Coastal Adaptation Study

for Alexandrina Council

PORT ELLIOT – GREEN BAY & CROCKERY BAY

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

Report to be cited as: Western, M, Bourman, R., Hesp, P (2019) Coastal Adaptation Study for Alexandrina Council (Cell SF8 Horseshoe Bay) prepared by Integrated Coasts, South Australia.

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Introduction

This document is a partial output for the Coastal Adaptation Study for Alexandrina Council (Port Elliott Cell SF8). This document also represents an output from the coastal adaptation assessment tool designed by Integrated Coast.

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

ASSESSMENT FRAMEWORK

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

- **Coastal fabric (geology)**

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

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

- **Coastal modifiers (human intervention)**

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

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

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

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

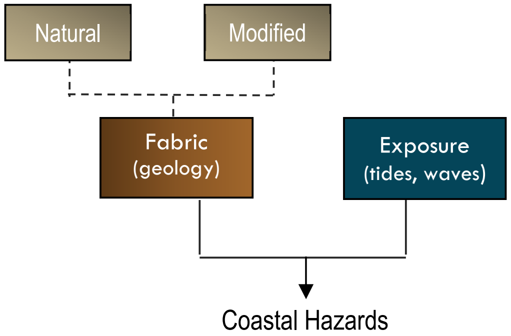
CHANGES IN THE RELATIONSHIP

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

Our sea levels have been quite stable for several thousand years. However, in recent times, the rate of sea level rise has escalated. Last century, sea levels rose at ~2-3mm per year. In this century, seas are rising on average at ~4-5mm per year in our region. The general consensus of the scientific community is that the rate of sea level rise will continue to escalate towards the end of this century (~10-15mm per year). These projections are based on sound physics, but the exact rate of change remains 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 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 7*** (Nature Maps).

These cells are depicted on the following pages.

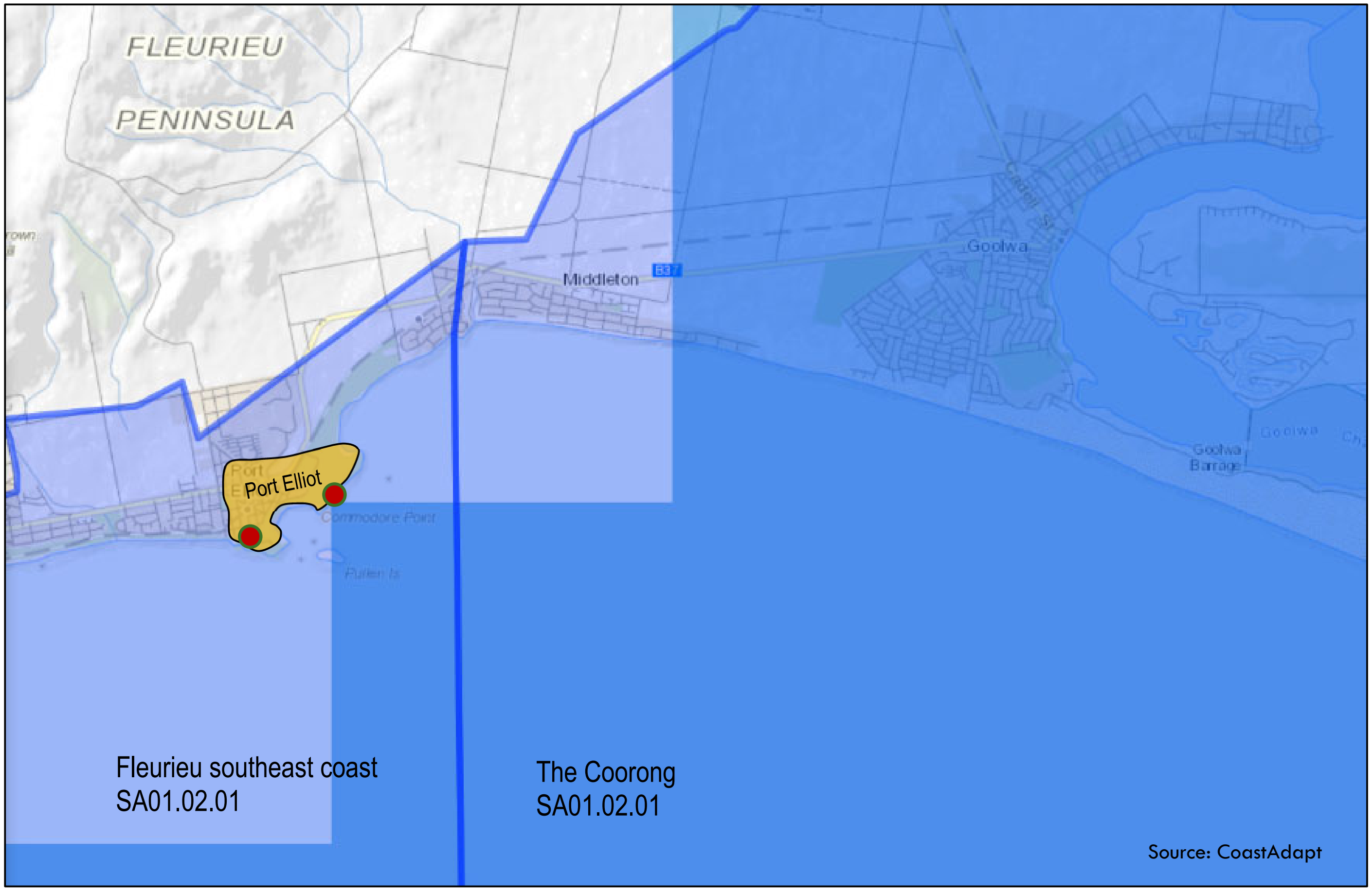
Introduction

Regional Setting

Map: SF8

Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Port Elliot (West)

Secondary Cell



Nature Maps

CoastAdapt:

Australian regional setting
Cell: Fleurieu - southeast coast.

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

Outcrops of Encounter Bay Granite dominate the Port Elliot cell forming headlands, islands, and rocky reefs. The resistant granite has a strong influence on the orientation of approaching waves, which have moulded sandy bays such as Horseshoe Bay and Crockery Bay.

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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

Introduction

Regional Setting

Map: SF8

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cells: Green and Crockery

Tertiary Cell

SA regional setting
Part of Conservation Cell: Southern Fleurieu 8 (Map SF8)

Cell extent
From Knights Beach in west to Southern end of Ratalang Basham.

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1. GEOMORPHOLOGY

1. Geomorphological context

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 6: 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.

1. Geomorphological context

Geomorphology

Map: SF8

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cells: Green and Crockery

Geomorphology

Outcrops of Encounter Bay Granite dominate the Port Elliot cell forming headlands, islands, and rocky reefs. The resistant granite has a strong influence on the orientation of approaching waves, which have moulded sandy bays such as Horseshoe Bay and Crockery Bay.

Green Bay has been eroded over a long period of time as weathering and wave action exploited weaknesses in the granite.

Main photograph: Coast Protection Board 2008

Inset: Green Bay (M. Western) 2018

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GREEN BAY

COASTAL FABRIC

In this section we evaluate coastal fabric in more detail:

- Overview of the current coastal fabric
- Changes to shoreline over seventy years
- Human intervention (coastal modifiers)

2. Coastal fabric - natural

Overview

Map: SF8-2

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cell: Green Bay

Form

Beach

Bedrock platform – coarse sand

Backshores

Backshore 1: Earthen embankment rising from 2.5m AHD to 18m AHD, protected at the base by boulders and cobbles.

Backshore 2: Rises to 28m at 300m inland, underpinned by quaternary rocks.

Bathymetry

Overall slope of ocean floor: -10m ~300m from beach (overall slope ratio 1:30).

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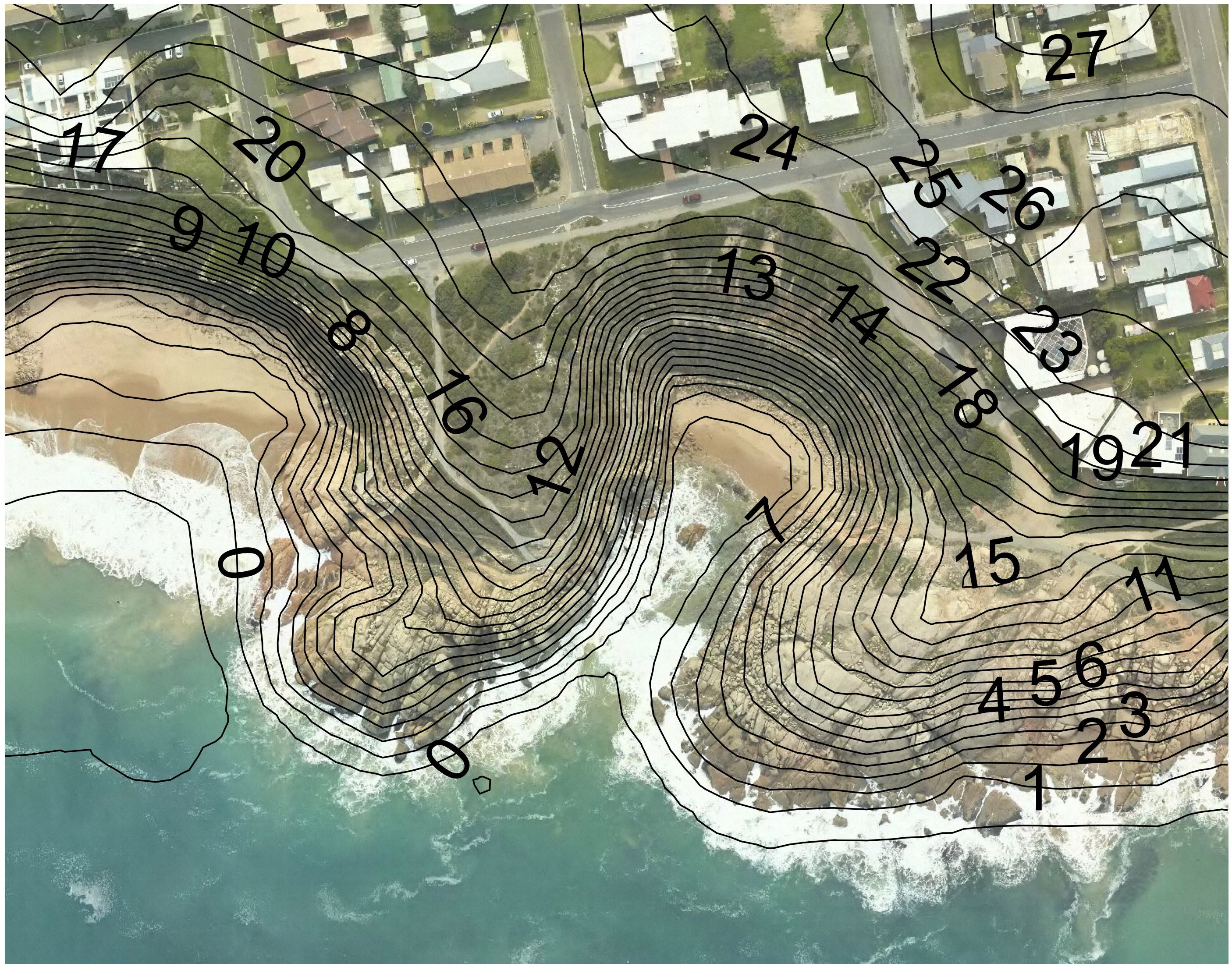

2. Coastal fabric - natural

Overview

Map: SF8-2

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cell: Green Bay

Geology

Geology

Beach and backshore 1:

Rocky beach and earthen backshore (bordered on each side by Encounter Bay Granite)

Age: Cambrian-Ordovician

Backshore 2 (landward of Green)

Undifferentiated Quaternary Rocks

Age: Pleistocene-Holocene

Figure opposite sourced from www.sarig.gov.au

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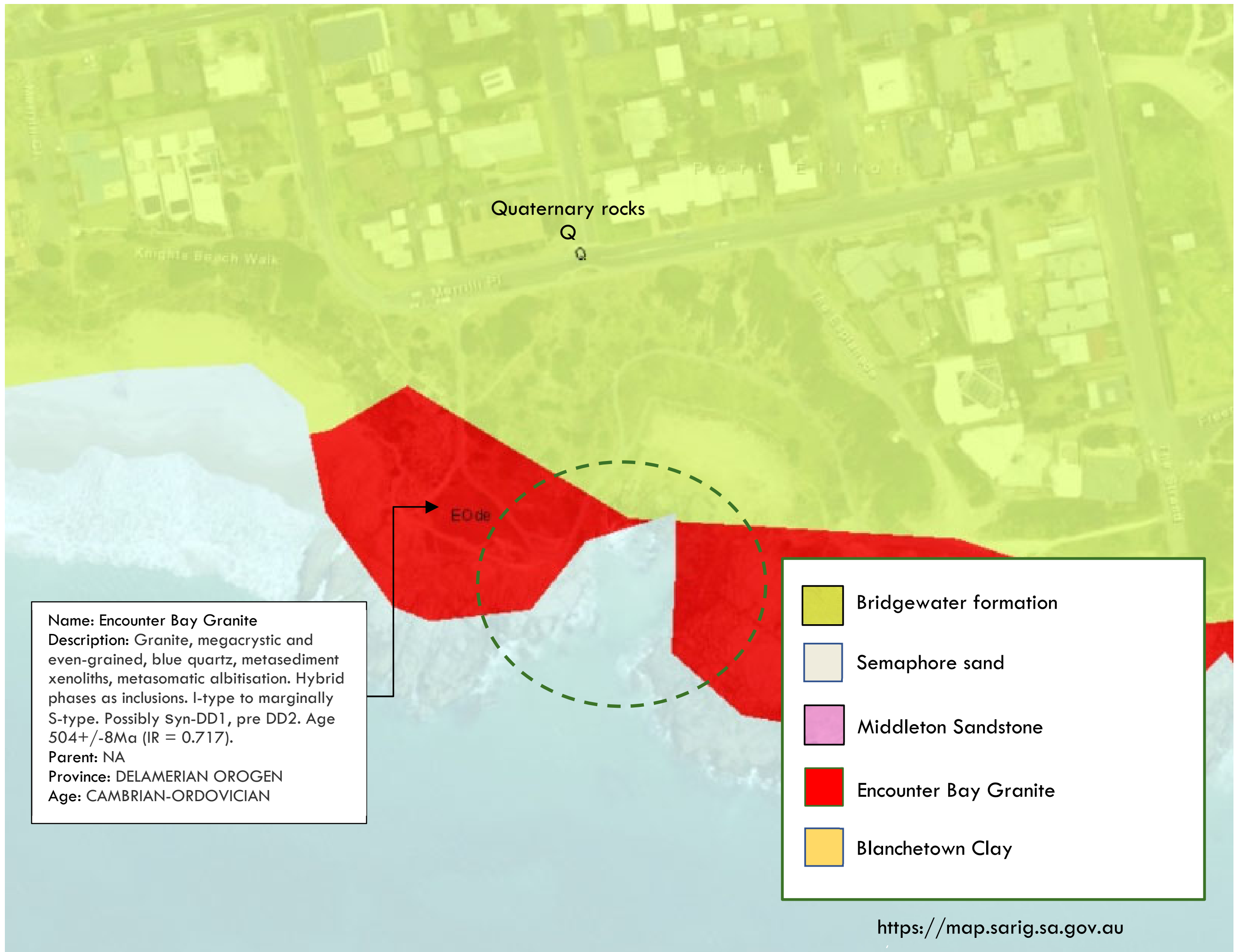

2. Coastal fabric - natural

Overview

Map: SF8-2

Secondary Cell: Fleurieu SA Coast

Tertiary Cell: Port Elliot

Minor cell: Green Bay

Benthic

Benthic

A continuous low profile reef underpins the surfzone of the bay.

