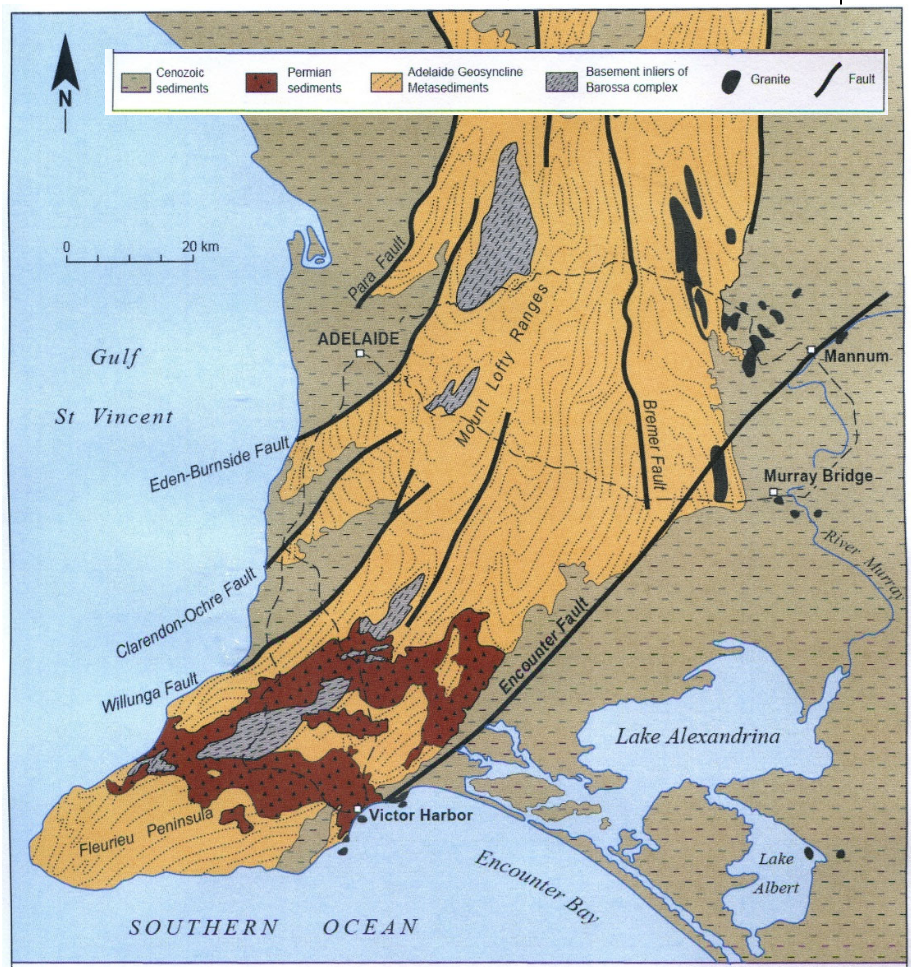


Figure 8: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

2. Coastal Fabric - natural

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

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

COASTAL FORMATION

Middleton Point (west of the creek)

Ancient, hard rocks are exposed at Middleton Point (bordering Cell SF7, Ratalang-Basham), producing a rocky shoreline with sandy patches. These rocks comprise the Middleton Sandstone of Cambrian (500 million years) age. The Middleton Sandstone is the youngest known part of the Kanmantoo Group of metasedimentary rocks that are exposed along the southern shore of Fleurieu Peninsula from Cape Jervis to Middleton. These rocks were originally sediments (muds, silts, sands and pebbles) deposited in the Adelaide Geosyncline and subjected to heat (<540oC) and pressure (<3 kb) during the intrusion of the Encounter Bay Granites and the folding of Kanmantoo Group rocks (the Delamerian Orogeny).

The original sedimentary bedding in the Middleton Sandstone has survived metamorphism and reveals cross bedding and indications that the sediments of the Middleton Sandstone were derived from sources to the west. Conspicuous pods of pale green epidote-rich segregations occur in the Middleton Sandstone here. Small-scale secondary folds are also readily visible in this Middleton Sandstone outcrop. There are occasional large isolated boulders of Middleton Sandstone, which have been possibly moved by storm waves

At Basham Beach and Middleton Beach the bedding in the Middleton Sandstone trends (strikes) east-west but in the Mount Lofty Ranges, a couple of kilometres to the north, the strike of identical rock is almost north-south, suggesting that a major geological structure such as a fault may separate the two outcrops. This observation supports the view suggested by the dislocation of the Last Interglacial Shoreline, as well as by gravity surveys, that a major fault line separates the Mount Lofty Ranges from the Murray Basin somewhere about this location.

The truncation of rock structures by erosion and other small-scale erosion features signifies that these hard rocks have been eroded by the sea, but because of their resistance, the rates of erosion are very slow and present a buffer to coastal erosion

This section of the coastline is exposed to quite strong wave attack from the open ocean and the area influenced by waves is indicated by the elevation of orange coloured lichen on the rocks; where the rocks are repeatedly wetted by waves no lichen occurs, but grows on the rocks above this level.

Key Points

The foreshore area of Middleton Point (west of the creek) is underpinned by hard ancient sandstone outcrops that bring stability to the coast and dissipate the energy of the waves.

Figure 9: Location of ancient sandstone outcrops that dissipate wave energy upon the coast.

2. Coastal Fabric - natural

Overview

Map: SF6-1
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Middleton Creek West
Form

Beach

Fine-medium sand beach (with rocky outcrops of sandstone)

Backshores

Backshore 1: Sandstone with sandy patches.

Backshore 2: Rises to 18m at 300m inland.

Bathymetry

Overall slope of ocean floor: -10m ~0.9km from beach (overall slope ratio 1:100) or < 5 deg.

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2. Coastal Fabric - natural

Overview

Map: SF6-1
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Middleton Creek
WEST
Geology

Geology

Beach and backshore 1:

Middleton Sandstone, low height former dune (now urbanised)

Sandstone - Cambrian

Backshore 2 (sloping hinterland)

Undifferentiated quaternary rocks rising to 18m at 300m inland.

Age: Pleistocene – Holocene

Map source: www.sarig.sa.gov.au

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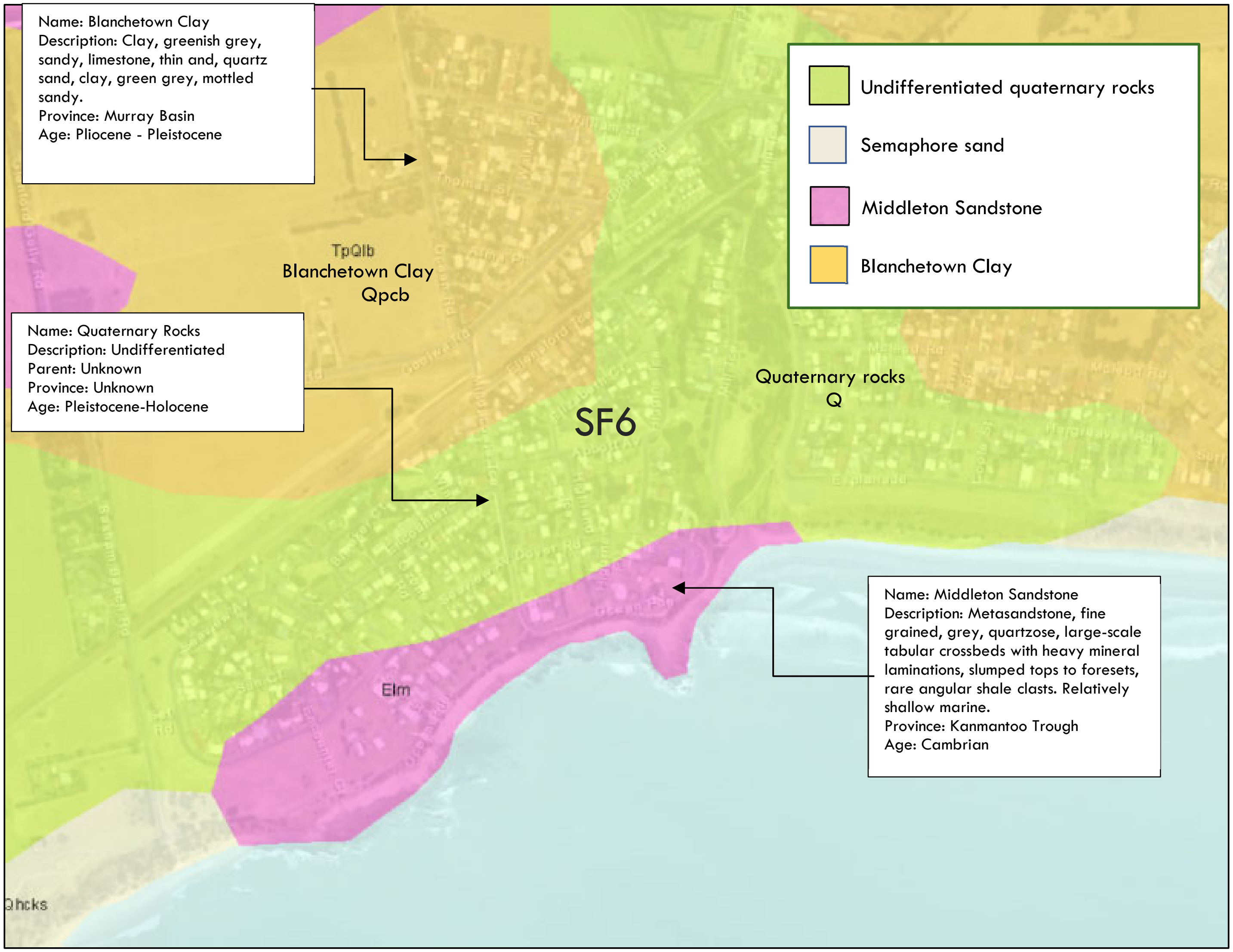

2. Coastal Fabric - natural

Overview

Map: SF6-1
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Middleton Creek
WEST

Benthic

Benthic

The low-profile reef within Ratalang Basham Cell extends into Middleton Creek, and also protects Middleton Point.

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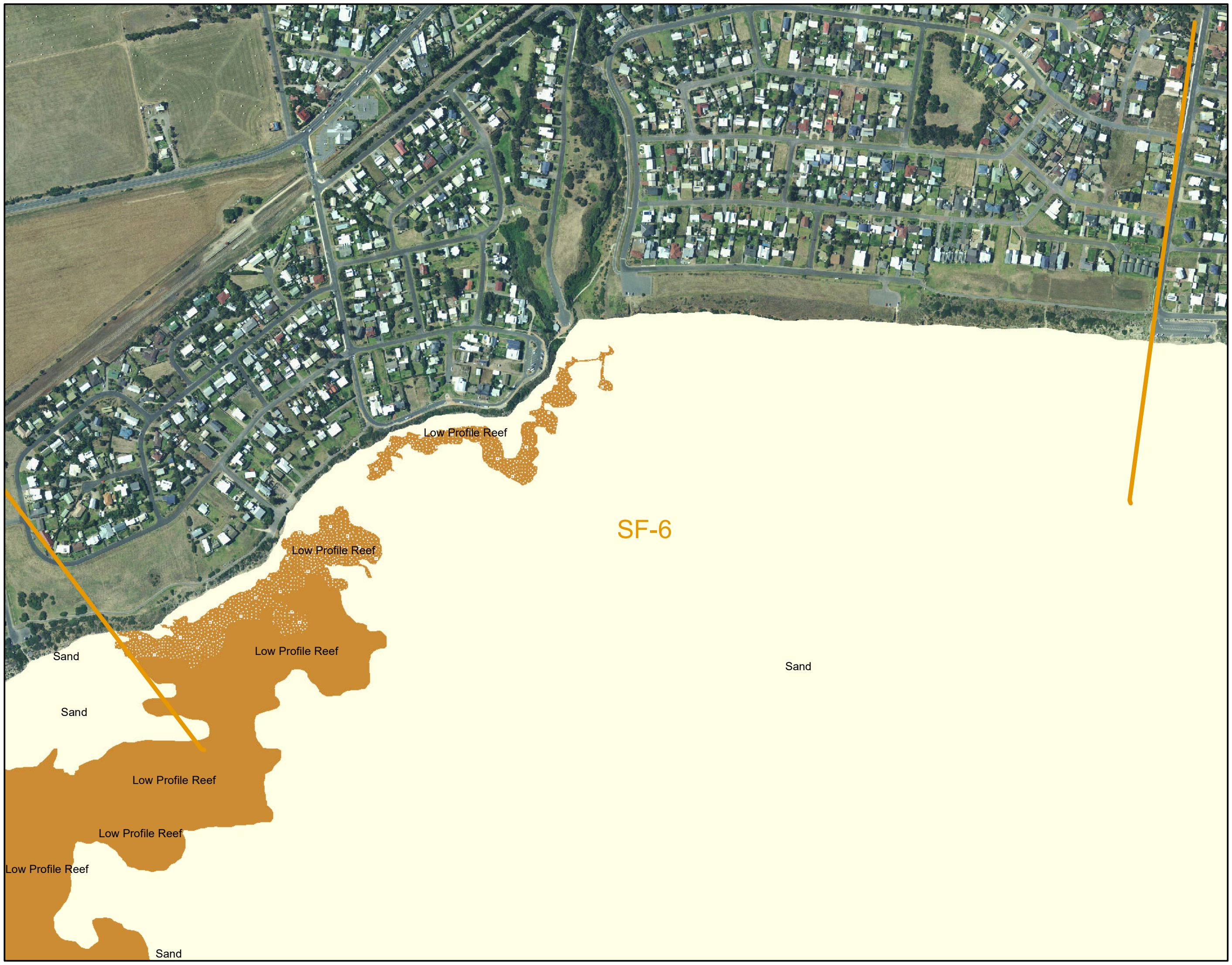

2. Coastal Fabric - natural

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

Medium term changes

Map: SF6-1

Middleton Creek West

Changes 1949 to 2016

1949

Assessment

Due to the varied nature of the coastline and backshores (1 and 2), this cell has been divided into 2 minor cells.

The photograph on this page is SF6-1, and includes Middleton east of the creek.

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2. Coastal Fabric - natural

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

Medium term changes

Map: SF6-1
Middleton Creek West
Changes 1949 to 2016
1949

Assessment

Due to the varied nature of the coastline and backshores (1 and 2), this cell has been divided into 2 minor cells.

The photograph on this page is SF6-1 and includes Middleton east of the creek.

The baseline escarpment position is depicted as a dotted line.

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2. Coastal Fabric - natural

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

Medium term changes

Map: SF6-1

Middleton Creek West

Changes 1949 to 2016

2006

Assessment

Due to the varied nature of the coastline and backshores (1 and 2), this cell has been divided into 2 minor cells.

The photograph on this page is SF6-1 and includes Middleton east of the creek.

Comparison to 1949, demonstrates 2-4m recession at portions of the coast (where shown).

It is likely (perhaps at the time the toilets were relocated) that protection has been added to the east of cliff escarpment adjacent the creek.

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2. Coastal Fabric - natural

Medium term changes

Map: SF6-1

Middleton Creek West

Changes 1949 to 2016

2016

Assessment

Due to the varied nature of the coastline and backshores (1 and 2), this cell has been divided into 2 minor cells.

The photograph on this page is SF6-1 and includes Middleton east.

Comparison between 2006 and 2018, demonstrates no further regression along this section of coast.

It is likely (perhaps at the time the toilets were relocated) that protection has been added to the east of cliff escarpment adjacent the creek.

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3. Coastal fabric - modified

HUMAN INTERVENTION

Protection items and/or infrastructure

<u>Protection strategies at:</u>

SF6-1: Surf Street

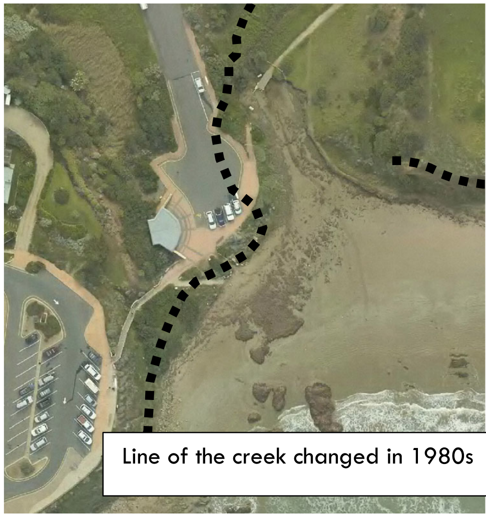
'Hold the line' storm water outlet at bottom of Surf Street. Sand levels are clearly lower at this point probably due to both factors.

SF6-1: Base of cliff escarpment, east of main carpark area and within lower carpark area. The archives speak of a problem in this vicinity in the 1970s but no resolution in hardcopy file. It appears as if the creek was remade and extra fill installed adjacent the base of the cliff and planted. However, changing the course of the creek has probably exacerbated erosion on the bend which is now creeping back to the road.

<u>Management strategies:</u>

Archives explain that management strategies were employed in the 1970s and 1980s including the installation of fencing and controlled beach access points.

A sea wall and embankment has been constructed to provide for the carpark behind. Storm water piping has also been installed through the wall (see exposure section, storm water)



Line of the creek changed in 1980s

3. Coastal fabric - modified

Urban settlements

Map: SF6-1
Secondary Cell: Fleurieu
Tertiary Cell: Middleton Creek

Land use

Land use: Council Reserve

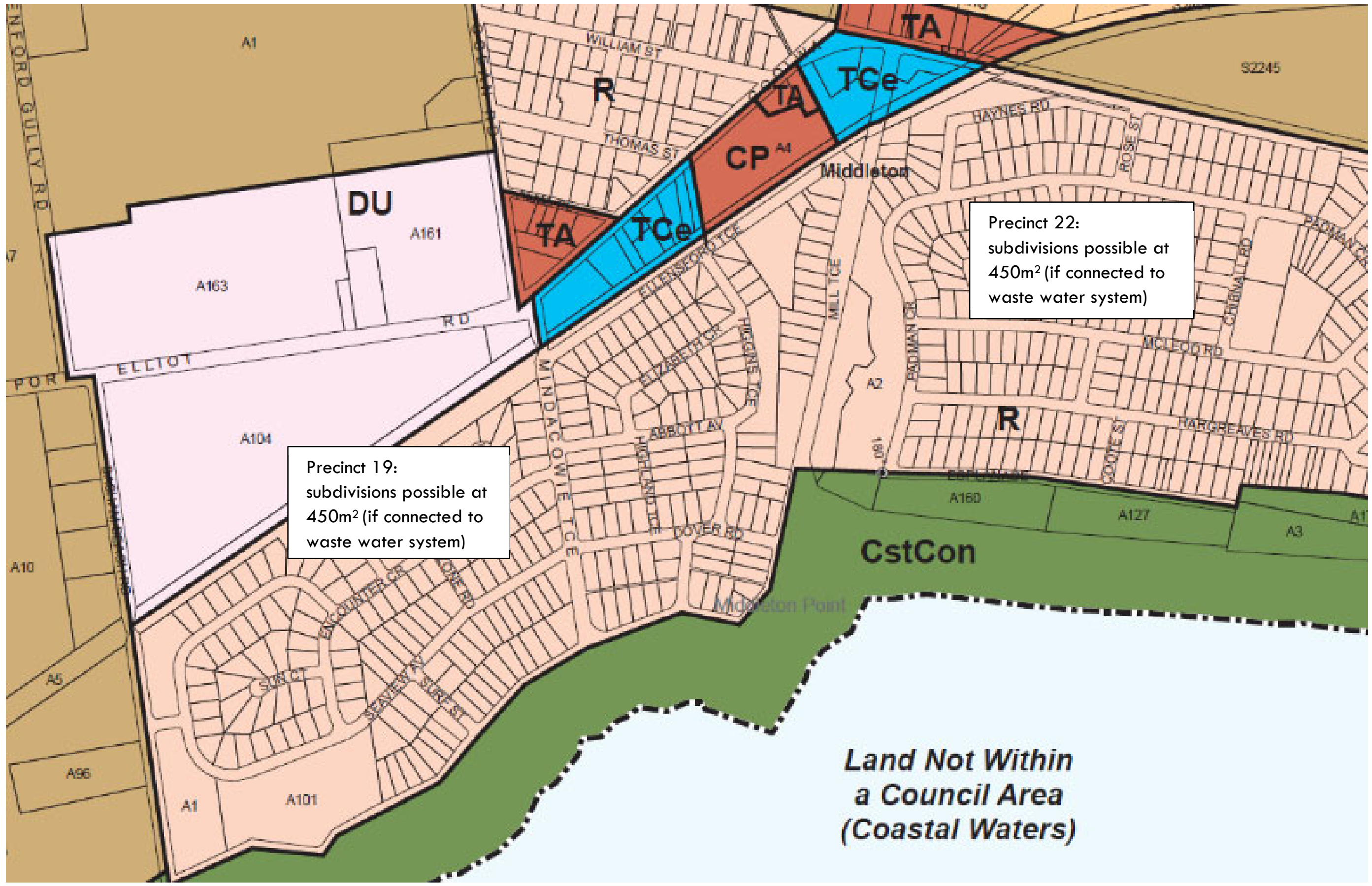
Zoning: Coastal Conservation (incorporates Council Reserve and foreshore). Zoning to the north of the reserves is predominantly Residential.

