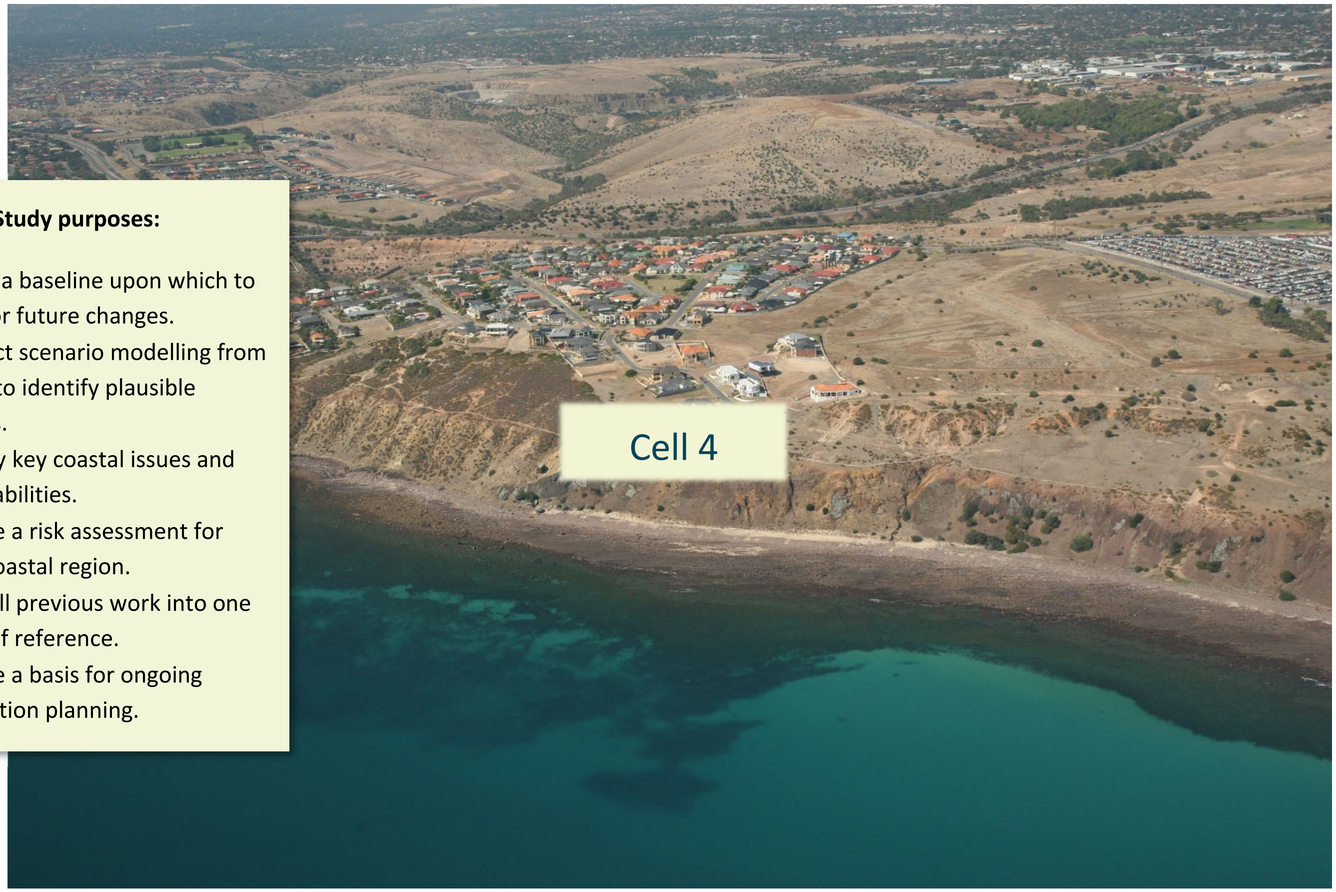
Coastal Adaptation Study

HALLETT COVE CLIFFS SOUTH

Study purposes:

- Create a baseline upon which to monitor future changes.
- Conduct scenario modelling from which to identify plausible futures.
- Identify key coastal issues and vulnerabilities.
- Provide a risk assessment for each coastal region.
- Bring all previous work into one place of reference.
- Provide a basis for ongoing adaptation planning.



By Integrated Coasts

Review date 1 December 2022

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Mark Western, Project Leader, Integrated Coasts (2018, 2022).

Joram Downes, Integrated Coasts, (2022).

Dr Graziela Miot da Silva, geology assessment (2018).

Professor Robert Bourman, geology and inherent risk assessment (2018).

Report reference:

Western, M. et al, 2022, Coastal Adaptation Study, Marino Cliffs, for City of Marion, Adelaide, South Australia.

Front cover:

South Australian Coast Protection Board, oblique photograph, 2014.

Review date:

1 December 2022 (prior study date, 1 November 2018)

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1. Introduction

This coastal cell report is a review of the *Coastal Adaptation Study for City of Marion, 2018*. These cell reports are now structured within a template so that future reviews can also build upon this report. The final section, *Summary and Recommendations*, is designed as a standalone section that can be used in other reporting contexts and acts in a similar way to an Executive Summary.

PROJECT SCOPE

Climate Variables

Managing projected climate change impacts involves dealing with 'deep uncertainty'[1]. This uncertainty is primarily related to the nature of long-term projections which are based on climate models. These models are computer-based simulations of the Earth-ocean-atmosphere system. Models are effective at simulating temperature, but their accuracy is much less for the simulation of rainfall[2]. Overall rainfall is expected to decline in our region over the coming century and the intensity of rainfall events is expected to increase, but these projections are not assigned with as much confidence as for temperature or sea level rise. Furthermore, the climate is a complex system and the variables interdependent. For example, on the one hand we might predict that declining rainfall would produce a more arid climate and therefore less vegetation but a recent study by NASA has found that over the last 35 years the planet has been greening, and that increased carbon dioxide in the atmosphere is 70% responsible[3]. As we learn more about the climate system and obtain more data over time, observable trends and projections will also become more certain.

Direct and indirect impacts

Some climate change impacts are more direct than others. Rising sea levels will directly impact the landforms adjacent the coast, either through increasing inundation of lower lying areas, or increasing erosion. Other impacts will be less direct. For example, projections for a drier climate are often associated with less vegetation in dunes, and the increased cracking of cliffs[5]. Increased intensity of rainfall events may increase the erosion and gullying of cliff-tops thereby increasing the potential for increased rates of recession and instability. The impact of rising sea levels can be assessed through sea flood modelling within digital models. The impact of vegetation loss cannot be easily quantified and as noted above, is based upon less certain projections. Attempting to incorporate too many impacts into a coastal study is likely to compound the level of uncertainty and deliver less clear outcomes.

Direct and indirect risks

Direct risks relate to the impact of rising sea level on the fabric of the coast. Different areas of coast will be vulnerable to different risks. Low lying areas will be more likely to be vulnerable to inundation and soft sediment backshores more vulnerable to erosion. In this study we evaluate the direct impact of *inundation* and *erosion* in four main receiving environments:

- Public assets
- Private assets
- Safety of people
- Ecosystem disruption.

Associated with these direct risks are a range of indirect risks. For example, the potential loss of a beach from erosion is a potential social and economic risk (if the beach is related to an activity such as tourism). A political risk may occur when the decision makers act in ways the communities do not support.

Project focus

To increase certainty, this project evaluates the *direct impacts* of inundation and erosion in the context of *rising sea levels*. In a bid to contain focus, this study assesses the *direct risks* to assets, people and ecosystems that are positioned within coastal regions.

[1] https://coastadapt.com.au/pathways-approach
[2] https://coastadapt.com.au/how-to-pages/how-to-understand-climate-change-scenarios
[3] https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth
[5] Resilient South (2014) Regional Climate Change Adaptation Plan, URPS and Seed Consulting, p.22 (and technical report p.3)

1. Introduction

ASSESSMENT FRAMEWORK

Coastal hazards experienced along a section of a coastline can be 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 coast (how resistant it is to erosion). Coastal geology is assessed 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 which 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. Coastal exposure is assessed in four main ways:

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

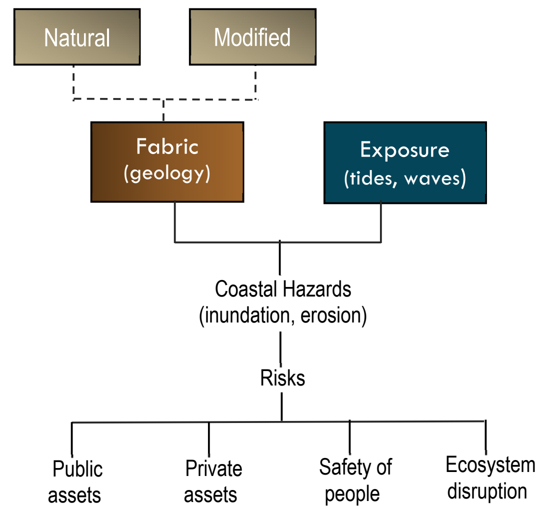
CHANGES IN THE RELATIONSHIP

Finally, 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 after a ~1m drop in sea level ~6000-4000 years ago. However, in recent times, the rate of sea level rise has increased. Last century, sea levels rose on average ~1.7mm per year. Since 1990, seas are rising on average at ~3-4mm per year in our region[6][7]. The consensus is that the rate of sea level rise will escalate towards the end of this century.

While the projected rate of sea level remains uncertain, what is certain is that if seas rise as projected, then the relationship between fabric and exposure will change significantly in coastal locations.

Figure a: Conceptual framework



The aim of 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 with rising sea levels. We conduct this evaluation within the regional setting of secondary coastal cell **Adelaide Coast** (CoastAdapt) and within tertiary cell, **Hallett Cove Cliffs South Cell 4.**

[6] Watson, P., 2020, Updated mean sea level analysis: Australia. Outer Harbor 2.5mm (1945 – 2018), satellite 3.5mm since 1990.

[7] See also sealevel.info and calculate rises from 1945 to 1990 (2.09mm) and compare with 1990 to 2022 (3.6mm).

1. Introduction

Regional Setting

Cell 4
Secondary Cell: Adelaide Coast
Tertiary Cell: Hallett Cliffs (South)

Secondary Cell

Australian regional setting
Marino Cliffs is situated within the Adelaide Coast secondary cell.

Geomorphology of the cell:
The northern section of this compartment comprises ~30km of Holocene sandy coast.

South of Adelaide, the coast is dominated by a series of arcuate north-easterly trending faults, uplifted zones associated with prominent cliffs and headlands, with sandy embayments occupying fault angle depressions.

There is minimal sediment supply, with small creeks and rivers. Littoral drift is to the north and sand supply is expected to decline causing recession to embayed beaches.

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 southwesterly swells and storms). Much of the Adelaide coast is protected from south-westerly swell waves because of the sheltering effect of Kangaroo Island. The tidal range increases from microtidal to mesotidal towards the head of Gulf St Vincent. **Source: https://coastadapt.com.au/sites/default/files/docs/sediment_compartments/SA02.01.04.pdf**

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1. Introduction

Regional Setting

Cell 4

Secondary Cell: Adelaide Coast

Tertiary Cell: Hallett Cliffs (South)

Tertiary Cell

Relative Exposure
Moderate

Wave energy
Low

Shoreline class
Rocky Platform

Sand rating
Exposed bedrock with both cobbles and coarse sand present.

Source: Nature Maps (SA).

Notes:
Minor cells represent in blue are areas where geomorphologic factors are different from neighbouring areas and require independent analysis.

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2. SETTLEMENT HISTORY

A historical review ensures that the circumstances in which the settlement was founded are understood, identifies how actions of the sea have interacted with the settlement, and builds appropriately on previous study. In this section we:

- Give a brief history of the settlement
- Review archives at Coastal Management Branch
- Identify key coastal studies

2. Settlement history

The first purpose of this section is to identify the key factors of settlement history in the context of the coastal environment. The second purpose is to identify key studies and plans so that we build upon previous work and bring all work into one place of reference.

BRIEF HISTORY

Aboriginal settlement at Hallett Cove is believed to date back 40,000 making it one of the earliest in Australia[8]. However, this settlement was likely north of the Field River (see Cell 3). After European settlement the land south of the Field River was used for farming.

Residential settlement and expansion.

Areas south of Field River were subdivided for residential use in the early 1990s. Subdivision applications were referred to Coastal Management Branch for comment[9]. Coastal Management Branch was not opposed to the development from a coastal risk viewpoint provided impacts on the adjoining cliff were minimised stating, 'without control of the disposal of stormwater from the site and increased pedestrian activity in the area the stability of the naturally erodible cliff area is at risk'. It was also recommended 'an engineering and geological study of the cliff area be undertaken to allow council to assess the suitability and design of the drainage system'[10].

[8] Lord, D. 2012, Coastal Management Study for City of Marion.

Coastal Management Branch also advised that a walking trail should be installed to minimise impact on cliff environs, and this appears to have been installed in the 1990s.

City of Marion advises allotment Q4102 in D91554 on the southern Council border has been approved for residential development. At time of writing, no works had been undertaken on this project. The unusual border alignment between City of Marion and City of Onkaparinga means that most of the coast is under the care of the latter in this location (Figure a). Project note: What are the conditions of approval in relation to storm water management?

COASTAL STRUCTURES

Due to evaluated coastal terrain and general inaccessibility to the beach, very few coastal structures have been installed to the beach area apart from a few posts. Debris from previous work operations remain on the beach or have floated into these locations from elsewhere (Figure b). The walking trail installed in the 1990s is primarily constructed along the natural ground and fenced on the seaward side. Some parts of the trail, particularly access ways from the surrounding roads, have been covered with a thin layer of gravel (Figure c).

[9] Coast Management Branch (now within DEW) 1993-1994, DA100.060.93 and DA100.026.94

Figure a. City of Marion advises of new subdivision proposed for area of land on the southern border (no details available).


Figure b. Debris from a previous era (function unknown).


Figure c. Walking trail (predominantly a natural surface).

[10] Project Note: Not known if this study was undertaken.

2. Settlement history

COASTAL STUDIES AND PLANS

The purpose of this section is to bring all previous work into one place of reference for the Hallett Cove Cliffs (South). It is also recognised that the production of studies and plans is ongoing, and these can be located from the City of Marion website.

Hallett Cove Coastal Management Study, 2012.

The focus of this study produced by Doug Lord is the Hallett Cove Beach and Field River area but provides a comprehensive review of the geomorphology, coastal processes, and history of the Hallett Cove region (See Cell 3 for a more complete review).

Coastal Management Strategy Plan, 1997.

This report prepared by Kinhill Engineers provides insight into issues under consideration at the time, including storm water run-off over cliffs, dune erosion, cliff stability issues. One of the main issues under consideration was the forming of the coastal walkway. The report also provides a full inventory of coastal features including storm water outlets, and coastal protection measures. The study stated,

> 'the coastal management strategy for Marion seeks to promote improvements in the management of the coastal strip by developing a coastal management plan which identifies appropriate uses and adjoining buffer areas, access paths, traffic management, car parking, the location of visitor facilities and tourist opportunities'.

In particular, the report recommends to:

- Develop opportunities for stormwater management improvements,
- Augment existing initiatives to protect sand dune areas where necessary to ensure the retention of dunes,
- Develop a revegetation programme for the coastal areas[11].

Resilient South, 2014.

The Southern Adelaide region (Holdfast Bay, Mitcham, Marion and Onkaparinga Councils) cooperated together to produce the Resilient South Climate Change Adaptation Plan (2014).

In relation to coastal adaptation, the plan explains the general impacts of rising sea levels, changes to rainfall patterns, and increased erosion, but does not specifically review the coastal environs of City of Marion. The plan did identify some general options for coastal adaptation but did not identify any preferred coastal adaptation options for City of Marion. Resilient South now has a website where all studies and projects can be accessed. Resilient South.

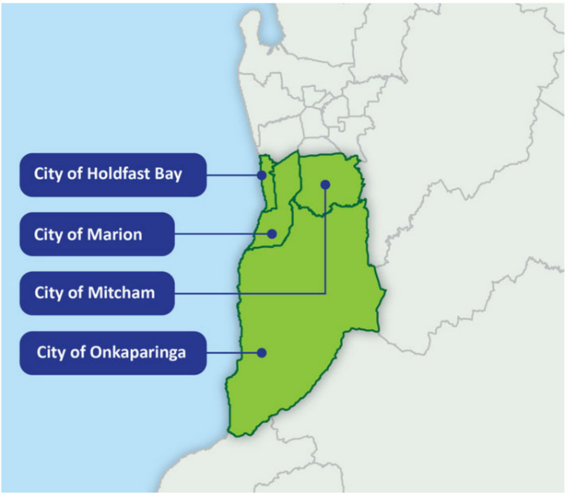

Figure a. Resilient South, and ongoing partnership between City of Holdfast Bay, City of Marion, City of Mitcham and City of Onkaparinga.

Climate Change Adaptation Governance Assessment Report for the City of Marion 2019.

This study prepared by Climate Planning and Seed Consulting Services in 2019 assessed how well City of Marion is incorporating climate change adaptation governance into their corporate processes and frameworks.

[11] Kinhill Engineers (1997) Draft Coastal Management Strategy Plan

2. Settlement history

The Project Team conducted a governance assessment of the City of Marion to explore how climate change was considered in their corporate documents. The City of Marion was assessed against ten quantitative governance indicators, with Figure a displaying Council's performance.

The report concluded that City of Marion has considerable inclusion of climate change in its formal governance documents. This meant that not only could staff identify key physical climate risks to the functions of Council, they could also identify clear corporate strategic drivers for decision making. There was also consistent understanding of climate change risks from an officer to senior executive level.

The fact that climate change has been considered in all of the ten key governance indicators sees it placed as the leader in Australia (compared to the 200 councils who have been assessed).