Sand dominates the sub-tidal zone covered by patchy seagrass.

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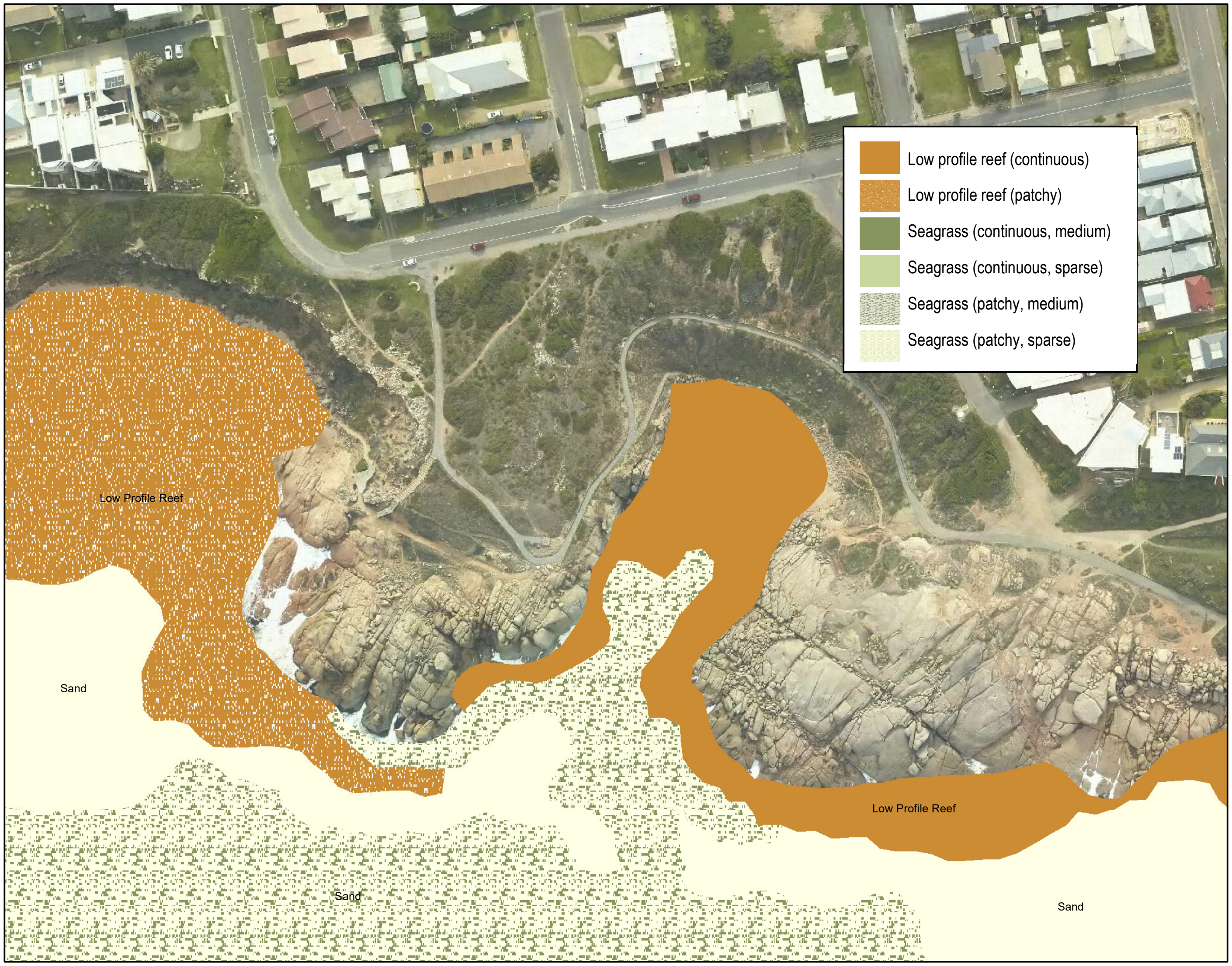

2. Coastal fabric - natural

Overview

Map: SF8-2

Secondary Cell: Fleurieu SA Coast

Tertiary Cell: Port Elliot

Minor cell: Green Bay

Classification

SA Classification

Shoreline class
Not assigned

Sand rating
Bedrock Platform

Exposure:
Moderate

Wave:
Moderate

Backshore 1:
Rocky/sandy beach, earthen embankment.

Backshore 2:

Quaternary rocks rising above 30m at 300m inland

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2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Map SF8-2

Green Bay

Historical comparison

1949

Assessment

The lines on this map:

Aerial photograph from 1949. Dotted line indicates base of the escarpment.

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Georeferencing

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

2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Map SF8-2

Green Bay

Historical comparison

1949-2006

Assessment

The lines on this map:

The position of the base of the escarpment in 1949 is depicted with a black dashed line.

The position and nature of the escarpment does not appeared to have changed from 1949.

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2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Map SF8-2

Green Bay

Historical comparison

1949-2018

Assessment

The lines on this map:

The position of the base of the escarpment in 1949 is depicted with a black dashed line.

The position and nature of the escarpment does not appeared to have changed from 1949.

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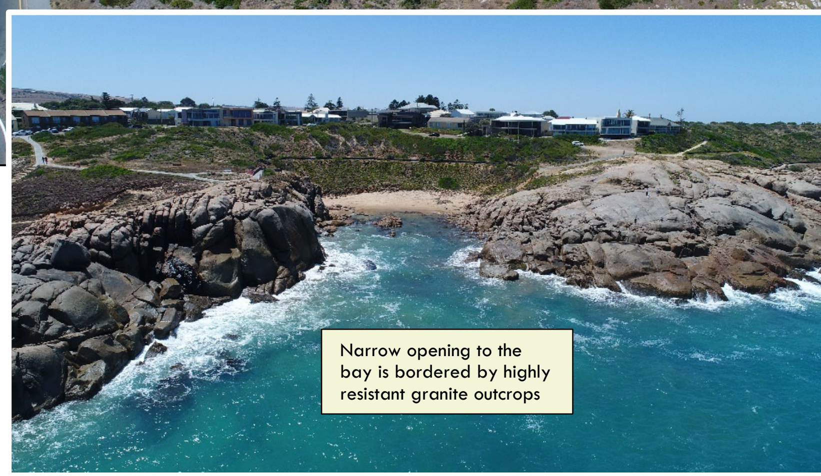
2. Coastal Fabric - natural

Summary

Map SF8-2

Green Bay

Observations



Assessment

The geological layout of Green Bay inherently protects the back of the bay from higher impacts from the sea.

This observation is supported by wave effects recorded at 0.6m lower than adjacent Knight Beach on 18 November 2018.

Rocky outcrops (underpinned by reef) dissipates wave energy.

The narrow opening into Green bay limits the impact of the swell.

Boulders and cobbles provide some protection to the rear of the bay.

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3. Coastal fabric- modified

HUMAN INTERVENTION

Protection items and/or infrastructure

Human intervention is limited to the installation of a formalised walking path half-way up the embankment and minor walking trails elsewhere.

Urban settlements

Land use: Council Reserve

Zoning: Coastal Conservation (incorporates Council Reserve and foreshore).

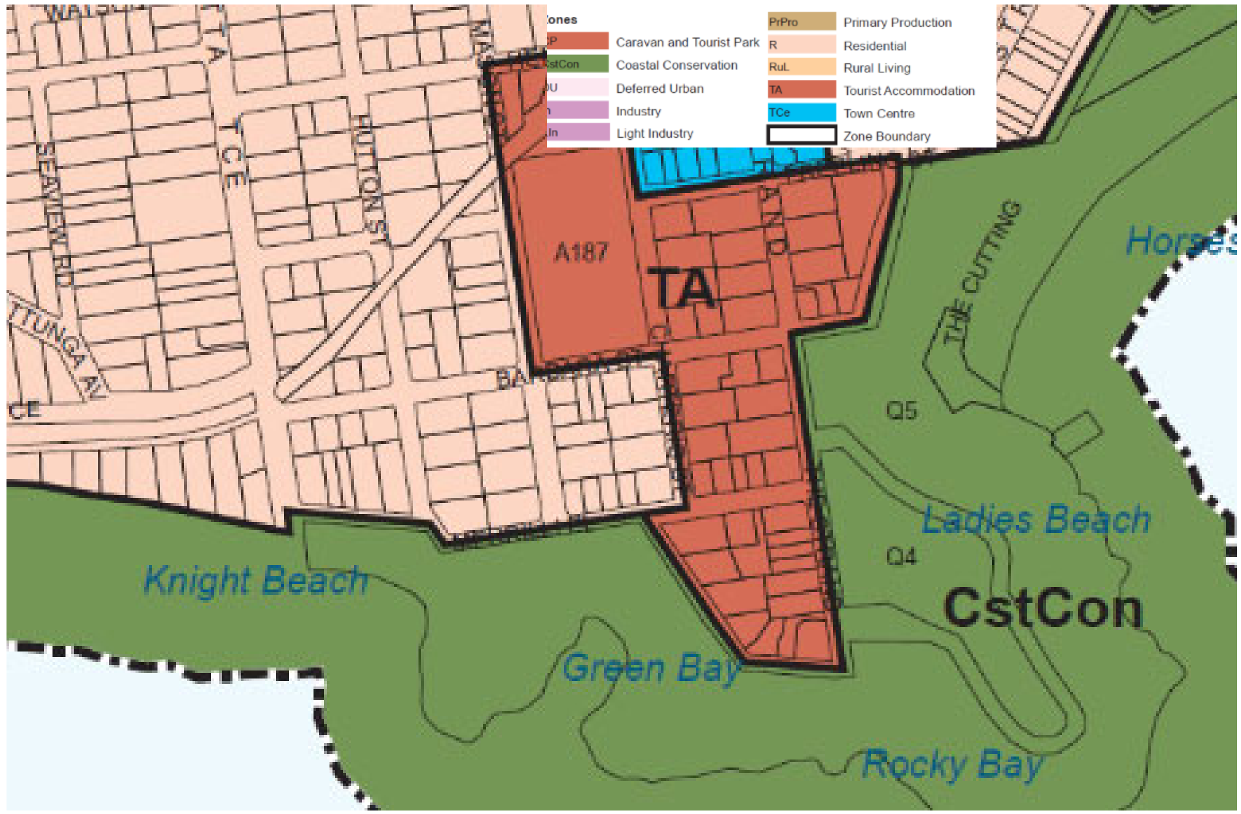
Policy Area: Nil

Precinct: Nil

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

Land use behind: Residential and Tourist Accommodation

(Source: Alexandrina Council Development Plan, 2019)



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).

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 SF8-2

Green Bay

Overview

SA Classification

Department of Environment and Water classification line depicted relates to the following classifications:

Shoreline class

Not Assigned

Sand rating
Bedrock Platform

Exposure:
Exposed (but the back of the bay is moderate due to rocky outcrops)

Wave:
Moderate to high

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4. Current exposure- storm event

Storm event

Map SF8-2

Green Bay

Event: 21-22 Nov 2018

Assessment

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

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

Analysis within SF8-2 of seaweed strands and other markers post event demonstrated wave effects were ~1.20m above tide gauge level. Wave set-up 0.3, wave runup 0.9. The modelling effectively replicates the event.

The impact in Cell 8-2 was nil.

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4. Current exposure – storm surge

Storm surge

Map SF8-2

Green Bay

Current risk:

1 in 100-year event

Assessment

The current 1 in 100-year 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 0.9m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the earthen escarpment. However boulders and cobbles at the base of the embankment would dissipate some of the energy.

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4. Current exposure – monthly high water

Monthly high water

Map SF8-2

Green Bay

Current risk:

Monthly high water

Assessment

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

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Green Bay. 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 0.6m is shown as light blue shading.

The current impact on beach and backshore is low.

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4. Current exposure – storm water

Storm water

Map SF8-2

Green Bay

Current risk:

Storm water

Assessment

No storm water piping drains into Green Bay.

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4. Current exposure - erosion

Erosion

Map SF8-2

Green Bay

Current risk:

Erosion outlook

Assessment

A comparison of historical aerial photographs supports the view that the base of the embankment has remained unchanged since 1949.

Rocky outcrops in the bay dissipate wave energy. Wave effects on 21 November 2018 were 0.7m lower than Knight Beach adjacent.

The current 1 in 100 ARI event does impact the rear of the bay but these are rare events.

Routine tides are not likely to be having any significant impact on the rear of the bay.

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Key Points:

Routine tides (1 every 1 or 2 months) is likely to be making limited impact at rear of bay.

1 in 100 ARI would impact the back of the bay, but these are rare events.

Rocks in Green Bay dissipate wave energy: wave effects on 21 November were 1.20m while in comparison, wave effects were 1.90m at Knights Beach adjacent.

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 SF8-2

Green Bay

2050 risk:

1 in 100-year event

Assessment

The1 in 100-year ARI event risk 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 0.9m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the escarpment. The impact would be considerable.