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

Precinct: Middleton 19 applies to west side of the Creek, Surfers Beach 22 applies to the east side of the Creek.

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

In Precinct 19 and 22, detached dwellings are only permitted dwelling type. Allotments connected to sewer scheme can be 450m².



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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.

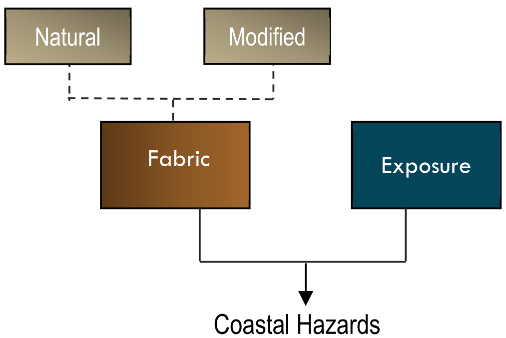
The 'flooding' section of 'Hazards' in the Development Plan (p. 38,39) has maintained standard South Australian planning policy library text apart from the insertion of PDC 7 that deals with development within the River Murray region (not relevant here).

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:

This South Australian conservation cell is split in two by Coast Adapt secondary cells: Fleurieu and Coorong. It represents the point where the series of headlands and embayed beaches that stretch from Chiton and Boomer to Middleton Point come to an end, and the long stretch of dissipative beach begins stretching from Middleton Creek to Cape Jaffa.

Beach

Fine-medium sand beach (within rocky outcrops of sandstone to the front of the beach and bordering both ends of the sand section of the beach)

Benthic

Mapping from Department of Environment and Water The low-profile reef within Ratalang Basham Cell extends into Middleton Creek, and also protects Middleton Point.

Backshore 1:

Small remnant sand dunes back the eastern side of the beach. Low height wall (1m) has been installed in front of the Surf Street carpark.

Backshore 2:

Undifferentiated quaternary rocks rising to 18m AHD at 300m inland.

Geology

This coastal cell is underpinned by hard sandstone outcrops, low profile reef, and some sections of sand. Further landward, the shore is underpinned by quaternary rocks rising to 18m AHD at 300m.

Recent changes:

Comparison between 1949 and 2018 demonstrates minor recession of the sand dunes (2-4m)

Stormwater appears to be dropping the level of the beach at the point of the outlet pipe.

Human intervention

Human intervention has occurred at the end of Surf Street where the backshore has been raised 1m to provide for the carpark, and storm water drains through the sea wall.

Human intervention has also taken place at the culmination of Mill Terrace (carpark and toilets). A comparison with 1949 photograph indicates that the line of the creek was altered to allow more room in the carpark.

The underpinning sand stone outcrops provide protection to the Surf Street area. The rising backshore to 18m AHD at 300m inland indicates that longer term erosion impacts will be contained / limited within the geological layout.

Erodibility rating:

Backshore 1: Moderate (2)

Backshore 2: Low erodibility (1)

4. 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

4. Current exposure – overview

Overview

Map SF6-1

Middleton Creek – West

Overview

SA Classification

Shoreline class
Patchy sand, underpinned by hard sandstone outcrops in foreshore area.

LTT and TBR (west of the creek)

Sand rating
Fine - medium sandy beach

Exposure:
Moderate

Wave:
Moderate

Backshore 1:
Former dune, now mostly urbanised.

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4. Current exposure- storm event

Recent event

Map SF6-1

Middleton Creek– West

Event:

21-22 November 18

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 SF6:1 of seaweed strands and other markers after the event demonstrated wave effects were ~1.30m above tidal gauge within Middleton West.

Wave set-up is assigned: 0.30m
Wave run-up is assigned: 1.00m
Total wave effects 1.30m

Modelling only applies to the beach in the mid-section.

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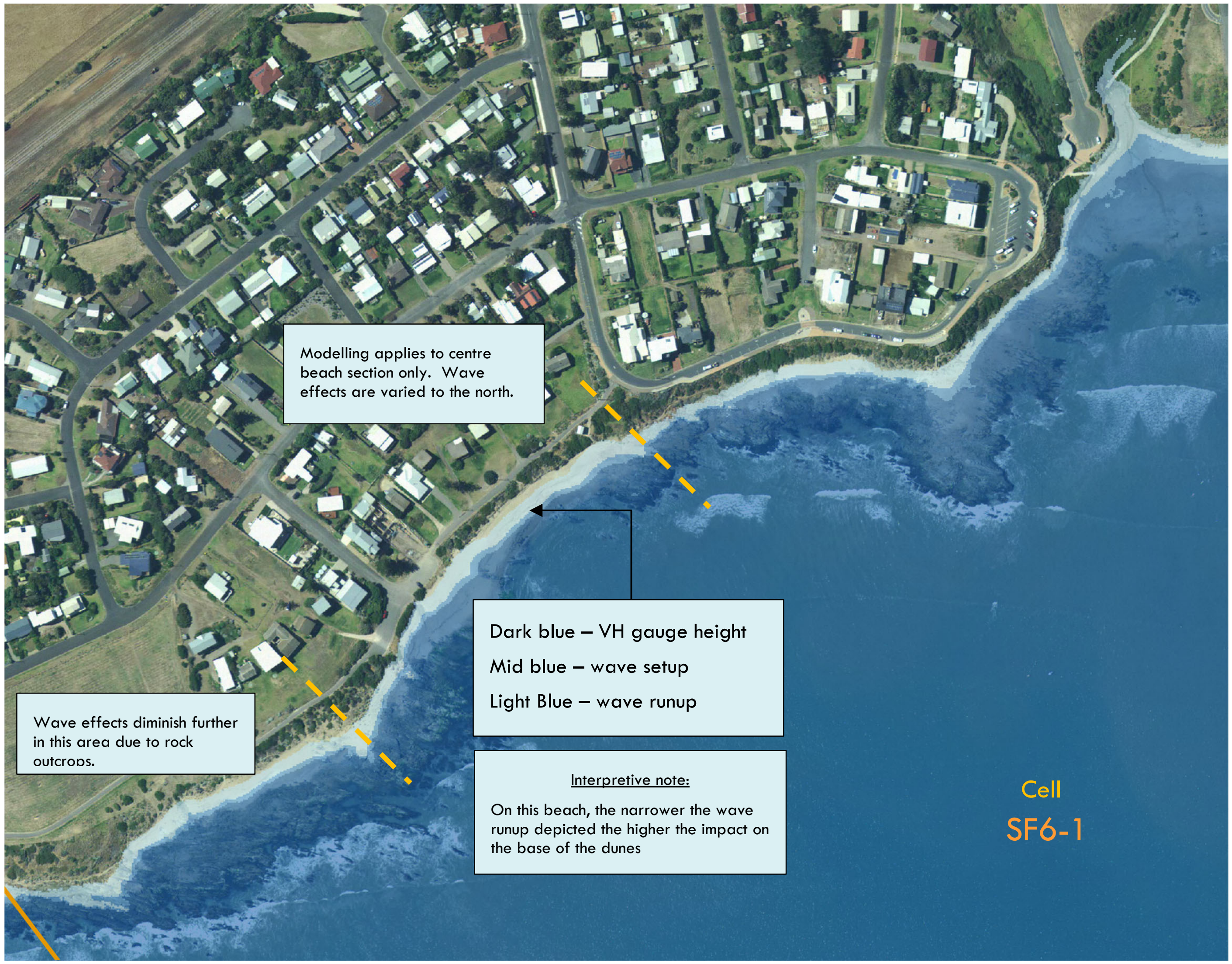


4. Current exposure – storm surge

Storm surge

Map SF6-1

Middleton Creek –West

Current risk:

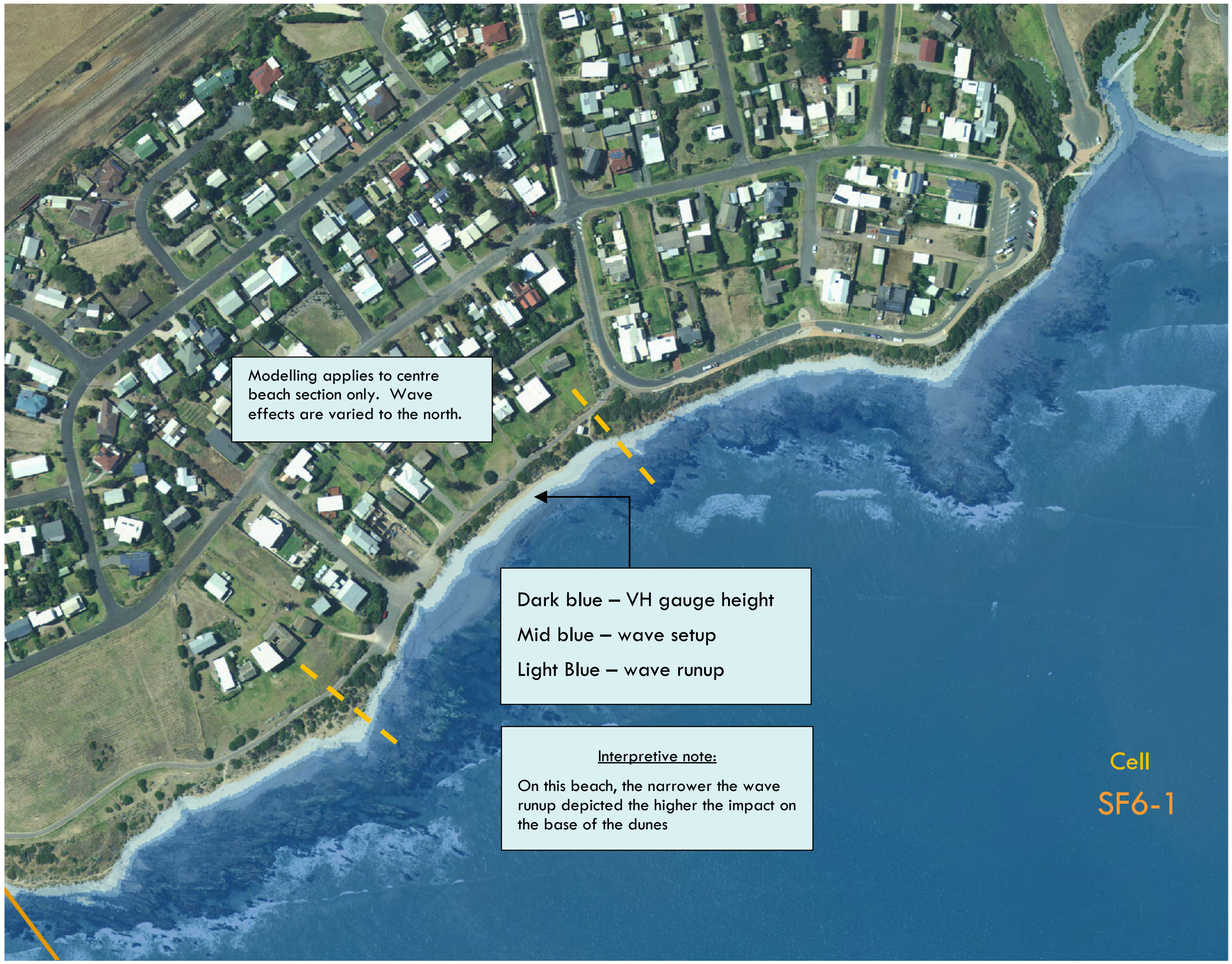
1 in 100-year event

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

Storm surge	1.75m AHD.
Wave set-up	0.30m
Risk	2.05m AHD

Wave run-up is 1.0m 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.



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4. Current exposure – monthly high water

Monthly high water

Map SF6-1

Middleton Creek– West

Current risk:

Monthly high water

Extreme events (ie 1 in 100-year risk) 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.

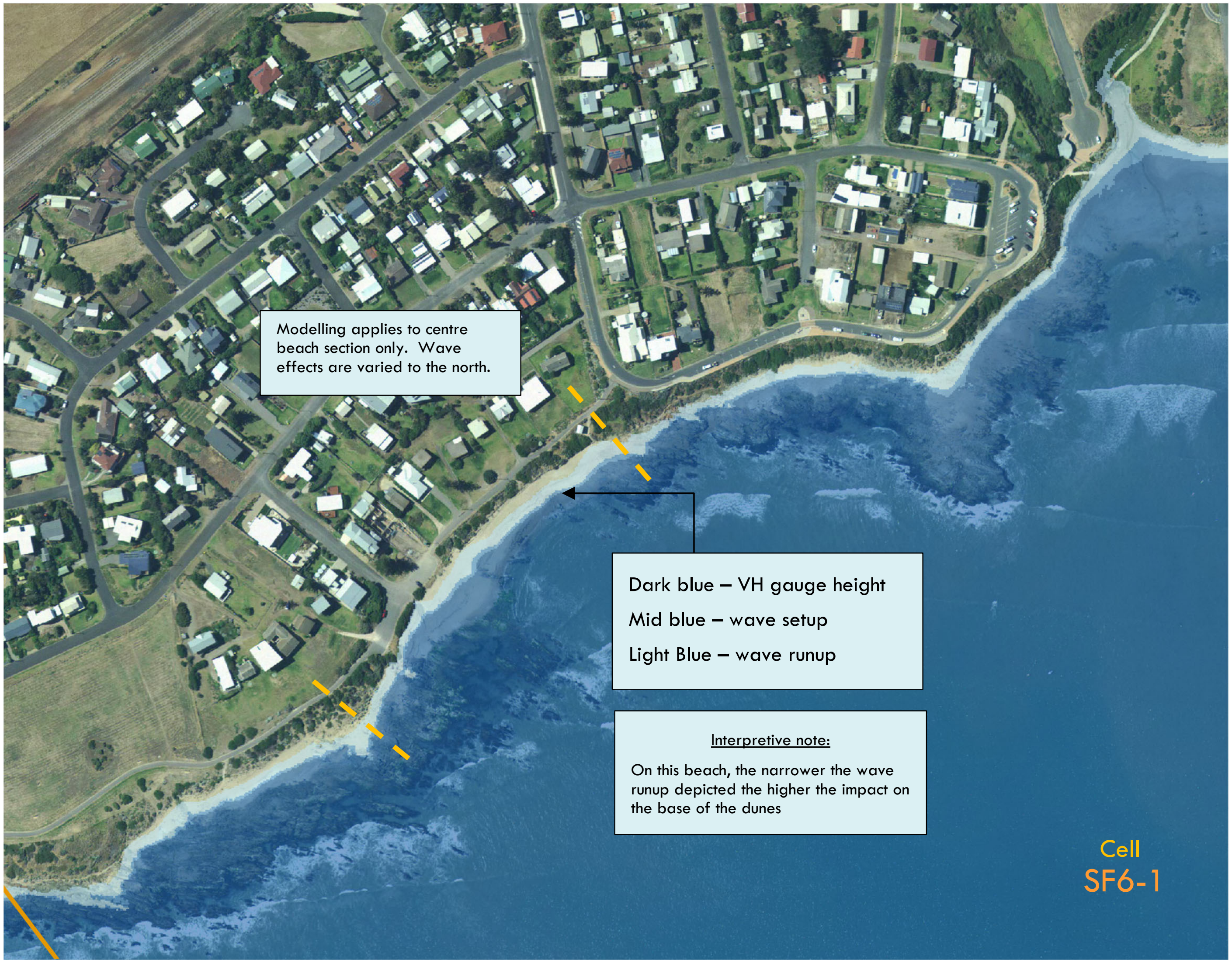
Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Goolwa Beach. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.20m
Total risk	1.70m

Wave run-up of 0.70m is included.

The current impact on beach and backshore is low in this section.



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4. Current exposure – storm water

Storm water

Map SF6-1

Middleton Creek- West

Current risk:

Storm water

Assessment

Storm water in SF6-1 drains to the coast in four places (see map).