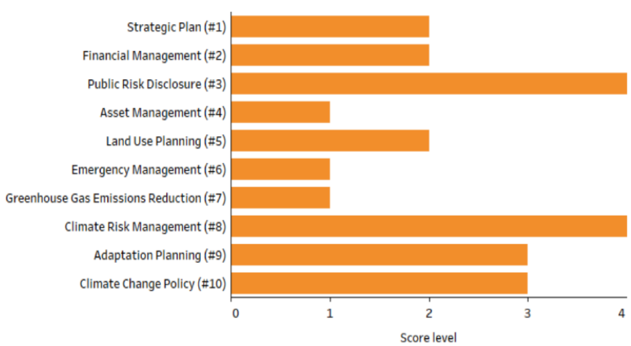

Figure a. Results of governance assessment for City of Marion.

STRATEGIC PLANS AND POLICIES

City of Marion develops and updates strategic plans and policies on a regular basis and these can be located on the City of Marion website:

Climate Change Policy (2021-2025)

City of Marion Climate Change Policy was adopted on 11 May 2021 and will be reviewed by 11th May 2025. The primary objectives of the policy are:

- To incorporate climate change mitigation and adaptation into strategic and operational activity…,
- To support residents, businesses, and local ecosystems to build resilience and adapt to the impacts of a changing climate.
- To work in collaboration with regional partners and the wider community.

Other strategic plans and policies

- Community Vision: Towards 2040 (adopted 26 July 2016)
- Strategic Plan 2019 – 2029 (endorsed August 2019)
- Business Plan 2019 – 2023 (June 2019)
- Environmental Policy (November 2019)
- Carbon Neutral Plan, 2020 – 2030.

[Project note: a full list of plans and updates is available from City of Marion website.]

Settlement History
Key Points

The land adjacent the coast south of Field River, was subdivided for residential occupation in early 1990s. Coastal Management Branch did not oppose the development if the cliff tops were managed for storm water and pedestrian access.

Council advises that a recent subdivision has been approved for the land on the southern border of City of Marion. The subdivision is set well-back from the cliff top, but storm water will require management.

Coast Protection Board gave advice in relation to two development applications in cliff top locations noting that they had no objections on the condition that storm water and pedestrian controls were adequate.

Coastal structures in Cell 4 are limited to:

- Minor structures on the beach (fence posts, purposes unknown),
- Some debris from previous operations (or perhaps washed up on the shore),
- Walking trail primarily on natural ground and fenced on the seaward side.

The ***Hallett Cove Coastal Management Study (2012)*** is a useful resource to understand the geomorphology, coastal processes, and history of the region.

3. GEOMORPHOLOGY

The study of coastal geomorphology analyses how the coast was formed and how the coast has changed over time. The study provides the 'bigger picture' for understanding how sea level rise may interrelate with the coastline in the future.

For a fuller explanation of the coastal geomorphology of the region see Hallett Cove Coastal Management Study by D. Lord completed for City of Marion, 2012.

3. Geomorphological context

GEOLOGICAL SETTING

Structure of the coastline[12]

The basic structure of the Adelaide Metropolitan coast is influenced by a series of prominent arcuate (curved) faults. In particular, the Eden-Burnside Fault, the Clarendon-Ochre Cove Fault and the Willunga Fault have produced major escarpments, which intersect the coastline and run out to sea, where the faults are best exposed. Uplift and back tilting of the fault blocks has produced associated fault angle depressions occupied by the Adelaide Plains Sub-Basin, the Noarlunga Embayment and the Willunga Embayment (Figure a), which have been infilled with sediments over the past 40 million years. More recently in the Holocene period, the sandy beaches and dunes were formed on the low-lying embayments. The City of Marion coastline is entirely positioned within the elevated Eden-Burnside Fault which separates the Noarlunga embayment to the south and the long stretch of low-lying Metropolitan beaches to the north.

Resistant Neoproterozoic rocks extend from the Marino Rocks boat ramp to Hallett Cove Conservation Park (Cell 1,2). Cliff exposures of siltstone, shales and sandstones from this period get progressively younger from north to south. Despite these sedimentary rocks now being metamorphosed into harder rocks, sedimentary layers are still distinguishable and form distinct shore platforms. There is very little sand, and any beaches comprise of shingles (rocks).

Hallett Cove Beach (Cell 3) is an internationally important site geologically because features of the Permian glaciation are preserved here, and numerous large boulders (glacial erratics) occur on the beach. The host sediments to the boulders, deposited during the Permian glaciation, have been more recently exposed by coastal erosion. The only river in this section of coast is the Field River at the southern end of Hallett Cove.

[12] Bourman et al, 2016, Coastal Landscapes of SA, University of Adelaide Press.

From Hallett Cove to Port Stanvac (Cell 4), ***resistant*** folded Neoproterozoic strata form cliffs up to 20 m high, with the adjacent serrated shore platforms revealing complex folds of the Delamerian Orogeny period (>500 million years).

Sea levels have cycled between 2m above present sea level during the Last Interglacial Maximum (the last time the earth was free of ice, 132-118ka) to 125m below present sea level during the Last Glacial Maximum (the maximum ice extent, 21 ka). These major cyclic fluctuations in sea level meant that the present area of Gulf St Vincent was periodically exposed as dry land, and some higher sea level events such as the Last Interglacial experienced even larger areas of sea coverage. Furthermore, the climate at that time was warmer and wetter than today, with the Leeuwin Current bringing warmer ocean surface waters from Indonesia and the north-eastern Indian Ocean.

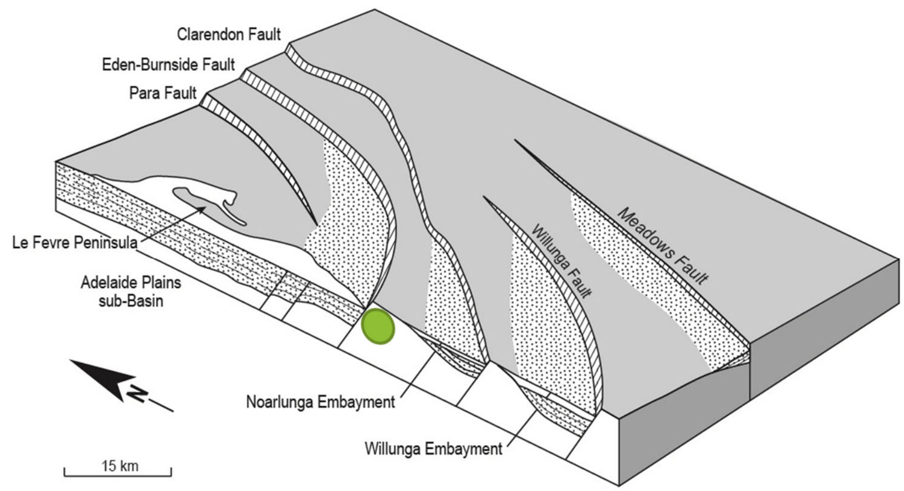

Figure a: The geological setting of the coastline between Sellicks Beach and the metropolitan area. The prominent fault scarps consist of uplifted ancient rocks, resistant to erosion, while the embayments are occupied by younger and more easily eroded rocks and sediments. The City of Marion coastline is positioned within the Eden-Burnside Fault.

3. Geomorphological context

GEOLOGICAL SETTING

In simple terms, the geomorphology of coasts is classified in three main parallel zones: the subtidal, intertidal and backshore. The intertidal zone consists of the area between low and high-water marks. The backshore is typically characterised as up to 500m inland of the intertidal zone[10].

The Marion Coastline has been divided into coastal cells based upon geological layout (Figure a). The Marion coastline is predominantly a combination of *sloping hard-rock shores* and *sloping soft-rock shores*. Sections of *undifferentiated rock shores* refer to locations which are not easily classified as hard or soft rock and can generally be assigned an erosion classification between the two. The Field River area is assigned as 'river mouth'. Hallett Cove Beach is assigned 'sloping soft-rock shores'. The elevated geology of the Marion Council coastline means that the coastline is not subject to inundation. The exceptions are The Esplanade, Marino, and the Field River area, but these are also backed by sloping backshores. The extensive areas of cliff categorised as *sloping hard rock shores and undifferentiated rock shores* suggest that the City of Marion coastline is not subject to rapid erosion. Areas categorised as *sloping soft rock shores* such as Hallett Cove Beach are more likely to be vulnerable to erosion. This assessment is supported by analysis by CoastAdapt which assigns almost the entire coast as *dominantly hard rock shores* with a low erodibility outlook[13].

Dr Miot da Silva and Dr Robert Bourman assess the cliff vulnerability in this region as 'low to moderate' erodibility composed by sedimentary to meta-sedimentary rocks ranging from Pleistocene to Neoproterozoic ages. These rocks are not the very 'low erodibility' type of rock associated with basement rocks such as igneous basalts and granites, nor high erodibility of the unconsolidated sediments of the recent Holocene period, and therefore fall between the two classifications. As such, these rocks are not readily erodible, but the presence of rock platforms indicate that cliffs have eroded and retreated in the past over long time periods.

[10] http://www.ozcoasts.gov.au/coastal/introduction.jsp
[13] https://coastadapt.com.au/coastadapt-interactive-map

3. Geomorphological context

SEDIMENT BALANCE – SAND SUPPLY FOR THE COASTLINE

Gulf St Vincent

Sand deposits along the coast were likely deposited by the wind in the last ice age when seas were up to 120m lower than present. As the ice melted and sea levels rose, these sediments formed the current layout of the beaches. Since sea levels stabilised over the last 7000 years the coast has slowly been losing sand which is unable to be replaced. This lack of sand supply to Gulf St Vincent is compounded because littoral drift (sand movement) is to the north and the Adelaide coastline only has small creeks and rivers that deliver minimal sediment to the coast. Therefore, sand supply is expected to decline causing recession to embayed beaches[14].

Hallett Cove and Marino beaches

The Hallett Cove Coastal Management Study (HCCMS) has thoroughly evaluated the coastal processes in Gulf St Vincent as they impact upon the Marion coastline and should be relied upon in the final coastal adaptation plan[15].

The HCCMS summarises the sediment environment in Hallett Cove Beach region:

> The foreshores of Hallett Cove present as a slowly receding coastline, starved of sediment. The available coastal process modelling indicates the potential for sand transport out of the Hallett Beach compartment (100,000m^3 / year) is an order of magnitude greater than the natural rate of sand supply along the coastline from the south (5000m^3/ year)[16]….
>
> While the community perception that the sand cover has reduced over the past 30 years may be true, the likelihood is that over historical times the volume of sand on the beach has always been small and variable, providing a thin sand veneer from time to time over sections of the exposed shingle [and that] additional sand cover is unlikely to be a practically achievable outcome.

Geomorphology
Key Points

1. The coastal lands of City of Marion are set in the vicinity of the Burnside-Eden fault (area of uplifted land) and therefore generally elevated well-above risk of inundation from current and future storm activity. The exceptions are The Esplanade at Marino and the area around Field River. However, in both these locations the backshores slope upward.

2. The coastline consists predominantly of hard-rock sloping shores (Coast Adapt) and Bourman et al (2016) characterise the cliffs areas as 'resistant'. Exceptions to this resistant characterisation exist with Hallett Cove Beach and Field River area (Cell 3) which are backed by softer sediments. Pockets of less resistant rocks also exist at Marino (The Esplanade and Marino Rocks carpark).

3. The City of Marion coastline is much older than the Onkaparinga coastline to the south and the Metropolitan beaches to the north (both which were formed in the Holocene Period, 11.7ka) when seas rose to their current level.

4. Generally, the City of Marion coastline has always consisted of rock platforms and pebble beaches. In relation to Hallett Cove Beach, it is likely that sand levels were higher in the past, but sand cover has always been limited to a thin veneer over a rocky beach.

5. Within Gulf St Vincent sand levels are expected to decline due to the inability of the coastal environment to replace sediments that were deposited at the last interglacial period. The movement of sand is northward, and Gulf St Vincent contains only small rivers and creeks that deliver minimal sediment to the coast.

[14] Bourman et al, Coastal Landscapes of SA, p. 66.
[15] D. Lord., Coastal Management Study, Hallett Cove, SA. 2012, pp 17-26.
[16] HCCMS suggests that this calculation is based on modelling at O'Sullivan Beach boat ramp.

4. 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)

Viewing instruction:

View the coastal fabric section utilising full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

4.1 Coastal fabric - overview

Introduction

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). In some locations, humans have intervened and changed the nature of the coastal fabric. For example, a construction of a seawall changes the fabric from sand to rock. The construction of an esplanade road too close to the coast can install rigidity in the backshore, which formerly could naturally adapt to erosion and accretion cycles. Some interventions change the way in which the beach operates, and new erosion problems are created.

Why evaluate shoreline change?

Beaches undergo normal cycles of accretion and erosion which may span time measured in decades. These changes can be observed in two main ways. The position of the shoreline changes, and the levels of sand change on the beach. In times of erosion, the shoreline tends to recede, and sand levels become lower. In times of accretion, the opposite is true. If sea level rises as projected, then shorelines are likely to go into longer term recession. The purpose of evaluating the historical changes to the shoreline is to formulate a baseline understanding of how the coast has been operating in the past. In the context of rising sea levels, identifying future shoreline recession trends will assist us to identify when the beach begins to operate outside its normal historical range.

What is the shoreline?

The shoreline is the position of the land-water interface at one instant in time. But in reality, the shoreline position changes continually through time because of the dynamic nature of water levels at the coastal boundary. The best indicator of shoreline position is the location of the vegetation line. In other circumstances the shoreline may be the base of a cliff, an earthen bank at the toe of a slope, or a seawall in locations where humans have intervened.

How will we analyse the shoreline?

The analysis includes:

- Comparisons of aerial photography from 1949 to current day. This requires very fine-grained georeferencing of photography to ensure that comparisons are accurate.
- Comparison of surveyed profile lines which have been conducted by SA Coast Protection Board since the 1970s (if within the cell).
- Evaluation as to how humans may have intervened in the coastal fabric and how this intervention may have changed the natural operation of the coast.

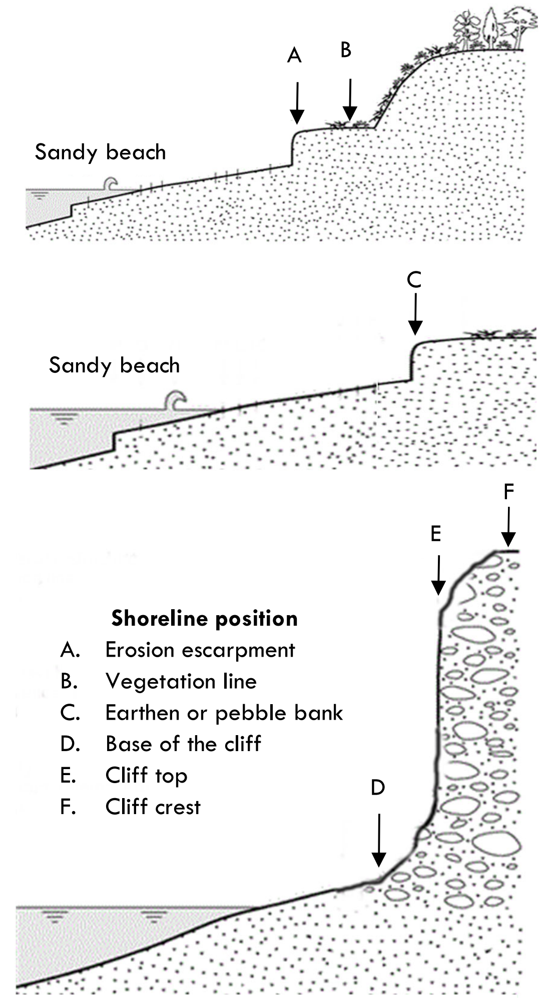

Figure a. Adapted from Boak and Turner (2005), Shoreline definition and detection.

4-1 Coastal fabric - overview

Overview

Marion (Cell 4)

Secondary Cell: Adelaide Coast

Tertiary Cell: Hallett Cove (South)

Form

Beach
Flat bedrock platform with cobbles and coarse sand present.

Backshores
Hard rock cliffs (at their base) are present, standing 40-60m tall.

Bathymetry
Overall slope of ocean floor:
-5m ~ 430m to 750m from beach (overall slope ratio ~1:64).

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4-1 Coastal fabric - overview

Overview

Marion (Cell 4)

Secondary Cell: Adelaide Coast
Tertiary Cell: Hallett Cove (South)

Geology

Geology

Backshore 4.1-3

The base of the cliff is similar geological fabric as Black Rock (Brachina Formation, Neoproterozoic, > 500 million years) and therefore resistant. The upper portions of the cliff (especially in southern sections of Southern Cliffs) are of more friable material (Hindmarsh Clay, 2.5 million to 11,500 years).