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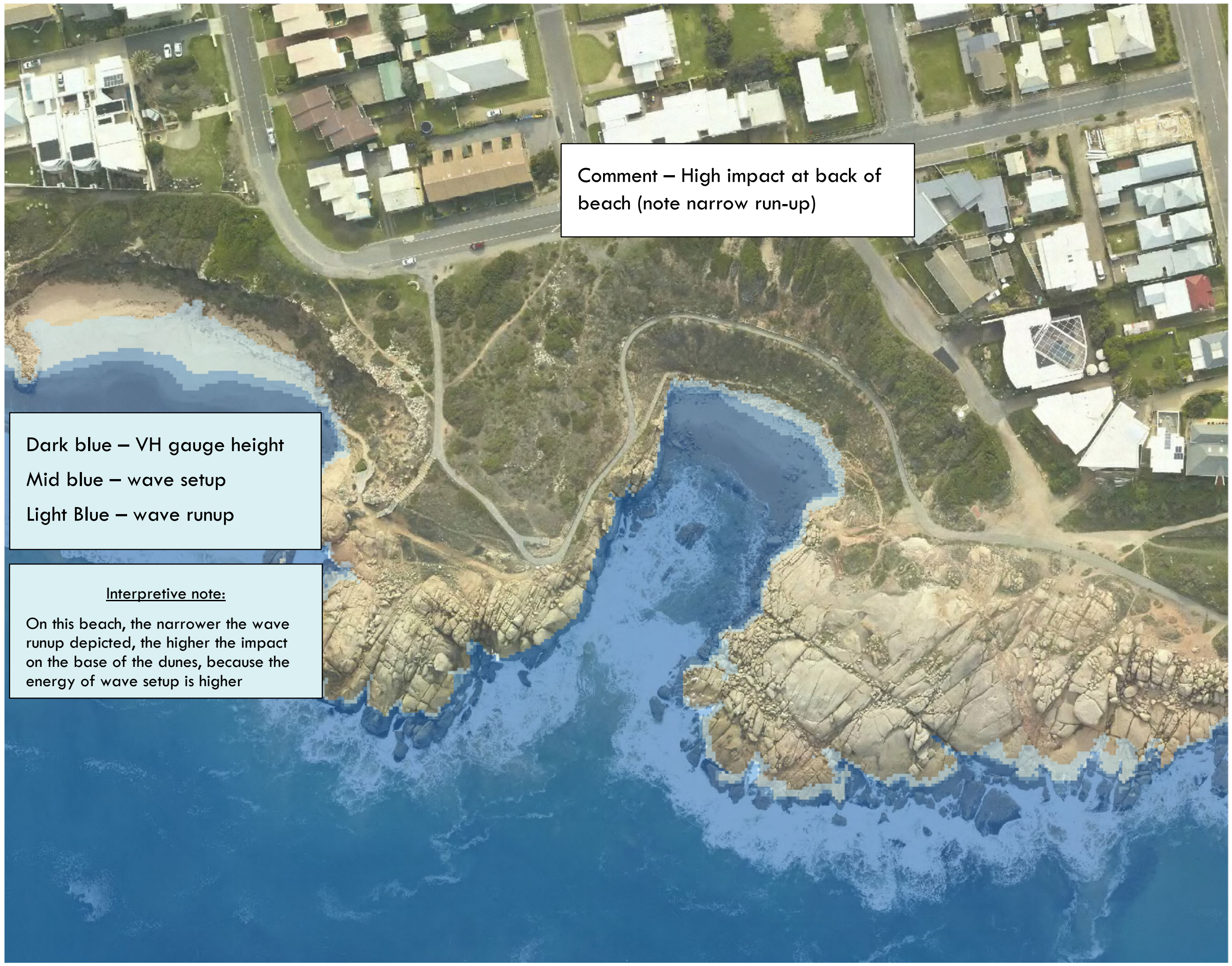

5. Future exposure – storm surge (2100)

Storm surge

Map SF8-2

Green Bay

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 0.9m 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 escarpment with significant impact.

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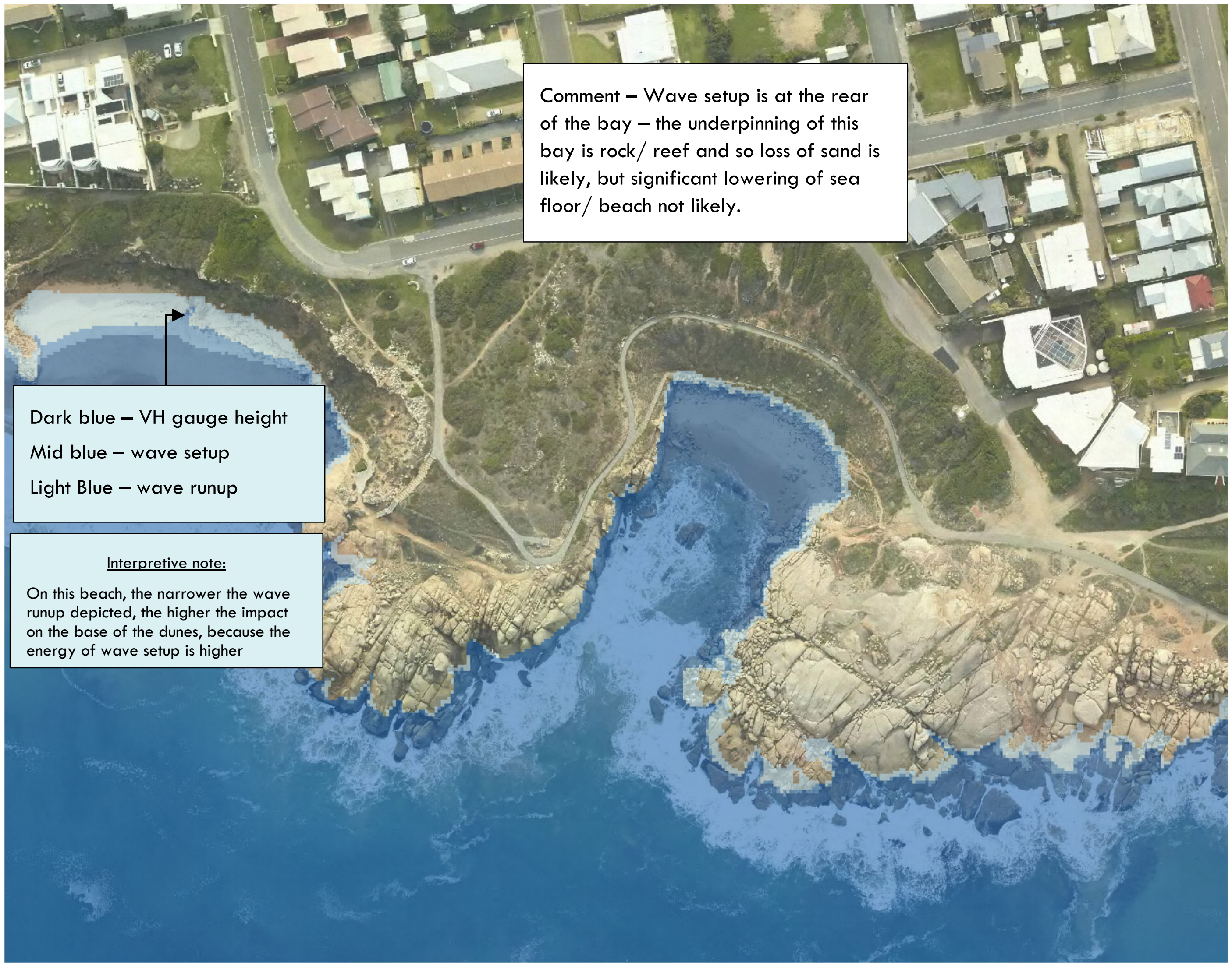

5. Future exposure – monthly high water (2050)

Monthly high water

Map SF8-2

Green Bay

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 at Green Bay. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of the backshore 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 0.6m has been included.

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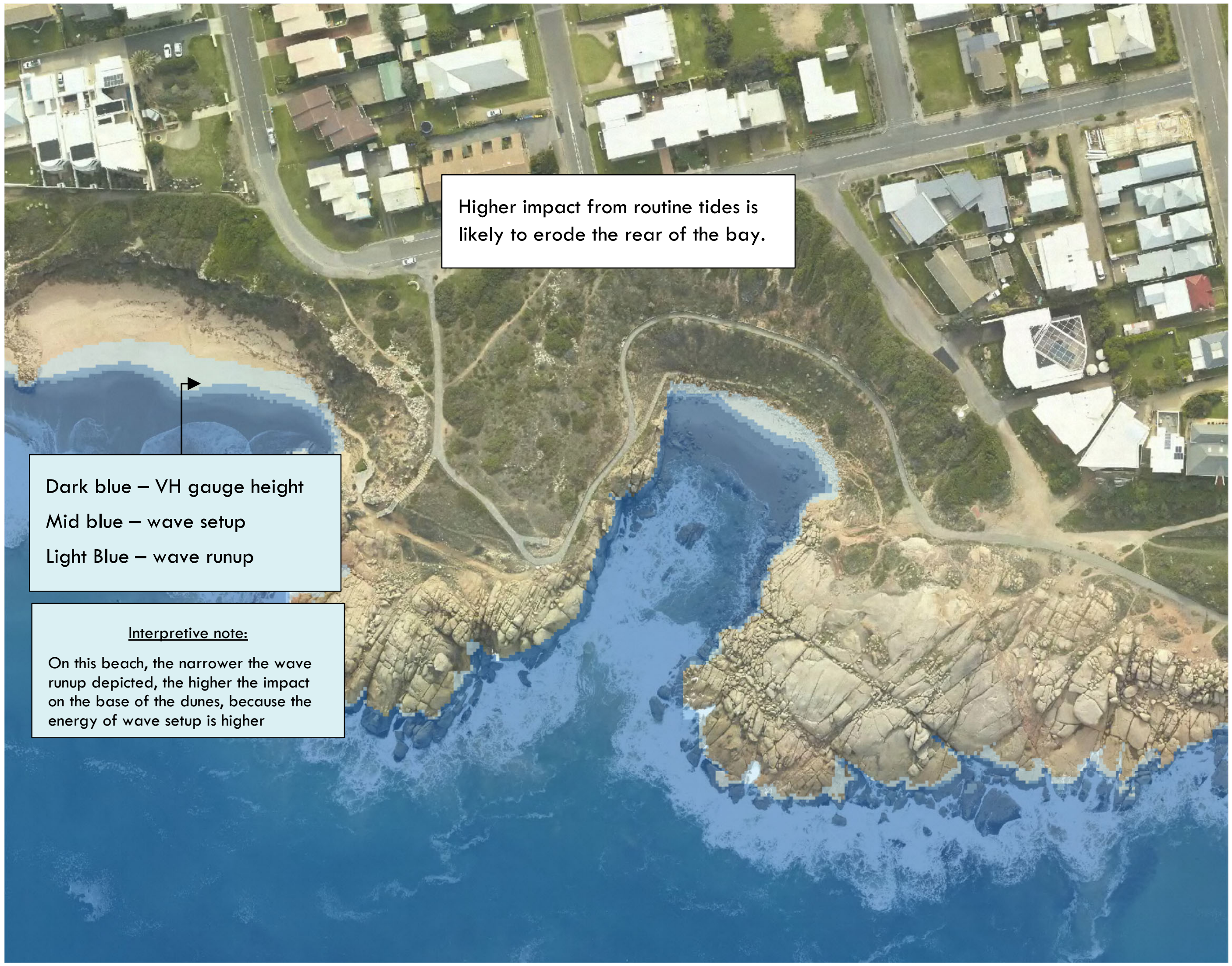

5. Future exposure – monthly high water (2100)

Monthly high water

Map SF8-2

Green Bay

2100 risk:

Monthly high water

Assessment

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

Routine tidal action would significantly undermine the base of the escarpment.

The event modelled:

Average high tide	1.50m
Plus sea level rise	1.00
	2.50m
Wave set up	0.20m
Total risk	2.80m

Wave run-up of 0.6m has been included.

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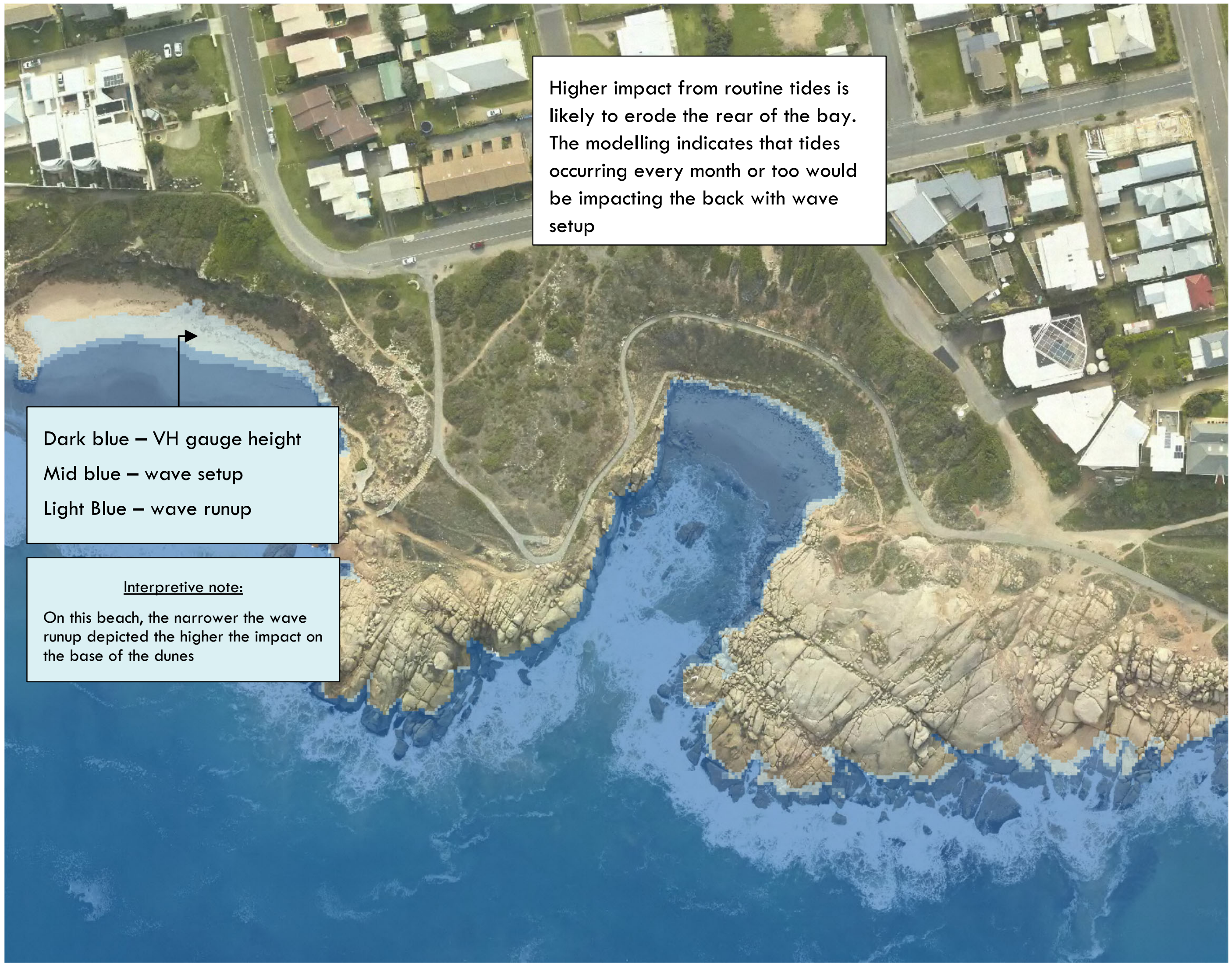

5. Future exposure - erosion

Future Exposure

Map SF8-2

Green Bay

2100 risk:

Erosion outlook

Assessment

No formal evaluation methodologies exist to estimate the rate of erosion at the rear of Green Bay.

Modelling demonstrates that should sea levels rise as projected the embankment at the rear of the bay will come under increasing pressure from impacts of the sea.

The boulders and cobbles at the rear of the bay are unlikely to be sufficient to prevent the undermining of the embankment.

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6. Inherent hazard risk assessment

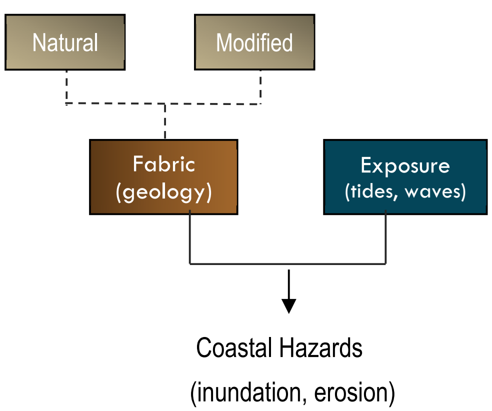
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

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

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

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



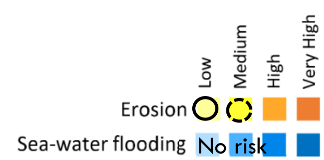
Inundation hazard risk

Due to the slope and elevation of backshores, there is no inundation hazard risk for Green Bay.