1. Drains across small portion of sand, and then across hard sandstone (satisfactory)

2. Drains from large catchment area direct to the coast (No end control). Sand levels are dropping in this location

3. Storm water drains across small portion of sand, and then across hard sandstone (satisfactory)

4 Storm water drains into creek area, no scouring was observed on 22 April, 2019 (but drought).

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4. Current exposure - erosion

Erosion

Map SF6-1

Middleton Creek - west

Current risk:

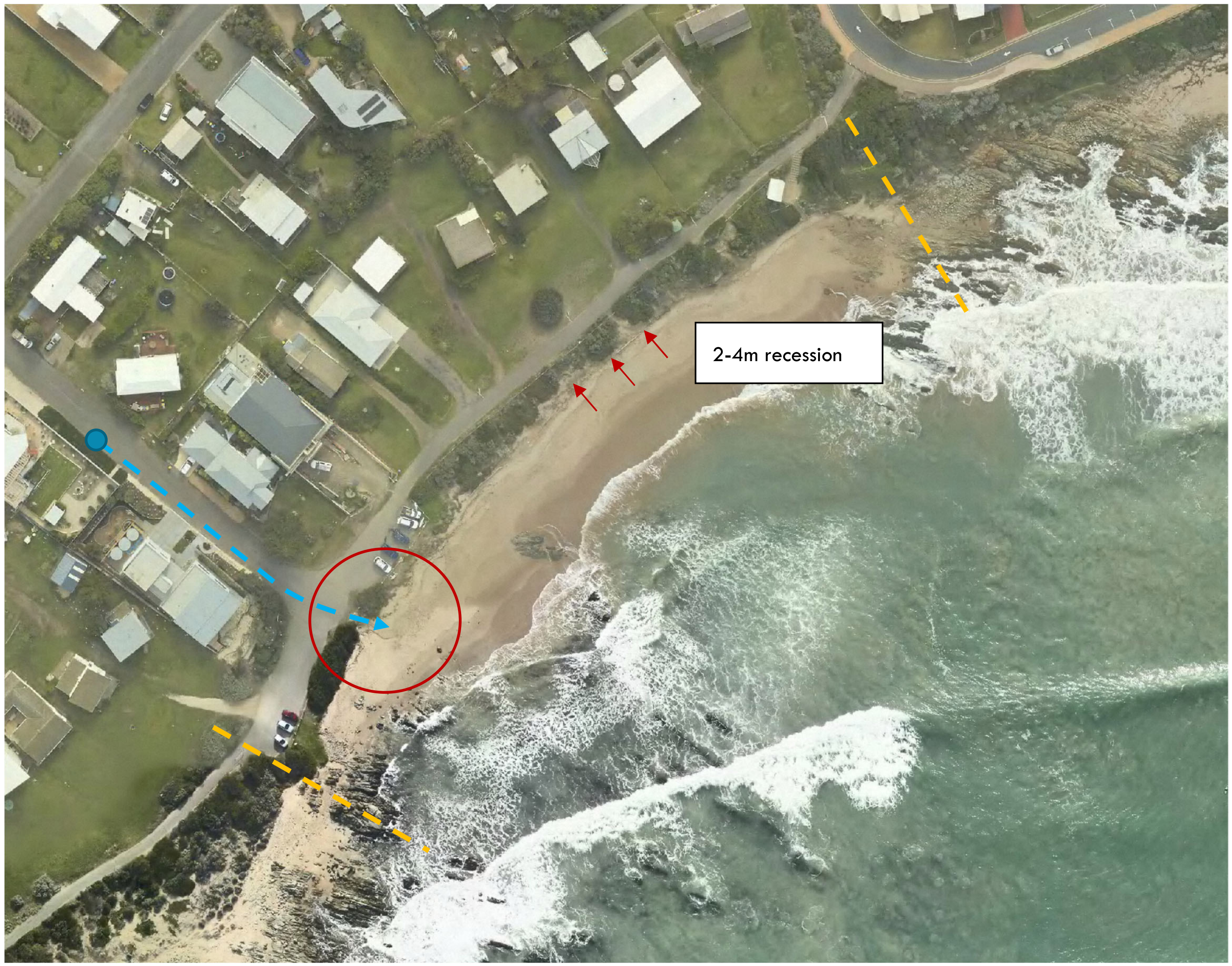
Erosion outlook

Assessment

The assessment in this region is contained to the beach portion of Middleton West.

A historical comparison revealed ~2-4m of dune recession in the centre of the beach.

Storm water flows on to the beach without any end control and this appears to be lowering sand levels in the vicinity of the outlet.



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5. 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

5. Future exposure – storm surge (2050)

Storm surge

Map SF6-1

Middleton Creek - West

2050 risk:

1 in 100-year event

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	0.30
Risk	2.35m AHD

Wave run-up of 1.00m has been depicted in lighter blue.

The impact of this event on the dune system from wave run-up may be significant.

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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.

5. Future exposure – storm surge (2100)

Storm surge

Map SF6-1

Middleton Creek - West

2100 risk:

1 in 100-year event

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	0.30
Risk	3.05m AHD

Wave run-up of 1.0m 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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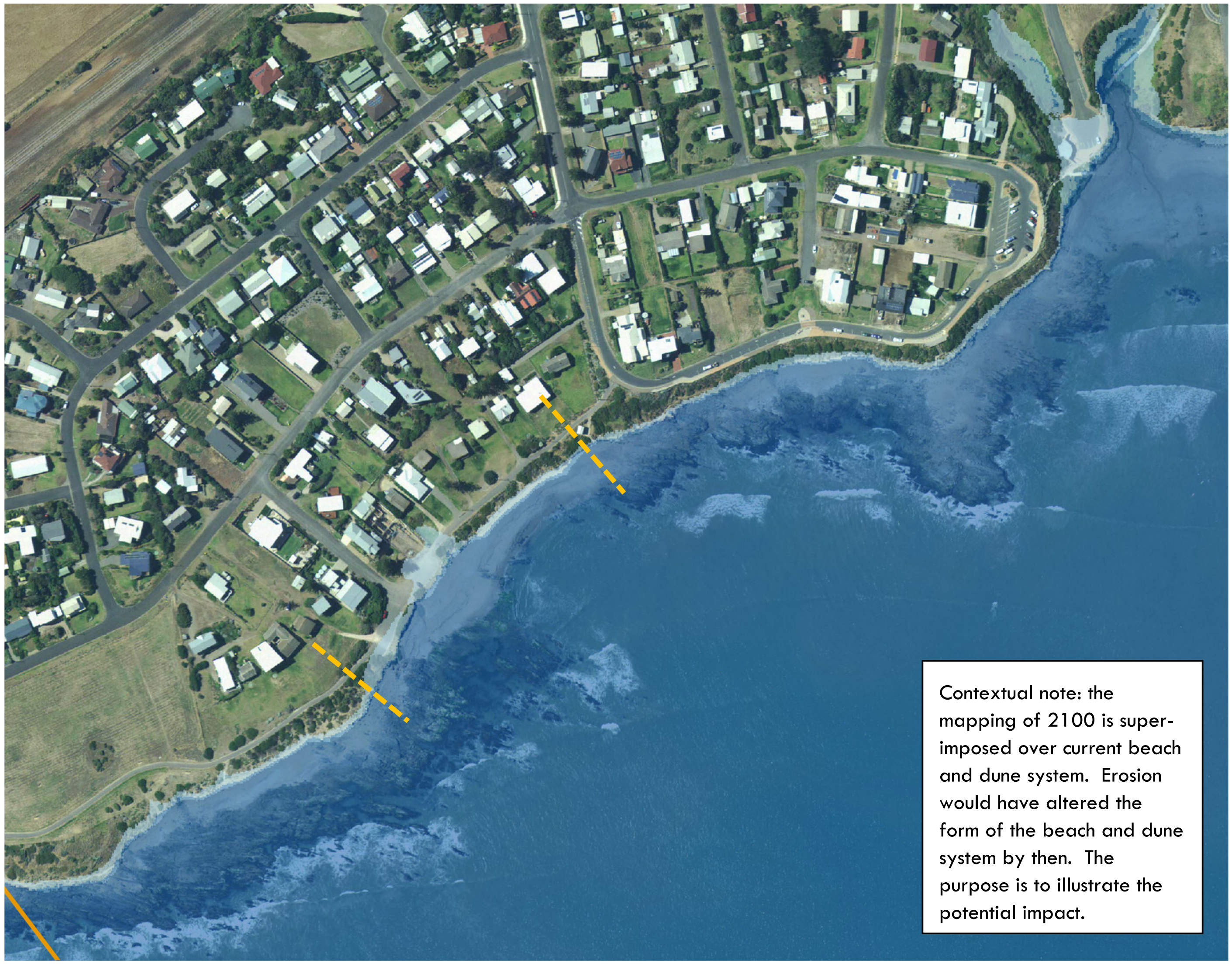

Contextual note: the mapping of 2100 is super-imposed over current beach and dune system. Erosion would have altered the form of the beach and dune system by then. The purpose is to illustrate the potential impact.

5. Future exposure – monthly high water (2050)

Monthly high water

Map SF6-1

Middleton Creek - West

2050 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. 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	0.30
	1.80m
Wave set up	0.20m
Total risk	2.00m

Wave run-up of 0.7m has been included. High tide appears to have little impact.

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5. Future exposure – monthly high water (2100)

Monthly high water

Map SF6-1

Middleton Creek - West

2100 risk:

Monthly high water

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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 0.7m has been included.

Routine tides projected in 2100 would severely impact this region.

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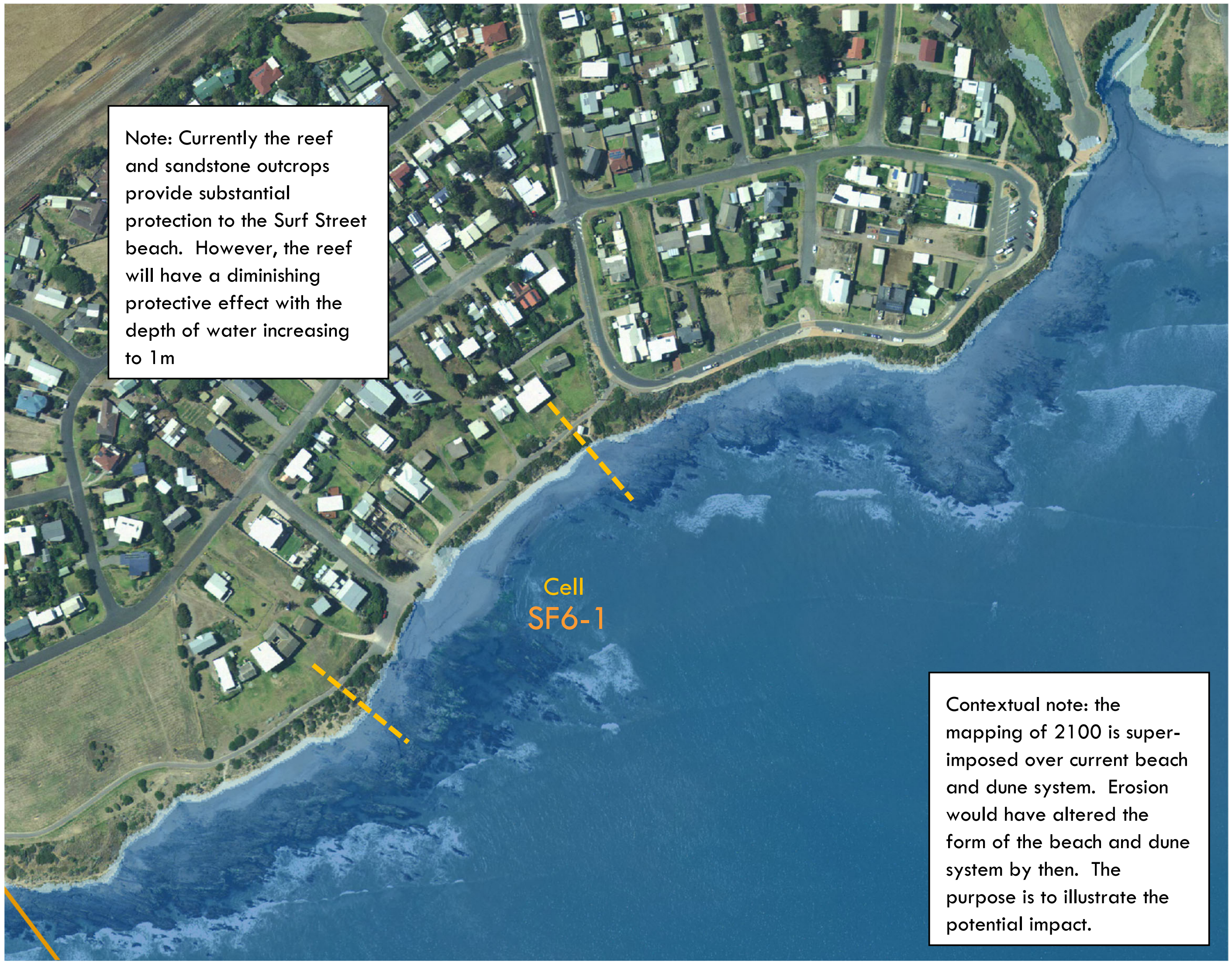

Note: Currently the reef and sandstone outcrops provide substantial protection to the Surf Street beach. However, the reef will have a diminishing protective effect with the depth of water increasing to 1m

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.

5. Future exposure - erosion

Future Exposure

Map SF6-1

Middleton Creek (West)

2100 risk:

Erosion outlook

Assessment

Methods to estimate the rate of erosion are not available for a coastal cell such as Middleton Point.

Currently, the strategy in this location is to 'hold the line'. An embankment/wall has been installed to the front edge of the carpark. A minor dune system is located in front of the walking trail and private houses.

Scenario modelling indicates that the impact of wave run up and wave set up would be significant on the foreshore region.

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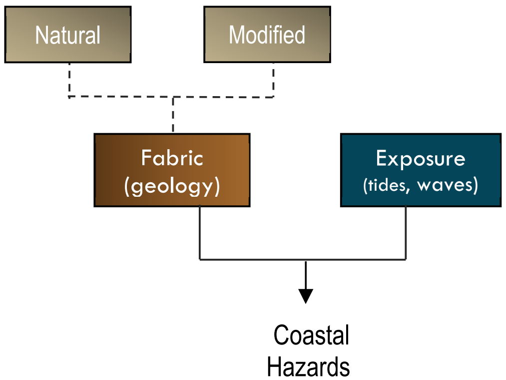
COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a review of settlement history, a cell overview 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 upon the beach at the end of Surf Street. Total wave effects on the beach totalled 1.30m.

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 dune system between the walkway and the beach and the embankment in front of the carpark would come under significant short-term impact. However, the dune and beach would like recover from this event.

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.

Erosion

Historical comparison revealed 2-4m erosion to the dune portion of the beach since 1949.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event with 0.3m sea level rise would significantly impact the dune system and the embankment in front of the carpark. Accompanied by higher tides in 2050, the dune system may not recover.

Monthly high water

Scenario mapping indicates that routine tides would not significantly impact the base of the dune (but this assumes sand levels are the same as current time). The embankment in front of the carpark would come under increasing pressure.

Future exposure (indicatively by 2100)

Storm surge and monthly high water

The 1 in 100 ARI storm event would significantly impact the dune and embankment. Combined with routine tides 1m higher, it is unlikely that the dune system and carpark infrastructure would be viable.

Modelling indicates that the height of the existing carpark at 4.0m AHD is unlikely to be elevated enough to be functional in moderate storm events with 1m of sea level rise.

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.

6. Inherent hazard risk assessment

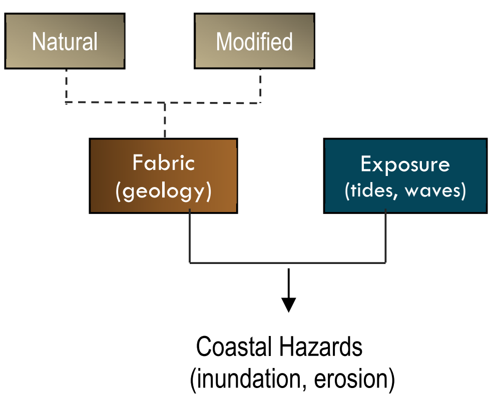
CoastAdapt identifies two main coastal hazards:

- Sea-water flooding
- 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.



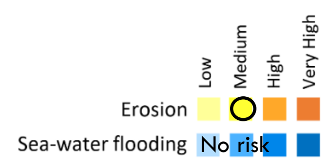
Inundation hazard risk

Due to the slope of backshores inundation is not a risk in Middleton Creek (West).

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- low height dunes, backshore 2: sloping shores underpinned by bedrock rising to 18m AHD 300m inland .	Medium
Should this rating be amended due to human intervention such as a protection item? If so, how?	Human intervention includes 1m high walling in vicinity of carpark, and construction of path behind dunes. Storm water outlet lowers sand levels on the beach.	Medium
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'moderate'.	Medium
Assess any impact on backshore 1	Sea-water runup periodically impacts the dunes but these tend to reform rather than recede.	Medium
Assess any influence from Benthic	Rocky outcrops and offshore reefs: with increasing depths of water exposure may increase.	Medium
Assess the sediment balance	Low height dunes have receded 2-4m. Low sediment rocky beach.	Medium
Assess any other factors that may warrant a change of inherent hazard risk.	This sandy beach is protected by rocky sandstone outcrops that dissipate much of the wave energy.	Medium

Inherent Hazard Risk – Middleton Creek (west)



7. 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

7a. Assets at risk (public)

Public assets

Map SF6-1

Middleton Creek - West

Assets at risk

Assets in include:

- Carpark
- Storm water infrastructure
- Walking path

In the short term, the embankment in front of the carpark may come under increasing pressure (especially if storm water reduces sand volume).

IN the longer term (2050 to 2100), the dune system is likely to erode away and the walking trail come under pressure.

The carpark is constructed at 4.0m AHD and is unlikely to be viable in storm events at 2100 (even moderate ones).

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7b. Assets at risk (private)

Private assets (land and dwellings) are situated behind the carpark and walking trail. Private assets will not be impacted until after the Council owned assets of walking trail and carpark have been impacted.

It is plausible that private property may be threated by 2100 but this is unlikely to include buildings (houses). The slope of the land behind the beach in this location suggests that erosion will be limited.

7c. Safety of people

People access the beach area for recreational purposes. These include walking, cycling, picnics, swimming and similar activities.

Any increase in coastal hazards due to sea level rise are not expected to increase risks to people above existing risks. In other words, in the context of a coastal adaptation study, this hazard/risk assessment is not focussed on risks to people accessing the park per se, but focussed on specifically on increased risks to safety because of sea level rise.

This assumes that Council maintains normal warning signs and fencing where required.

7d. Ecology at risk

The assessment of ecology of risk in the context of this project is confined to that which may be described as ‘ecosystem disruption’ with the intent that this disruption would occur on a wide scale. For example, sea water flooding through the dunes at Ratalang Basham will irreversibly change the nature of the ecosystem on a large scale.

The geological layout of Middleton (west) with rising backshore means that no larger scale ecology is at risk.

8. 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.

8. 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:

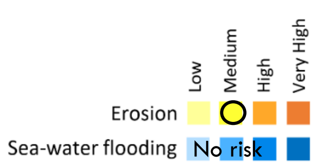
- Sea-water flooding
- Erosion

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

Rocky beach backed by gently sloping shore underpinned by bedrock rising above 18m AHD



Specific Risk Assessment

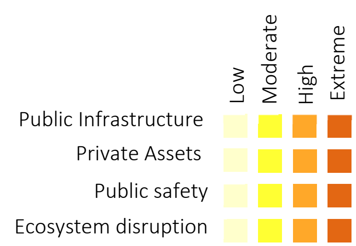
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Environment

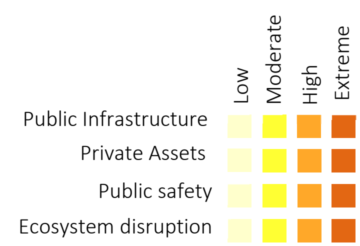
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

This 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 assessment utilises the risk assessment of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion (See next pages).

Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Yet to be assigned

8. Risk Assessment

Erosion assessment

Middleton West (SF6-1)

Risk identification: Erosion is currently, or may in the future, threaten the backshore of the beach at Surf Street

Coastal processes	Middleton Point (beach) is underpinned by reef, and bordered by sandstone outcrops which dissipate wave energy. The beach is backed by a small dune system in the east and an embankment in front of the carpark. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach is impacted by larger events and has eroded 2-4m since 1949. Analysis of future regimes suggests that the backshore will come under increasing impacts from the sea if seas rise as projected.