Geological data opposite sourced and adapted from www.sarig.gov.au

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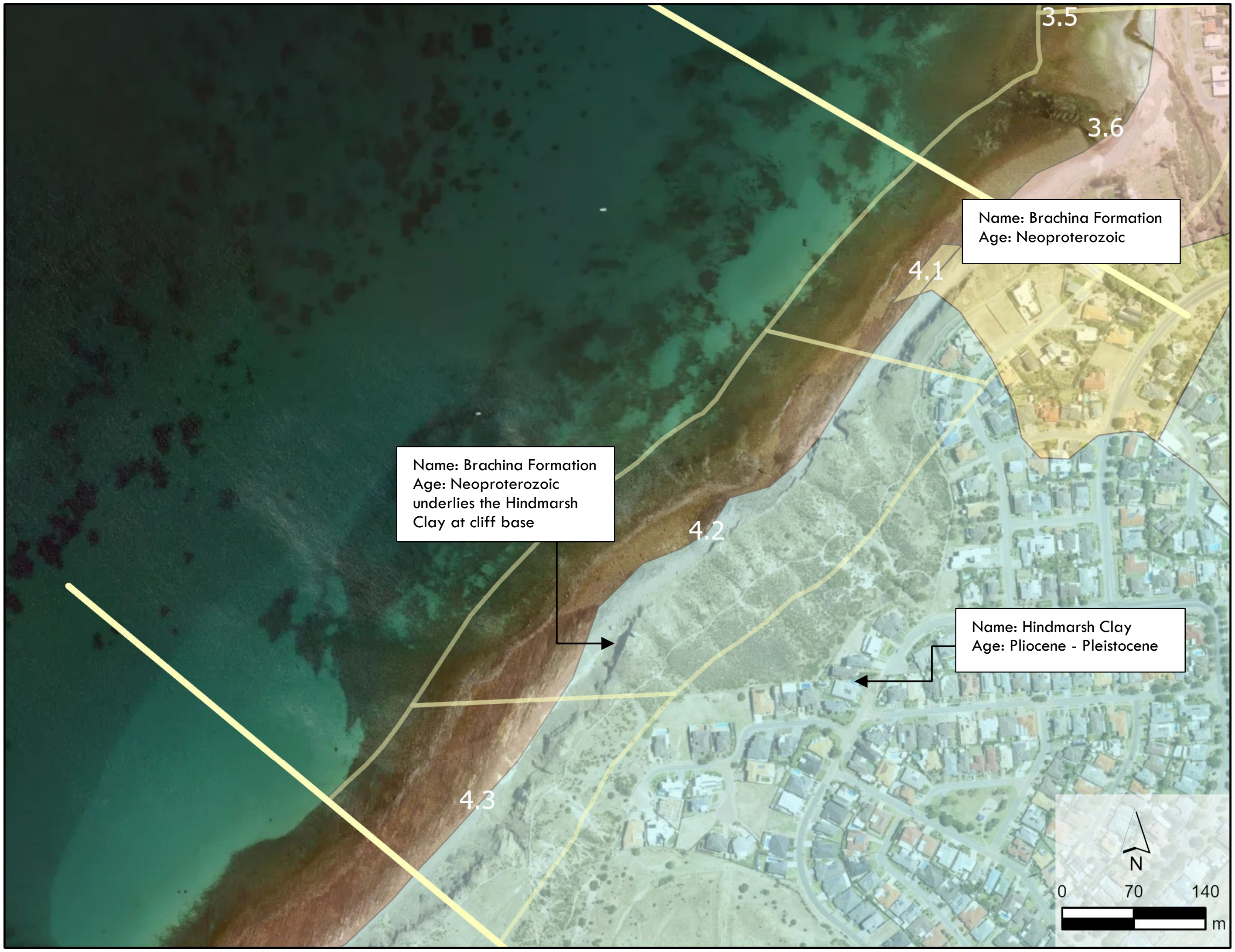

4-1 Coastal fabric - overview

Overview

Marion (Cell 4)

Secondary Cell: Adelaide Coast

Tertiary Cell: Hallett Cove (south)

Benthic

Benthic

Nearshore dominated by low profile reef (<250m from shore), bare sand (250<450m from shore), and seagrass meadow (>450m from shore).

Benthic data sourced from Nature Maps (SA).

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4-2 Coastal fabric – geology (Cell 4.1)

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Notes

The base of the cliff is similar geological fabric as Black Rock (Brachina Formation, Neoproterozoic, >500 million years) and therefore resistant to erosion. The upper portions of the cliff (especially in southern sections of Southern Cliffs) are of more friable material (Hindmarsh Clay, Pliocene – Pleistocene, glaciation cycles, 2.5 million to 11,500 years ago). Care required in managing storm water runoff in upper cliff.

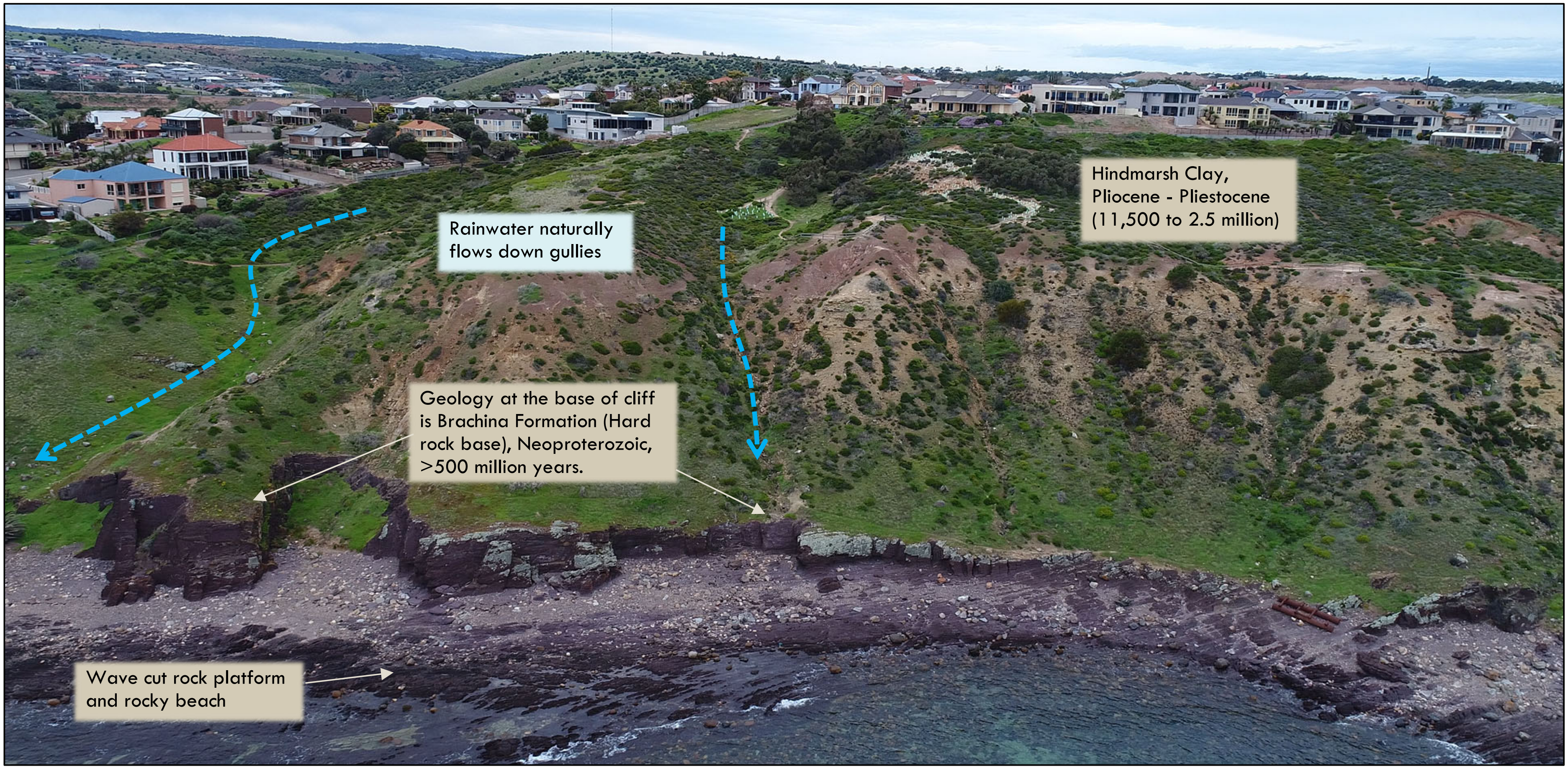
Map

Hallett Cliffs (South) 4:1

Geological assessment

Dr Graziela Miot da Silva (2019)

4-2 Coastal fabric – geology (Cell 4.2)



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Notes

The base of the cliff is similar geological fabric as Black Rock (Brachina Formation, Neoproterozoic, >500 million years) and therefore resistant to erosion. The upper portions of the cliff (especially in southern sections of Southern Cliffs) are of more friable material (Hindmarsh Clay, Pliocene – Pleistocene, glaciation cycles, 2.5 million to 11,500 years ago). Care required in managing storm water runoff in upper cliff.

Map

Hallett Cliffs (South) 4:2

Geological assessment

Dr Graziela Miot da Silva (2019)

4-2 Coastal fabric – geology (Cell 4.3)

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Notes

The base of the cliff is similar geological fabric as Black Rock (Brachina Formation, Neoproterozoic, >500 million years) and therefore resistant to erosion. The upper portions of the cliff (especially in southern sections of Southern Cliffs) are of more friable material (Hindmarsh Clay, Pliocene – Pleistocene, glaciation cycles, 2.5 million to 11,500 years ago). Care required in managing storm water runoff in upper cliff.

Map

Hallett Cliffs (South) 4:3

Geological assessment

Dr Graziela Miot da Silva (2019)

4-3 Coastal fabric – shoreline changes (Cell 4)

Why compare historical photographs?

Comparing photographs taken from the ground rather than the air provides an alternative perspective on changes to coasts over time. Furthermore, aerial photographs are only available from 1949. The assessment is more qualitative, but we can evaluate:

- Changes to beach levels,
- Changes to backshores (behind the beach),
- Rates of erosion of rocks,
- History of human intervention such as protection items or other coastal infrastructure.

100 Years of Coastal Change.
No changes are observed in the backshores. In particular, there is no increased tidal action below the cliff.

Figure a. Man on Hallett Cove Cliffs (south), 1920, State Library of SA, B69399-29.

Figure b. Same location as Figure a., M. Western, 12 June 2022.

Figure c. Looking from field River dunes to Hallett Cove Cliffs (south), 1900, State Library of SA, B77127-60-25 (cropped).

4-3 Coastal fabric – shoreline changes (Cell 4)

100 Years of Coastal Change
Assessment of photographs needs to consider different camera perspectives and the poorer resolution of older photographs.

Figure a & b (above)
There appear to be no observable changes to the beach and backshore. Photograph a, 1920, State Library of SA, B69399-25, Photograph b, M. Western, June 2022.

Figure c & d (left)
Minor changes are observed to the rock situated about 100m south of Field River. The rock in 2022 appears more weathered and fissured. This analysis provides a context to consider the rate of erosion of rock within a tidal zone. Photograph c, 1900, State Library of SA, B77127-60-85, Photograph d, M. Western, June 2022.

4-3 Coastal fabric – location map (Cell 4.1)

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)
Historical comparison

Location Map

Location:
Albatross Walk

Aerial photograph from 2017 provides the basis for comparison of coastal change over the last 70 years. Comparisons are made with aerial photography from:

- 1949
- 1979
- 1989
- 2002
- 2007
- 2012
- 2017

In this location the shoreline is the base of the cliff. Qualitative comparisons are made where observed.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Albatross Walk
Year 1949

General observations

Very low vegetation cover.

Possible loss of base embankment.

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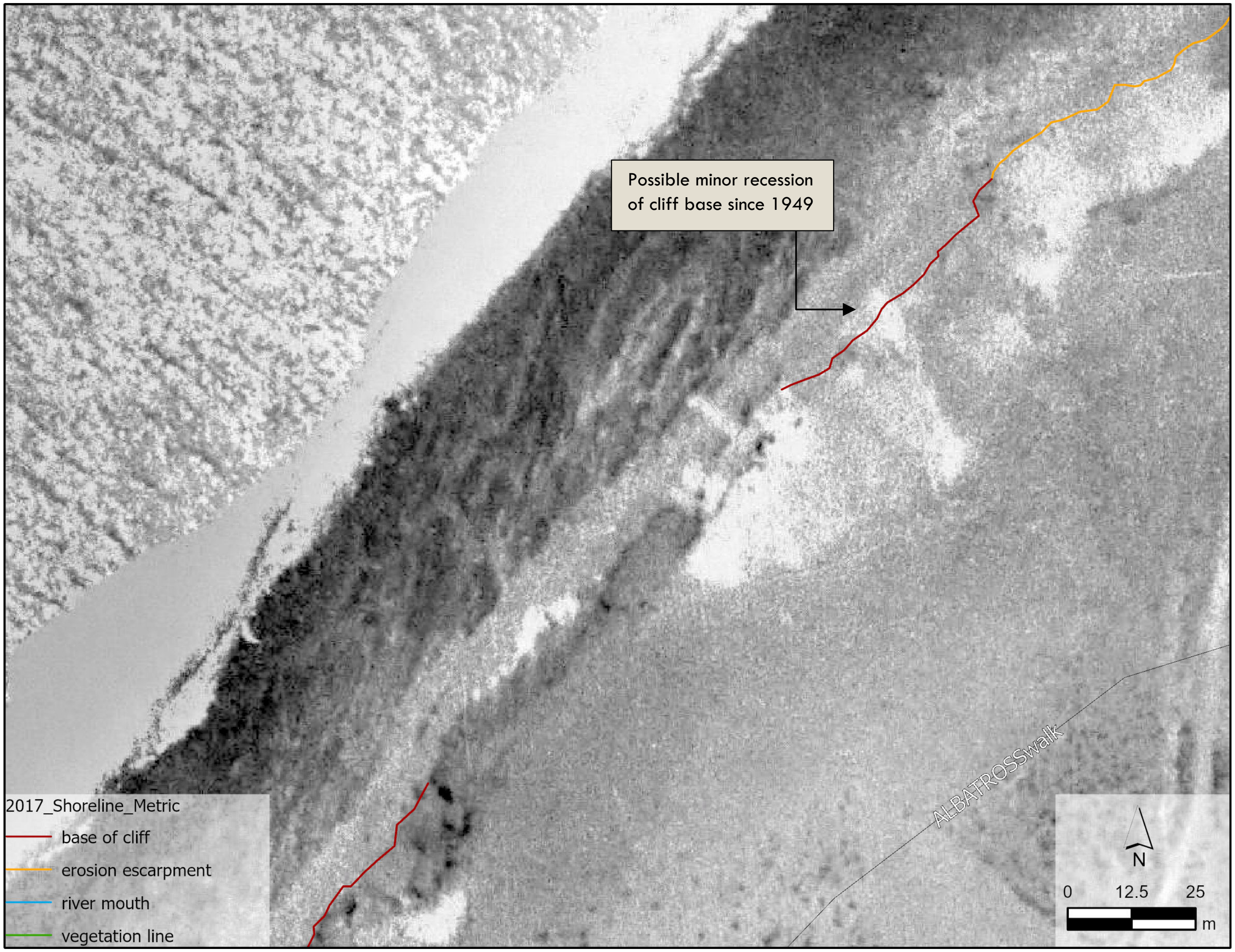

4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)
Historical comparison

Shoreline

Location:
Albatross Walk
Year 1979

Shoreline recession:
Possible minor, where shown.

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Sparse

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)
Historical comparison

Shoreline

Location:
Albatross Walk
Year 1989

Shoreline recession:
No recession from 1979

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Sparse

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Albatross Walk
Year 2002

Shoreline recession:
Nil, since 1979.

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Sparse

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)
Historical comparison
Shoreline

Location:
Albatross Walk
Year 2007

Shoreline recession:
Nil, since 1979.

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Grassed (Photograph taken in May).

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Albatross Walk
Year 2012

Shoreline recession:
Possible wave attack in the north changes vegetation position.

Cliff top recession:
Nil

Rock falls and slumps
nil

Gullying
None observed

Vegetation
Declined from 2007 (but photograph taken in January).

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4-3 Coastal fabric – shoreline changes (Summary)

Medium Term Changes

Cell 4.1

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Albatross Walk
Summary

70 years (1949-2017)
Very few changes observed apart from possible recession where shown on 1949 photograph.

40 Years (1979 to 2017)
Nil changes, apart from minor changes to vegetation.

10 years (2007-2017)
Nil recession over last decade (apart from minor changes to vegetation).

Summary

Location has been very stable over 70-year period as is to be expected in a sloping hard rock cliff location.

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4-3 Coastal fabric – location map (Cell 4.2)

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)

Historical comparison

Location Map

Location:
Petrel Close

Aerial photograph from 2017 provides the basis for comparison of coastal change over the last 70 years. Comparisons are made with aerial photography from:

- 1949
- 1979
- 1989
- 2002
- 2007
- 2012
- 2017

In this location the shoreline is the base of the cliff. Qualitative comparisons are made where observed.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Petrel Close
1949

General observations

Well vegetated in upper crest slope.

Cliff base and top is same position as 2017.