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (See Main Report)	Bedrock platform, backshore 1: steeply sloping, backshore 2: soft rock rising to 26m 300m inland. Note – some sand is present on the beach but the predominant form is rock.	Low
Should this rating be amended due to human intervention such as a protection item? If so, how?	No, human intervention is limited to installation of walking paths	Low
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'moderate'.	Low
Assess any impact on backshore 1	Minimal action of the sea upon backshore 1	Low
Assess any influence from Benthic	Offshore reefs: with increasing depths of water exposure may increase.	Low-medium
Assess the sediment balance	Green is essentially a closed cell with limited amount of sand moving to the east.	Low-medium
Assess any other factors that may warrant a change of inherent hazard risk.	Granite outcrops on either side of the bay and within the bay reduce the exposure	Low-medium

Inherent Hazard Risk – Green Bay



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 SF8-2

Green Bay

Assets at risk

Notes

Within Green Bay the only asset at risk is the formalised walking trail constructed halfway up the embankment. If the base of the embankment was eroded, the slope of the embankment would increase and become increasingly unstable.

In the much longer term (ie in the latter part of this century or the next), if the embankment become unstable and the top of the escarpment receded, then Merrilli Place and the Esplanade would also come under threat.

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7b. Assets at risk (private)

Private Assets

Map SF8-2

Green Bay

Assets at risk

Notes

Private assets (houses) are positioned behind council roads. Therefore, as long as the roads are not impacted, private assets will remain protected.

It is difficult to imagine a scenario where private assets will come under threat, but this assumes that the base of the escarpment would also be given protection if required.

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7c. Safety of people

The assessment conducted within this project is only related to how impacts of the sea may increase the risk to people accessing the area. It is not related to any risks that the beach and backshore currently pose to the safety of people. This assessment remains with Council in its normal operation of risk.

Some potential risks include but should not be regarded as exhaustive:

- Increased wave action is likely within the bay over time (especially post 2050). People on the beach area and surrounding rocks may be more vulnerable to impact from waves.

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 would irreversibly change the nature of that ecosystem on a large scale.

The geological layout of Green Bay indicates 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.

Specific Risk Assessment

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

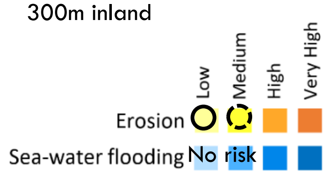
- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

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

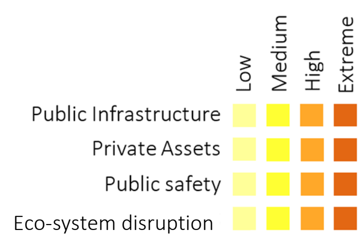
The risk assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The assessment utilises the risk assessment framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: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

Inherent Hazard Rating

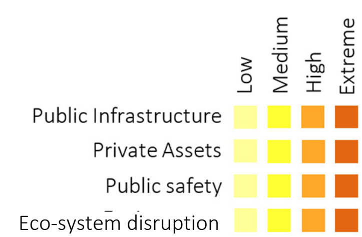
Rock platform backed by soft rock shores rising to 26m AHD 300m inland



Erosion Hazard Rating
(Current outlook- 2020)



Erosion Hazard Rating
(Future outlook-2100)



Yet to be assigned

8. Risk Assessment

Erosion assessment

Green Bay (SF8-2)

Risk identification: Erosion is currently, or may in the future, threaten the backshore of Green Bay

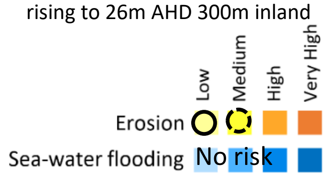
Coastal processes	Green Bay is categorised as a rocky beach, underpinned by reef, and bordered by granite headlands. The beach is backed by earthen embankment which rises from 2.5m AHD at the beach to ~20mAHD. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach has not, and is currently not being impacted by actions of the sea. Analysis of future regimes suggests that this may change.

Are any strategies employed to mitigate the risk? Nil

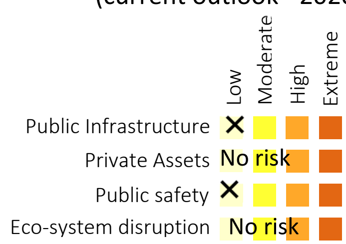
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Merrilli Place and The Esplanade are roads situated above Green Bay. A formalised walking path has been constructed half way up the embankment.	current	*Rare*	*Moderate*	low
		2100	*Possible*	*Significant*	high
Private assets	Private assets are positioned behind council roads. Unlikely that erosion will occur to such an extent that private assets are impacted over the course of 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*	*Insignificant*	low
		2100	*Rare*	*Significant*	moderate
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

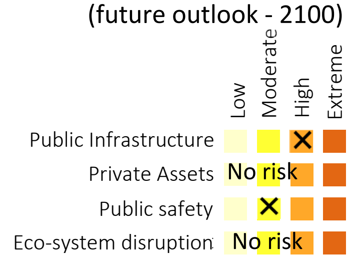
Pocket beach underpinned by rock and backed by soft rock shores rising to 26m AHD 300m inland



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	Green Bay has shown no evidence of erosion to the backshore since 1949. Scenario modelling suggests that only extreme events may reach 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. If this undermining does occur, then the slope of the escarpment will continue to increase and become unstable. Long term instability will likely result in the loss of the walking path in the centre of the embankment and a recession of the top of the escarpment towards the roads (Merrilli Place and The Esplanade).

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 that 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.

GREEN BAY

The modelling and assessment indicate that the backshore of Green Bay is currently not under threat from actions of the sea.

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

To protect private and public infrastructure over time, a **hold the line** methodology is recommended.

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

Should increased impacts be observed, then protection options will need to be considered, such as sandbags or rock revetment.

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

Hold the line

Map SF8-2

Green Bay

Adaptation proposal

Approach: incremental

Monitor

The base of the escarpment should be regularly monitored, especially after storm events. (See end of Crockery Bay for explanation of monitoring strategies)

Respond – hold the line

Should increase impact to the base of the escarpment occur, then protection options should be considered – rock revetment, sand bags (or similar).

Should erosion begin to impact the base of the escarpment, the most effective way to protect the rear of the beach would be to install rock revetment. However, access to the beach would be problematic and a crane would require the reach of 50m to deliver rock to the beach. An alternative would be large sand bags. A final alternative may be to locate rocks from the bay itself.

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Monitoring overview

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'

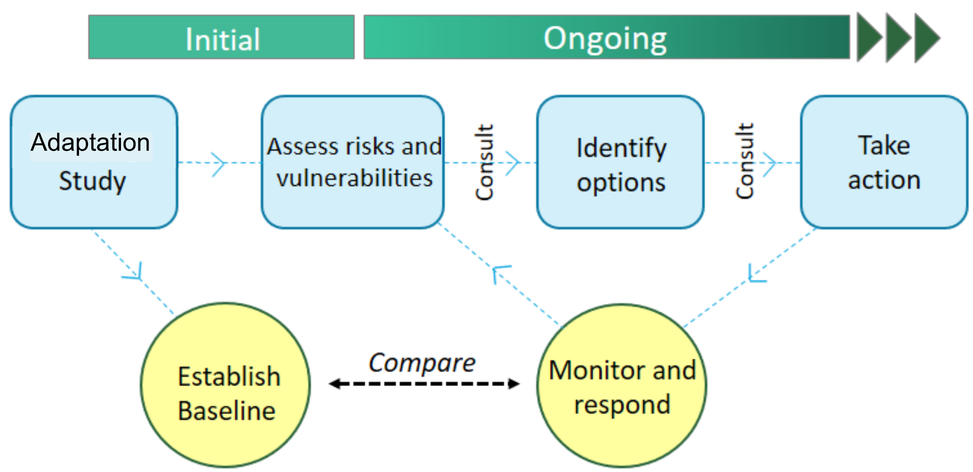
Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

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 or other sand monitoring techniques.

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

Coastal Adaptation Model

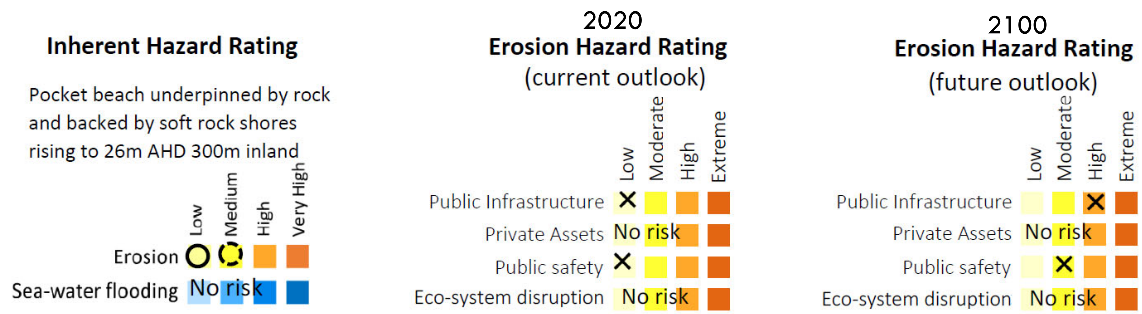


Integrated Coasts (2017)

Adaptation proposal: Green Bay (Cell SF8-2)

Coastal processes	Green Bay is categorised as a rocky beach, underpinned by reef, and bordered by granite headlands. The beach is backed by earthen embankment which rises from 2.5m AHD at the beach to ~20mAHD. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach has not, and is currently not being impacted by actions of the sea. Analysis of future regimes suggests that this may change.

Risk outlook



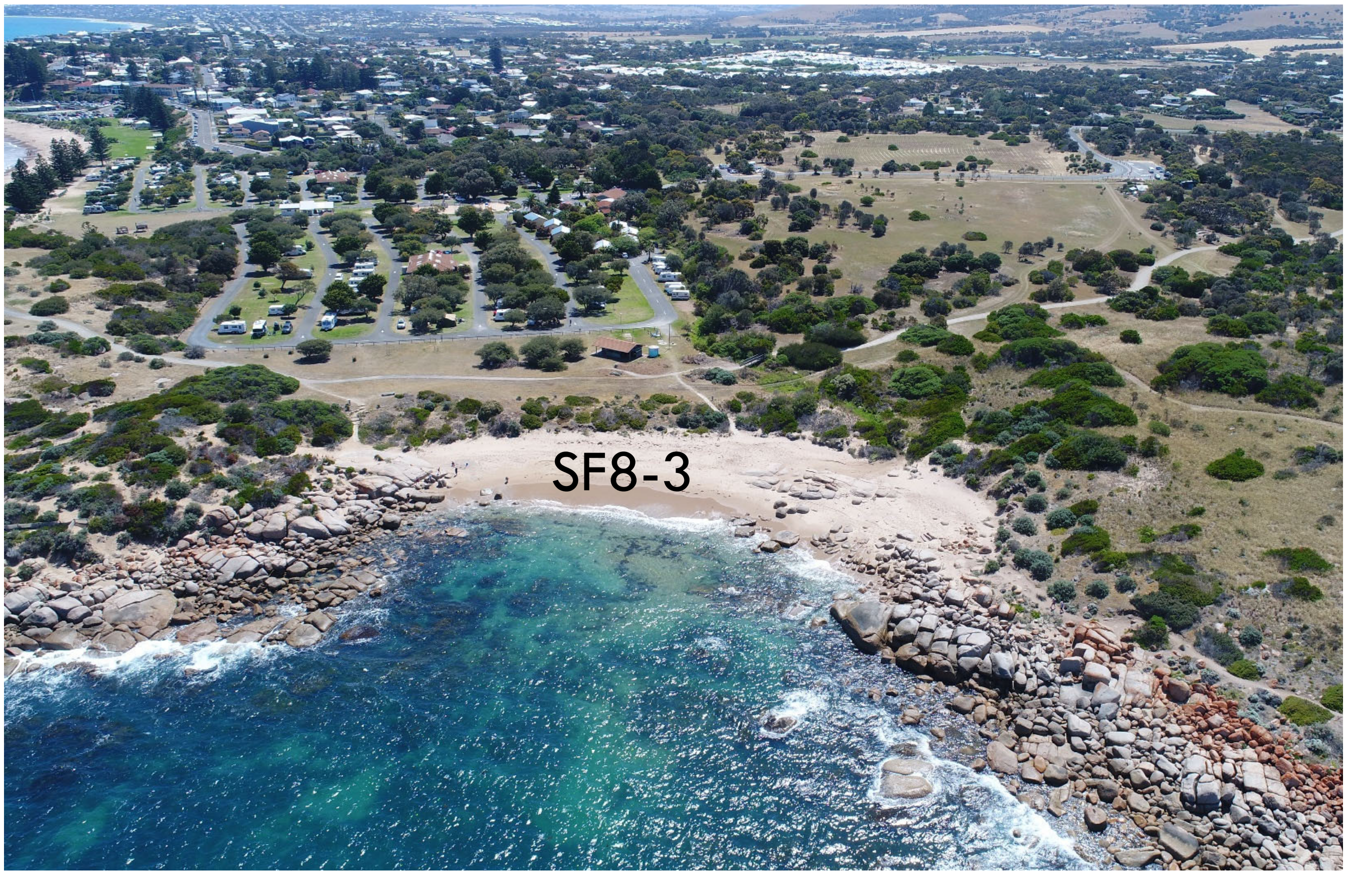
Adaptation overview:

The long-term strategy for Green Bay is to hold the line and protect the base of the escarpment. This strategy is likely to be effective in the geological setting in which Green Bay is located. 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.

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Green Bay Cell SF8-2	Incremental (monitor and respond)	Monitor [no immediate works are likely to be required]	Monitor [protection may be required by 2050, or the latter part of this century]	Hold the line: protect backshore [Public infrastructure is positioned behind Green Bay]	Engineering: rock revetment or similar at base of escarpment	Storm impacts on backshore

CROCKERY BAY



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:

- Overview of the current coastal fabric
- Changes to shoreline over seventy years
- Human intervention (coastal modifiers)

2. Coastal fabric - natural

Overview

Map: SF8-3

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cell: Crockery Bay

Form

Beach
Coarse sand (with shingles)

Backshores

Backshore 1: Low embankment. This is likely to be imported fill at the time of the construction of the caravan park.

Backshore 2: Behind the embankment is likely to be some imported fill, but previous to this it was a sand dune.

See settlement history Port Elliot.

Bathymetry

Overall slope of ocean floor:
-10m ~500m from beach (overall slope ratio 1:50).

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2. Coastal fabric - natural

Overview

Map: SF8-3

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cell: Crockery Bay

Geology

Geology

The map depicts Crockery Bay as underpinned by Encounter Bay Granite.