Are any strategies employed to mitigate the risk? Earthen embankment in front of carpark, dune system in front of pedestrian walkway.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carpark, walking trail, and storm water infrastructure	current	*Unlikely*	*Minor*	low
		2100	*Almost certain*	*Significant*	high
Private assets	Private assets are positioned behind the public walking trail and carpark. Private assets will only be impacted after these. It is unlikely that erosion will impact private property by end of this century.	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Minor*	low
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 geology of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk

Inherent Hazard Rating

Rocky beach backed by gently sloping shore underpinned by bedrock rising above 18m AHD

	Low	Medium	High	Very High
Erosion		O		
Sea-water flooding	No risk			

Erosion Hazard Rating
(Current outlook - 2020)

	Low	Moderate	High	Extreme
Public Infrastructure	X			
Private Assets	No risk			
Public safety	X			
Ecosystem disruption	No risk			

Erosion Hazard Rating
(Future outlook - 2100)

	Low	Moderate	High	Extreme
Public Infrastructure			X	
Private Assets	X			
Public safety	X			
Ecosystem disruption	No risk			

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	Surf Street (beach) has eroded 2-4m when compared with 1949. Scenario modelling suggests that only storm events are reaching the backshore. Sea level rise is likely to bring increased impact to the rear of the beach and this may undermine the base of the escarpment and dune system. The carpark and walking trail are likely to come under threat from erosion later in this century (may be impacted earlier by larger events). The carpark at elevation 4.0m AHD is unlikely to be viable at 2100.

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.

SURF STREET BEACH

An **incremental approach** to adaptation is recommended to Surf Street Beach area.

To protect public infrastructure over time, a **hold the line** methodology is recommended. The cost of holding the line is likely to be borne by Council. Because there is unlikely to be any immediate threat, the approach should be to **monitor** the beach, with special attention to impacts to the back shore.

Should increase impacts be observed, then protection options will be required to protect the carpark and walking trail:

- Rock revetment in front of the carpark is likely to be effective in medium term
- Should the dune system erode away, harder protection will be needed for the walking path

Review **Planning** controls and consider amending so that no further densification can occur for the sites adjacent the coast. Review access issues to ascertain whether access to dwellings on the south-western end may be able to obtain access from Mindacowie Road.

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Hold the line

Map SF6-1

Middleton Creek (west)

Adaptation proposal

Monitor

The base of the escarpment in front of the carpark and the condition of the dunes in front of the walking trail **(See end of this report for more information about monitoring strategies).**

Hold the line (protect)

Should increase impact to the base of the escarpment occur, then protection options should be considered. The cost of response is likely to be borne by Council.

Other

Consider diverting storm water from the beach (see photograph, right)

Review **Planning** controls and consider limiting further densification of sites adjacent the shore (Inc. access issues)

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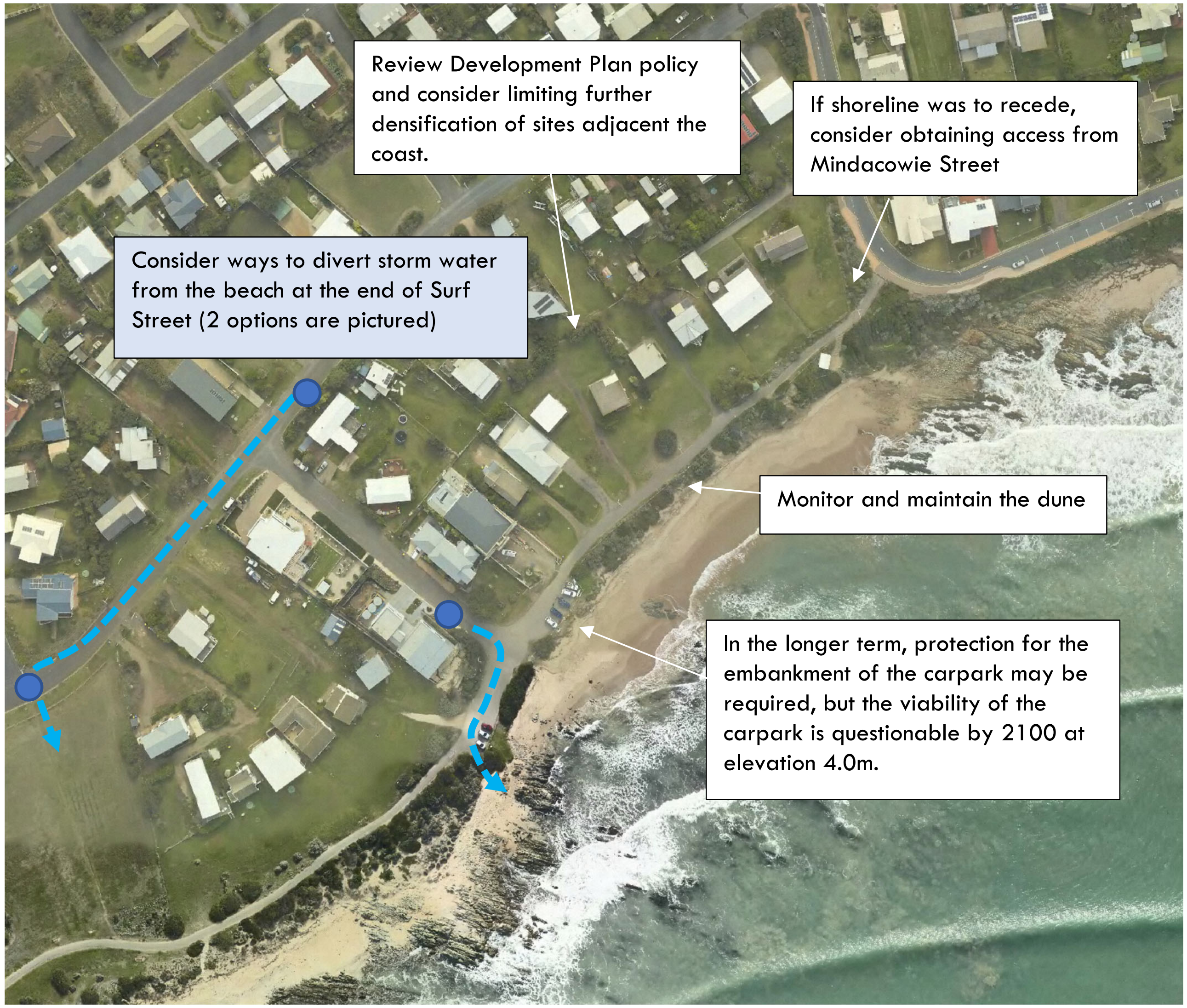


Monitoring strategies

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'

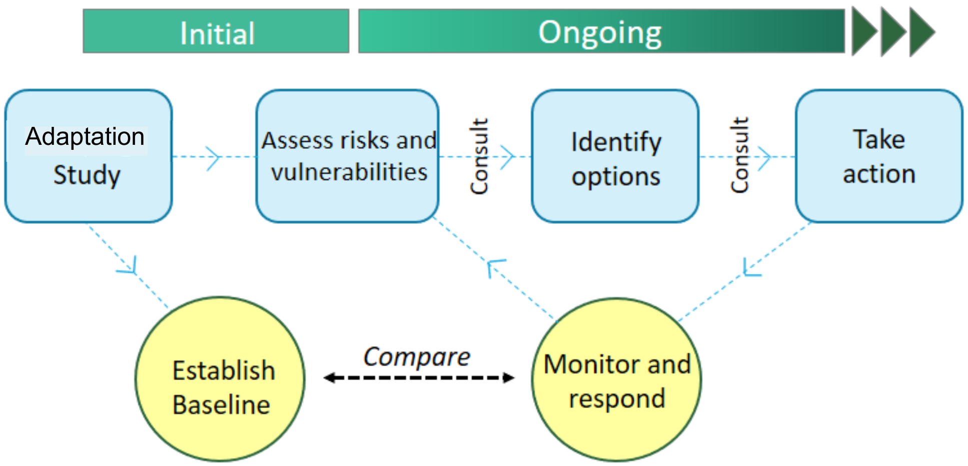
Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

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)

Coastal Adaptation Model



Integrated Coasts (2017)

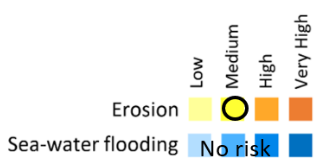
Adaptation Strategy – Middleton Creek (west) (Cell SF6-1)

Coastal processes	Middleton Point (beach) is underpinned by reef, and bordered by sandstone outcrops which dissipate wave energy. The beach is backed by a small dune system in the east and an embankment in front of the carpark. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach is impacted by larger events and has eroded 2-4m since 1949. Analysis of future regimes suggests that the backshore will come under increasing impacts from the sea if seas rise as projected.

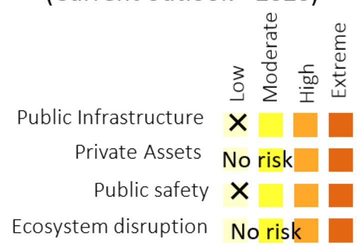
Risk outlook

Inherent Hazard Rating

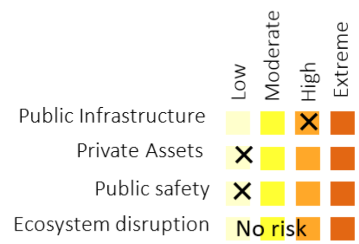
Rocky beach backed by gently sloping shore underpinned by bedrock rising above 18m AHD



Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Adaptation overview:

The long-term strategy for Middleton Creek (west) is to hold the line and protect the backshore (carpark, dune system). This strategy is likely to be effective in the geological setting in which Crockery Bay is located (although dune width is likely to narrow). An incremental approach to adaptation is recommended. Monitoring of beach processes, sand volumes, and impact to backshore will provide the decision-making context for when protection is required. Storm water outflows should be assessed and alternative flow path provided to the sea (see proposed works on following pages).

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Middleton Creek (West) Cell SF6-1	Incremental [monitor and respond]	Monitor [storm water infrastructure required to provide alternative flow path]	Monitor [protection may be required by 2050, or the latter part of this century]	Hold the line: protect backshore [Car park and walking track behind beach]	Engineering: Storm water diversion Protection to carpark	Shoreline position (dunes) Storm impacts on backshore

Engineering items for Surf Street, Middleton

Storm water diversion away from beach to outlet to rocky outcrop

SURF STREET – MIDDLETON
SCALE 1:1000

CONCEPT ONLY
THE ARRANGEMENT SHOWN IS FOR DISCUSSION PURPOSES ONLY. IT MUST NOT BE USED FOR CONSTRUCTION.

ISSUE	AMENDMENTS	INT./DATE
A	PRELIMINARY ISSUE	TH 01.07.19

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CLIENT:
ALEXANDRINA COUNCIL
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PROJECT:
COASTAL ADAPTION STRATEGY

PROJECT ADDRESS:
GOOLWA TO CHITON ROCKS

TITLE:
PLAN

CONTRACTORS MUST VERIFY ALL DIMENSIONS PRIOR TO ANY OFF SITE FABRICATION.

DESIGN: WS	SCALE: AS SHOWN	DATE: FEB. 2019
SHEET SIZE: A3	DRAWING NUMBER: 18084–18	REVISION: A

MIDDLETON CREEK (EAST)

2. COASTAL FABRIC

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

In this section we evaluate coastal fabric in more detail:

- Ancient coastal formation
- Changes to shoreline over seventy years
- Changes to seafloor since 1977
- Human intervention

2. Coastal Fabric - natural

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

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.

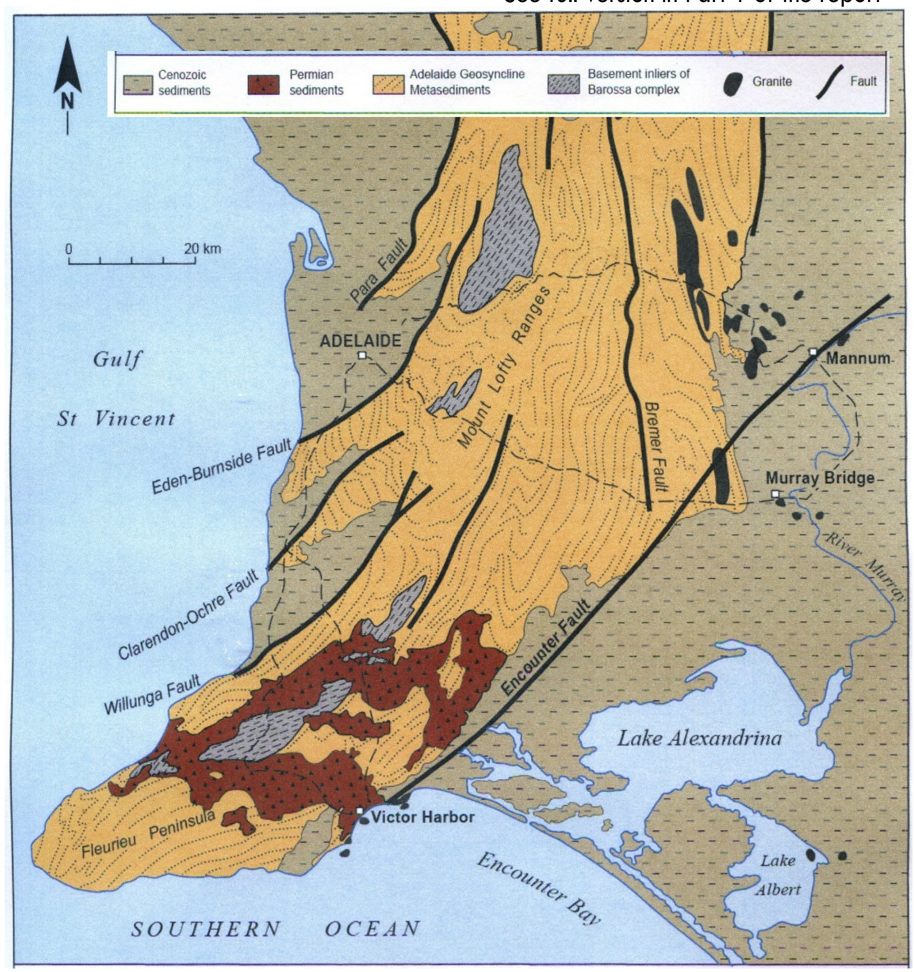

Figure 8: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

2. Coastal Fabric - natural

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

Middleton Cliffs (east of the creek)

At Middleton Beach the character of the coastline changes dramatically with the hard ancient rocks of the Middleton Sandstone being replaced by a sandy beach backed by eroding cliffs developed in alluvial deposits. The alluvial cliffs at Middleton (8 m) gradually decrease in height towards the east (2), reflecting the original surface of the alluvial fan that spreads out from the foot of the Mount Lofty Ranges to the north and west. At the extreme eastern end of the alluvial deposits of Middleton Beach a marl-like bench is traceable into a soil A-horizon developed on the alluvium.

The alluvial character of the cliff-forming material is evident by the layers and lenses of gravels and pebbles, present sporadically throughout the sediments, revealing the work of former streams. The alluvium of the Middleton cliffs is red to brown in colour and deposits of calcium carbonate mark the upper part of the deposit, some following old root channels and generally occurring in the Bca (sub-soil) horizon. This alluvial deposit, known as the Pooraka Formation is widespread in South Australia, underlying large areas of the Adelaide Plains and extending into the north of the state, flanking the Mount Lofty and Flinders Ranges. It is of interest that the mega-fauna, the Diprotodont, has been found in this material. Pods, lenses and straight and wavy horizons of pedogenic carbonate occur towards the surface, and these are typical of the soil B-horizon developed in the Pooraka Formation.

Overlying the alluvial cliffs of Middleton are recent sand dunes at the base of which Aboriginal shell midden commonly occur. The age of these small dunes is not known directly, but by comparison with other nearby situations they are approximately 3 to 4,000 years old.

The Pooraka Formation also forms high-level river terraces in many parts of South Australia, including Fleurieu Peninsula. In fact, the red alluvial terraces of the Hindmarsh River at Victor Harbor grade to a former shoreline 125,000 years old, demonstrating that they are of equivalent ages. This has subsequently been verified by thermoluminescence dating. Small, low, grey/black coloured terraces are inset within the main valley of Middleton Creek and in one locality these sediments are intercalated with marine shells that were almost certainly Aboriginal middens. From comparisons with areas nearby, both the grey/black sediments and the shells are probably about 4 to 5,000 years old.

Middleton Cliffs (1860s to 1949)

As noted in the settlement history section a significant amount of erosion has occurred in Middleton Cliff area.

Global rises in sea level, increased storminess, diminished sand supplies and human interference have all been cited as possible causes of erosion. As there are no records of major coastal works in the area, and as removal of beach material has been of minor importance, the coastal recession at Middleton does not seem to be related to human interference. Furthermore, there is no evidence for a suddenly decreased sand supply either from offshore or alongshore.

Increased storm frequency, diminished sand supply and a slight rise in relative sea level may have accelerated coastal erosion at Middleton, but these are general causes of erosion, whereas the rate of erosion of the Middleton cliffs exceeds that demonstrated at other locations and requires a specific explanation. For example, coastal erosion has occurred in similar alluvial sediments at Tunkalilla Beach 20 km to the west, within the Mount Lofty Range Province, but the amount of erosion is 10 times less than at Middleton. Consequently, the dominant cause of erosion appears to be localised, and may relate to tectonic subsidence as there was a series of earth tremors, which affected the area around the turn of the century and coincided with the onset of the erosion phase. For example, a major seismic event centred on the Beachport area to the southeast of Middleton occurred on May 10th, 1897, with aftershocks continuing at intervals for some months. The epicentre was on Beachport (Intensity 9) with an Intensity of between 8 and 9 near Middleton. Another earthquake (September 19, 1902), with its epicentre at Warooka on Yorke Peninsula (Intensity 8) also affected the Middleton area (Intensity 5). This event was reported as a severe tremor in Goolwa where it cracked some of the buildings.

Key Points

Solid evidence exists to support that an earthquake occurred off-shore in 1897. As a result 200m of coastal erosion was experienced at Middleton Beach

However, since 1949 only about 12m of erosion has occurred, and virtually none in the last ten years.

2. Coastal Fabric - natural

Overview

Map: SF6-2
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Middleton Creek
EAST
Form

Beach

Fine-medium sand beach

Backshores

Backshore 1: Alluvial cliffs ~8m high decreasing to 2m high eastward.

Backshore 2: Rises to 14m at 500m inland.

Bathymetry

Overall slope of ocean floor: -10m ~1km from beach (overall slope ratio 1:100) or < 5 deg.

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2. Coastal Fabric - natural

Overview

Map: SF6-2
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Middleton Creek
EAST
Geology

Geology

Beach and backshore 1:

Map indicates some underpinning by undifferentiated quaternary rocks in the Middle Creek area.