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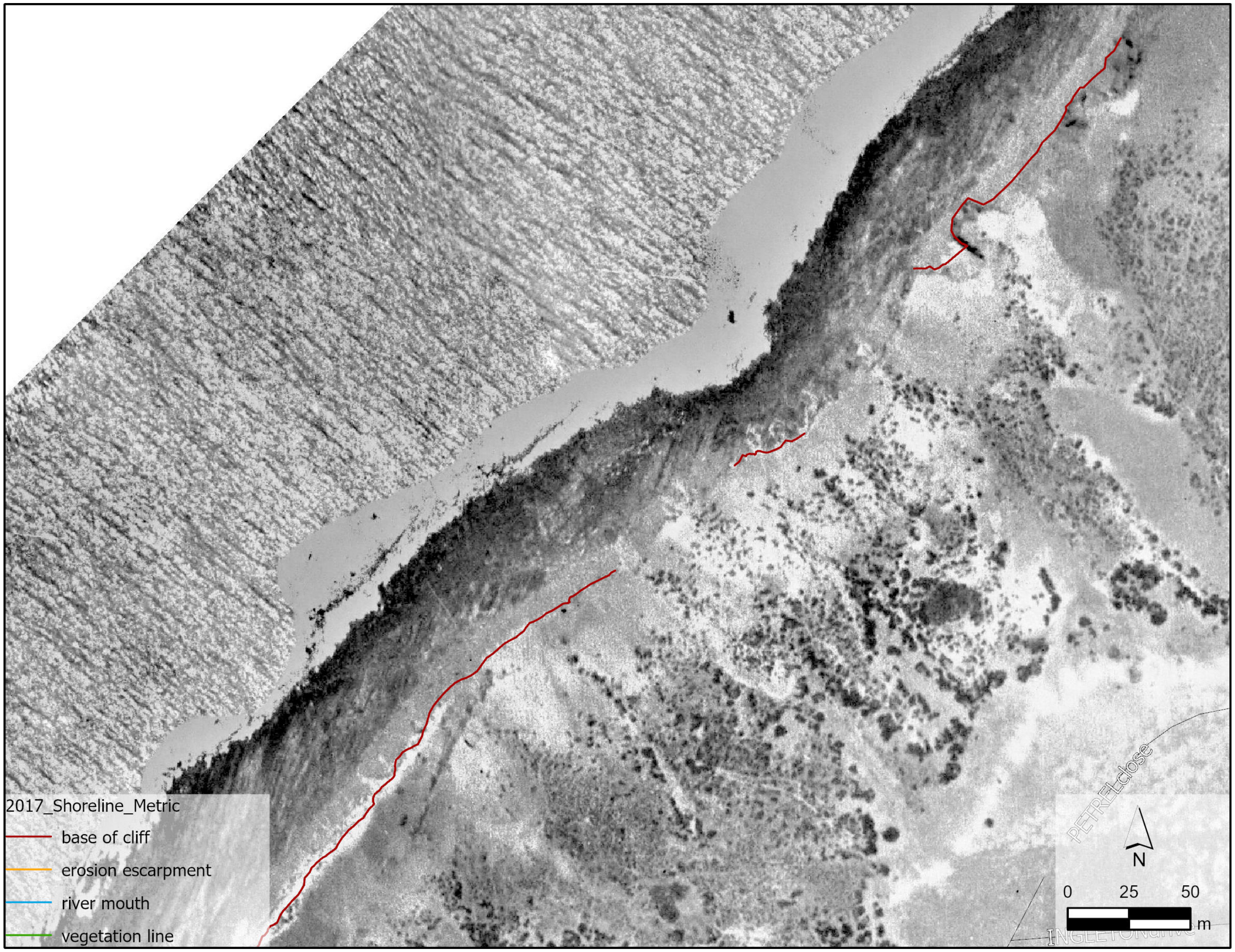


4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Petrel Close
Year 1979

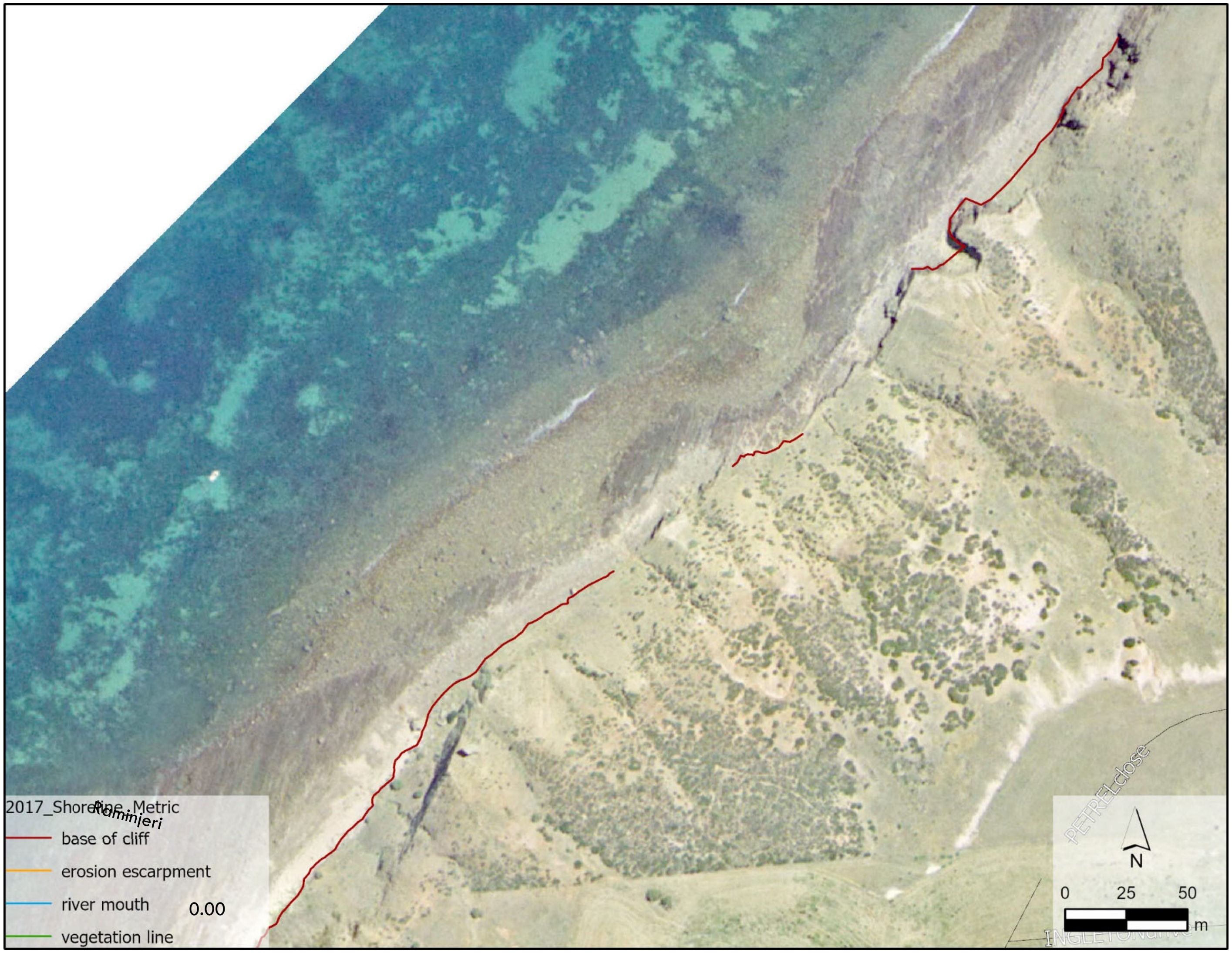
<u>Shoreline recession:</u>
Nil. More sand at toe of slope, less vegetation than 2017.

<u>Cliff top recession:</u>
Nil

<u>Rock falls and slumps:</u>
Nil

<u>Gullying</u>
None observed

<u>Vegetation cover</u>
More sand at toe of slope, less vegetation than 2017.



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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Petrel Close
Year 1989

Shoreline recession:
Nil

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Similar to 1979.

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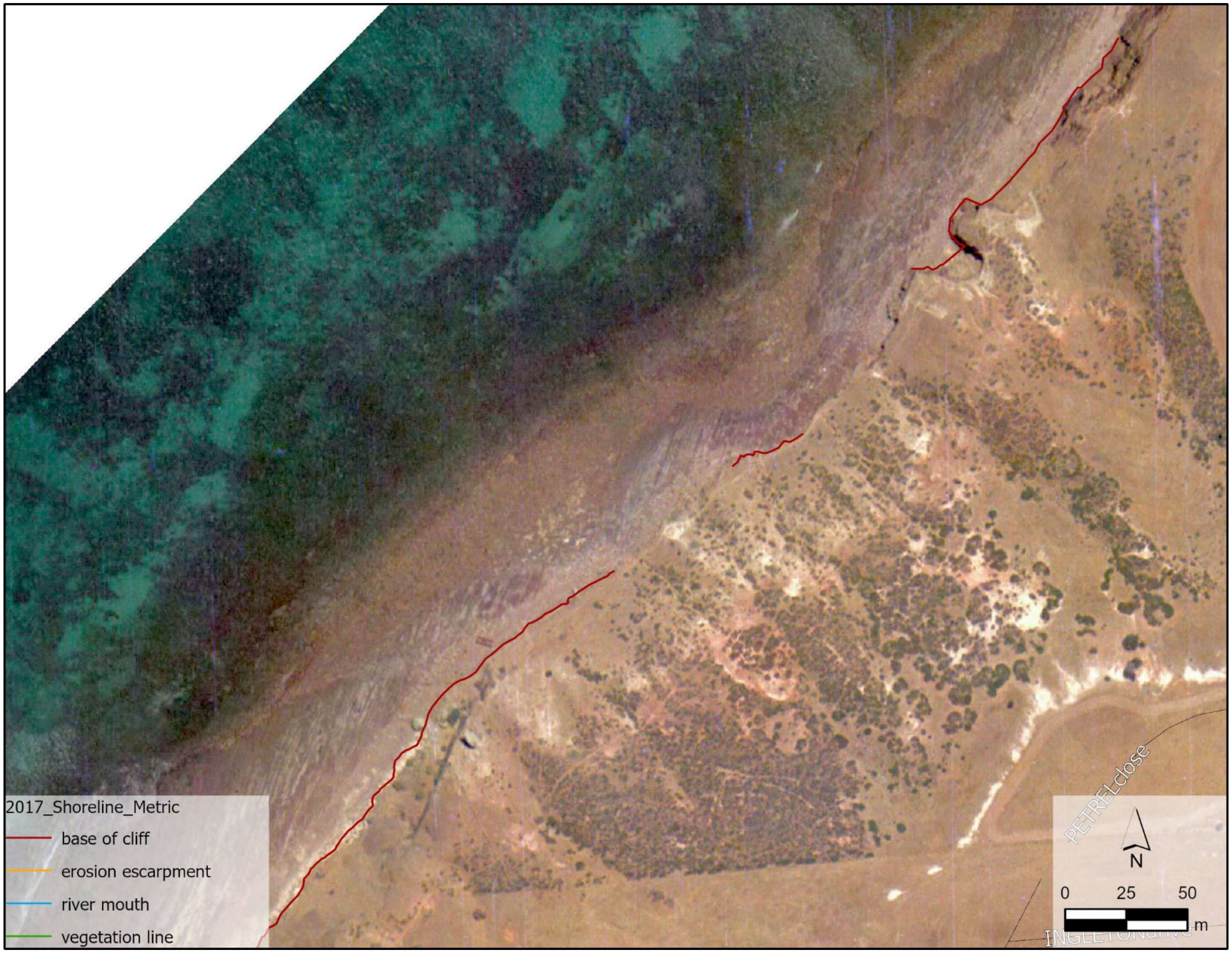

4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)
Historical comparison

Shoreline

Location:
Petrel Close
Year 2002

Shoreline recession:
Nil

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Increasing from 1989.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)
Historical comparison

Shoreline

Location:
Petrel Close
Year 2007

Shoreline recession:
Nil

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Vegetated sandy embankment at base of the cliff (photograph taken in May). Generally, more grass cover.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Petrel Close
Year 2012

Shoreline recession:
No recession from 1979

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
None observed

Vegetation cover
Similar to 2017.

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4-3 Coastal fabric – shoreline changes (Summary)

Medium Term Changes

Cell 4.2

Hallett Cove Cliffs (South)
Historical comparison

Shoreline

Location:
Petrel Close
Summary

70 years (1949-2017)
Nil changes observed.

40 Years (1979 to 2017)
Nil changes, apart from minor changes to vegetation.

10 years (2007-2017)
Nil recession over last decade (apart from minor changes to vegetation).

Summary

Location has been very stable over 70-year period as is to be expected in a sloping hard rock cliff location.

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4-3 Coastal fabric – location map (Cell 4.3)

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)
Historical comparison

Location Map

Location:
Balboa Drive

Aerial photograph from 2017 provides the basis for comparison of coastal change over the last 70 years. Comparisons are made with aerial photography from:

- 1949
- 1979
- 1989
- 2002
- 2007
- 2012
- 2017

In this location the shoreline is the base of the cliff. Qualitative comparisons are made where observed.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
1949

General observations

More sand on the beach above the rock platform.

Cliff position is same as 2017.

Possible increased gullying

Care in assessment is required due to low resolution photograph which is also over-exposed.

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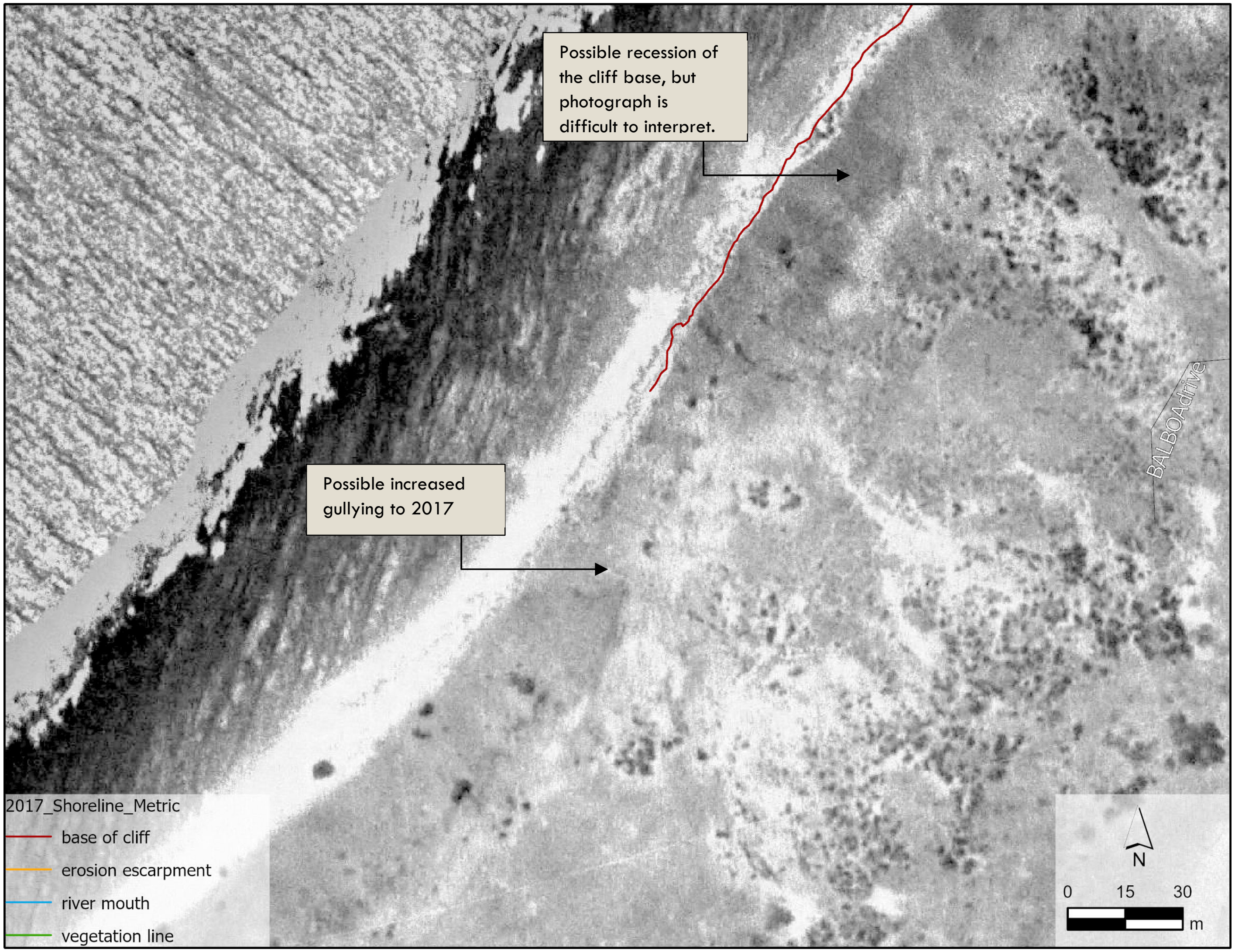

4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
1979

Shoreline recession:
Nil. Increased sand levels at beach.

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
Small gully (in location where storm water has now cut gully from housing development in 1990s).

Vegetation
Increased sand levels, more vegetation in 2017.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
1989

Shoreline recession:
Nil

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
Small gully (in location where storm water has now cut gully from housing development in 1990s).

Vegetation

Difficult to interpret due to photo.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
2002

Shoreline recession:
Nil (less sand on beach).

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
Gully at base of cliff is 1m wide in 2002, now 3.0m to 3.5m wide.

Vegetation
Increasing vegetation in upper cliff crest and at base of cliffs in south.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
2007

Shoreline recession:
Nil (more sand on beach than 2002 and 2017)

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
Gully at base of cliff is a little narrower than 2017.

Vegetation
Vegetation increased, more grass cover, photograph captured in May.

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4-3 Coastal fabric – shoreline changes

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
2012

Shoreline recession:
Nil (Sand removed since 2007)

Cliff top recession:
Nil

Rock falls and slumps:
Nil

Gullying
Stormwater pipes in gully not visible. Gully is wider than 2017, perhaps because the sidewalls are more vertical due to recent erosion events.

Vegetation

Similar to 2017.

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4-3 Coastal fabric – shoreline changes (Summary)

Medium Term Changes

Cell 4.3

Hallett Cove Cliffs (South)

Historical comparison

Shoreline

Location:
Balboa Drive
Summary

70 years (1949-2017)
Possible recession, but 1949 photograph unclear.

40 Years (1979 to 2017)
Nil changes, apart from increased gullying from stormwater from residential development (1990s).

10 years (2007-2017)
Nil changes, apart from increased gullying from storm water.

Summary

Location has been very stable over 70-year period as is to be expected in a sloping hard rock cliff location.

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4-5 Coastal fabric – human intervention (Cell 4)

MODIFIED COASTS

Urban settlements placed too close to the top of cliffs may be threatened if cliffs are not appropriately resistant to erosion (from wave attack, rain water, or aeolian impact). Hallett Cove Cliffs (South) was established in the 1990s and due care was undertaken to position residential development at appropriate distances from the cliff top. The development in most areas of this cell is well set back except for development on Albatross Walk, but this section of cliff is Brachina Formation and resistant to erosion (See inset photo). The only other human intervention in this cell is the coastal walking trail which is predominantly constructed on natural ground and with a fence positioned on the seaward side.