Age: Cambrian- Orovician

Backshore 2 (caravan park)

Semaphore Sand (but modified by caravan park)

Age: Holocene

Figure opposite sourced from www.sarig.gov.au

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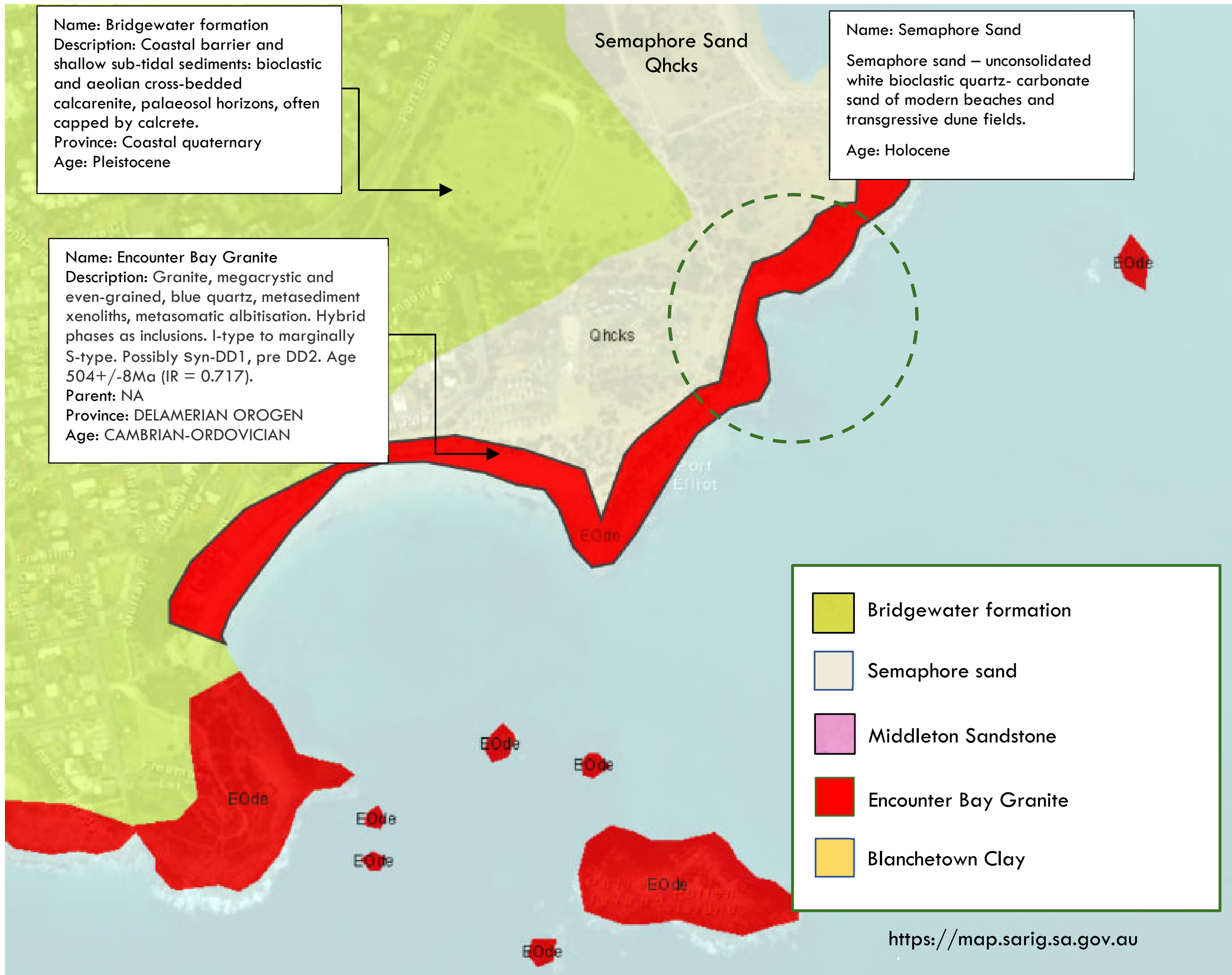


2. Coastal fabric - natural

Overview

Map: SF8-3

Secondary Cell: Fleurieu SA Coast

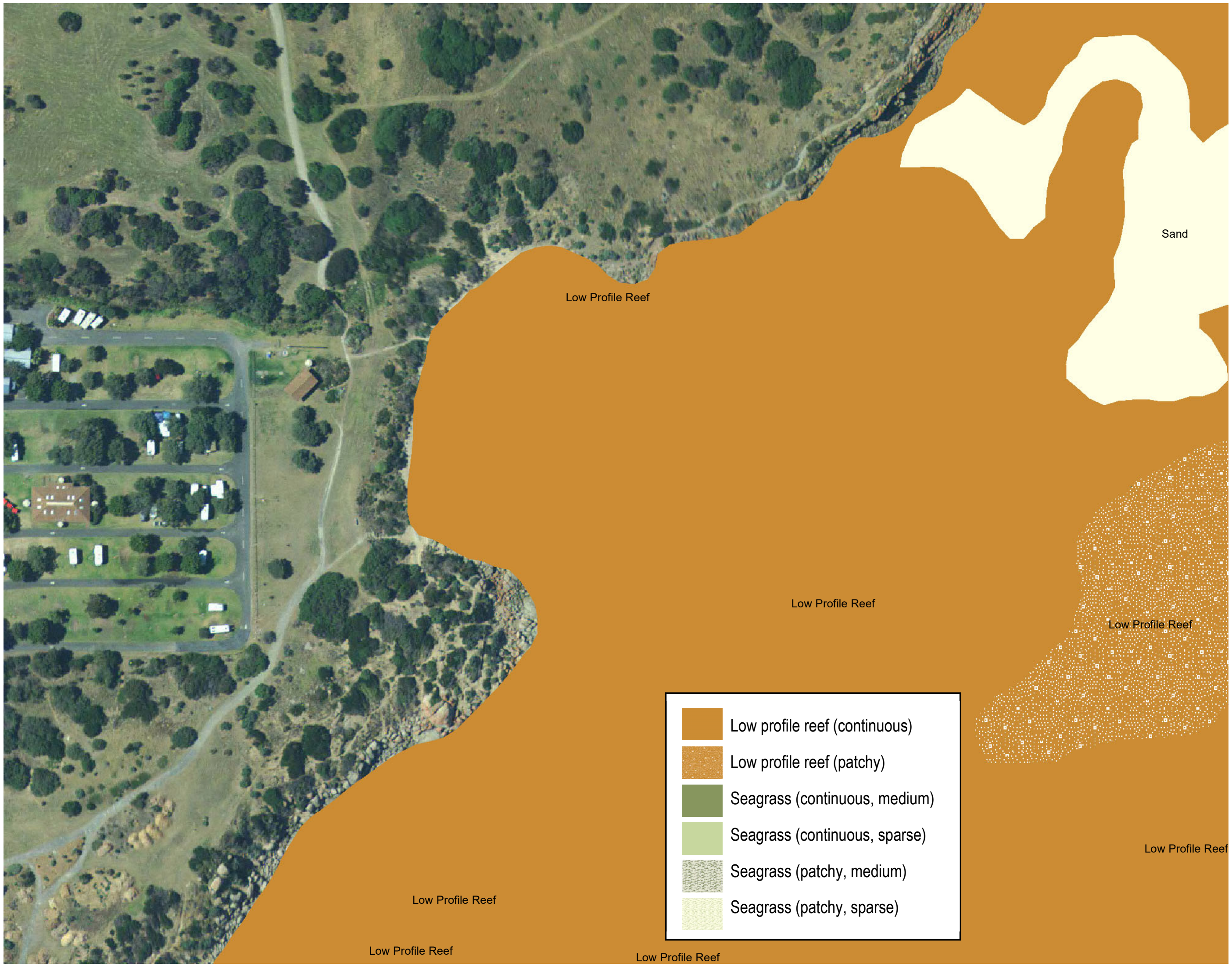
Tertiary Cell: Port Elliot

Minor cell: Crockery Bay

Benthic

Benthic

The surf zone, intertidal zone and sub-tidal zone are dominated by low profile reef.



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2. Coastal fabric - natural

Overview

Map: SF8-3

Secondary Cell: Fleurieu SA Coast

Tertiary Cell: Port Elliot

Minor cell: Green Bay

Classification

SA Classification
Nature Maps coastal line indicates the following coastal characteristics:

Shoreline class
Not applied

Sand rating
Bedrock Platform

Exposure:
Moderate

Wave:
Moderate

Backshore 1:
Rocky/sandy beach, earthen embankment.

Backshore 2:

Semaphore Sand

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2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Map SF8-3

Crockery Bay

Historical comparison

1949

Assessment

The lines on this map:

Aerial photograph from 1949.

The dotted line indicates the location of the base of the backshore in 2018.

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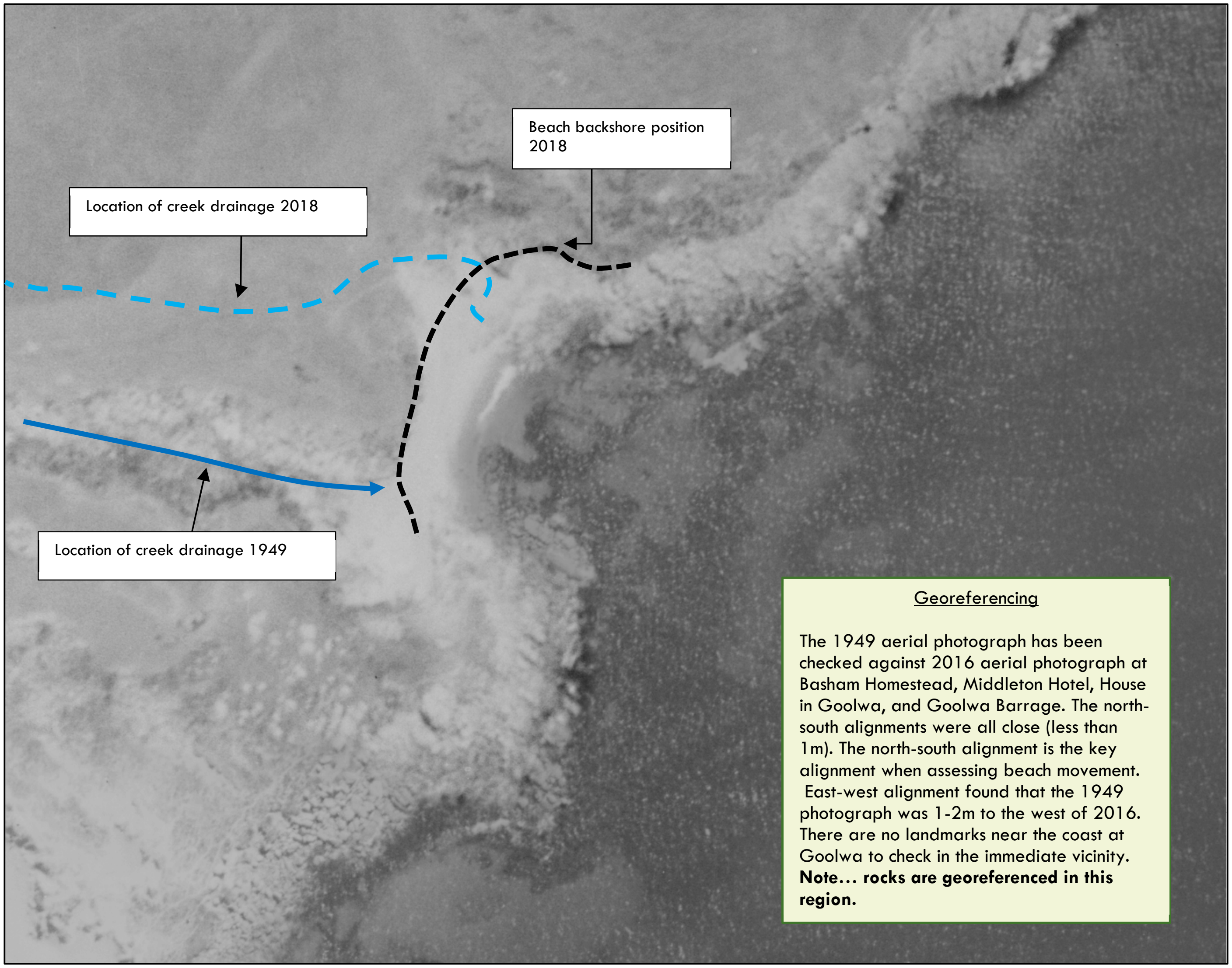

Georeferencing

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

2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Map SF8-3

Crockery Bay

Historical comparison

2006

Assessment

It is likely that when the caravan park was installed that the drainage creek was moved further north and fill has been imported into the area behind Crockery Bay.

Therefore, the rear of the bay now is an earthen embankment.

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2. Coastal Fabric - Natural

MEDIUM TERM CHANGES

Map SF8-3

Crockery Bay

Historical comparison

2018

Assessment

The position of the backshore has been consolidated since 1949. This is likely to do with human intervention in the formation of the caravan park in the 1980s.

It is likely that when the caravan park was installed that the drainage creek was moved further north and fill has been imported into the area behind Crockery Bay.

Therefore, the rear of the bay now is an earthen embankment.

Note: dotted line indicates position of backshore in 2018.

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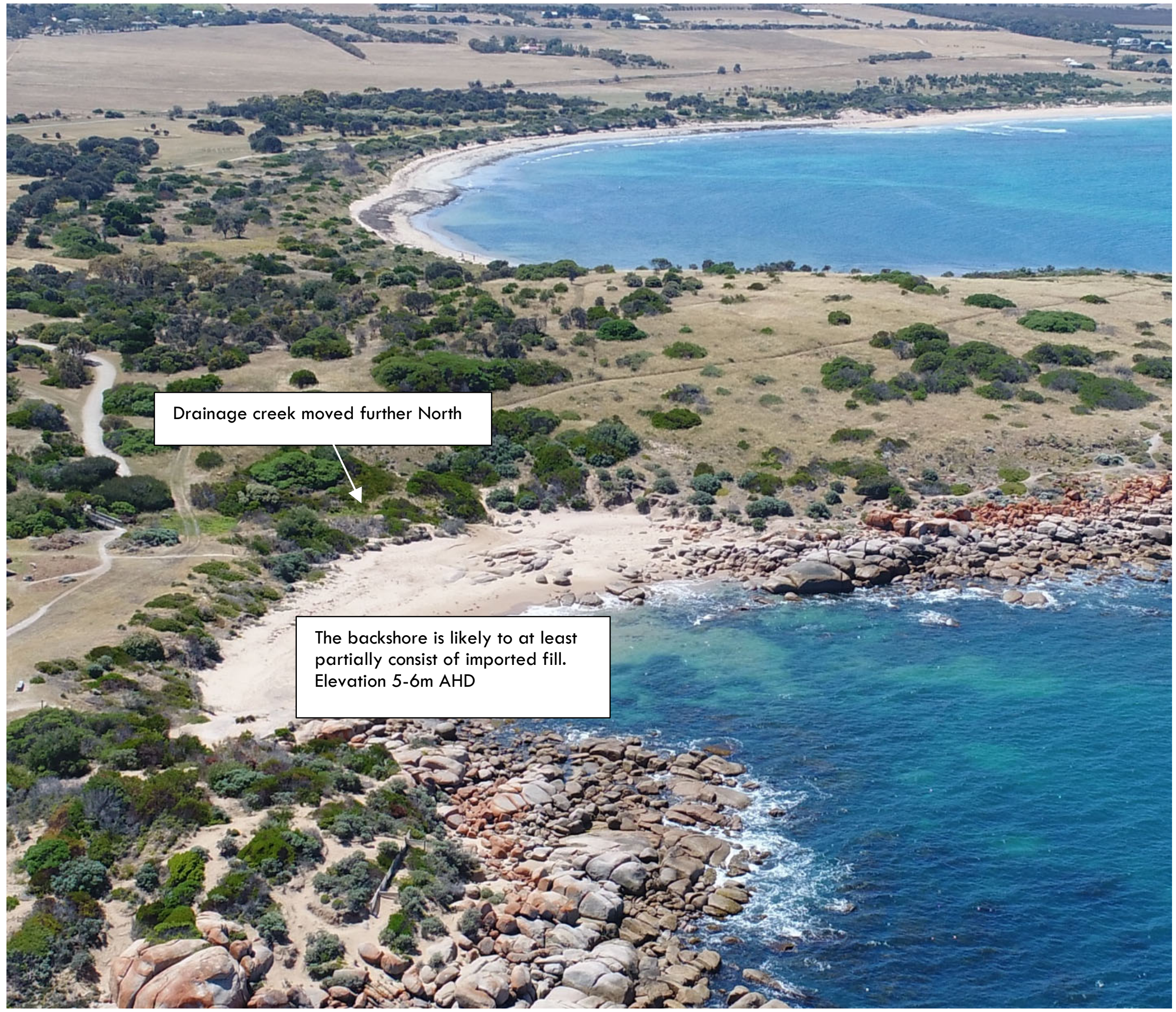
3. Coastal fabric - modified

HUMAN INTERVENTION

Protection items and/or infrastructure

The line of the creek has changed – this was likely changed in the 1980s when the caravan park was formed to allow for greater site area.