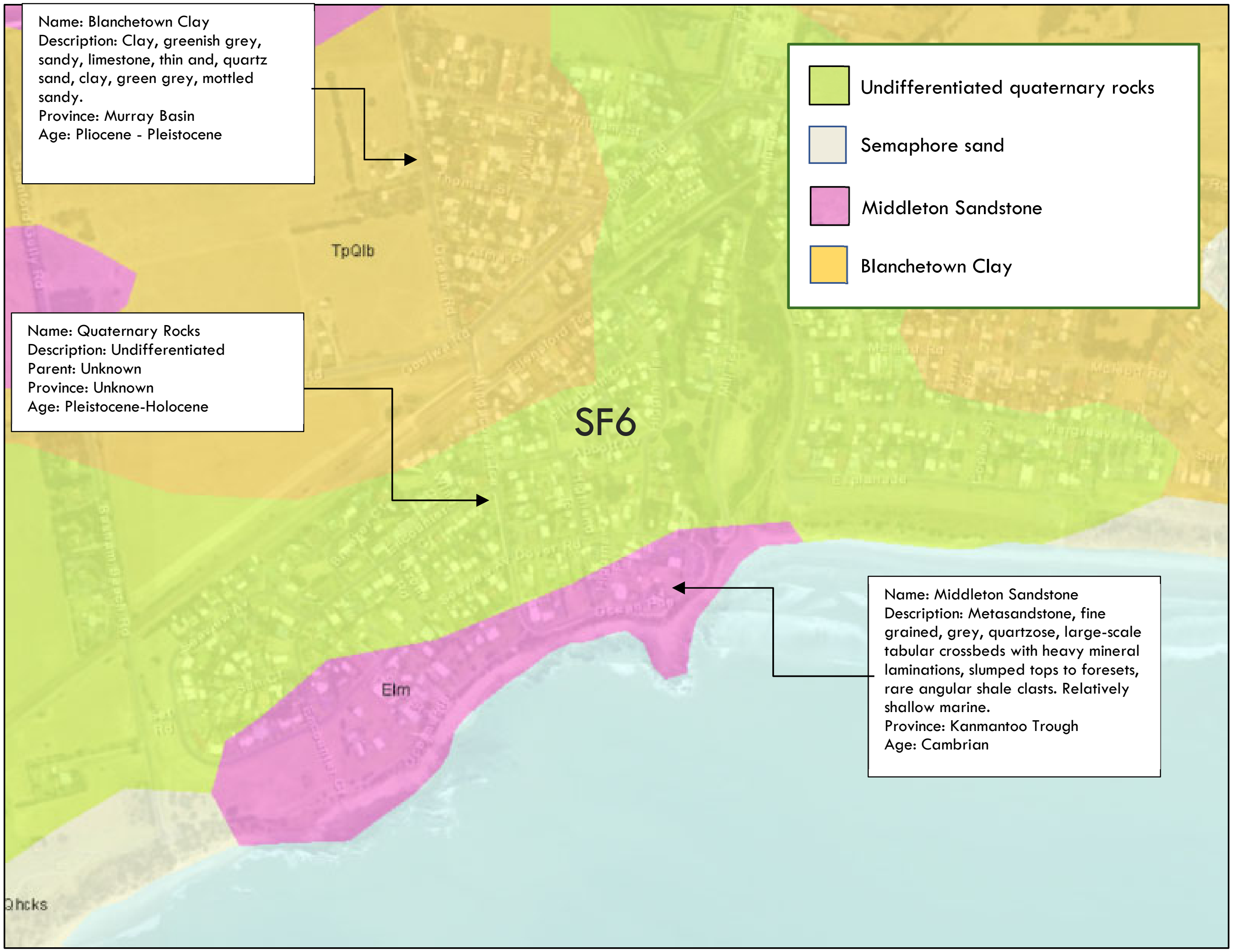
Backshore at the surface is 8m high alluvial cliff.

Substrate- fine sand.

Backshore 2 (sloping hinterland)

Undifferentiated quaternary rocks rising to 14m at 500m inland.

Age: Pleistocene – Holocene



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2. Coastal Fabric - natural

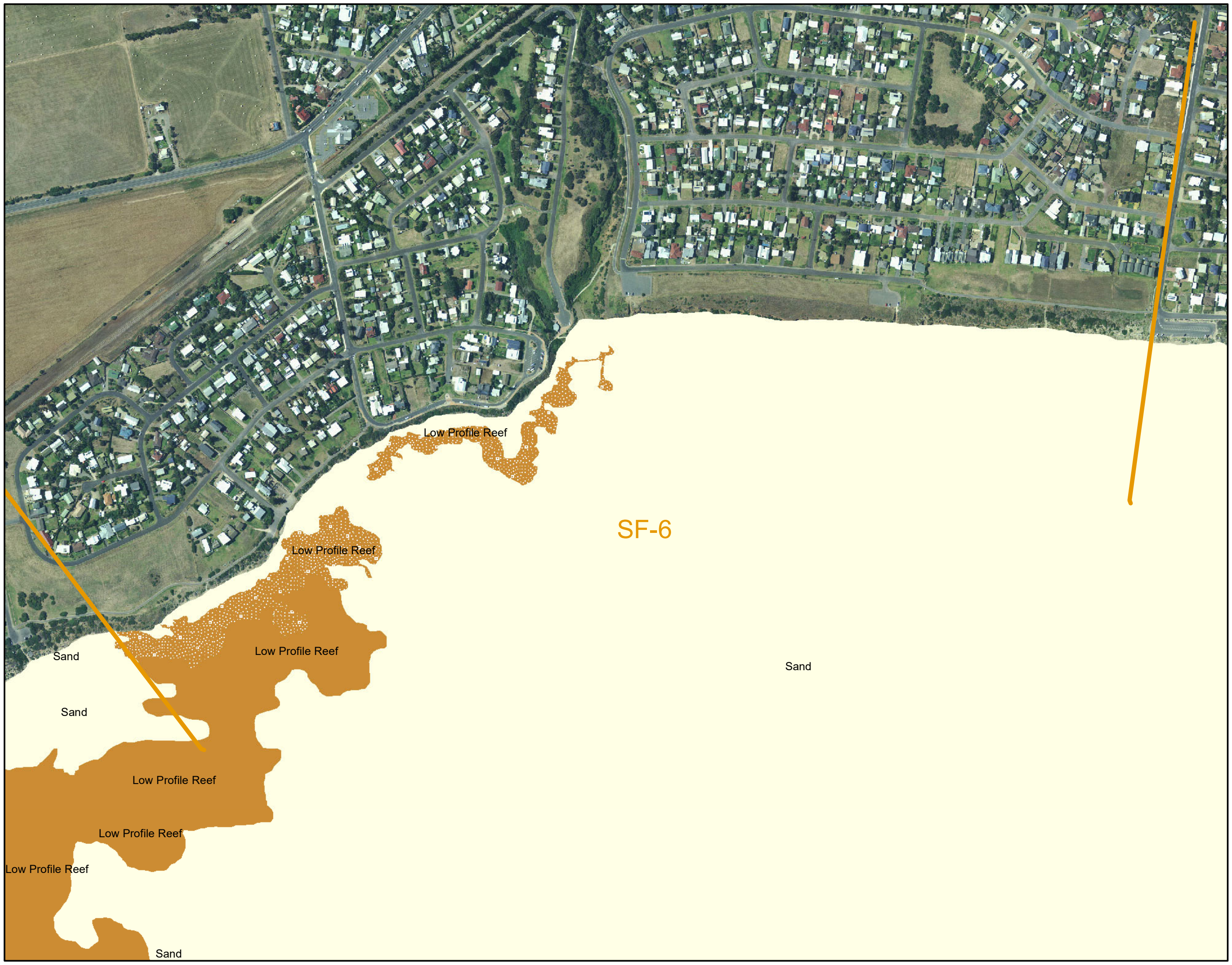
Overview

Map: SF6-2

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Middleton Creek EAST

Benthic



Benthic

East of Middleton Creek, the nature of the beach changes to a dissipative nature and is therefore dominated by sand.

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Coastal Fabric – shoreline changes (1949)

Medium term changes

Map: SF6-2

Middleton Creek (East)
Changes 1949 to 2016
1949

Assessment

The photograph on this page is SF6-2, from Middleton Creek to Chapman Rd.

The top of the cliff escarpment in 1949 is depicted as a dotted line.

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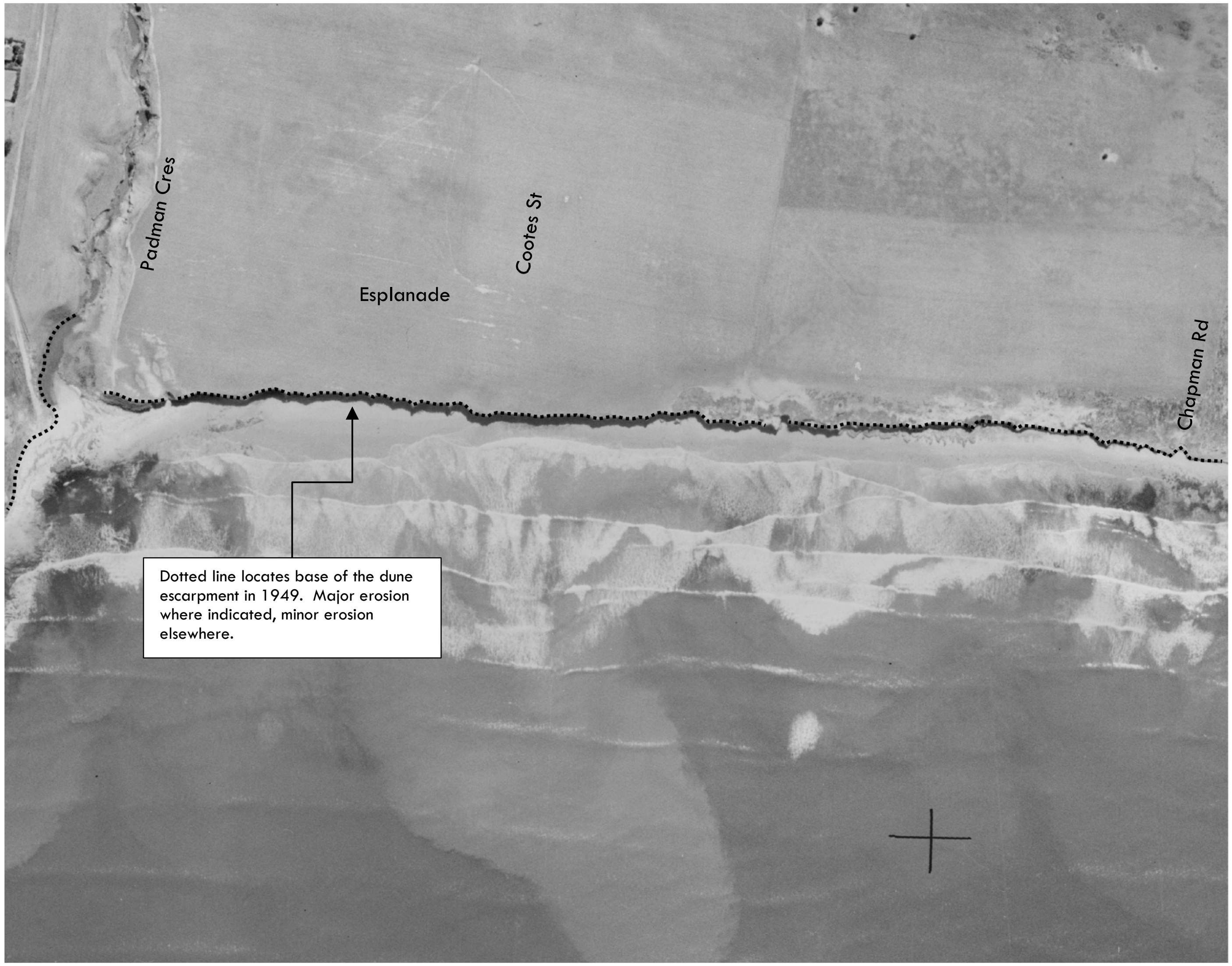

Coastal Fabric – shoreline changes

Medium term changes

Map: SF6-2

Middleton Creek (East)

Changes 1949 to 2016

2006

Assessment

The photograph on this page is SF6-2, from Middleton Creek to Chapman Rd (not shown).

The top of the cliff escarpment in 1949 is depicted as a dotted line.

Comparison of 1949 to 2016, demonstrates the cliff top has eroded 7 to 13m. A low height dune 10-15m wide has formed over the last ten years at the base of the cliff escarpment.

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Coastal Fabric – shoreline changes (2018)

Medium term changes

Map: SF6-2

Middleton Creek (East)

Changes 1949 to 2016

2018

The photograph on this page is from Middleton Creek to Chapman Road carpark (just situated off to the left of the photograph).

The top of the cliff in 1949 is shown as a dotted line.

A comparison of 1949 to 2018 demonstrates the cliff top has receded 7m to 13m since 1949.

Over the last ten years a low height dune has formed up to 15m forward of the base of the cliffs.

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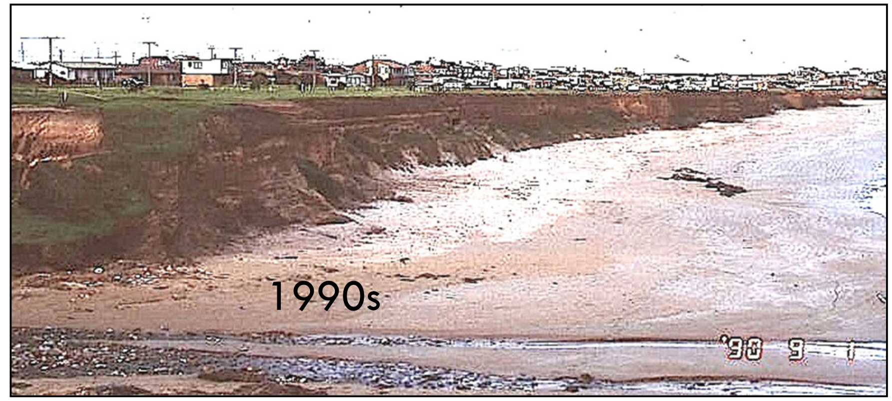
Coastal Fabric – shoreline changes (1972 -2018)

Snapshots in time of the shoreline



Middleton Beach photographed in 1972. The original sand dunes have now been completely eroded, with the beach now being backed by alluvial cliffs. Note the accumulation of sand at the base of some of the cliff line and the outcrop of hard Middleton Sandstone in the swash zone. Source of photographs, Dr Bob Bourman.

Coastal Fabric – beach profile changes (1977 – 2009)

Medium term changes

Map: SF6-2

Middleton Creek (East)

Changes 1977 to 2018

Sediment Change

Assessment

Coastal Management Branch from Department of Water and Environment (DEW) has conducted two profile surveys (number 615006, 615007) of the ocean floor from 1977 to 2009.

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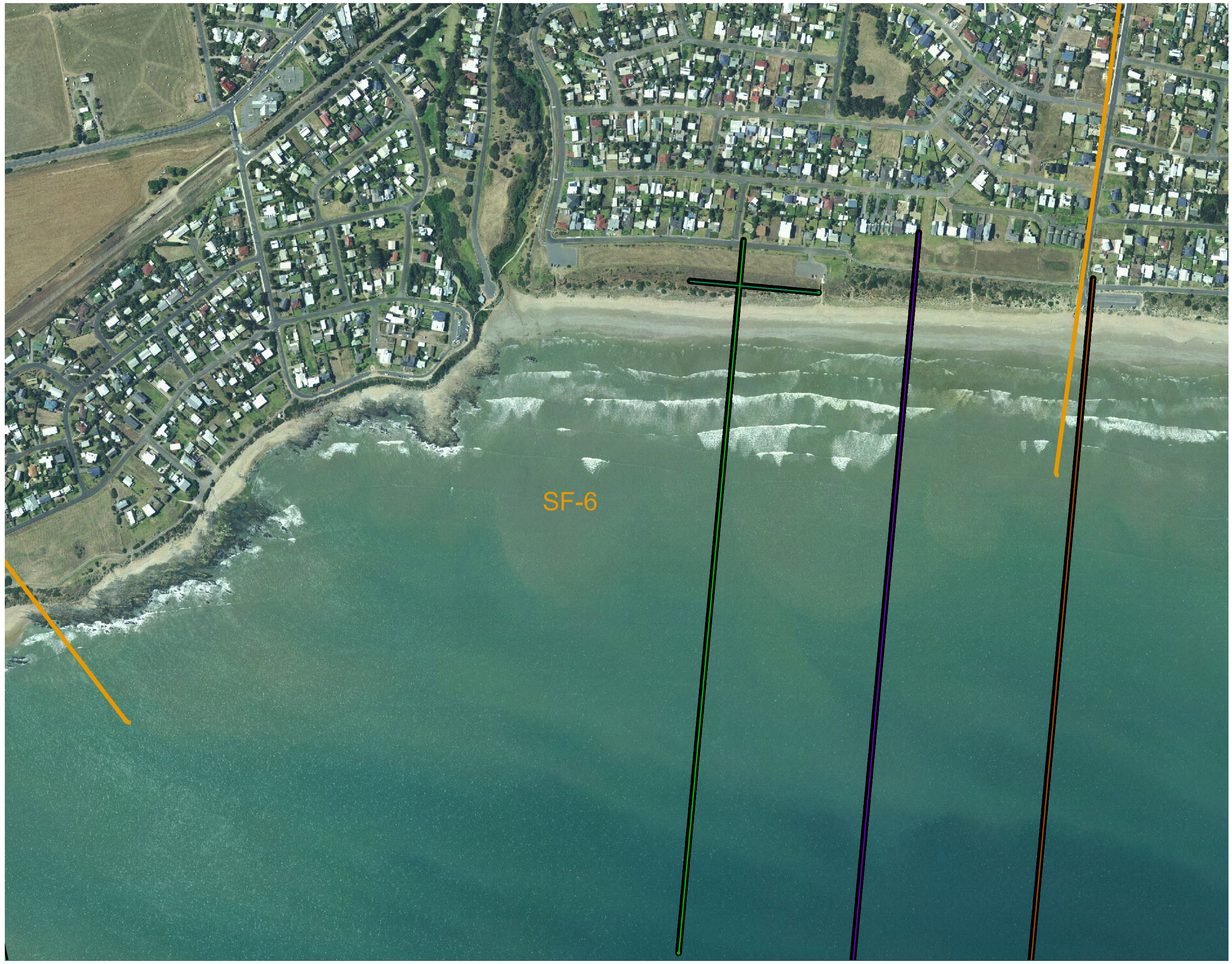


3. Coastal fabric - modified

HUMAN INTERVENTION

Protection items or infrastructure:

<u>Protection strategies at:</u>

SF6-1: Base of cliff escarpment, east of main carpark area and within lower carpark area. The archives speak of a problem in this vicinity in the 1970s but no resolution in hardcopy file. It appears as if the creek was remade and extra fill installed adjacent the base of the cliff and planted. However, changing the course of the creek has probably exacerbated erosion on the bend which is now creeping back to the road.

SF6-2 No protection items are installed.

<u>Management strategies:</u>

Archives explain that management strategies were employed in the 1970s and 1980s including the installation of fencing and controlled beach access points.