4-5 Coastal fabric – human intervention (Cell 4)

LAND USE ZONING

The current urban planning controls are briefly reviewed here to ascertain if existing development controls are adequate in the context of coastal areas.

Zoning and policy areas

Hills Neighbourhood

Desired Outcome: Low density housing minimises disturbance to natural landforms and existing vegetation to mitigate the visible extent of buildings, earthworks and retaining walls.

Performance outcome (sample): Predominantly low-density residential development with complementary non-residential uses compatible with natural landforms and a low-density residential character.

Allotment widths (20m-24m) and *allotment areas* depend on gradient of the land: 700m^2 -1100m^2.

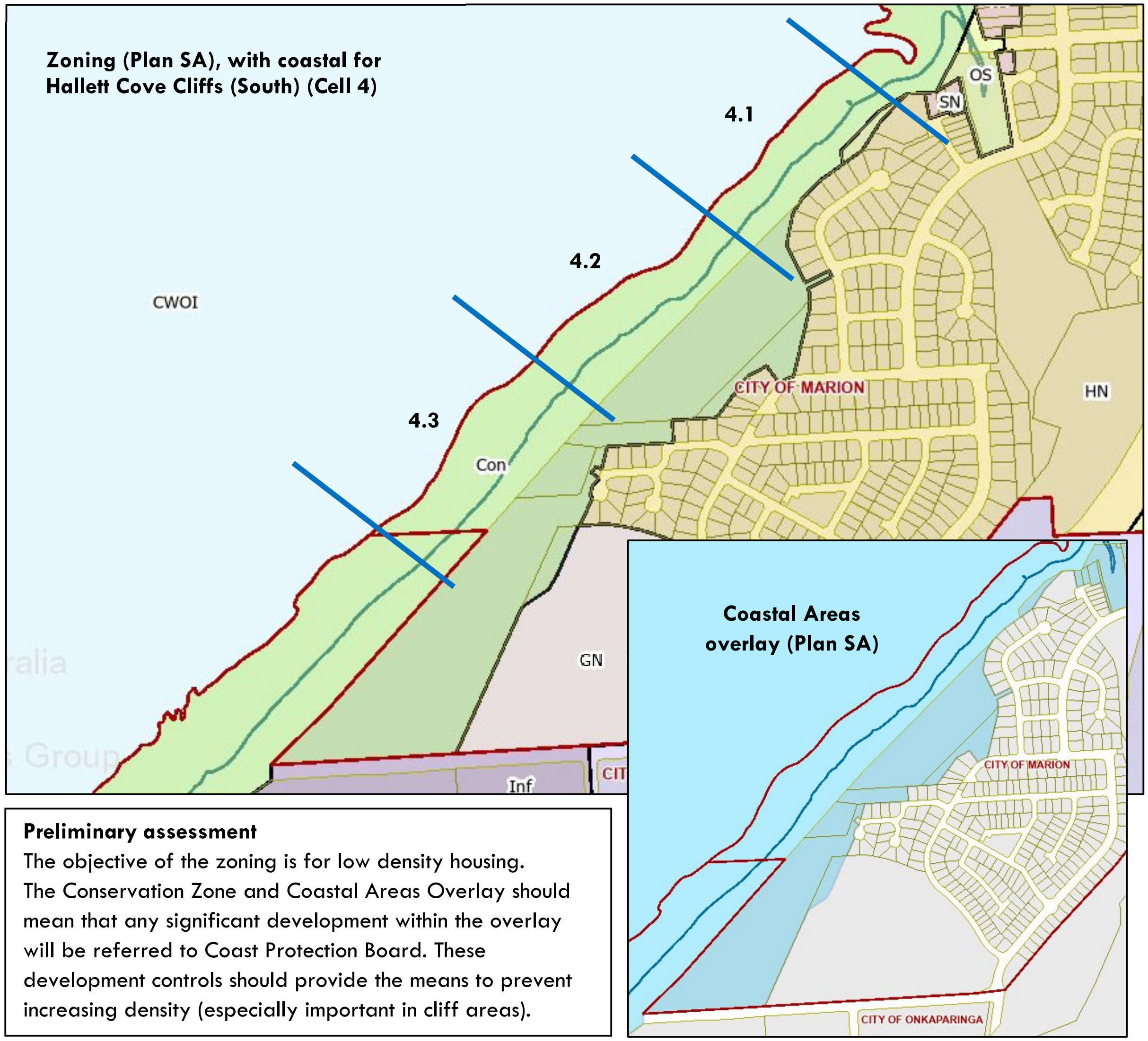
Conservation Zone

A Conservation Zone is positioned along the coast which significantly reduces development options.

Overlays

Coastal Areas (only one reported here)

The Coastal Areas overlay is positioned in a similar location as the Conservation Zone and will trigger a referral to Coast Protection Board for some types of development applications.



Preliminary assessment
The objective of the zoning is for low density housing.
The Conservation Zone and Coastal Areas Overlay should mean that any significant development within the overlay will be referred to Coast Protection Board. These development controls should provide the means to prevent increasing density (especially important in cliff areas).

4-5 Coastal fabric – human intervention (Cell 4)

LAND USE ZONING

City of Marion informs that Lot Q4102 in D91554 is approved for residential development (and other complementary uses). The site is 145m from the Mean High-Water Mark at the nearest point and is landward of the Conservation Zone and Coastal Areas Overlay (See previous page for these locations).

Zoning – General Neighbourhood

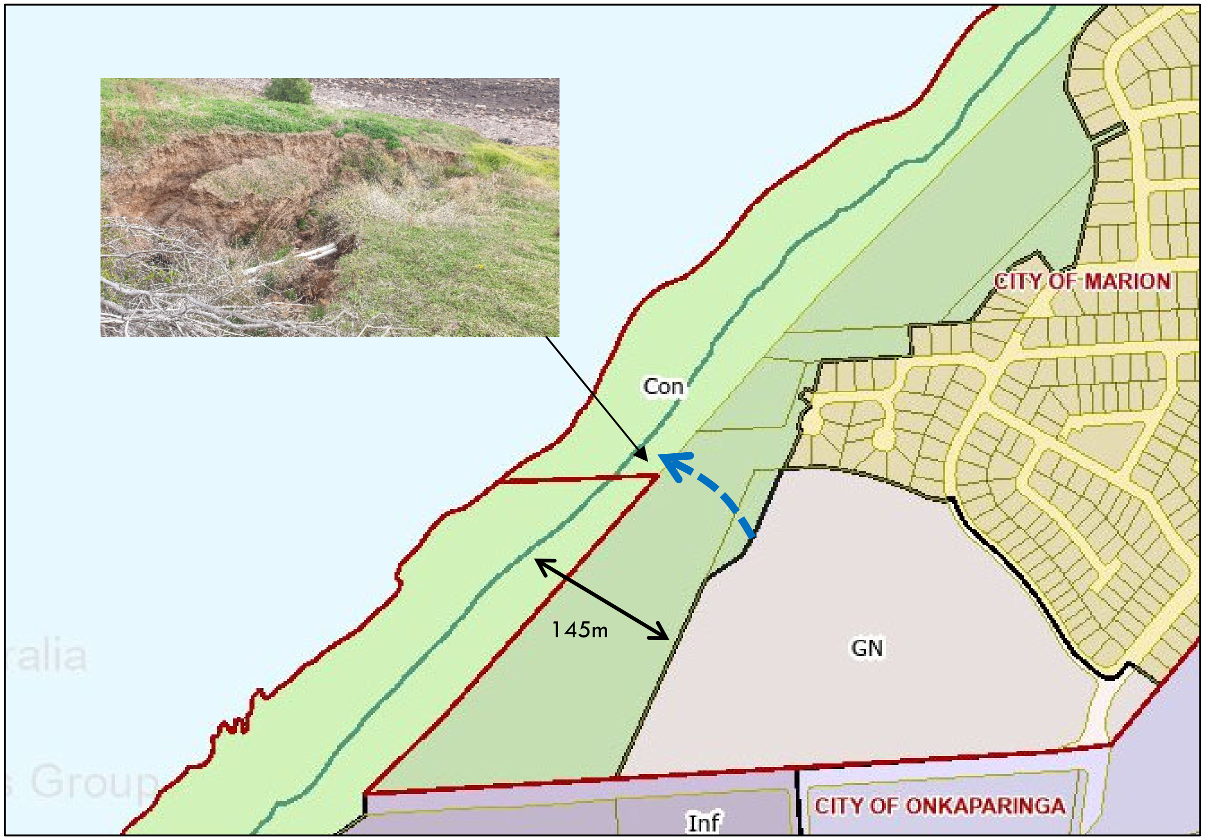
Desired Outcome: low and medium-density housing that supports a range of needs and lifestyles located within easy reach of services and facilities.

Performance outcome (sample): Predominantly residential development with complementary non-residential uses that support an active, convenient, and walkable neighbourhood.

Medium Density: Detached, semi-detached, group dwellings, residential flat buildings (300m2) and row dwellings (250m2).

Stormwater control

It is understood that the design of the neighbourhood will include storm water controls. However, it is likely that excess storm water will need to flow over the cliff to the ocean. Currently, stormwater from Bilboa Drive area flows uncontrolled down the cliff face and has cut a channel through the earthen bank to the beach (see inset photograph).



Preliminary assessment
This assessment is restricted to observations regarding the proposed development in regard to storm water flows to the coast. Currently, smaller flows have minimal impact on the beach (apart from cutting a channel through the earthen bank at the base of the cliff). Storm water design will need to be adequate to control storm water flows down the cliff face, and through the back of the beach to the ocean. Consideration could be given to restoring the bank and piping the water through (see also storm water section below).

4. Coastal fabric – summary table (Cell 4)

Hallett Cliffs (South)		Coastal context - natural				Modified	Coastal changes		
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	70 years	10 years	Erodibility
4.1	Albatross Walk	-5m depth ~ 750m from beach (overall slope ratio ~1:150).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand.	Hard rock cliffs at base, 20m high (Brachina Formation). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set back 20m from cliff top.	Possible minor shoreline recession. Possible loss of slope in upper cliff (photograph unclear).	Nil change	**Low erodibility**
4.2	Petrel Close	-5m depth ~ 750m from beach (overall slope ratio ~1:150).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand	Hard rock cliffs at base, 5-10m high (Brachina Formation). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set back 90m from cliff top.	No cliff base or top recession observed. No increases in rock falls or slumps.	Nil change	**Low erodibility**
4.3	Balboa Drive	-5m depth ~ 430m from beach (overall slope ratio ~1:65).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand.	Hard rock cliffs at base, 10-15m high (Brachina). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set 45m from cliff top. Storm water outlet in gully.	No cliff base or top recession observed. No increases in rock falls or slumps. Gullying from storm water since 2000.	Nil overall change (increased gullying at storm water outlet)	**Low erodibility**

Hallett Cove Cliffs (South): key points

Predominantly hard rock sloping shores that are resistant to erosion at the base, dominated by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. No changes to this coastal area since 1979 apart from variations in sand volume and vegetation (generally increasing). Human interventions include a walking trail set close to the cliff crest and storm water disposed within gully to the south. Residential development is set well back from the top of cliffs (exception at Albatross walk which is set 20m from cliff of resistant rock). **Erodibility rating:**

5. COASTAL EXPOSURE

To evaluate how actions of the sea currently impact the coastal fabric and how actions of the sea are projected to impact in the future in this section we complete the following:

- Review impact of storms (if any)
- Apply current 1 in 100 sea-flood risk scenario,
- Analyse routine high-water impact,
- Analyse these scenarios in time frames: 2020, 2050, 2100.

Viewing instruction:
View sea-flood modelling using full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

5. Coastal exposure – overview

COASTAL EXPOSURE EXPLAINED

The concept of coastal exposure is something we tend to understand intuitively. For example, if we find ourselves on the shore of a protected bay, we 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.

In this study we are primarily concerned with the exposure of coastal landscapes to wave energy and ocean swell. However, coastal landforms can also be vulnerable to exposure from rainfall run-off or from the impact of wind. These can also increase the erosion of coastal landscapes, especially in cliff regions of softer constituency.

Due to its location within Gulf Saint Vincent, which is afforded protection by Kangaroo Island from the Southern Ocean, Nature Maps (SA) has assigned the exposure rating for City of Marion coastline as 'moderate' and the wave energy as 'low'[1].

Storm surges

Despite this protection, when several meteorological conditions combine, storm surges can produce water levels up 1-2m higher than the predicted astronomical tide in Gulf St Vincent. To manage the risk of these events upon human infrastructure, SA Coast Protection Board has set storm surge policy risk levels for the 1 in 100-year event. In terms of probability, this event is predicted to occur once every hundred years. However, 'nature' does not read our probability charts and there is no reason why these large events could not occur closer together, albeit less likely. While storm surges may have significant impact on the coast, these by their very nature are rare events. Over time beaches may rebuild and we can repair the damage.

[1] https://data.environment.sa.gov.au/NatureMaps

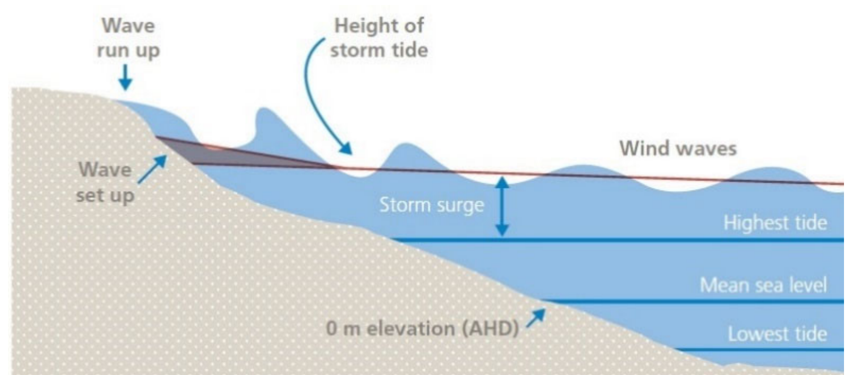
[2] CD stands for Chart Datum and relates to tide heights recorded in the local tide charts.

[3] Australian Height Datum (AHD) is the same measurement system that a surveyor would utilise and generally relates to mean sea level (the middle height of water between high and low water).

The event of 9 May 2016 was the highest event recorded at the Outer Harbor tide gauge and was recorded at 3.80m CD[2] or 2.35 AHD[3]. This event came close to the *1 in 100-year event* set by South Australian Coast Protection Board at 2.50m AHD. *Wave setup* of 0.30 has been adopted for the entire City of Marion coastline[4]. *Wave runup* allocations have been made for each cell based upon surveys conducted of seaward strands from four storms in 2021-2022 (Figure a).

Routine high water

While storm surges can have a significant impact on the coast, these are rare events. If seas rise as projected, routine tidal action is likely to have a greater impact on beaches and backshores over time. In the context of a cliff coast, areas that are currently receiving intermittent wave impact will receive constant wave impact and this is likely to increase the rate of erosion. To calculate the height of this tide, the average monthly high tide from March to September from the tidal record at Port Stanvac was calculated at 1.40m AHD[5]. It is likely that this tidal regime would occur on average one to three times per month.



[4] Set by SA Coast Protection Board. In the context of a storm surge, the water from wave action cannot flow back to the sea and water levels rise against the coast. This is known as 'wave setup'.

[5] Port Stanvac gauge operated from 1992 to 2010. Actual height was calculated at 1.42m AHD which represents 90% of the height at Outer Harbor for the same period at 1.59m AHD.

5. Coastal exposure – overview

COASTAL PROCESSES

Wave action on the Marion Council coastline

The degree of susceptibility of a coastline to wave erosion is related to the degree of exposure of the coast to wind, current and wave attack. There are two main types of waves which fashion beaches: storm (forced waves); and swell (constructional waves). Forced waves scour the beach, erode sand from beach faces and form offshore bars. When storms subside, constructional waves tend to push sand back onto the beach.

The alignment of Marion's coastline tends more to the north-east/ south-west in contrast to Onkaparinga and Adelaide metropolitan coastline which tends to orientate north-south. Swell waves are generated in the Southern Ocean, but after passing through Investigator Strait, and having 'refracted, diffracted and attenuated due to bottom friction', wave heights are much reduced as they approach the Marion coastline. Swell waves that propagate to the Marion coastline region have 12-16 second periods, heights below 1m, and directions close to 260˚. Sea waves within the Gulf St Vincent are generally of short-wave period and quite steep, frequently with white caps and approach the shore from the direction of the wind, mostly west-south-west winds, but can roll in at range 250˚ - 310˚. Combine with south-west swells, the net wind-wave direction is northward. Wind waves are generally lower than swell waves but have been recorded at 2.6m in Gulf St Vincent[6] (Figure a).