It is likely that the backshore of the bay has been also consolidated, probably at the same time.



3. Coastal fabric - modified

HUMAN INTERVENTION

Urban settlement

Land use: Council Reserve

Zoning: Coastal Conservation (incorporates Council Reserve and foreshore).

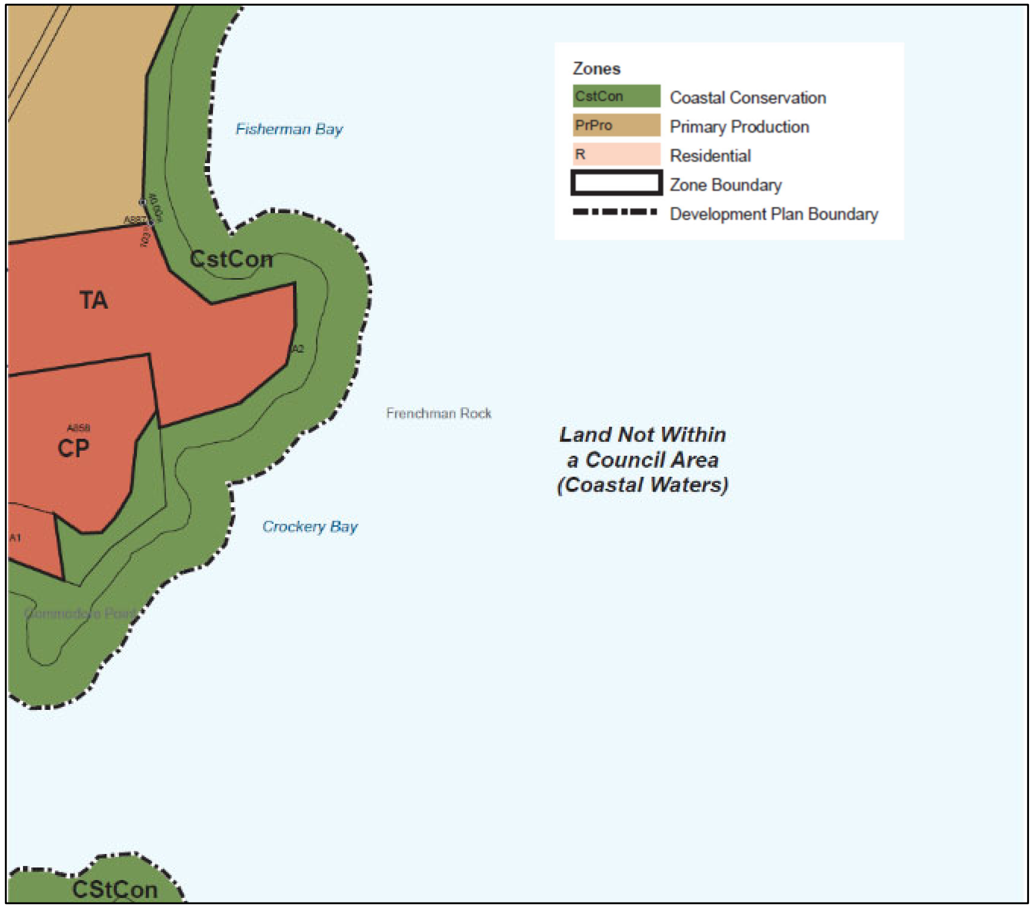
Policy Area: Nil

Precinct: Nil

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

Land use behind: Caravan Park and Tourist Accommodation.

(Source: Alexandrina Council Development Plan, 2019)



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).

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 SF8-3

Crockery Bay

Overview

SA Classification
Nature Maps line on map represents following coastal characteristics.

Shoreline class
NA

Sand rating
Bedrock Platform

Exposure:
Moderate

Wave:
Moderate

Backshore 1:
Is likely to be at least partially imported fill.

Backshore 2:
Semaphore sand

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4. Current exposure- storm event

Recent event

Map SF8-3

Crockery Bay

Event: 21-22 Nov 2018

Assessment

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

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

Analysis within SF8-3 of seaweed strands and other markers post event demonstrated wave effects were ~1.30m above tide gauge level. Wave set-up 0.3, wave runup 1.0. The modelling effectively replicates the event (see also separate report).

The impact in Cell 8-3 was nil.

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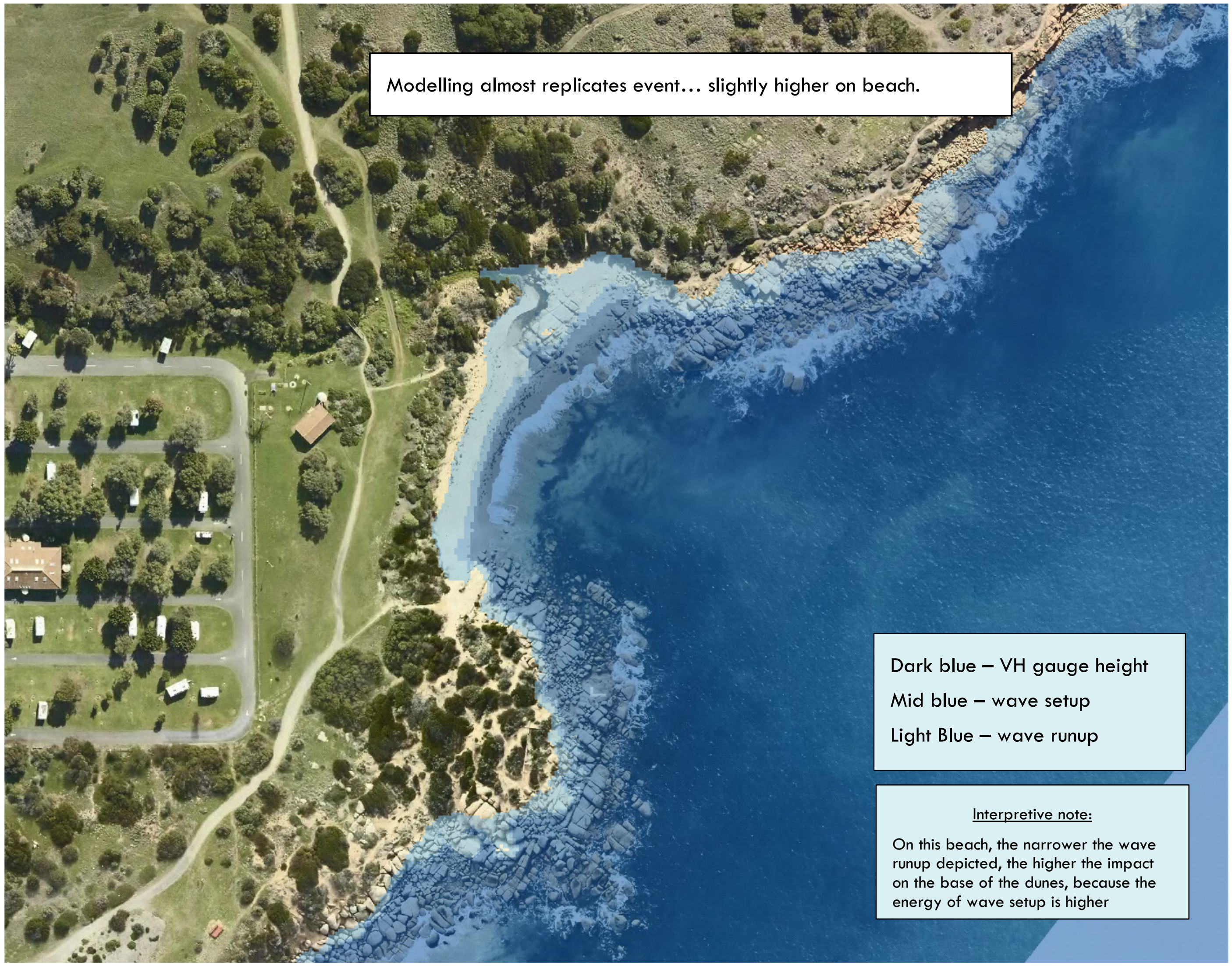

4. Current exposure – storm surge

Storm surge

Map SF8-3

Crockery Bay

Current risk:

1 in 100-year event risk

Assessment

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

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

Wave run-up is 1.0m and depicted in light blue.

In the context of Crockery Bay this event is likely to have minimal impact.

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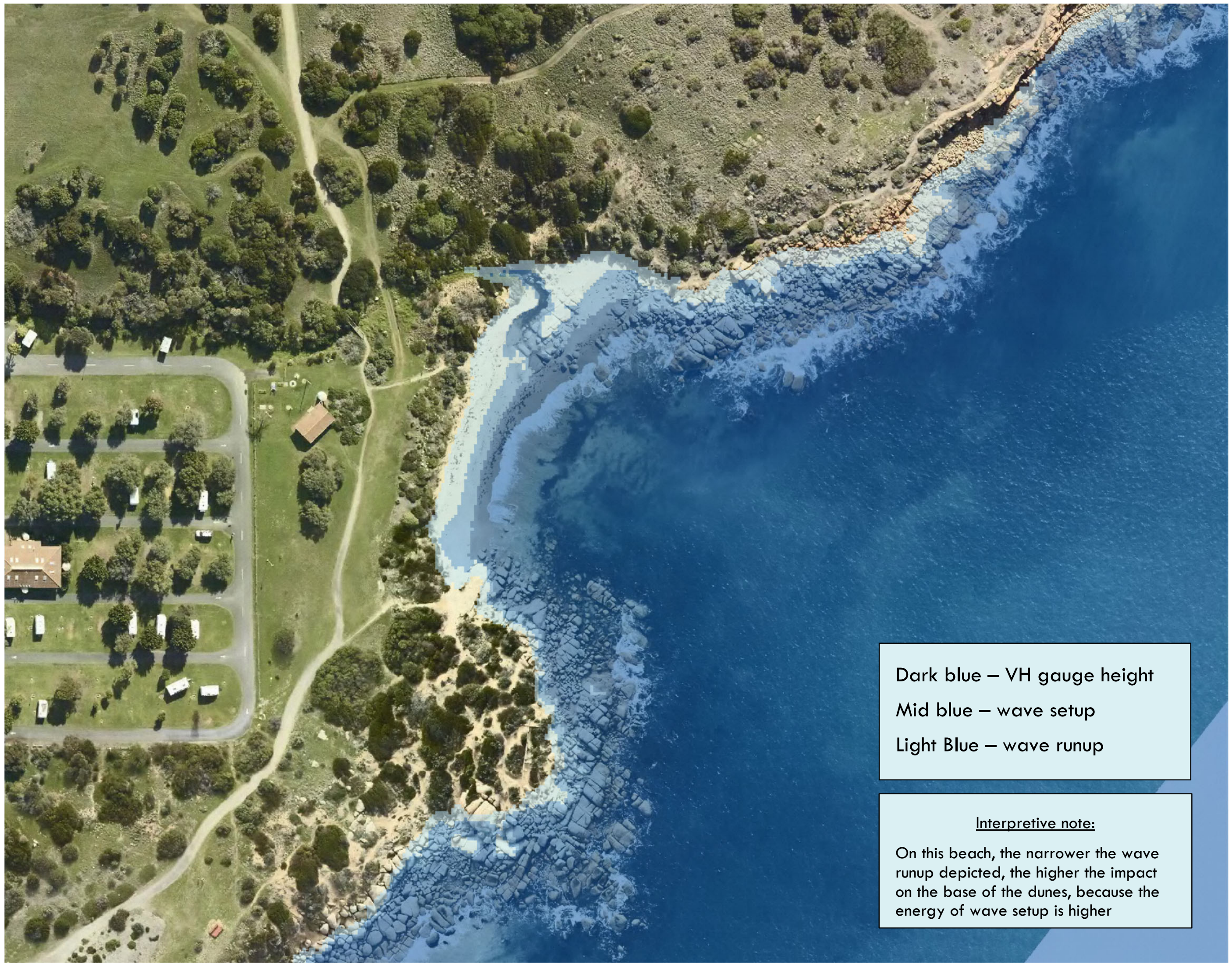

4. Current exposure – monthly high water

Monthly high water

Map SF8-3

Crockery Bay

Current risk:

Monthly high water

Assessment

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

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Crockery Bay. 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 shown as light blue shading.

The current impact on beach and backshore is low.