3. Coastal fabric - modified

Urban settlements

Map: SF6-2

Secondary Cell: Fleurieu

Tertiary Cell: Middleton Creek EAST

Land use

Land use: Council Reserve

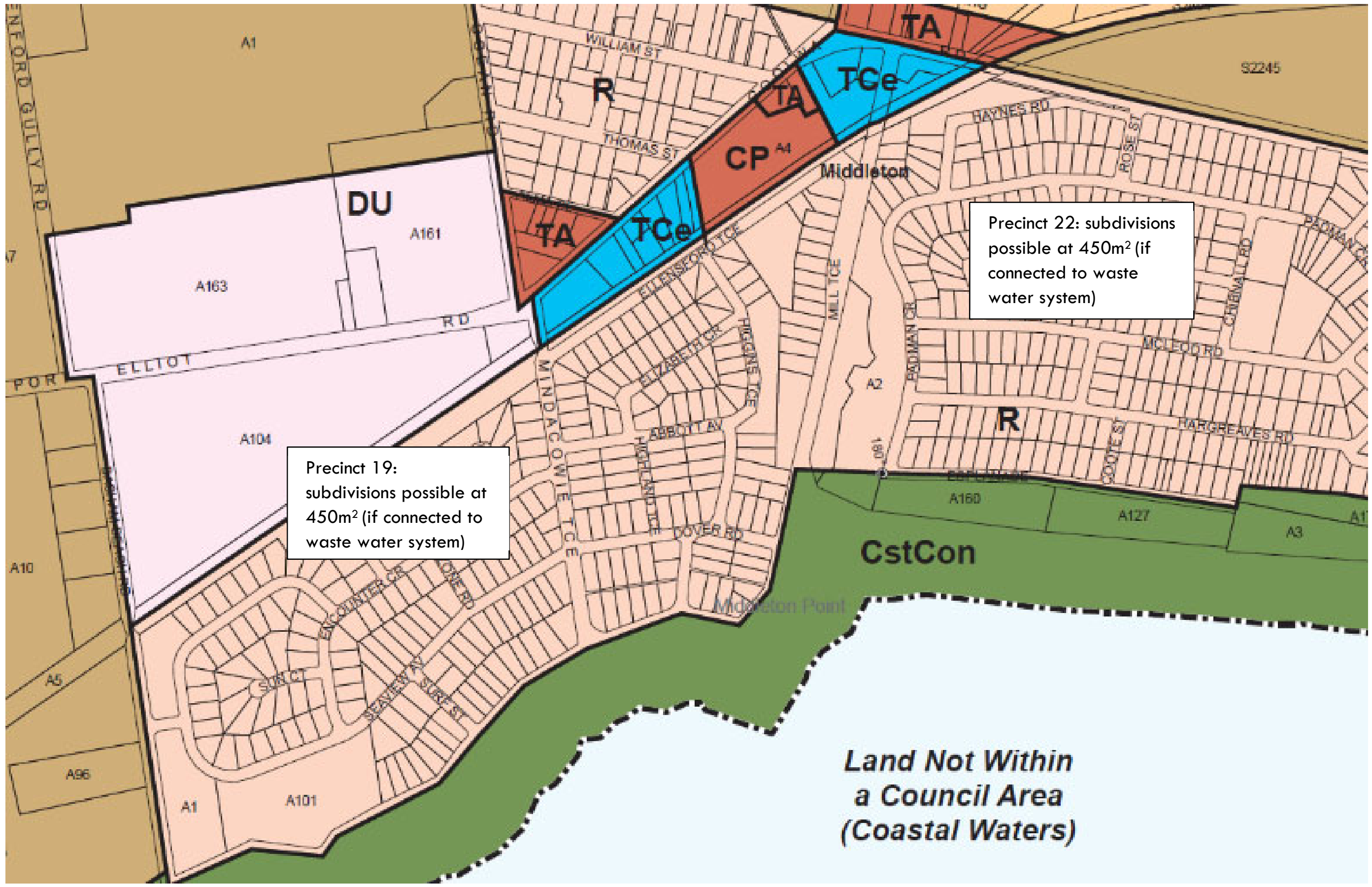
Zoning: Coastal Conservation (incorporates Council Reserve and foreshore). Zoning to the north of the reserves is predominantly Residential.

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

Precinct: Middleton 19 applies to west side of the Creek, Surfers Beach 22 applies to the east side of the Creek.

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

In Precinct 19 and 22, detached dwellings are only permitted dwelling type. Allotments connected to sewer scheme can be 450m².



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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.

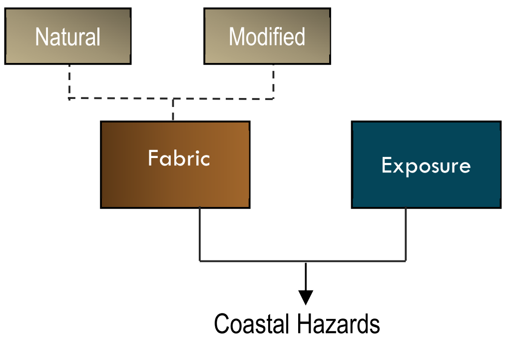
The 'flooding' section of 'Hazards' in the Development Plan (p. 38,39) has maintained standard South Australian planning policy library text apart from the insertion of PDC 7 that deals with development within the River Murray region (not relevant here).

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:

This South Australian conservation cell is split in two by Coast Adapt secondary cells: Fleurieu and Coorong. It represents the point where the series of headlands and embayed beaches that stretch from Chiton and Boomer to Middleton Point come to an end, and the long stretch of dissipative beach begins stretching from Middleton Creek to Cape Jaffa.

<u>Beach</u>

Fine-medium sand beach

<u>Benthic</u>

East of Middleton Creek, the nature of the beach changes to a dissipative nature and is therefore dominated by sand.

<u>Bathymetry</u>

Overall slope of ocean floor:
-10m ~1km from beach (overall slope ratio 1:100) or < 5 deg.

<u>Backshore 1:</u>

Alluvial cliff ~8m high decreasing to 2m high eastward.

<u>Backshore 2:</u>

Undifferentiated quaternary rocks rising to 14m AHD at 500m inland.

<u>Geology</u>

Portion of this cell is underpinned by undifferentiated quaternary rocks. Portions in the eastern section of the cell are dominated by semaphore sand.

<u>Recent changes:</u>

Historically there is strong evidence that an earthquake occurred offshore from Middleton in 1897 and altered the seafloor. As a result, evidence suggests that up to 200m of erosion occurred to Middleton Beach. However, since 1949, historic comparisons show that the cliff top has eroded 7-13m.

More recently a small dune has built at the base of the cliffs at a distance of 10-15m.

<u>Human intervention</u>

No human intervention with beach and backshore 1 apart from beach access stairs.

2 carparks situated 40-50m back from dune escarpment (or 20-25m back from top of cliffs)

The western side embankment of Middle Creek appears to have been altered to provide room for the carpark (lower carpark adjacent toilets).

Erodibility rating:

Backshore 1: high erodibility (3)

Backshore 2: high erodibility (3)

4. 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

4. Current exposure- overview

Overview

Map SF6-2

Middleton Creek - East

Overview

SA Classification

From Nature Maps (Department of Environment and Water)

Shoreline class
Sandy Beach

Dissipative

Sand rating
Fine sandy beach

Exposure:
High

Wave:
High 1m

Backshore 1:
Alluvial cliffs ~8m AHD.

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4. Current exposure- storm event

Storm event

Map SF6-2

Middleton Creek - East

Event:

21-22 Nov 2018

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 a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF6:2 of seaweed strands and other markers after the event demonstrated wave effects were ~1.30m above tidal gauge height at Chapman Road but graded down to 0.7m at Middleton Creek. The lesser has been used to assess the risk to alluvial cliffs.

Wave effects were very large but this event occurred at a lower tide. The storm took 2-3m bite from dune.

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4. Current exposure – storm surge

Storm surge

Map SF6-2

Middleton Creek - East

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	0.20m
Risk	1.95m AHD

Wave run-up is included at 0.7m

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

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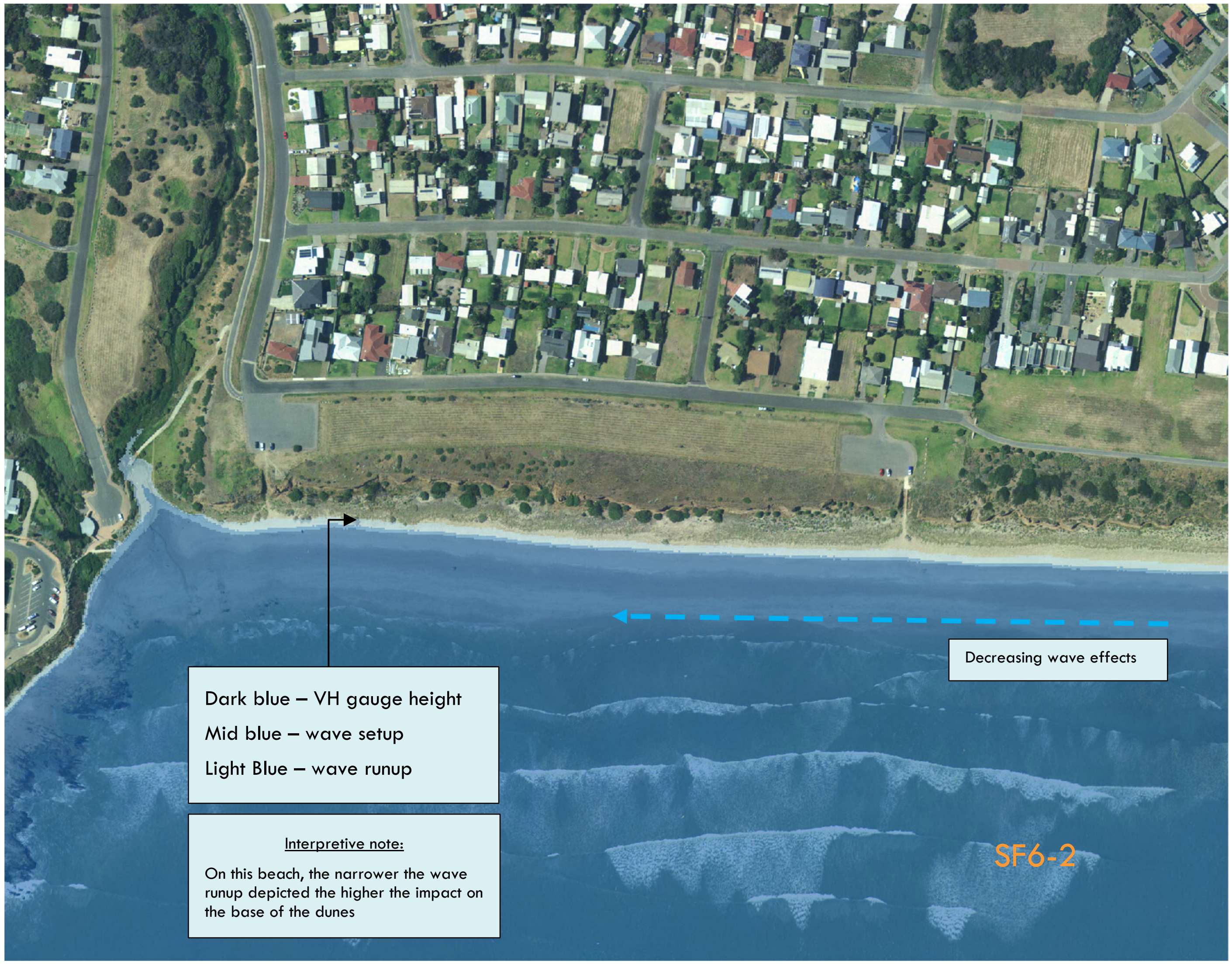

4. Current exposure – monthly high water

Monthly high water

Map SF6-2

Middleton- East

Current risk:

Monthly high water

Extreme events (ie 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	0.10m
Total risk	1.60m

Wave run-up of 0.30m is included. Current impact is likely to be very minor or nil.

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4. Current exposure – storm water

Storm water

Map SF6-2

Middleton Creek - East

Current risk:

Storm water

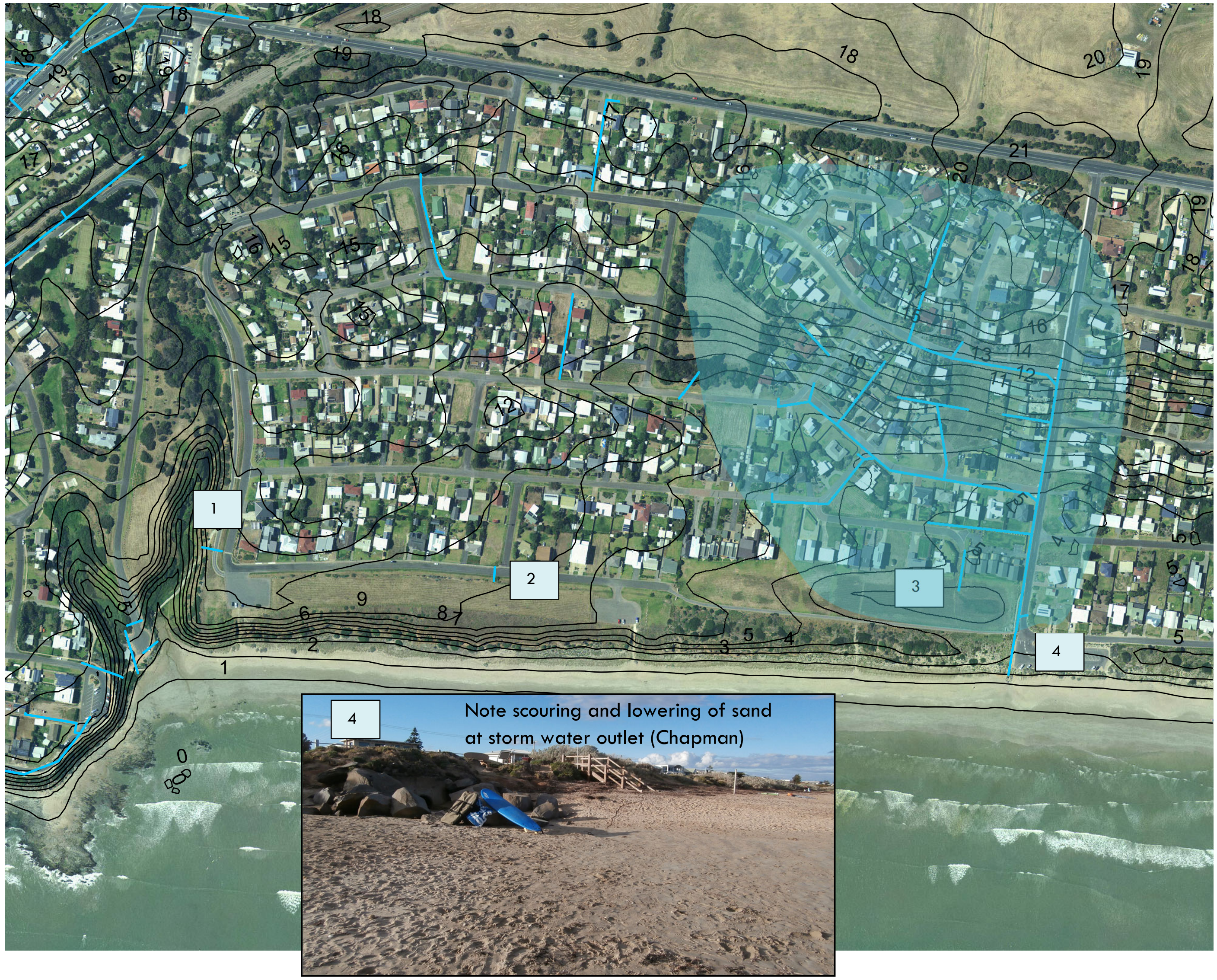
Assessment

Storm water in SF6-2 either drains to the sea (at 4), or into Middleton Creek (at 1, but presumably minor flows), and appears to be draining into small swales at 2 and 3.

The main concern is the size of the catchment of 4 which empties on to the beach adjacent Chapman Street Carpark.

Storm water outflows lower the beach in this location.

See also next page.



Note scouring and lowering of sand at storm water outlet (Chapman)

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4. Current exposure – storm water

Storm water

Map SF6-2

Middleton Creek - East

Current risk:

Storm water

Assessment

The main concern is the size of the catchment of 4 which empties on to the beach adjacent Chapman Road Carpark.

Inspection on 22 April 2019 revealed that this outlet was blocked with sand and seaweed. (Perhaps a result of the long dry).

Note the scouring of the beach from storm water outflow. Storm effects will be greater upon the shore line where the beach is lowered.

Sea level rise will exacerbate this problem.

Storm water collected in Side Entry Pit and piped to foreshore (outlet blocked).

Left: Note the scouring from storm water outflow (DEM 2018). Impacts from storm effects will be greater in locations where the beach has been lowered. Sea level rise will exacerbate the problem.

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4. Current exposure - erosion

Erosion

Map SF6-2

Middleton Creek - East

Current risk:

Erosion outlook

Assessment

The Middleton Cliff region suffered significant erosion at the turn of the 20th century, likely as a result of an offshore earthquake.

Erosion since 1949, has been in the order of 7-13m. Comparisons between 2006 and 2016 identify little change to the cliff top.

However, since 2006 an incipient foredune has developed seaward of the base of the cliffs by 10-15m. Reasons why this dune has developed: Alexandrina coastline appears to be going in an accretion stage, and the invasive vegetation type grows closer to the sea.

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4. Current exposure - erosion

Erosion

Map SF6-2

Middleton Creek - east

Current risk:

Erosion outlook

Assessment

The historical comparisons demonstrate that the line of the creek has been altered to allow room for the carpark.

Storm water events are now having a greater impact on the bend in the creek, and the bank is eroding toward the road.

A significant event in the past has severed the walking trail between Middleton East and Middleton West.

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Update: 3rd July 2019. Council has installed gabion protection to both sides of the creek to limit impacts of storm water erosion to the banks.

Above: Storm water outflows in the creek are eroding the bank back towards the road. A previous event has severed the walking trail/ bridge over the creek.

Left: The embankment between the creek and the road is being eroded by storm water flows.