Storm action on the Marion Council coastline

The conditions that produce the highest levels of water in Gulf St Vincent have been documented by Flinders Ports[7]. With the passage of a deep depression across the Southern Ocean, the winds are from the North which then swings to the North-West. A strong gusty north-westerly wind, with a depression in the Southern Ocean, backing to the south-west at about the time of low water, will cause a storm surge of maximum amplitude from the Southern Ocean, and heights may be expected from 1m to 2m

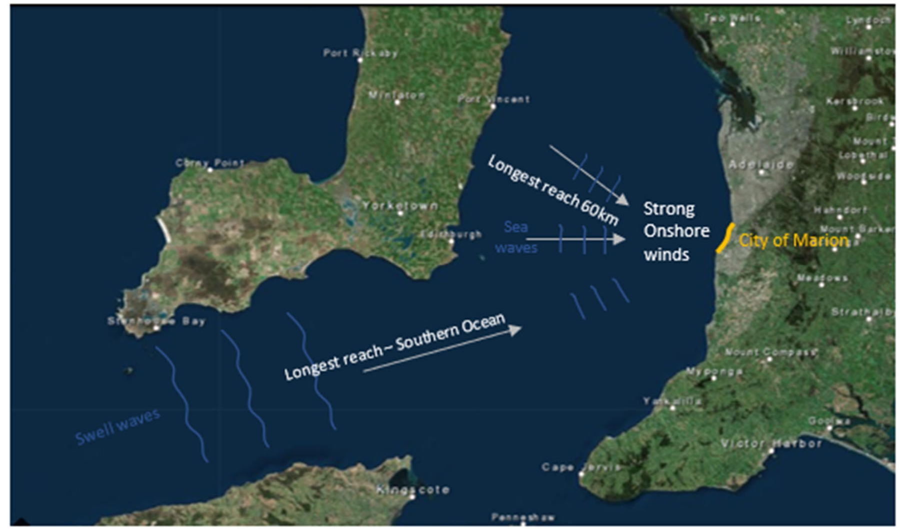


Figure a. The orientation of the City of Marion coastline to wave energy (M. Western, 2018)

Tidal Range on the Marion City Council coastline

The effect of tides pushing up through a narrowing Gulf increases the tidal range in the northern parts of the Gulf. In the Marion region, the categorisation is borderline in the upper ranges of micro-tidal as assessed by Doug Lord 2012.

Level	Chart Datum (m)	AHD (m)
Lowest astronomical tide	0.00	-1.45
Mean sea level	1.30	-0.15
Australian Height Datum	1.45	0.00
Mean high water neaps	1.30	-0.15
Mean high water springs	2.40	0.95

Figure b. The tidal range at City of Marion is characterized as micro-tidal (upper range).

6 D. Lord., Coastal Management Study, Hallett Cove, SA. 2012

7 Flinders Ports (ND) Port User Guide – General Information

5. Coastal exposure – overview

SEA LEVEL RISE

Climate change occurs over long timescales in response to solar variations, changes in the Earth's orbit around the Sun, volcanic eruptions, and natural variability. Sea levels reflect the state of the climate system. During ice ages a large volume of water is stored on land in the form of ice sheets and glaciers, leading to lower sea levels, while during warm interglacial periods, glaciers and ice sheets are reduced and more water is stored in the oceans[8]. Over the last few thousand years sea levels have stabilised, and also within this time frame, urban settlements have been established near the coast all over the world.

Global mean sea levels

The average level of the ocean is known as *global mean sea level* (GMSL). Long term tide gauges show that seas began to rise in the 19th century and this trend has continued throughout the 20th century at an average rate of 1.7mm per year. However, this average rate of rise was not constant. Rates of sea level rise were higher in the period 1920s to1940s[9] (in the context of higher temperatures and melting of the Greenland ice sheets[10]). In the 1990s sea levels again rose at a faster rate, comparable to that of the 1920s to 1940s. Since 1990, satellites have been tracking mean sea level rise at 3-4mm per year in our region[9]. However, this shorter-term record is likely to contain an element of natural variability and the current rate of rise not unusual in the context of natural variability and the data record from last century[11]

[8] Coast Adapt, 2017.
[9] IPCC, WG1AR5, Sea level change, 2014, Watson, P, 2020.

Regional sea levels

Regional changes occur in sea level, but these do not change the overall mass of the ocean. For example, regional sea levels change in accordance with the climate variability associated with El Nino and La Nina cycles. During El Nino years sea level rises in the eastern Pacific and falls in the western Pacific, whereas in La Nina years the opposite is true. Longer term changes are also associated with changes in the Trade Winds which bring increases in sea levels in the Western Tropical Pacific region[2]. Sea levels can also change in relationship to the vertical movement of land. If an area of land is falling, then in relative terms, sea levels will rise, and vice versa.

Projected sea level rise

Projections of future climate change are carried out using climate models that use various greenhouse gas emissions scenarios. These models are computer-based simulations of the earth-ocean-atmosphere system that identify plausible futures as to how the climate will respond over the coming century[4]. Sea level rise projections are based upon these various scenarios. In 1993, South Australian Coast Protection Board (CPB) adopted sea level rise allowances into planning policy of 0.3m rise by 2050 and 1.0m rise by 2100. These sea level rise projections are similar to the high emissions scenario shown in Figure a.

[10] Curry, J., Sea level and climate change, 2019.
[11] CSIRO, 2020, Sea level, waves and coastal extremes.

Scenario modelling

In this project we take the current storm surge risk levels and current routine high-water data and model the impact of these in a digital model captured in 2018. We then take the sea level allowances set by CPB at 0.3m by 2050 and 1.0m by 2100 and model the projected impact of sea level rise upon the coast.

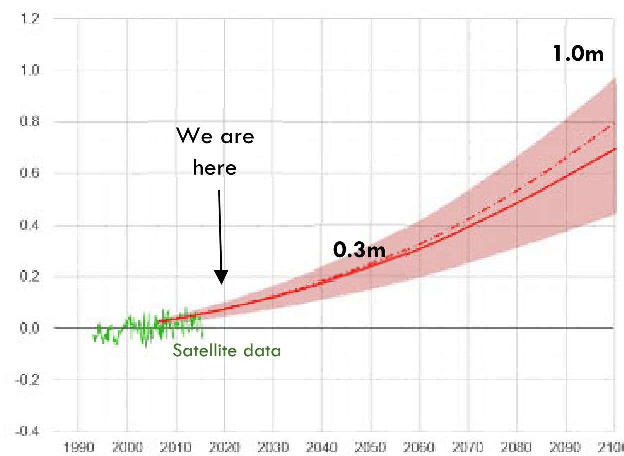


Figure a: Sea level rise high emissions scenario (Coast Adapt, 2017). Coast Protection Board sea-level rise policy added.

5. Coastal exposure – previous storm impact

HISTORICAL STORMS

The analysis of previous storms provides a window into the past to assist us to identify where the coast is most vulnerable. This analysis also provides a window into the future because it provides a context from which to consider how storms will impact the coast if seas rise as projected. In some ways, storms are 'natures' vulnerability assessment of how resilient our coast currently is, and how it may respond in the future.

Storm events

The three highest storm surges on record at Outer Harbor tide gauge occurred:

- 9 May 2016 – 2.35m AHD (3.80 CD)
- 3 July 2007 – 2.27m AHD (3.71 CD)
- 25 April 2009 – 2.22m AHD (3.65 CD)

Using a comparison of Port Stanvac and Outer Harbor gauges from 1992 to 2010 it is likely that the event of 9 May 2016 was 2.12m AHD along the City of Marion coast (see inset table).

There is no local data or photographs relating to how storms have impacted this cell. Based on the sea-flood modelling, impacts are likely to have been very low.

Event: 17 September 2021
Seaweed strands were surveyed at 2.60m AHD after this moderate event of 1.69m (3.12 CD) at Outer Harbor tide gauge. Wave effects are therefore 0.90m above Outer Harbor.

Comparison of Port Stanvac and Outer Harbor tidal data

A comparison of all monthly high tides showed Port Stanvac was on average 87% lower than Outer Harbor.

A comparison of monthly high tides (April to September) revealed that Port Stanvac was 90% lower.

A comparison of storm events within the period:

- 3 July 2007 (2.07 PS, 90% of 2.27OH is 2.04m)
- 25 April 2009 (1.95 PS, 90% of 2.22m is 2.00m)

Therefore, 9 May 2016 was likely to have been in vicinity of 2.12 at Port Stanvac and is adopted for this event.

5. Coastal exposure – location map (Cell 4.1)

Location

Cell 4.1

Hallett Cove Cliffs (South)

Location Map

Albatross Walk

The scenarios modelled are:

- Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.
- 1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

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5. Coastal exposure – routine high water (2020)

Routine high water

Cell 4.1

Hallett Cove Cliffs (South)

2020 scenario

Event: Routine high water

Albatross Walk

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Wave set-up	0.30m
Total risk	1.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The modelling is congruent with observations. The current impact on the rocky beach and backshore is very low.

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5. Coastal exposure – routine high water (2050)

Routine high water

Cell 4.1

Hallett Cove Cliffs (South)

2050 scenario

Event: Routine high water

Albatross Walk

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Sea level rise	0.30m
Wave setup	0.30m
Total risk	2.20m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The impact on the rocky beach and backshore for projected sea level rise for 2050 is very low.

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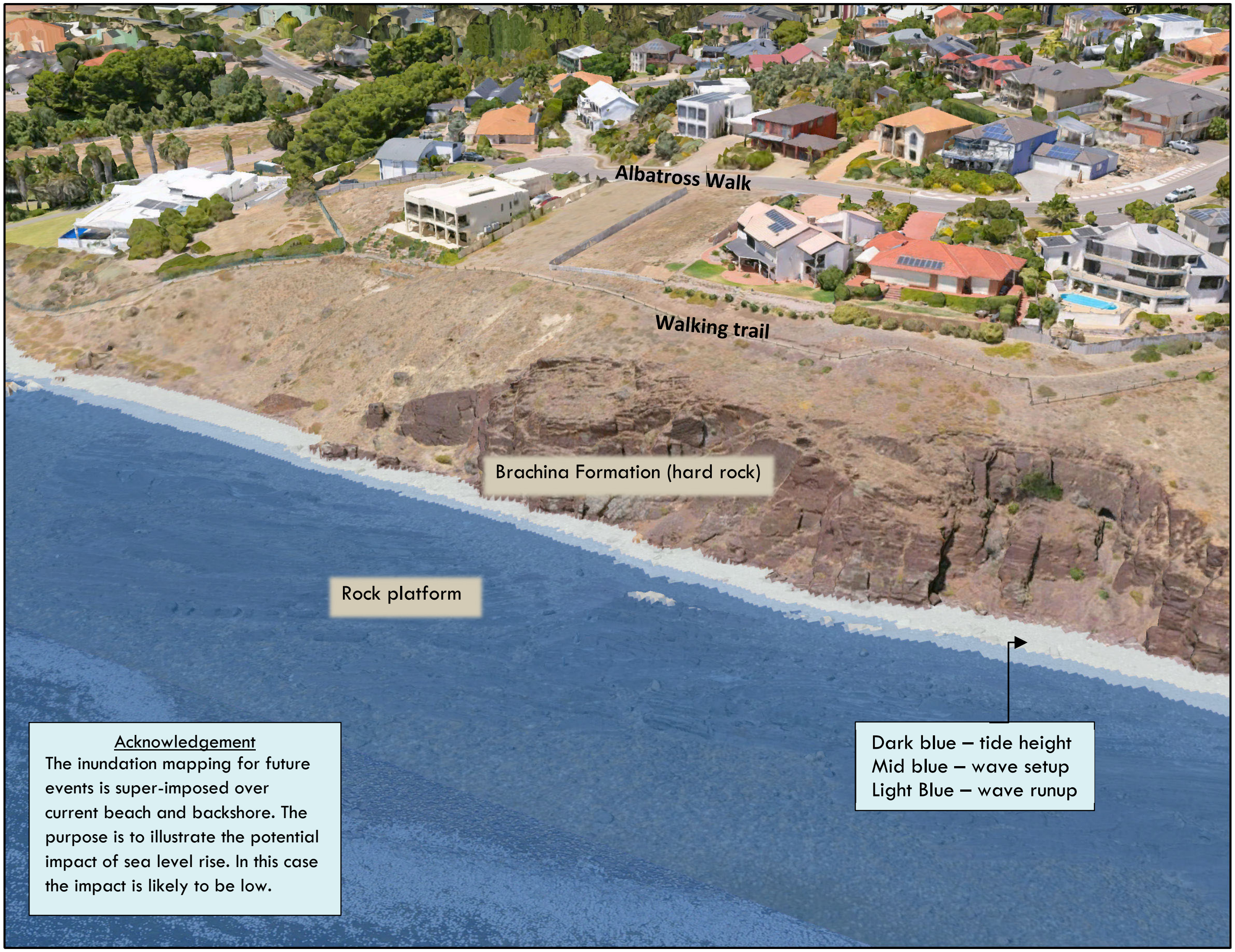

Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – routine high water (2100)

Routine high water

Cell 4.1

Hallett Cove Cliffs (South)

2100 scenario

Event: Routine high water

Albatross Walk

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Sea level rise	1.00m
Wave setup	0.30m
Total risk	2.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The impact on the rocky backshore for projected sea level rise for 2100 is likely to be low. Some erosion to the clay escarpment is likely, but overall impact is low.

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5. Coastal exposure – storm surge (2020)

Storm surge

Cell 4.1

Hallett Cove Cliffs (South)

2020 scenario

Event: 1 in 100 sea-flood risk

Albatross Walk

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

Storm surge	2.30m AHD.
Wave set-up	0.40m
Risk	2.70m AHD

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be very low.

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5. Coastal exposure – storm surge (2050)

Storm surge

Cell 4.1

Hallett Cove Cliffs (South)

2050 scenario

Event: 1 in 100 sea-flood risk

Albatross Walk

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

Storm surge	2.30m AHD
Sea level rise	0.30m
Wave set-up	0.40m
Risk	3.00m AHD

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be very low.

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Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

Dark blue – tide height
Mid blue – wave setup
Light Blue – wave runup

5. Coastal exposure – storm surge (2100)

Storm surge

Cell 4.1

Hallett Cove Cliffs (South)

2100 scenario

Event: 1 in 100-year event

Albatross Walk

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

Storm surge	2.30m AHD
Sea level rise	1.00m
Wave set-up	0.40m
Risk	3.70m AHD

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be low.

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The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

Dark blue – tide height
Mid blue – wave setup
Light Blue – wave runup

5. Coastal exposure – summary (Cell 4.1)

Summary

Cell 4.1

Hallett Cove Cliffs (South)

Summary

Albatross Walk

2020-2050

Sea levels 0.3m higher than present are unlikely to have any major impact on beach and backshore.

2050-2100

If sea levels rise as projected in the latter part of this century, a rare storm event is unlikely to have any impact on beach and backshore. Routine high water may erode the escarpment on the left, but this area is also underpinned by rock.

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5. Coastal exposure – location map (Cell 4.2)

Location

Cell 4.2

Hallett Cove Cliffs (South)

Location Map

Petrel Close

The scenarios modelled are:

- Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.
- 1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

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5. Coastal exposure – routine high water (2020)

Routine high water

Cell 4.2

Hallett Cove Cliffs (South)

2020 scenario

Event: Routine high water

Petrel Close

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Wave set-up	0.30m
Total risk	1.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The modelling is congruent with observations and the current impact on beach and backshore is very low.

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5. Coastal exposure – routine high water (2050)

Routine high water

Cell 4.2

Hallett Cove Cliffs (South)

2050 scenario

Event: Routine high water

Petrel Close

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

<u>The event modelled:</u>

Routine monthly tide	1.60m AHD
Sea level rise	0.30m
Wave setup	<u>0.30m</u>
Total risk	2.20m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The impact on the rocky beach and backshore for projected sea level rise for 2050 is low.

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<u>Acknowledgement</u>
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – routine high water (2100)

Routine high water

Cell 4.2

Hallett Cove Cliffs (South)

2100 risk:

Event: Routine high water

Petrel Close

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Sea level rise	1.00m
Wave setup	0.30m
Total risk	2.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The Hindmarsh Clay slopes above the rocky base may undergo some recession and the slope increase. The overall erosion outlook is low.

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Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – storm surge (2020)

Storm surge

Cell 4.2

Hallett Cove Cliffs (South)

2020 scenario

Event: 1 in 100 sea-flood risk

Petrel Close

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

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

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be very low.

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Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – storm surge (2050)

Storm surge

Cell 4.2

Hallett Cove Cliffs (South)

2050 scenario

Event: 1 in 100 sea-flood risk

Petrel Close

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

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

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be low.

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Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – storm surge (2100)

Storm surge

Cell 4.2

Hallett Cove Cliffs (South)

2100 scenario

Event: 1 in 100-year event

Petrel Close

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

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be low, but the combination of higher routine tides and storm surges is likely to cause some recession of the Hindmarsh Clay base and increase the slope. However, it is likely that the harder rock lays underneath the base.

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5. Coastal exposure – summary (Cell 4.2)

Summary

Cell 4.2

Hallett Cove Cliffs (South)

Summary

Petrel Close

2020-2050

Sea levels 0.3m higher than present are unlikely to have any major impact on beach and backshore.

2050-2100

If sea levels rise as projected in the latter part of this century, a rare storm event is unlikely to have any impact on beach and backshore. Routine high water may erode the Hindmarsh Clay escarpments, but this area is also likely underpinned by rock.