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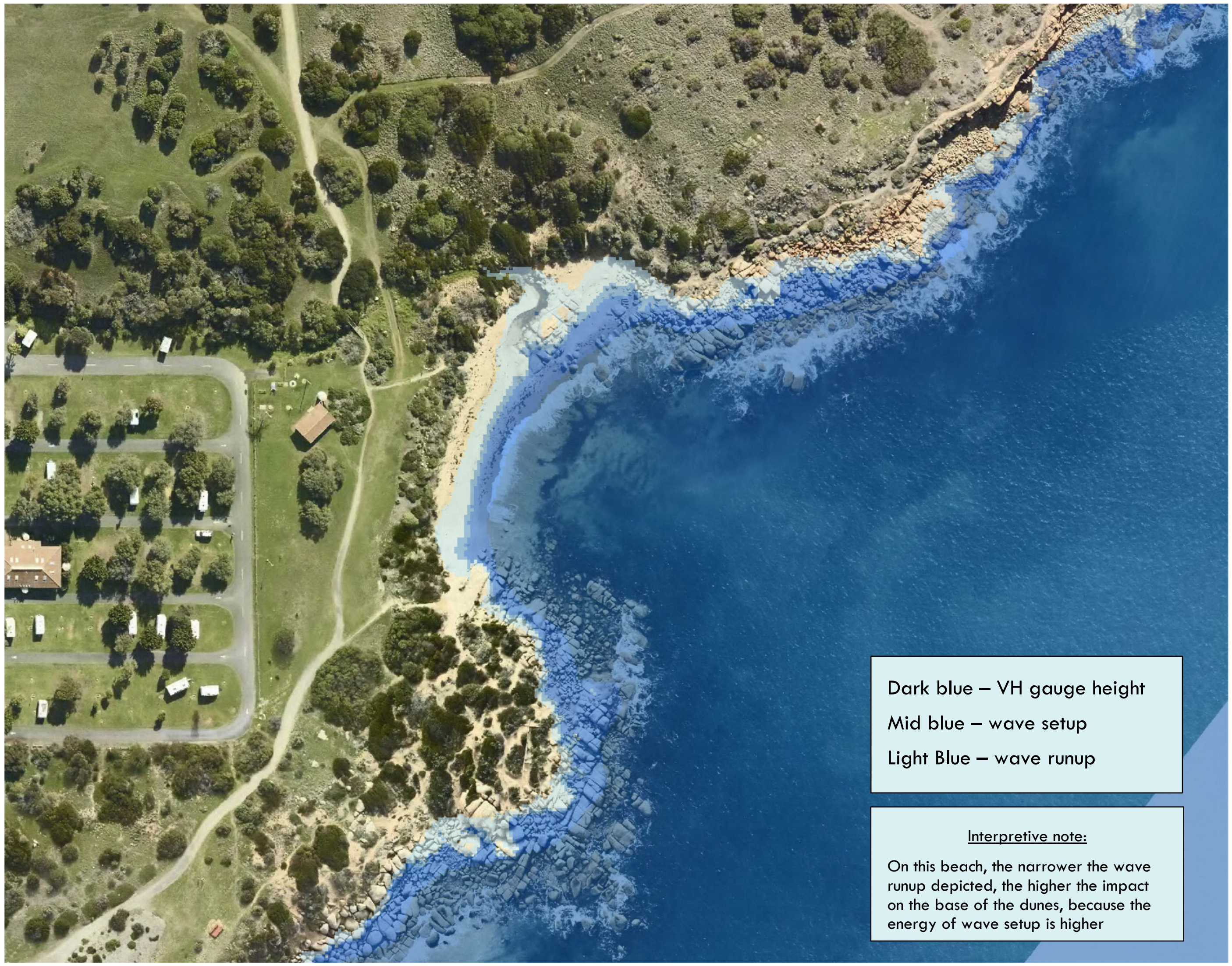

4. Current exposure – storm water

Storm water

Map SF8-3

Crockery Bay

Current risk:

Storm water

Assessment

Storm water drains into the creek and drains to the sea. The storm water drains to a rocky section of beach with minimal impact upon the beach

Storm water from the caravan park is draining into the creek (also possibly from higher up). Storm water flows on to the beach at location of rocky outcrops and appears to be effectively dissipated.

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4. Current exposure - erosion

Erosion

Map SF8-3

Crockery Bay

Current risk:

Erosion outlook

Assessment

A comparison of historical aerial photographs demonstrates that some modification has been made to the backshore (imported fill to form embankment).

The storm event of 21-22 November did not impact the back shore.

1 in 100 ARI events may impact the rear of the beach, but the energy of these would also be dissipated on rocky outcrops and boulders.

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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 SF8-3

Crockery Bay

2050 risk:

1 in 100-year event risk

Assessment

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

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.30
Risk	2.35m AHD

Wave run-up of 1.00m has been depicted.

Scenario modelling demonstrates that some impact would occur on the earthen embankment, especially on the northern section.

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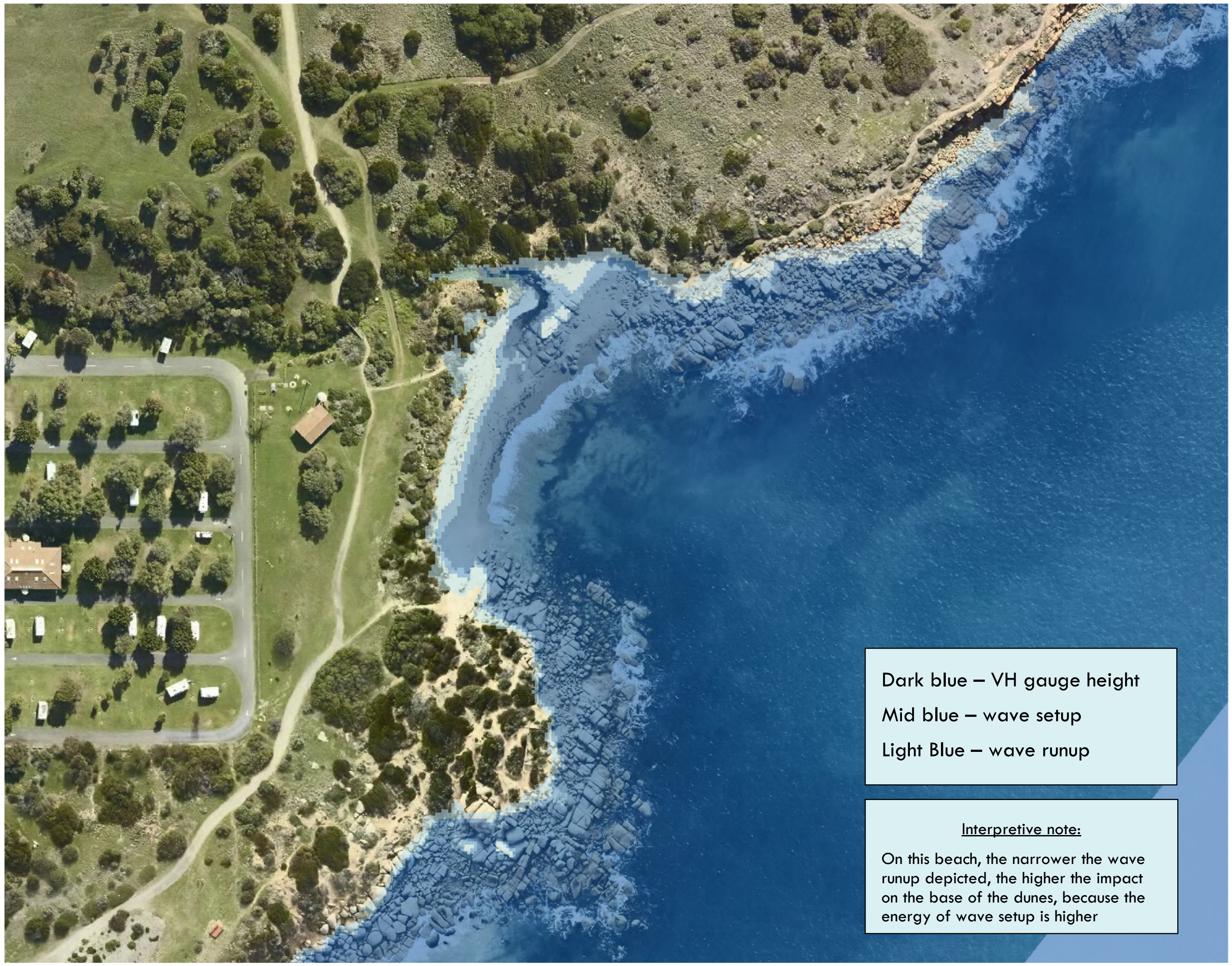

5. Future exposure – storm surge (2100)

Storm surge

Map SF8-3

Crockery Bay

2100 risk:

1 in 100-year event risk

Assessment

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

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.30
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 embankment, and overtopping would be severe. Erosion extreme.

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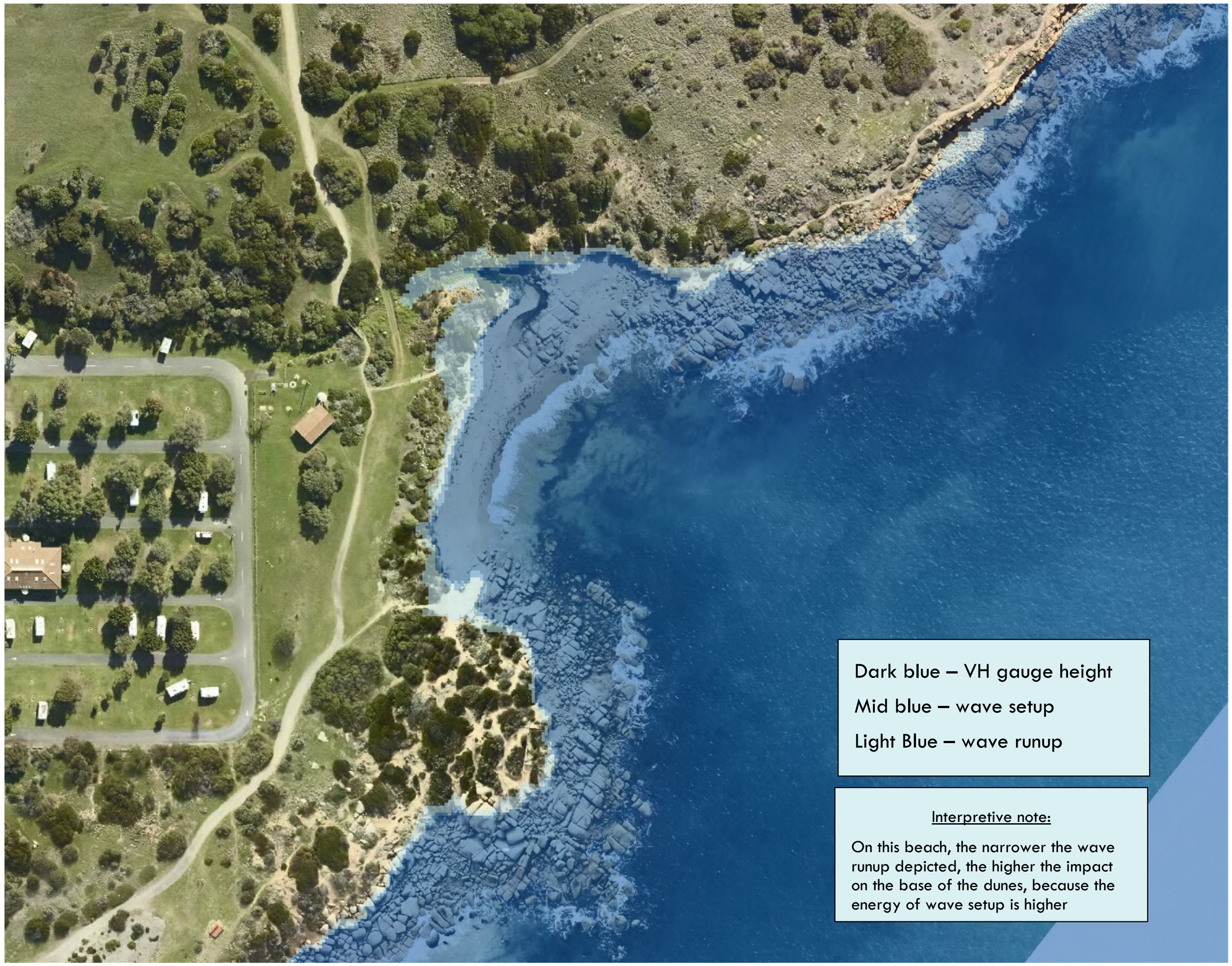

5. Future exposure – monthly high water (2050)

Monthly high water

Map SF8-3

Crockery Bay

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 at Crockery Bay.

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. The impact of monthly high water is likely to be minimal by 2050.

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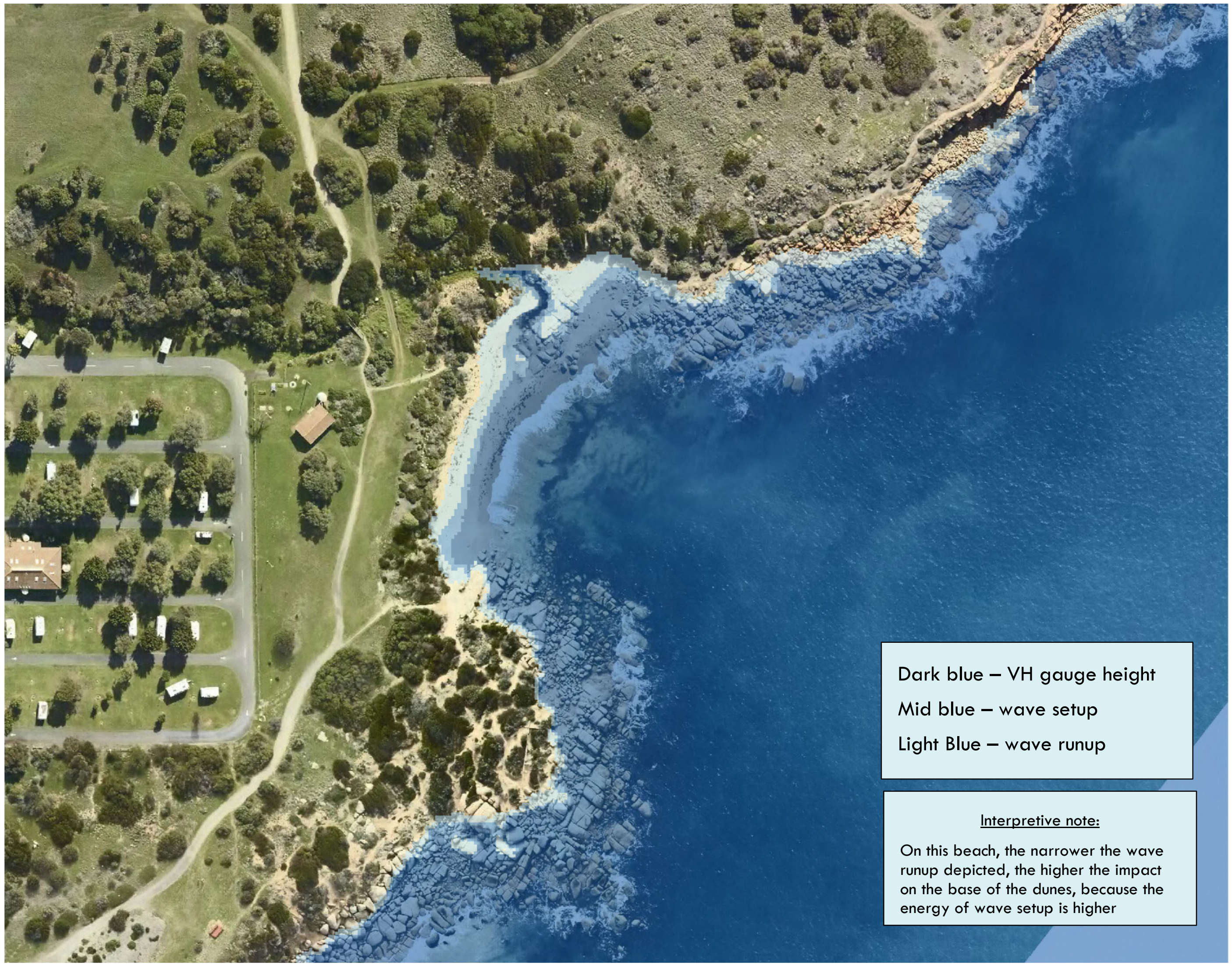

5. Future exposure – monthly high water (2100)

Monthly high water

Map SF3-8

Crockery Bay

2100 risk:

Monthly high water

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Crockery Bay.