5. 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

5. Future exposure – storm surge (2050)

Storm surge

Map SF6-2

Middleton Creek - East

2050 risk:

1 in 100-year 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	0.30
Risk	2.55m AHD

Wave run-up of 0.70m 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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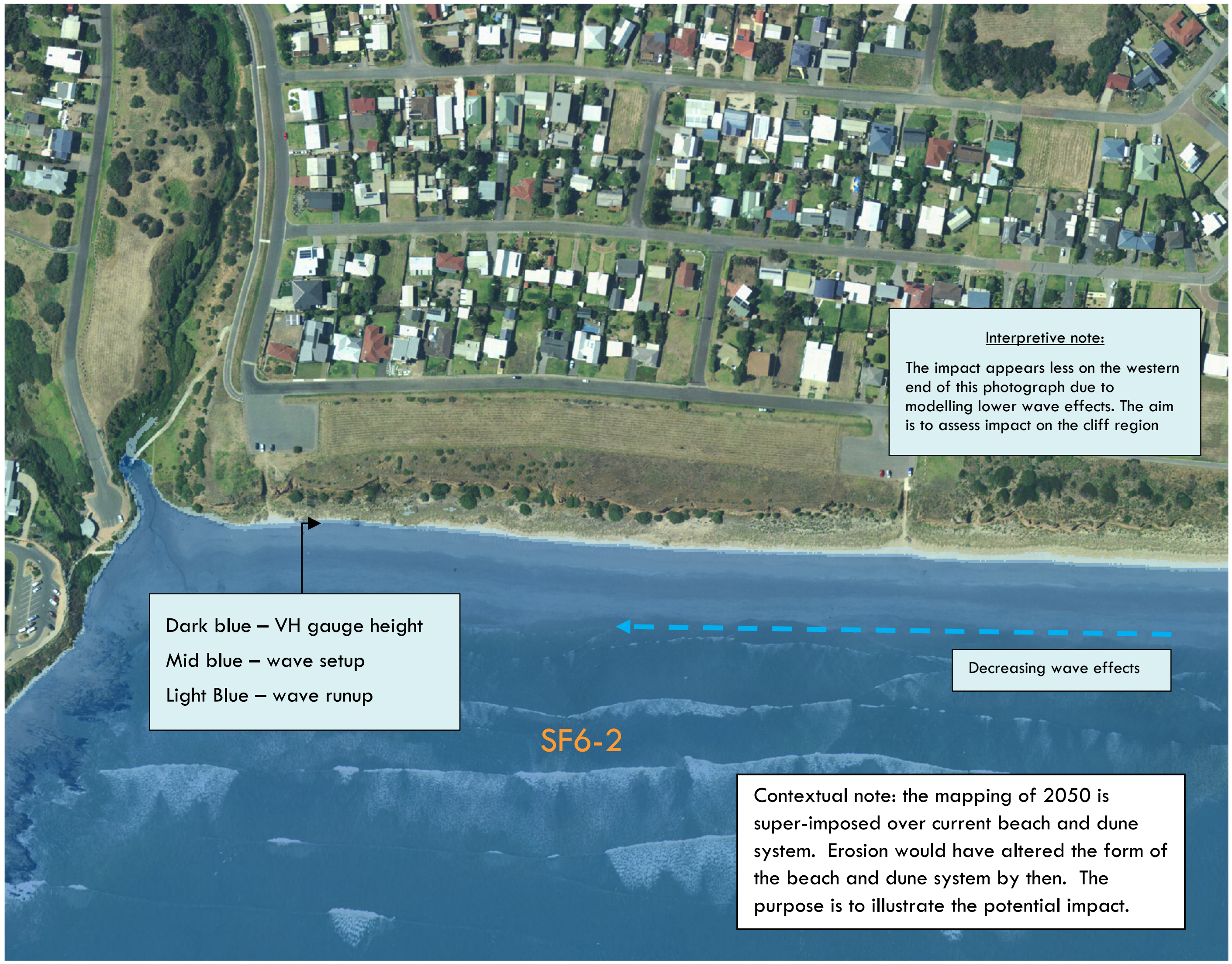

5. Future exposure – storm surge (2100)

Storm surge

Map SF6-2

Middleton Creek - East

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	0.30
Risk	3.25m AHD

Wave run-up of 0.7m 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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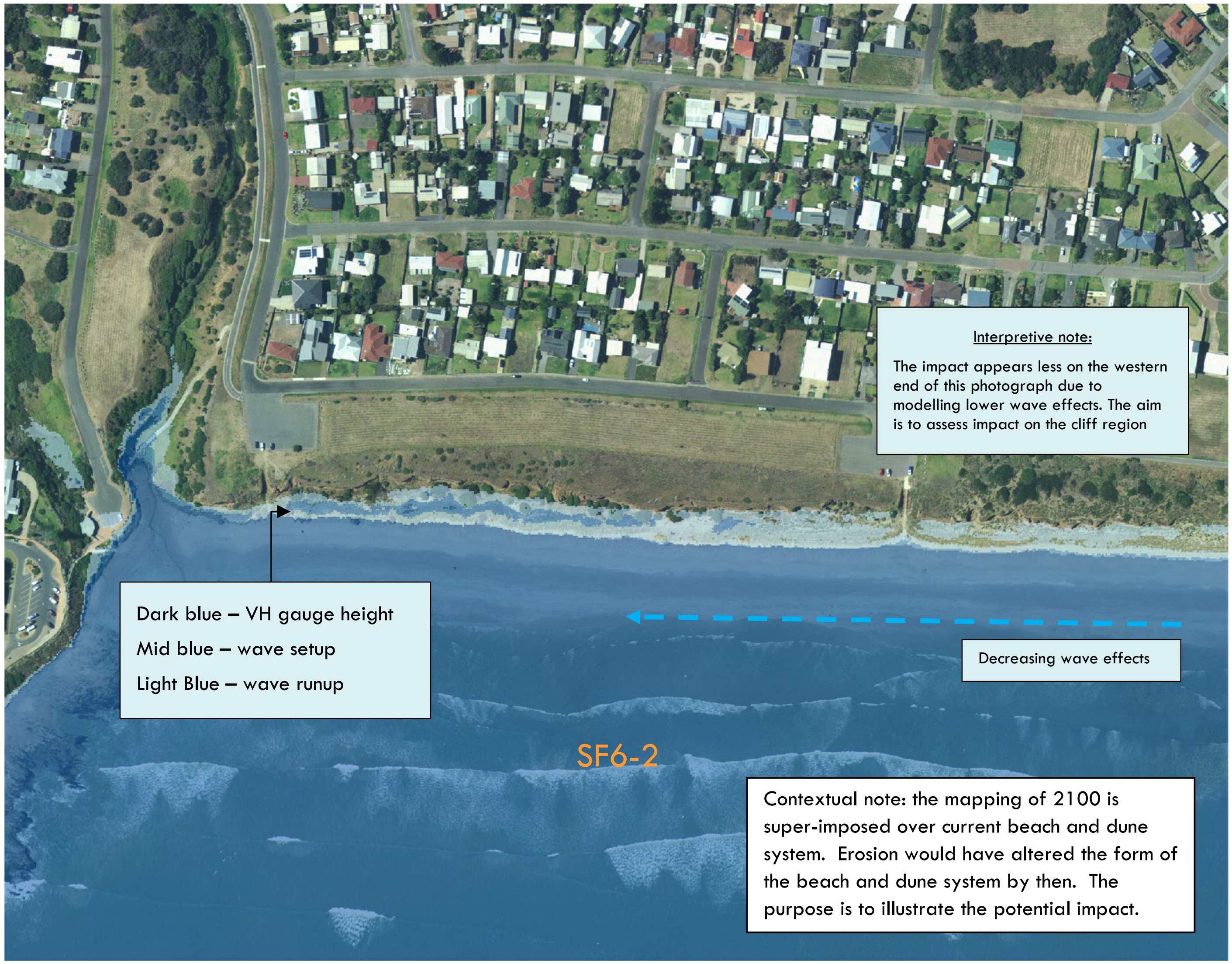

5. Future exposure – monthly high water (2050)

Monthly high water

Map SF6-2

Middleton Creek- East

2050 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. 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	0.30
	1.80m
Wave set up	0.30m
Total risk	2.10m

Wave run-up of 0.7m has been included (light blue)

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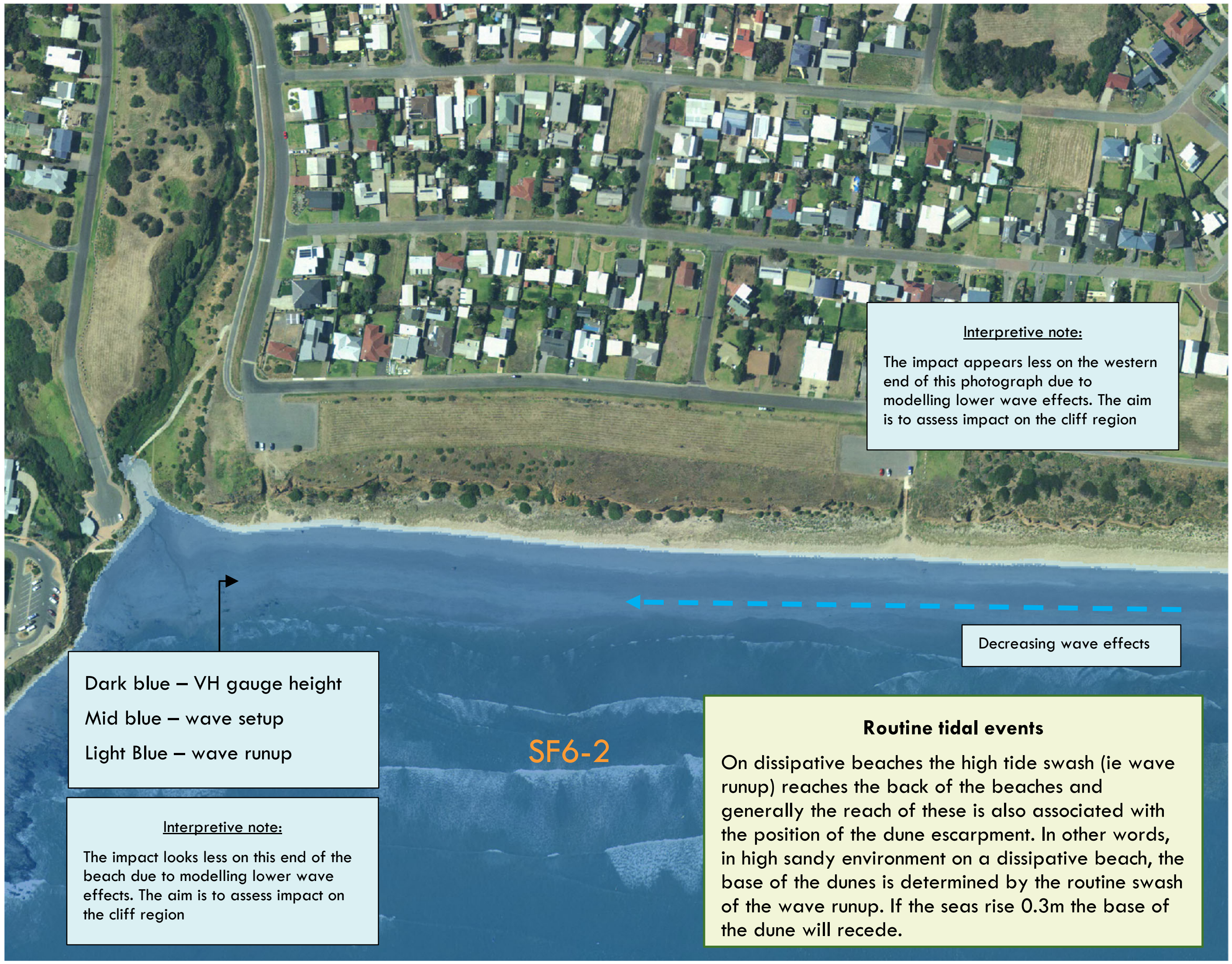

5. Future exposure – monthly high water (2100)

With sea level rise

Map SF6-2

Middleton Creek - East

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. 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 0.7m has been included.

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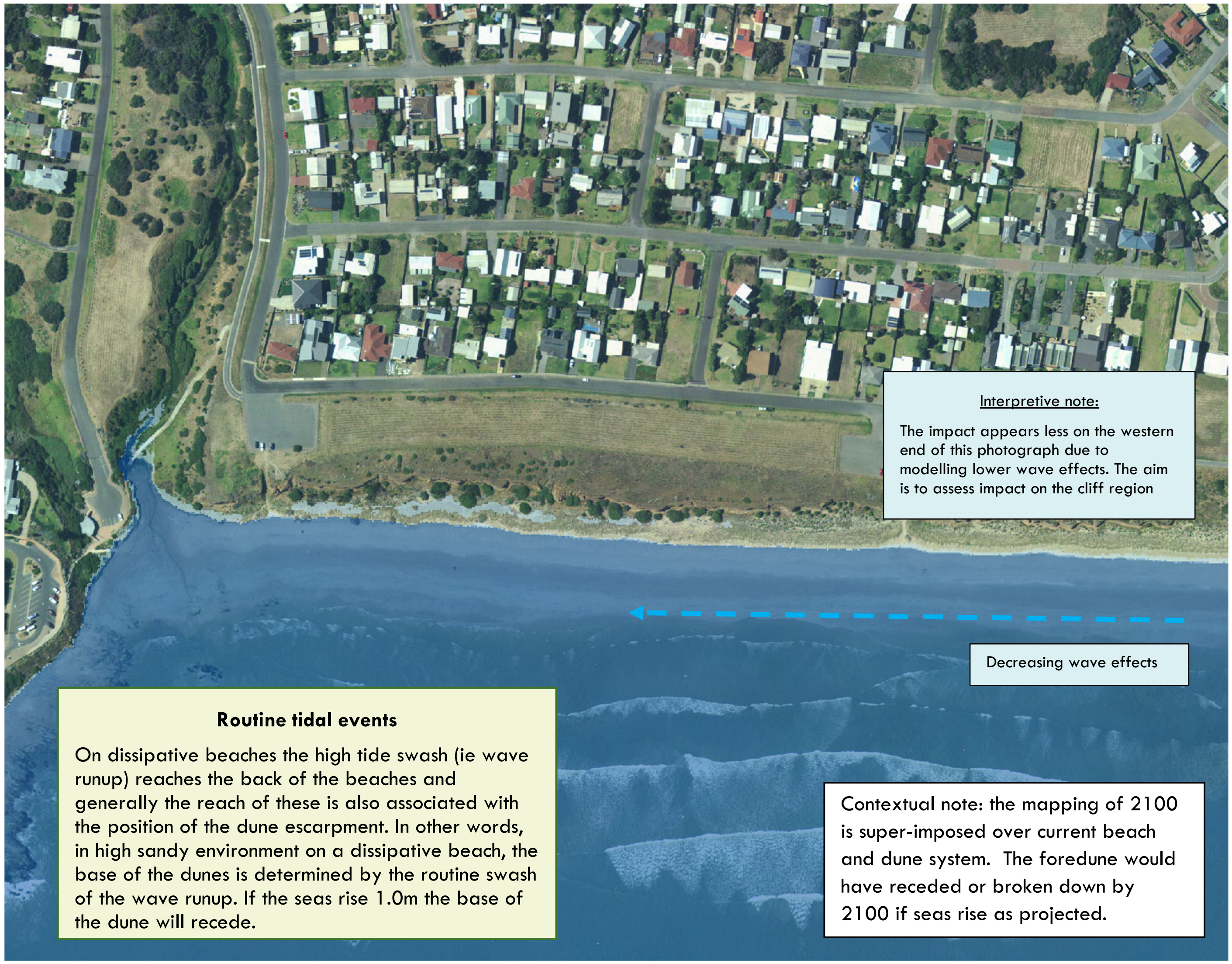


5. Future exposure - erosion

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 at Middleton Beach 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.

$S = -\,S p\,(W / dc + B)$ *(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):

$h = 8.9\overline{Hs}$ *(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.

Middleton Beach (Creek area)

There is extremely limited information available at Middleton 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 Middleton Beach (DEW Profile 615004, See figure below).

Note that the profile line only extends out to -8m below AHD water depth and this line has been guesstimated out to -20m below AHD, the presumed closure depth. The estimate of shoreline recession here must be treated with caution.

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 widths (*W in eqn 1)* of 2200m, the Bruun Rule indicates a shoreline recession of 101m by 2100. For a sea level rise of 0.3m by 2050, the shore will recede by 30.5m.

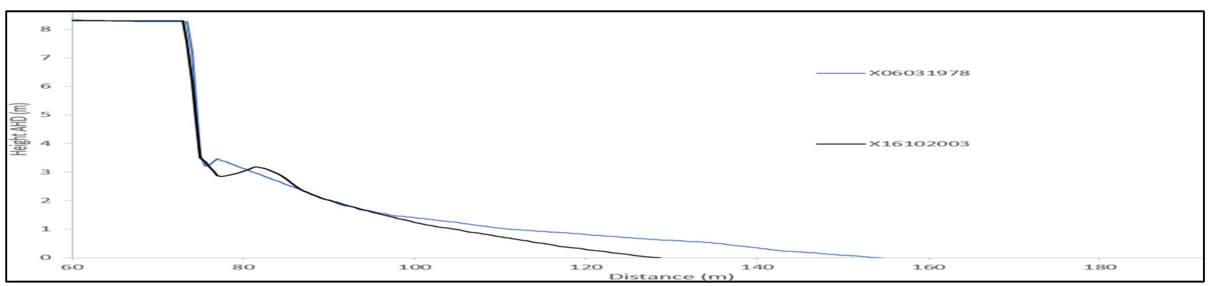


Figure: Profile line 615004, DEW

5. Future exposure - erosion

By Dr Patrick Hesp

See full version in Part 1 of the report

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.

Figure (on page above) indicates detail of the beach-dune system segment of the latest available topographic profile (615004) from a 1989 survey, and the estimated translated topographic profile for 2100. Past -3m water depth there is considerable shallow reef, and it is impossible to translate this material.

It may be seen that the beach-foredune system will translate approximately 114.4 metres by 2100. 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 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.

Note that as future sea level rises over the reef dominated nearshore region, wave energy will increase due to the fact that there will be less dissipation of waves over the reefs as the water depths increase. This will increase wave energy at the beach face and impact several of the factors considered above (storm wave heights and runup, significant wave heights).

Interpretive note:

The erosion modelling assumes that the beach and backshore are natural environments and no human intervention is taken to slow the rate of erosion.

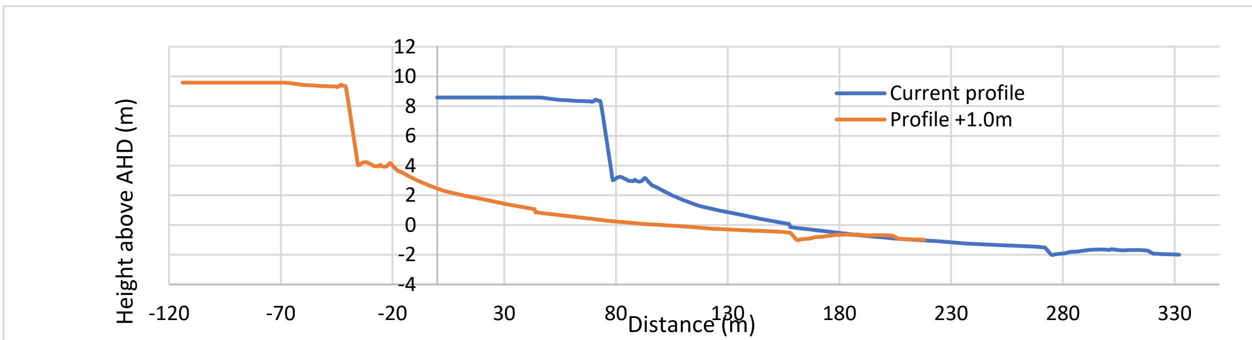


Figure: Topographic profile surveyed in 1989 and translated profile for a sea level rise of 1m by 2100.