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5. Coastal exposure – location map (Cell 4.3)

Location

Cell 4.3

Hallett Cove Cliffs (South)

Location Map

Balboa Drive

The scenarios modelled are:

- Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.
- 1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

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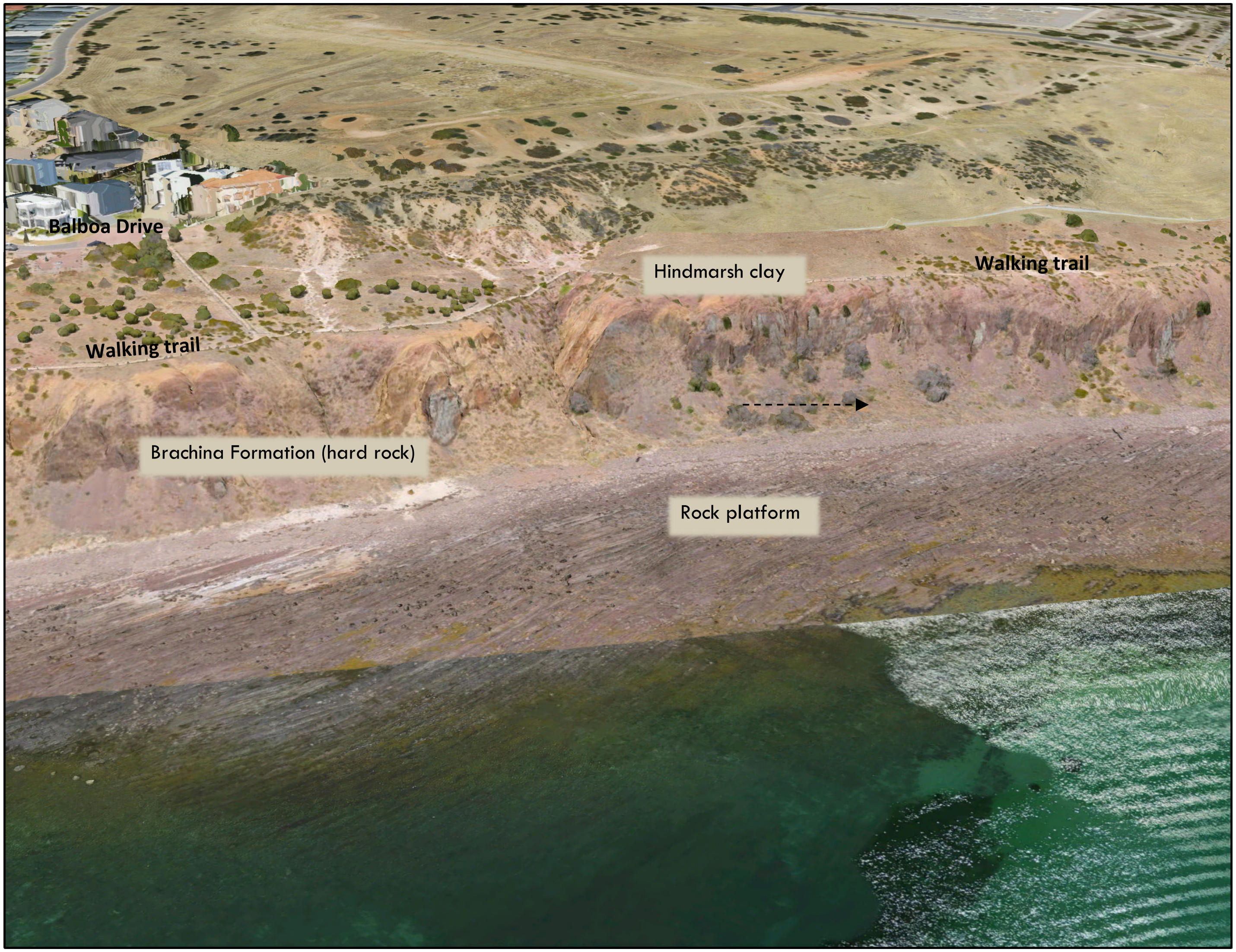

5. Current exposure – routine high water (2020)

Routine high water

Cell 4.3

Hallett Cove Cliffs (South)

2020 scenario

Event: Routine high water

Balboa Drive

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Wave set-up	0.30m
Total risk	1.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The modelling is congruent with observations. The current impact on the rocky beach and backshore is very low.

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5. Coastal exposure – routine high water (2050)

Routine high water

Cell 4.3

Hallett Cove Cliffs (South)

2050 scenario

Event: Routine high water

Balboa Drive

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Sea level rise	0.30m
Wave set-up	0.30m
Total risk	2.20m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Assessment: The impact on the rocky beach and backshore for projected sea level rise for 2050 is very low.

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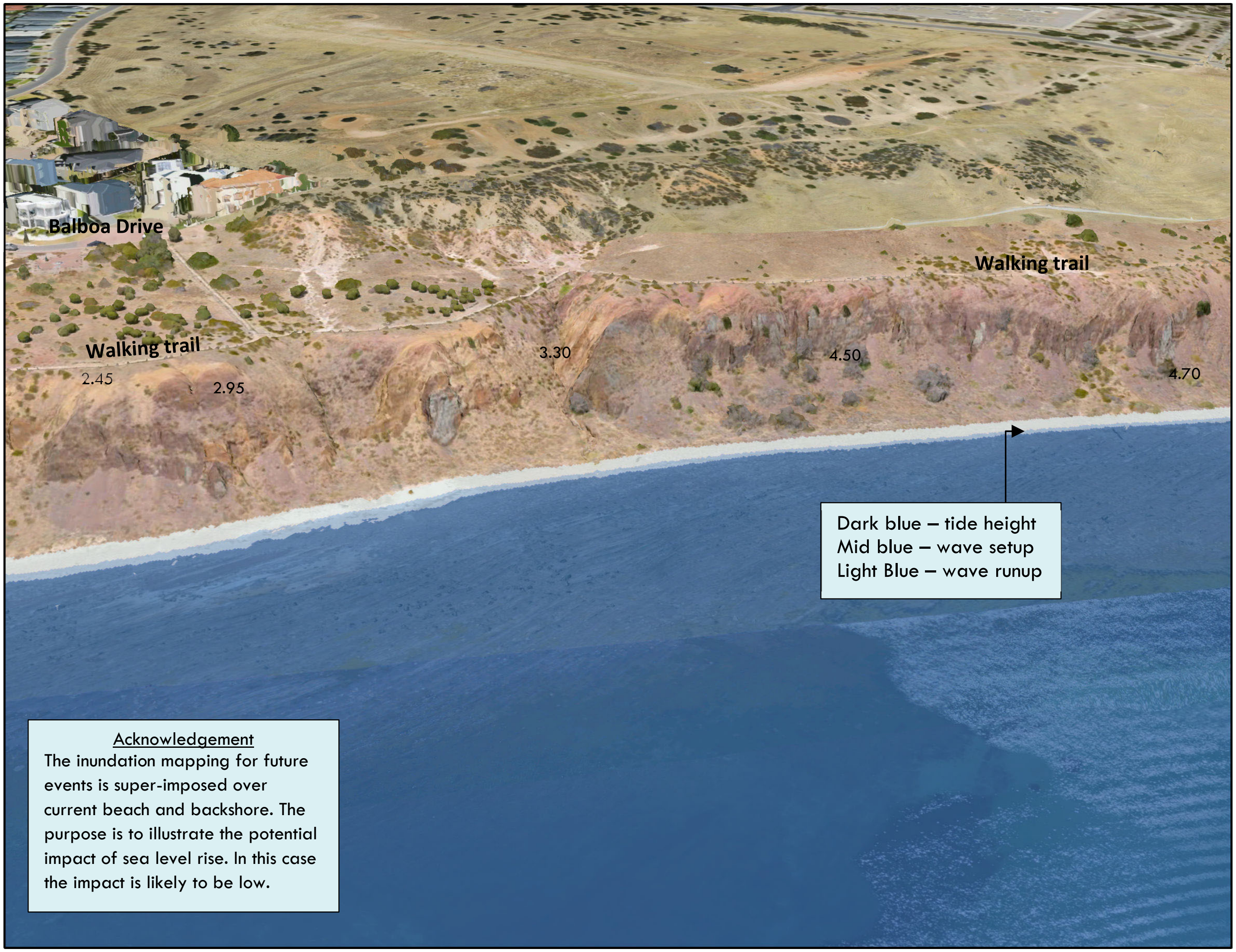

Dark blue – tide height
Mid blue – wave setup
Light Blue – wave runup

Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – routine high water (2100)

Routine high water

Cell 4.3

Hallett Cove Cliffs (South)

2100 scenario

Event: Routine high water

Balboa Drive

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

Inputs are based on analysis on data from Outer Harbor and analysis of five storms (2021, 2022)

The event modelled:

Routine monthly tide	1.60m AHD
Sea level rise	1.00m
Wave set-up	0.30m
Total risk	2.90m AHD

Wave run-up is an additional 0.80m and depicted in light blue.

Routine high-water events of this nature, and in context of higher storms, will cause recession of the shoreline back to the road. The

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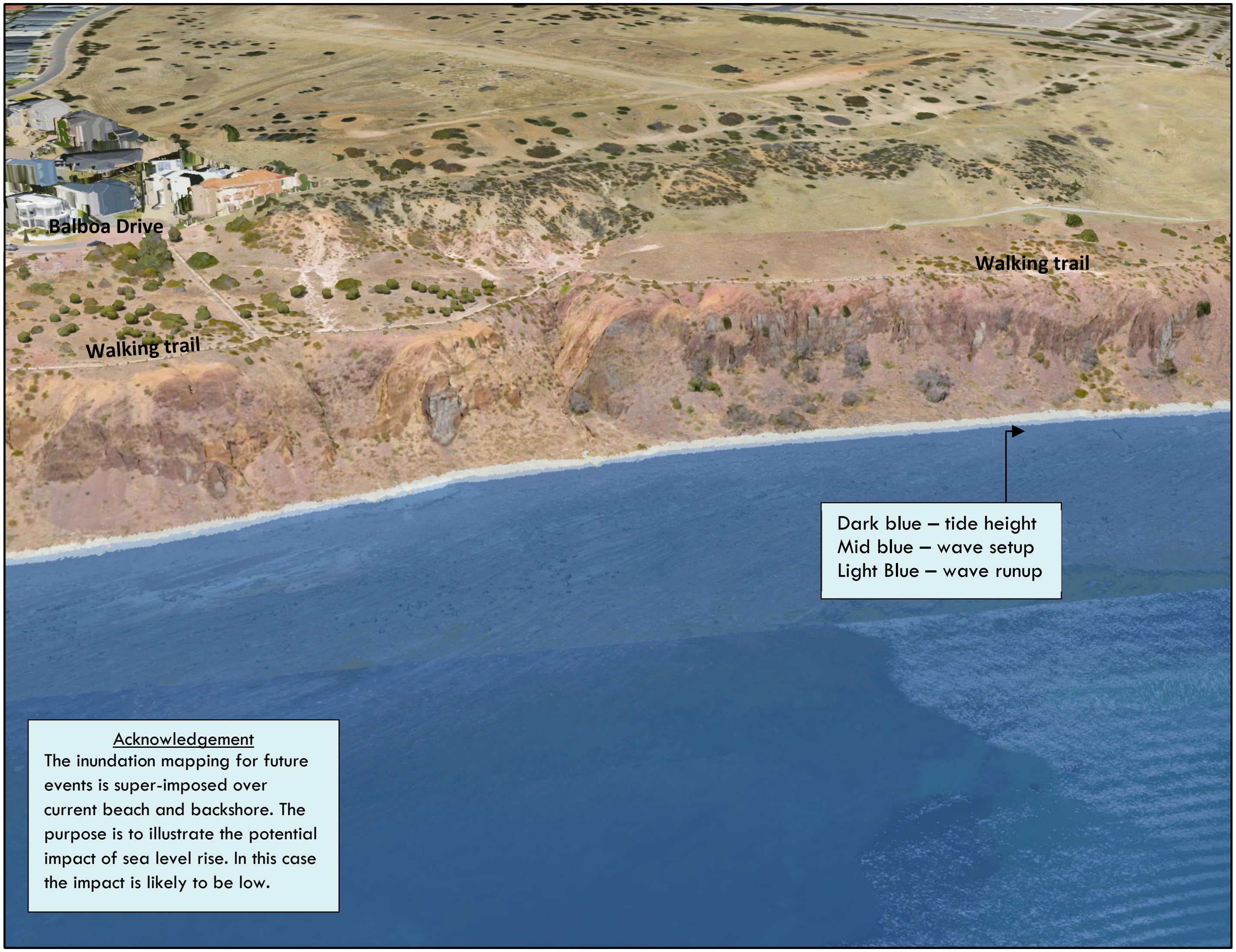

5. Coastal exposure – storm surge (2020)

Storm surge

Cell 4.3

Hallett Cove Cliffs (South)

2020 scenario

Event: 1 in 100 sea-flood risk

Balboa Drive

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

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

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be very low.

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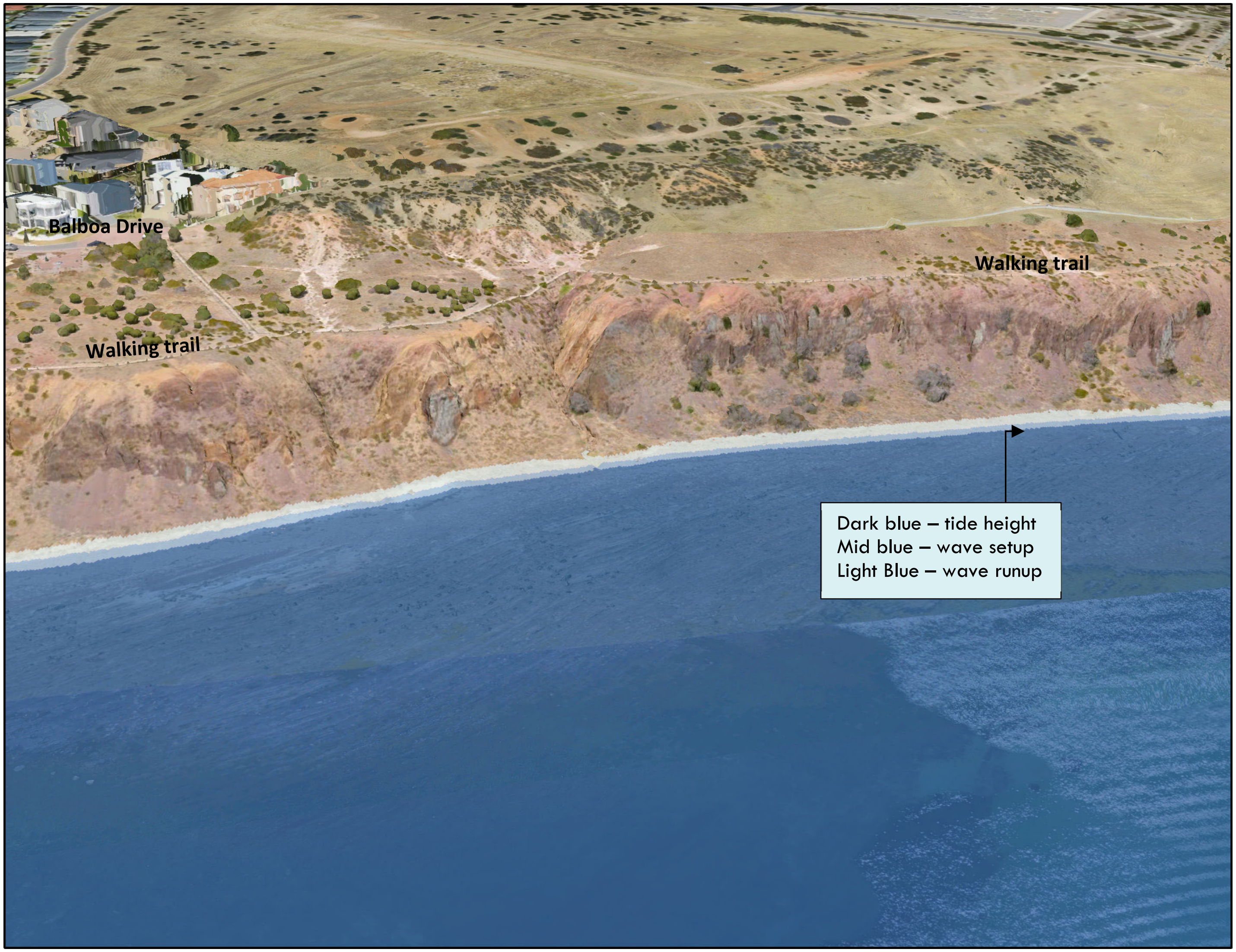

5. Coastal exposure – storm surge (2050)

Storm surge

Cell 4.3

Hallett Cove Cliffs (South)

2020 scenario

Event: 1 in 100 sea-flood risk

Balboa Drive

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

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

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be low.