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	0.20m
Total risk	2.70m

Wave run-up of 0.7m has been included.

Monthly high water is likely to have an ongoing impact on the backshore.

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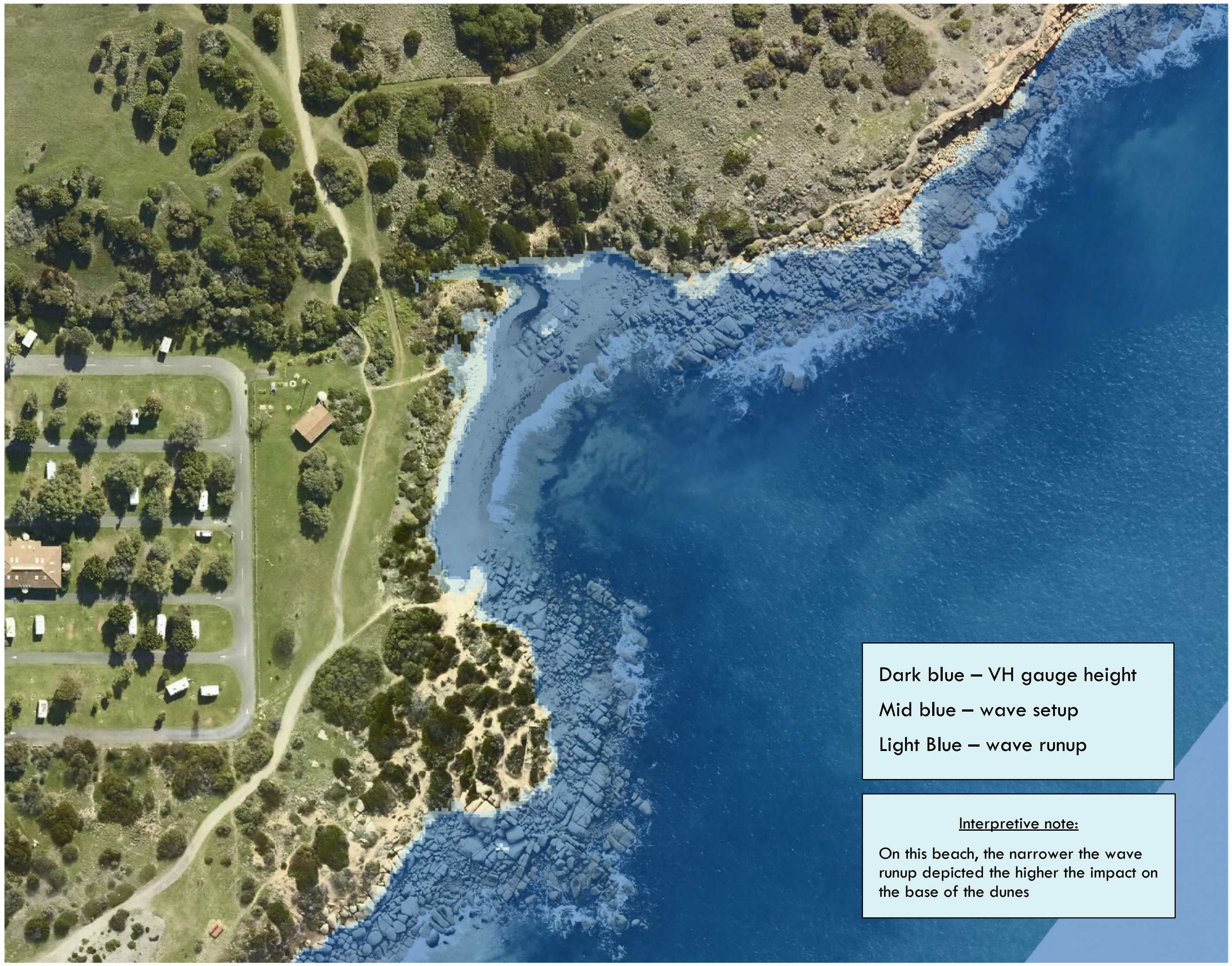

5. Future exposure - erosion

Erosion

Map SF8-3

Crockery Bay

2100 risk:

Erosion outlook

Assessment

There are no current evaluation methods to calculate the likely erosion within a location such as Crockery Bay.

The modelling for 2100 does show increased impact at the back of the bay which is likely to cause the breakdown of the embankment (likely to also include imported fill).

However, even in the worst case scenario, recession of the backshore would be limited by the nature of the geological layout (rocky outcrops and rocky beach). Recession beyond 5-10 m is unlikely.

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6. Inherent hazard risk assessment

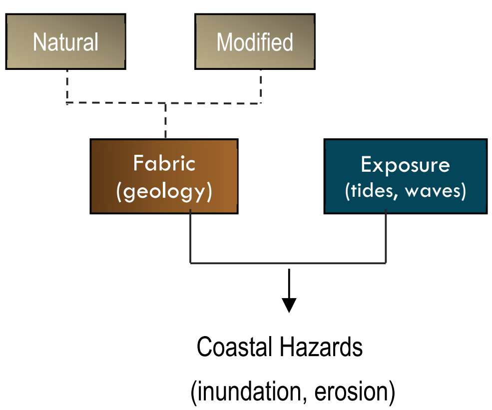
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

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

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

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



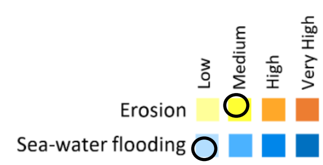
Inundation hazard risk

Due to the slope and elevation of backshores, there is no inundation hazard risk for Crockery Bay apart from within the storm water creek.

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (See Main Report)	Pocket beach underpinned by rock, backshore 1: earthen escarpment, backshore 2: sediment at 4-5m AHD. Note – some sand is present on the beach but the predominant form is rock.	Medium
Should this rating be amended due to human intervention such as a protection item? If so, how?	It is likely that imported fill forms part of the backshore which has elevated the backshore and possibly improved stability.	Medium
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'moderate'.	Medium
Assess any impact on backshore 1	Minimal action of the sea upon backshore 1	Medium
Assess any influence from Benthic	Offshore reefs: with increasing depths of water exposure may increase.	Medium
Assess the sediment balance	Crockery is a pocket beach underpinned by bedrock.	Medium
Assess any other factors that may warrant a change of inherent hazard risk.	Granite outcrops on either side of the bay and within the bay reduce the exposure	Medium

Inherent Hazard Risk – Crockery Bay



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 SF8-3

Crockery Bay

Assets at risk

Notes

The caravan park is situated 50-60m from Crockery Bay and is therefore unlikely to be impacted by actions of the sea over the coming century.

Sewer infrastructure to service the caravan park is located 40m from Crockery Bay and also unlikely to be impacted by rising sea levels and associated erosion.

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7b. Assets at risk (private)

No private assets are at risk.

7c. Safety of people

The assessment conducted within this project is only related to how impacts of the sea may increase the risk to people accessing the area. It is not related to any risks that the beach and backshore currently pose to the safety of people. This assessment remains with Council in its normal operation of risk.

Some potential risks include but should not be regarded as exhaustive:

- Increased wave action is likely within the bay over time (especially post 2050). People on the beach area and surrounding rocks may be more vulnerable to impact from waves.

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 would irreversibly change the nature of the ecosystem on a large scale.

The geological layout of Crockery Bay effectively limits any broadscale ecological impact from rising sea levels.

The ecology of the drainage creek may be altered, but this will be contained to 50m upstream from the beach.

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:

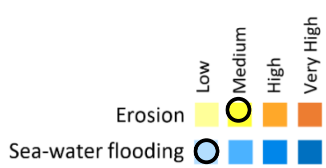
- Sea-water flooding
- Erosion

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

Rock platform pocket beach backed by sediment at ~4m AHD



Specific Risk Assessment

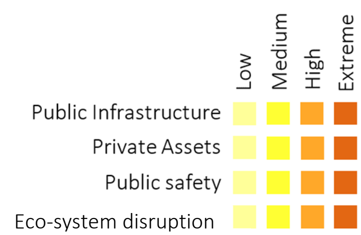
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

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

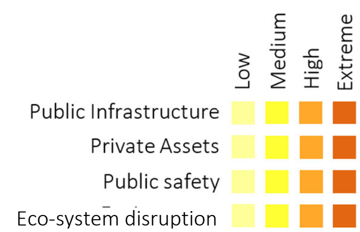
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

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 (see next page).

Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Yet to be assigned

8. Risk Assessment

Erosion assessment

Crockery Bay (SF8-3)

Risk identification: Erosion is currently, or may in the future, threaten the backshore of Crockery Bay

Coastal processes	Crockery Bay is categorised as a rocky beach, underpinned by reef, and bordered by granite outcrops. The beach is backed by earthen embankment at elevations 5m to 6m AHD. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach has not, and is currently not being impacted by actions of the sea. Analysis of future regimes suggests that this may change.

Are any strategies employed to mitigate the risk? Earthen embankment to the rear of the bay.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The caravan park is situated 50m from the bay, and the sewer infrastructure 40m away.	current	*No risk*	*No risk*	No risk
		2100	*Rare*	*Moderate*	low
Private assets	No private assets in this location.	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

Pocket beach underpinned by rock and backed by sediment ~4-5m AHD

	Low	Medium	High	Very High
Erosion		O		
Sea-water flooding	O			

Erosion Hazard Rating (current outlook)

	Low	Moderate	High	Extreme
Public Infrastructure	X			
Private Assets	No risk			
Public safety	X			
Eco-system disruption	No risk			

Erosion Hazard Rating (future outlook)

	Low	Moderate	High	Extreme
Public Infrastructure	X			
Private Assets	No risk			
Public safety	X			
Eco-system 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	Crockery Bay has shown no evidence of erosion to the backshore since 1949, but evidence exists to indicate that fill has been imported to the rear of the bay at the time the caravan park was relocated. Scenario modelling suggests that only extreme events may currently reach 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 cause some recession. However, infrastructure is set well back from the bay and not likely to be at risk by 2100.

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.

CROCKERY BAY

The modelling and assessment indicate that the backshore of Crockery Bay is currently not under threat from actions of the sea.

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

To protect private and 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** this beach over time, with special attention to changes/impacts to the back shore. Should increased impacts be observed in the latter part of the century, then protection options could be considered – sand bags or rock revetment, or conversely, managed retreat (10m).

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

Hold the line

Map SF8-3

Crockery Bay

Adaptation proposal

Approach: incremental

Monitor

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

Respond – hold the line

Should increase impact to the base of the escarpment occur, then protection options should be considered – rock revetment, sand bags (or similar).

However, managed retreat is also an option here, and then further installation of protection works.

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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'

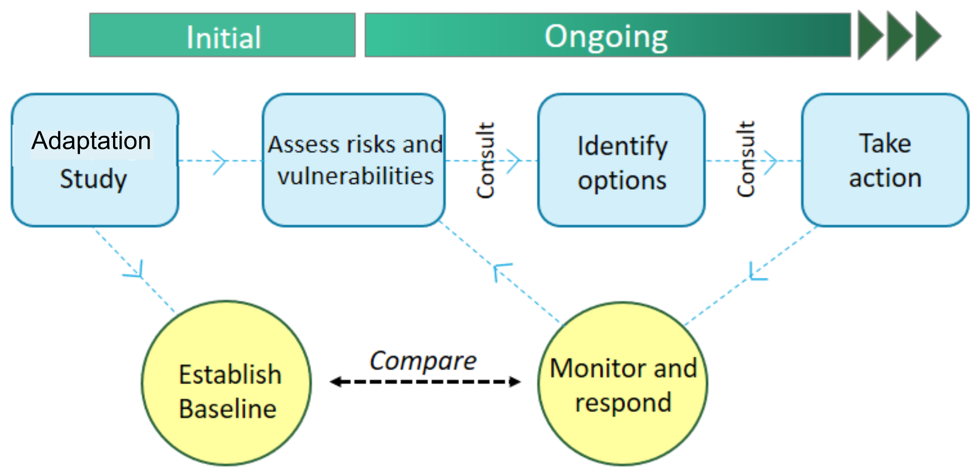
Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

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

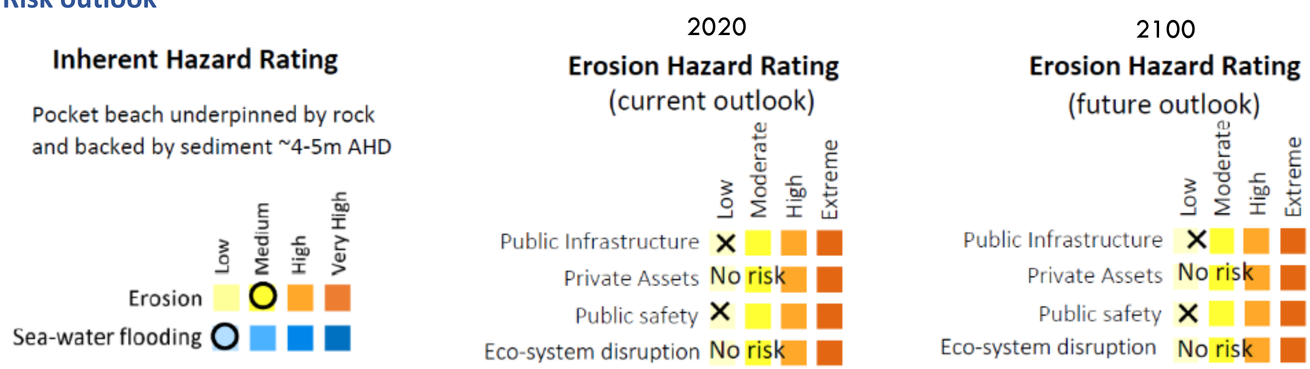


Integrated Coasts (2017)

Adaptation strategy: Crockery Bay (Cell SF8-3)

Coastal processes	Crockery Bay is categorised as a rocky pocket beach, underpinned by reef, and bordered by granite outcrops. The beach is backed by earthen embankment at elevations 5m to 6m AHD. Exposure is categorised as 'moderate', and wave energy moderate at ~1m. Historical analysis indicates that the back-shore of the beach has not, and is currently not being impacted by actions of the sea. Analysis of future regimes suggests that this may change.

Risk outlook



Adaptation overview:

The long-term strategy for Crockery Bay is to hold the line and protect the earthen backshore. This strategy is likely to be effective in the geological setting in which Crockery Bay is located. An incremental approach to adaptation is recommended. Council infrastructure is set well-back from the coastline. Monitoring of beach processes, sand volumes, and impact to backshore will provide the decision-making context for when protection is required.

Summary table:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Crockery Bay Cell SF8-3	Incremental [monitor and respond]	Monitor [no immediate works are likely to be required]	Monitor [protection may be required by 2050, or the latter part of this century]	Hold the line: protect backshore [Caravan Park and sewer infrastructure is positioned behind Crockery Bay]	Engineering: rock revetment or similar at base of embankment	Storm impacts on backshore