5. Future exposure – erosion (2100)

By Dr Patrick Hesp

See full version in Part 1 of the report

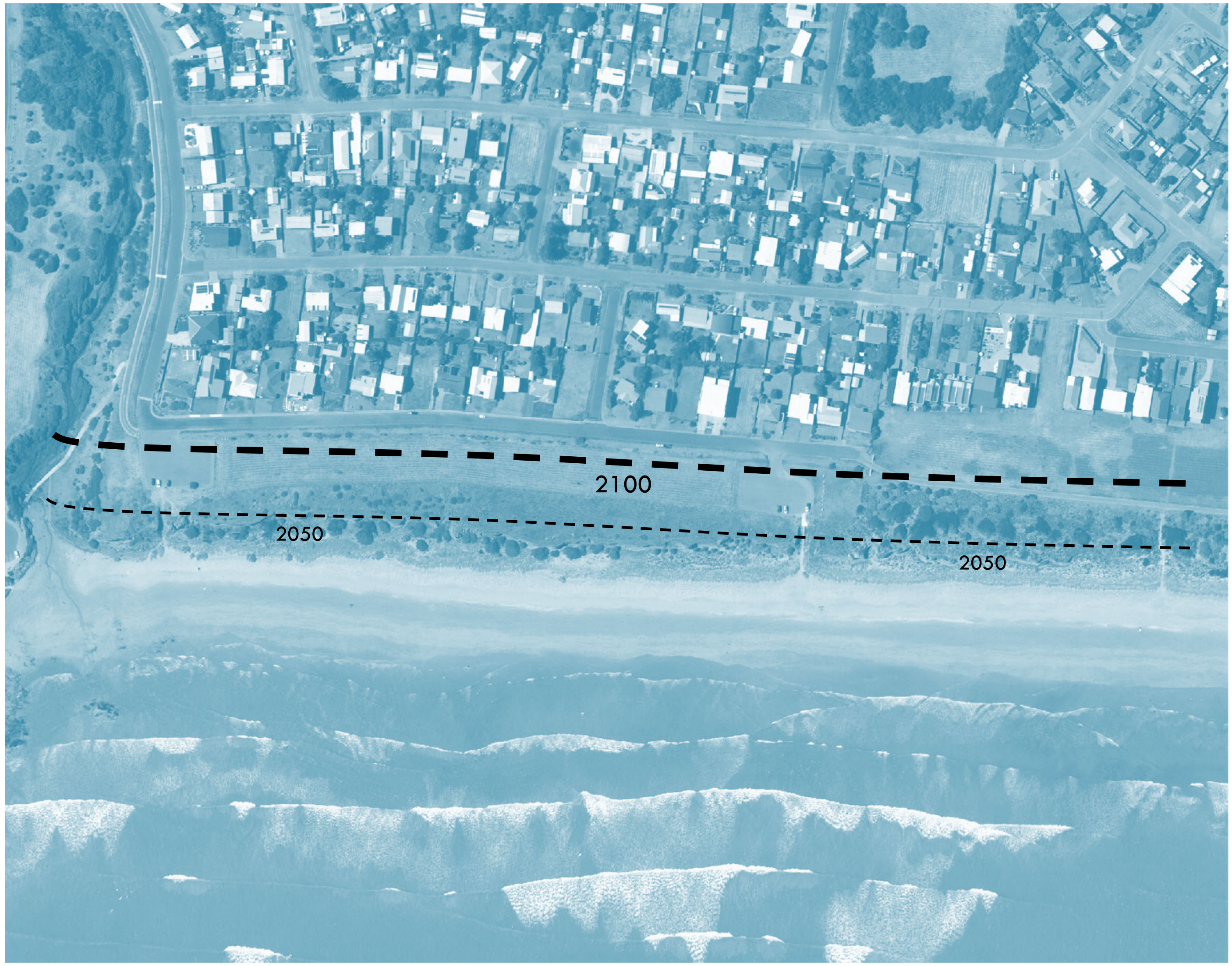
Future Exposure

Map SF6-2

Middleton Creek - East

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.

Erosion assessment is made difficult by the presence of a substantial off-shore reef and lack of sediment data. Estimates of shoreline recession range between 97 and 114m by 2100.

Lines drawn on the map provide a visual representation of the estimate.

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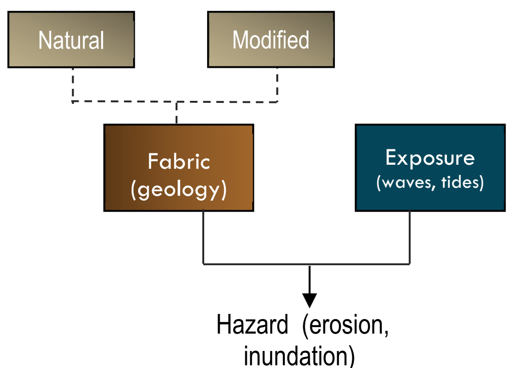
COASTAL EXPOSURE

Summary and Conclusions

Progress report:

So far, we have completed a settlement history, an overview of the cell 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 Middleton Beach. (It is recommended that one or two more events are analysed in the future). Total wave effects in SF6-2 totalled 1.30m at Chapman Road carpark grading down to 0.7m at the Creek.

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 wave runup would impact the escarpment of the incipient dune at the base of the alluvial cliffs. However, it is likely that the dune would rebuild (unless the coast is undergoing its erosion phase).

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.

Erosion and accretion cycles

The historical analysis has demonstrated that the Alexandrina coastline moves through cycles of accretion and erosion phases. Currently the coastline appears to have been in an accretion phase.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the base of the incipient dune or the alluvial cliffs (if no frontal dune).

Monthly high water

Impact upon the base of the dunes or alluvial cliffs would be more direct and some recession likely.

Erosion modelling

Erosion modelling indicates a possible recession of 30m by 2050.

Future exposure (indicatively by 2100)

Storm surge and high water events

The 1 in 100 ARI storm event would significantly impact the beach and dune causing recession of the alluvial cliffs. High tidal action 1m greater than today would also routinely impact the dunes (probably removing them) and directly attacking the base of the alluvial cliffs.

Erosion modelling indicates a possible recession of 100m by 2100.

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.

6. Inherent hazard risk assessment

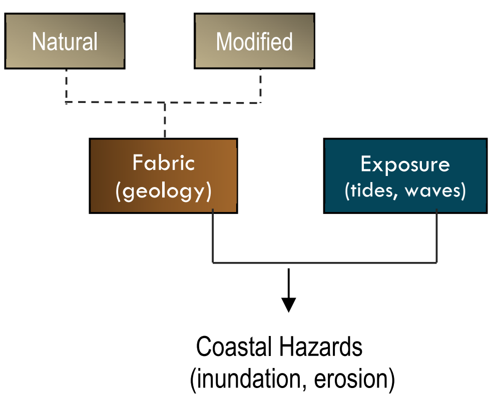
CoastAdapt identifies two main coastal hazards:

- Sea-water flooding
- 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.



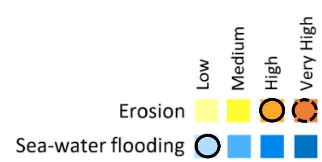
Inundation hazard risk

Due to the slope of backshores inundation is not a risk in Middleton Creek (east). (Note, assessment has not been completed for impact within Middleton Creek).

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main report)	Sandy beach, alluvial cliffs, backshore 2: sedimentary plane (?), but rises to 14m AHD at 300m inland.	High
Should this rating be amended due to human intervention such as a protection item? If so, how?	Nil	High
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of Highly exposed.	Very high
Assess any impact on backshore 1	Seawater impacts the incipient dune at the base of the cliffs (this section of shore in accretion mode over the last 10 years)	Very high
Assess any influence from Benthic	Dissipative beach is dominated by sand	Very high
Assess the sediment balance	Coast in this region has been accreting over last ten years.	High – very high
Assess any other factors that may warrant a change of inherent hazard risk.	Nil	High-very high

Inherent Hazard Risk – Middleton Creek (east)



7. 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

7a. Assets at risk (public)

Public assets

Map SF6-2

Middleton Creek (East)

Assets at risk

Short term outlook

Notes

Erosion modelling indicates long term recession of the alluvial cliffs if seas rise as projected. This assessment assumes that no actions are taken to slow the rate of erosion.

Assets at risk include:

- Beach access (2)
- Fencing on cliff top

Assets in need of reconstruction include:

The pedestrian access across Middleton Creek (in progress at date of writing).

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7a. Assets at risk (public)

Public assets

Map SF6-2

Middleton Creek (East)

Assets at risk

Short term outlook

Notes

Research suggests that Alexandrina coastline is currently in an accretion phase. Example of sand accumulation in proximity of final posts indicate that the stairs were installed when sand levels were lower.

As this point in time these access ways are not under threat from actions of the sea.

However, if upgrades are required care needs to be taken to understand which phase the beach is in at the time of construction.

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Access SF6-2
Access stairs through alluvial cliffs are set behind incipient dune. Sand adjacent final posts at about 700 above base of the post.

7a. Assets at risk

Public assets

Map SF6-2

Middleton Creek (East)

Assets at risk

Long term outlook

Notes

Research suggests that Alexandrina coastline is currently in an accretion phase. Example of sand accumulation in proximity of final posts indicate that the stairs were installed when sand levels were lower.

As this point in time these access ways are not under threat from actions of the sea.

However, if upgrades are required care needs to be taken to understand which phase the beach is in at the time of construction.

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7b. Assets at risk (private)

Private assets are situated behind the esplanade road at a distance greater than 100m and are therefore, according to the erosion modelling, not likely to be impacted by impacts of the sea in this current century

7c. Safety of people

People access the foreshore for recreational purposes. These include walking, cycling, picnics, swimming and similar activities.

Any increase in coastal hazards due to sea level rise are not expected to increase risks to people above existing risks. In other words, in the context of a coastal adaptation study, this hazard/risk assessment is not focussed on risks to people accessing the park per se, but focussed on specifically on increased risks to safety because of sea level rise.

The assumption here is that Council will continue normal operations with warning signage and fencing.

7d. Ecology at risk

The assessment of ecology of risk in the context of this project is confined to that which may be described as 'ecosystem disruption' with the intent that this disruption would occur on a wide scale. For example, sea water flooding through the dunes at Ratalang Basham will irreversibly change the nature of the ecosystem on a large scale.

The geological layout of Middleton Beach indicates that major ecosystem disruption is not a risk.

Access Point 2

8. 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.

8. 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:

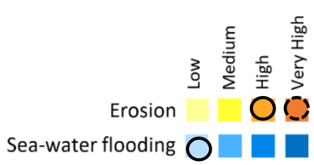
- Sea-water flooding
- Erosion

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

Sandy dissipative beach backed by alluvial cliffs



Specific Risk Assessment

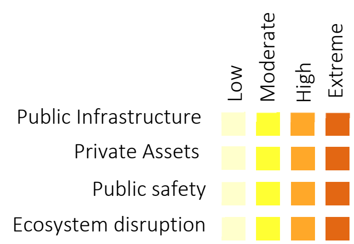
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Environment

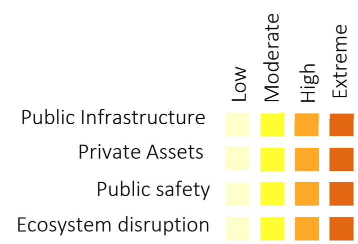
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

This 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 assessment utilises the risk assessment framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion.

Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Yet to be assigned

8. Risk Assessment

Erosion assessment

Middleton Creek East (SF6-2)

Risk identification: Erosion may cause the alluvial cliffs to recede impacting public infrastructure

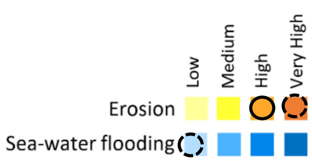
Coastal processes	Middleton Beach (cliff section) marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach is backed by a small dune system that has formed over the last ten years. Behind the dunes are alluvial cliffs. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical research found that this area underwent large scale erosion at the turn of the 19th century. Since 1949, the cliffs have receded 12-15m, but the rate of erosion appears to have almost ceased.

Are any strategies employed to mitigate the risk? Nil.

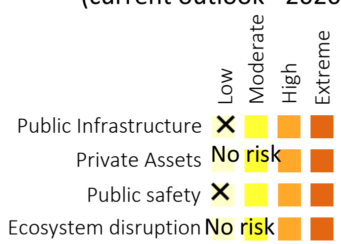
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks x2, access stairs x2, fencing atop the cliff. Risk assessment conducted here in the context of carparks.	current	*No risk*	*No risk*	No risk
		2100	*Likely*	*Significant*	high
Private assets	Private assets are situated at greater distances than 100m from the shoreline and therefore, according to the erosion modelling, unlikely to be at risk this century.	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 geology of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk

Inherent Hazard Rating

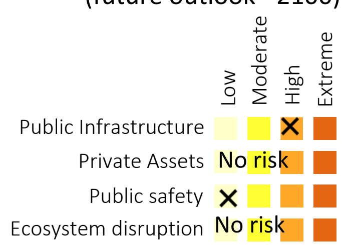
Sandy dissipative beach backed by alluvial cliffs



Erosion Hazard Rating
(current outlook - 2020)



Erosion Hazard Rating
(future outlook - 2100)



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 the beach is in stable condition (perhaps still accreting). However, if sea levels rise as projected, it is likely the small foredune would be eroded away and then the alluvial cliffs would follow. Currently beach access stairs are well set back. Any upgrades should consider the long term trend of the beach. The carparks on top of the cliff are likely to be positioned far enough back that these will not come under attack until the second half of the century. However, if any upgrades were envisaged, the carparks could be reconfigured to allow a greater distance between the carparks and the cliff tops.

9. 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.

MIDDLETON BEACH (CLIFFS)

The modelling and assessment indicate that the alluvial cliffs are currently not under threat from actions of the sea.

An **incremental approach** to adaptation is recommended.

As the cost of protecting the base of alluvial cliffs in this location is unlikely to be viable, a managed **retreat strategy** should be employed.

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.

Any upgrades to beach access ways should take into account normal erosion and accretion cycles.

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

Retreat

Map SF6-2

Middleton Creek (East)

Adaptation proposal

Approach: incremental

Monitor

The base of the escarpment should be regularly monitored, especially after storm events.

Respond – retreat

If seas rise as projected and the alluvial cliffs begin to recede, then a **retreat** strategy should be employed. When carparks are due for upgrade, these could be reconfigured and constructed further away from the cliff top.

If cliffs receded, consider closing off the access on eastern side and install access to the beach through Middleton Creek (east side)

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Protection option:

Rock protection is likely to be required at the bend in Middleton Creek (in vicinity of former walkway). Update 7th July 2019: Gabion baskets have been installed to Middleton Creek (see next page).

Adaptation proposals

Magryn and Associates were contracted to review the work by Integrated Coasts and to provide expert advice and preliminary designs and costings where required. It was anticipated that Middleton Creek would be a location requiring review and input as part of this project. The site was inspected by Will Souter (Magryn) on 28 June 2019. The following observations were made (see also full report from engineer):

Middleton Creek

A new pedestrian bridge is under construction, to replace the previous bridge that was destroyed.

A gabion wall has been constructed either side of the creek (with geofabric behind), in an effort to minimise future erosion. The gabions appear to be galvanised mesh baskets, filled with bluestone spalls. The gabion walls may provide some erosion protection; however the steel mesh is not considered suitable for a coastal site. The highly corrosive environment will significantly limit the life of the structure. It is probable the zinc protection will be compromised, and the steel will begin to corrode in several years.

Concrete abutments have been constructed adjacent the gabion baskets.

Small rocks have been provided to the base of the creek (presumably for scour protection). These are too small and will likely be washed away under high flow conditions during a storm event.
No scour protection has been provided to the southern half of the creek (with the gabion walls), and erosion has occurred seaward of the creek.

The overall level of the beach south of the creek has dropped as a result of stormwater outflow across the beach.

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.

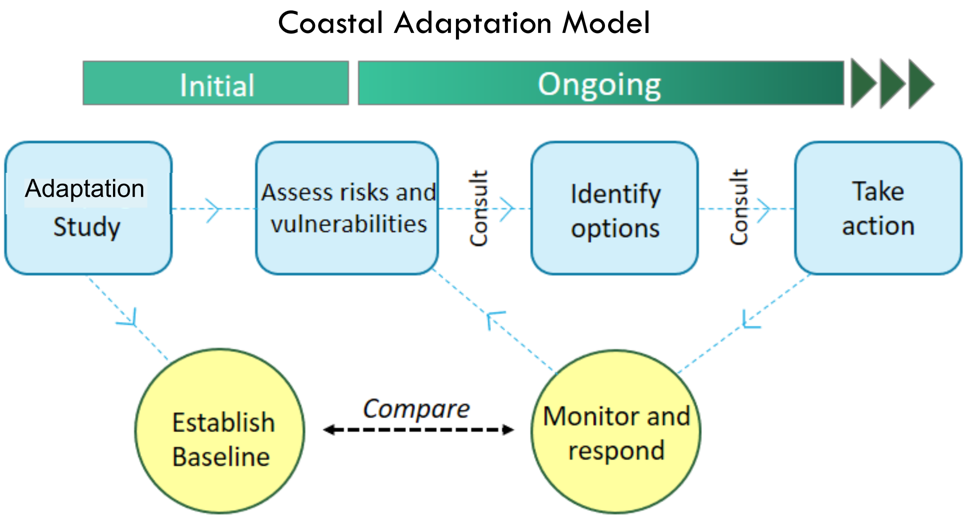
Prime response – 'monitor and respond'

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)

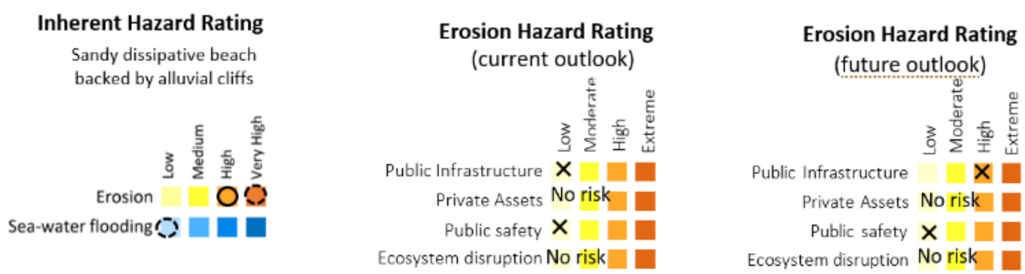


Integrated Coasts (2017)

Adaptation strategy: Middleton Creek (east) (Cell SF6-2)

Coastal processes	Middleton Beach (cliff section) marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach is backed by a small dune system that has formed over the last ten years. Behind the dunes are alluvial cliffs. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical research found that this area underwent large scale erosion at the turn of the 19^{th} century. Since 1949, the cliffs have receded 12-15m, but the rate of erosion appears to have almost ceased.

Risk outlook



Adaptation overview:

The long-term strategy for Middleton Creek (east) is managed retreat if seas rise as projected. Erosion assessment indicates coastline could recede ~97m to 114m. The carparks on top of the cliff are likely to be positioned far enough back that these will not come under attack until the second half of the century. However, if any upgrades were envisaged, the carparks could be reconfigured to allow a greater distance between the carparks and the cliff tops. Beach access stairs are set well back from current shoreline, but any upgrade of these should consider erosion outlook (ongoing monitoring will provide decision context)

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type (when required)	Monitoring strategy
Middleton Creek (East) Cell SF6-2	Incremental [monitor and respond]	Monitor [no immediate works are likely to be required]	Monitor [It is unlikely that erosion will impact carpark in this time frame]	Managed retreat [Carpark is set well back – reconfigure further away from shoreline at time of upgrade]	Engineering: Construct carpark further away from shoreline.	Shoreline position Storm impacts on backshore Sand volumes