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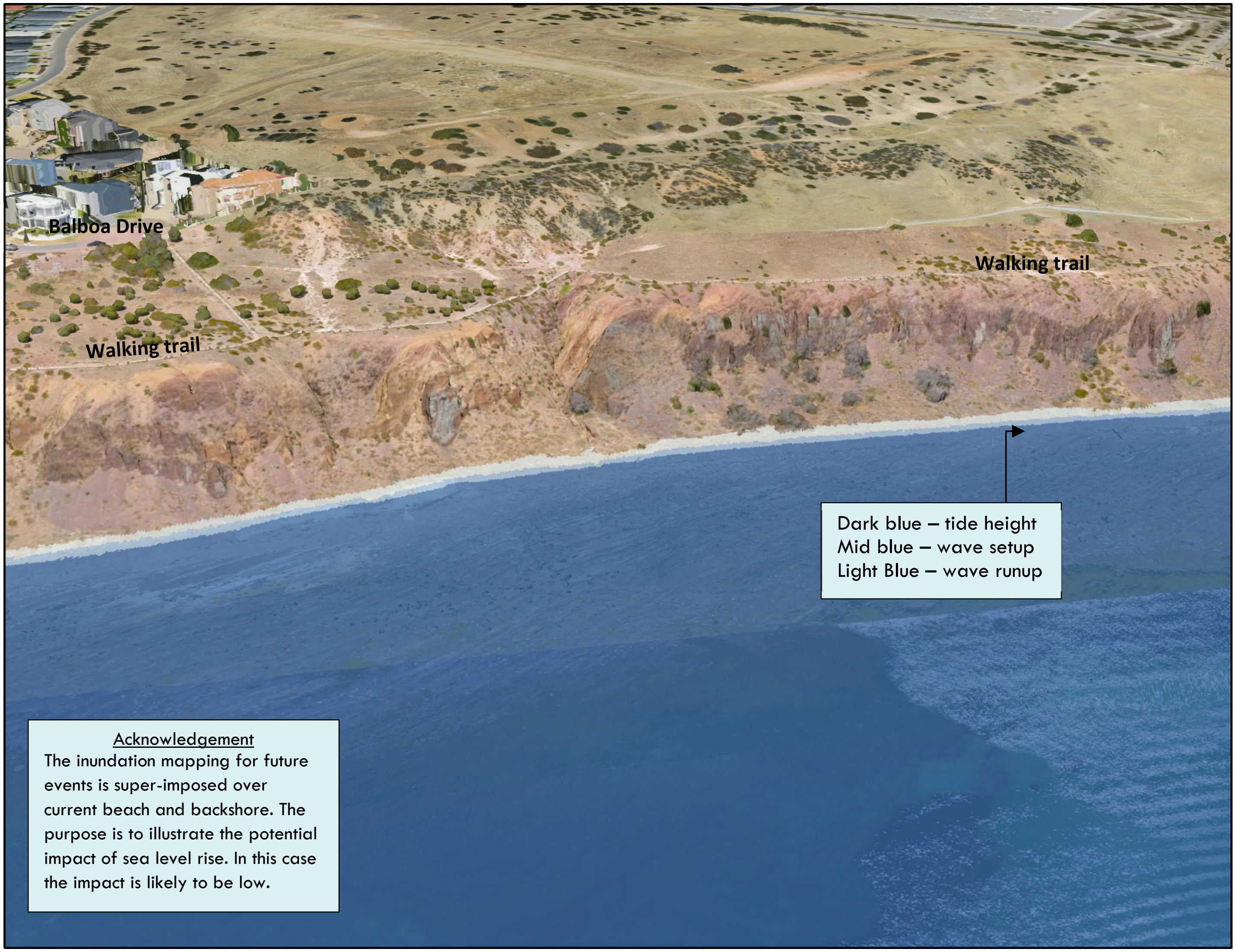

Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise. In this case the impact is likely to be low.

5. Coastal exposure – storm surge (2100)

Storm surge

Cell 4.3

Hallett Cove Cliffs (South)

2020 scenario

Event: 1 in 100 sea-flood risk

Emma St to Murto Road

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

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is an additional 1.00m and depicted in light blue.

Assessment:
As a very infrequent event, the impact is likely to be low, but the combination of higher routine tides and storm surges is likely to cause some recession of the Hindmarsh Clay base and increase the slope. However, it is likely that the harder rock lays underneath the base.

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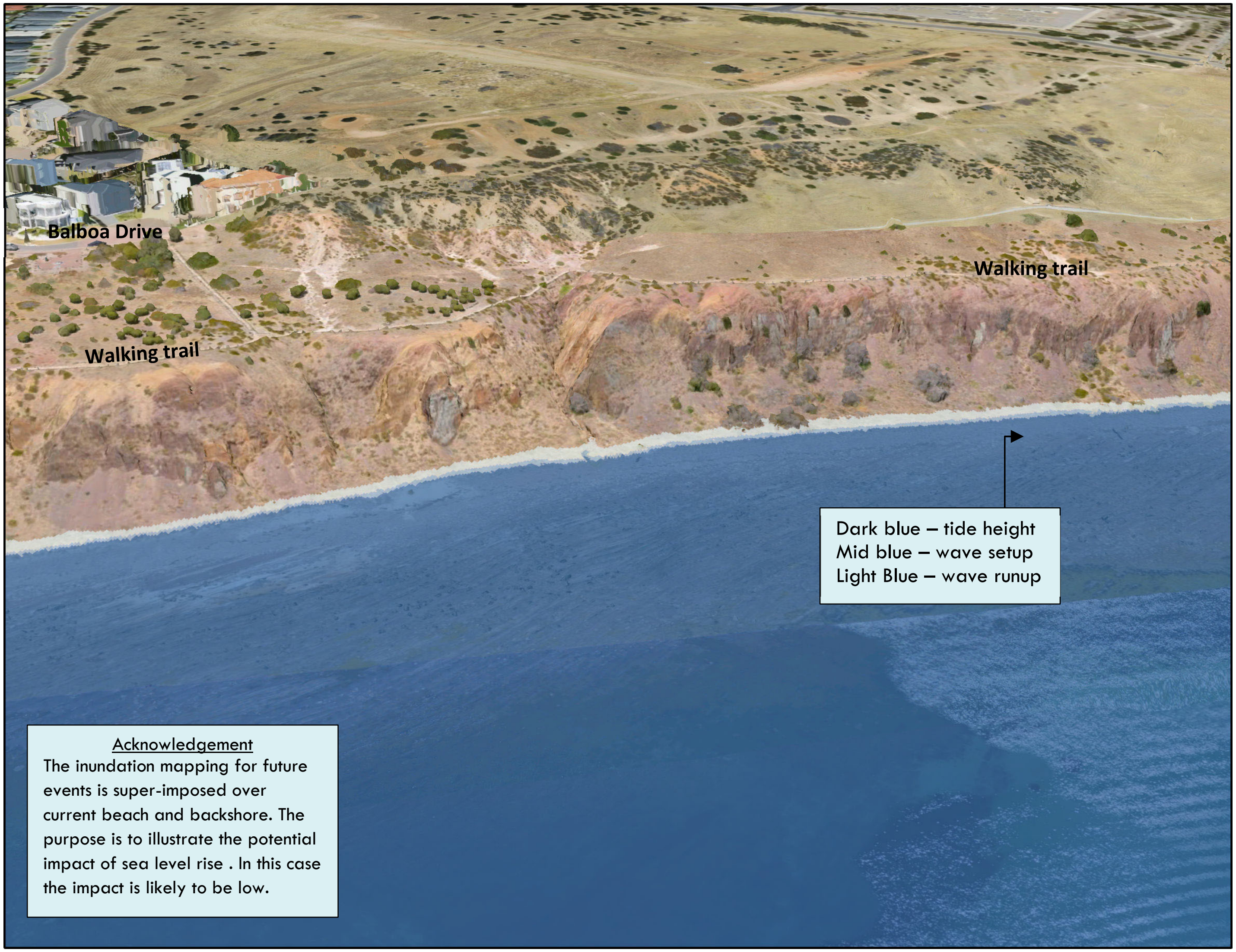

Acknowledgement
The inundation mapping for future events is super-imposed over current beach and backshore. The purpose is to illustrate the potential impact of sea level rise . In this case the impact is likely to be low.

5. Coastal exposure – summary (Cell 4.3)

Summary
Cell 4.3 Hallett Cove Cliffs (South) Summary

Balboa Drive

2020-2050

Sea levels 0.3m higher than present are unlikely to have any major impact on beach and backshore.

2050-2100

If sea levels rise as projected in the latter part of this century, a rare storm event is unlikely to have any impact on beach and backshore. Routine high water may erode the Hindmarsh Clay escarpments, but this area is also likely underpinned by rock.

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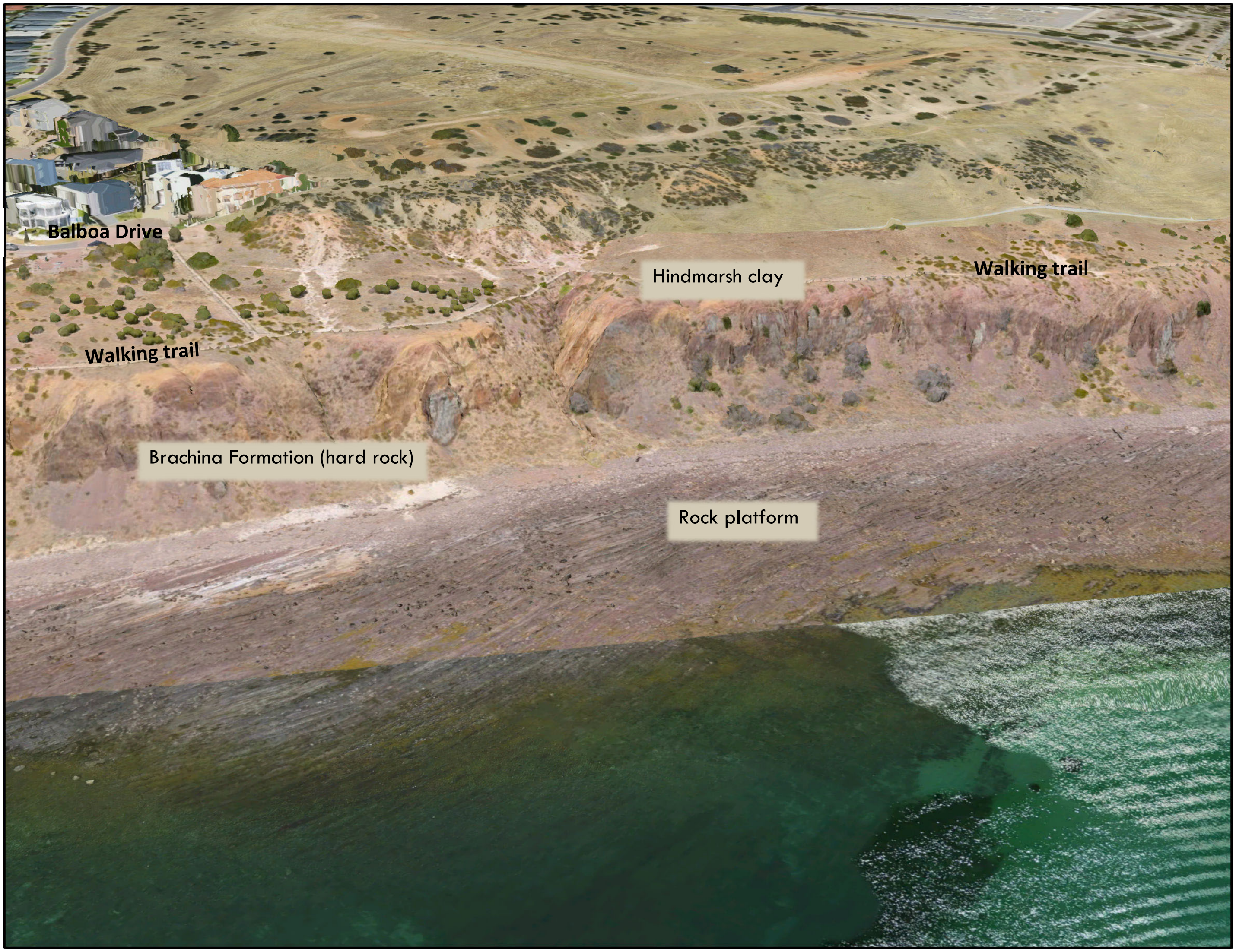

COASTAL EXPOSURE – Summary table

Hallett Cove Cliffs (South) (Cell 4)

Hallett Cliffs (S)		Coastal context - natural				Modified	Exposure*	Scenario Modelling	
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	Waves	2020 - 2050	2050-2100
4.1	Albatross Walk	-5m depth ~ 750m from beach (overall slope ratio ~1:150).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand.	Hard rock cliffs at base, 20m high (Brachina Formation). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set back 20m from cliff top.	Moderate exposure Low wave energy	Current sea levels and 0.3m higher than present are unlikely to have any major impact on beach and backshore.	Rare storm events unlikely to have impact on beach and backshore. Routine high water may erode any clay at the base, but these are likely underpinned by rock.
4.2	Petrel Close	-5m depth ~ 750m from beach (overall slope ratio ~1:150).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand.	Hard rock cliffs at base, 5-10m high (Brachina Formation). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set back 90m from cliff top.	Moderate exposure Low wave energy	Current sea levels and 0.3m higher than present are unlikely to have any major impact on beach and backshore.	Rare storm events unlikely to have impact on beach and backshore. Routine high water may erode any clay at the base, but these are likely underpinned by rock.
4.3	Balboa Drive	Steepening slope to the south. -5m depth ~ 430m from beach (overall slope ratio ~1:65).	Nearshore - low profile reef, then bare sand, then seagrass meadow.	Flat bedrock platform with cobbles and coarse sand.	Hard rock cliffs at base, 10-15m high (Brachina). Hindmarsh clay in upper cliff slopes (friable).	Walking trail. Residential development set 45m from cliff top. Storm water outlet in gully.	Moderate exposure Low wave energy	Current sea levels and 0.3m higher than present are unlikely to have any major impact on beach and backshore.	Rare storm events unlikely to have impact on beach and backshore. Routine high water may erode any clay at the base, but these are likely underpinned by rock.

***Exposure Rating: Sheltered (2)** (assigned by SA Nature Maps)

Hallett Cove Cliffs (South) – Key Points

Predominantly hard rock sloping shores that are resistant to erosion, dominated by low profile offshore reef and rocky beach platform. In the short term (2020 to 2050) impacts will be low from storm events and routine high-water events. If seas rise as projected (2050-2100) there will be increasing impact with the backshore but in this location the impact is likely to be minor.

6. Storm water runoff from urban settlement

6. Storm water runoff from urban settlement

Purpose of the study

The purpose of this study is to evaluate the impact of storm water that flows from urban areas to the coast. Large volumes of rainwater can quickly accumulate and flow from the impervious surfaces of urban settlements. Storm water flowing over softer embankments can cause gullying and instability and scouring of dunes and beaches. Over time cliffs, embankments and dunes break down and sand levels are likely to drop on the beach. In the context of sea level rise, the locations where storm water is impacting beaches and backshores may be locations where incursions of seawater occur first. Finally, in some locations the potential exists for a confluence of events where storm water and sea storms combine and produce greater levels of flooding.

Four questions are assessed in this project:

(1) Does Council manage storm water from urban settlement so that it does not flow uncontrolled over backshores and beaches?

(2) What impact is occurring on the backshores and beach due to storm water runoff?

(3) Is there any potential for increased flooding due to confluence of rain events with sea storm events?

(4) Do any storm water outlets require review[12]?

Methodology

A drone was utilised to capture photography of the City of Marion coastline after rain events to check for scouring of backshores and beaches, or debris deposits on beaches. Two captures were achieved, one in 2021 and one in 2022.

Storm water monitoring (2021)

In the last two weeks of July, rain fell on 11 out of 14 days. The rain fall for July was ~50% above the 20-year mean. Specifically, 14mm of rain fell on 31st July. No evidence of scouring or slides within cliff escarpments, nor sediment transfer to the beach was observed apart from some moderate mud staining on the beach at Hallett Cove from storm water runoff from the Conservation Park[13].

Storm water monitoring (2022)

Significant rain events occurred in early June 2022, but these have not been evaluated at the time of writing this report[14]. For example, 52mm rain fell on 5 June 2022 and 15.4mm on 6th June (Happy Valley gauge). The drone photographic capture of the whole coast was undertaken on 9th June 2022. The findings were similar to those of 2021 (see above).

Storm water outlet review

On 9 and 10 June 2022 (after significant rain events), every storm water outlet that could be located was reviewed, photographed, and assessed within the GIS environment. In particular, the following items were catalogued and assessed:

1. Location of outlet (e.g. top of cliff)
2. Outlet type (e.g. 300mm pipe)
3. End control (e.g. Headwall)
4. Condition of infrastructure
5. Vegetation cover (e.g. overgrown)
6. Nature of backshore (e.g. cliff, embankment)
7. Nature of beach (e.g. rocky, sandy)
8. Impact on backshore (e.g. scouring, gullying)
9. Impact on beach (e.g. scouring, gullying)
10. Comments and recommendations.

Outputs from the study

Two main outputs are generated from this study:

- A digital file (GIS) with locations, photographs, and an attribute table for each of the storm water outlets.
- This report which provides a summary of the findings on the following pages.

[12] In this cell, Question 4 was not relevant due to the elevated nature of backshores.

[13] See Cells 1-4, Coastal Monitoring program for City of Marion, year 2021.

[14] See Cells 1-4, Coastal Monitoring Program for City of Marion, year 2022 (not completed at date of writing).

6. Storm water runoff from urban settlement

Studies and plans

Hallett Cove Creeks Storm Water Management Plan, Southfront, 2012.

Overview of the study

The Hallett Cove Creeks Stormwater Management Plan (2012) produced by Southfront is a thorough investigation of the current storm water system for three catchment areas located in Cell 2 and 3, and a suggested improved management strategy.

This area of interest for this study did not include Cell 4, Hallett Cove Cliffs South.

The remainder of this page intentionally left blank as a place to record any future storm water studies for this cell.

6. Storm water runoff from urban settlement

Storm water

Cell 4.1
Hallett Cove Cliffs (South)
Storm Water
2022

Storm water outlet assessment Albatross Walk

1. Is storm water managed appropriately?

Storm water from urban environments flows away from the coast and into the Field River catchment area.

2. What impact is occurring on the backshores and beach due to storm water runoff (if any)?

None observed.

3. Outlets requiring review.

Nil.

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6. Storm water runoff from urban settlement

Storm water

Cell 4.2

Hallett Cove Cliffs (South)

Storm Water

2022

Storm water outlet assessment
Petrel Close

1. Is storm water managed appropriately?

Storm water from urban environments flows away from the coast and into the Field River catchment area.

2. What impact is occurring on the backshores and beach due to storm water runoff (if any)?

None observed from urban environments.

3. Outlets requiring review.

Nil.

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6. Storm water runoff from urban settlement

Storm water

Cell 4.3

Hallett Cove Cliffs (South)

Storm Water

2022

Storm water outlet assessment Balboa Drive

1. Management of storm water.

Storm water is managed so that it doesn't run uncontrolled over cliff surfaces (but see also below 4.2).

2. Impacts on beaches and backshores (if any)

Minimal impacts on beach, gullying through bank at base of cliff.

3. Outlets requiring review

Outlet 4.2 – pipes broken at bottom of cliff; storm water has created a gully through the clay bank. In the context of this coastal environment impact is rated 2 out of 4, but a review is recommended.

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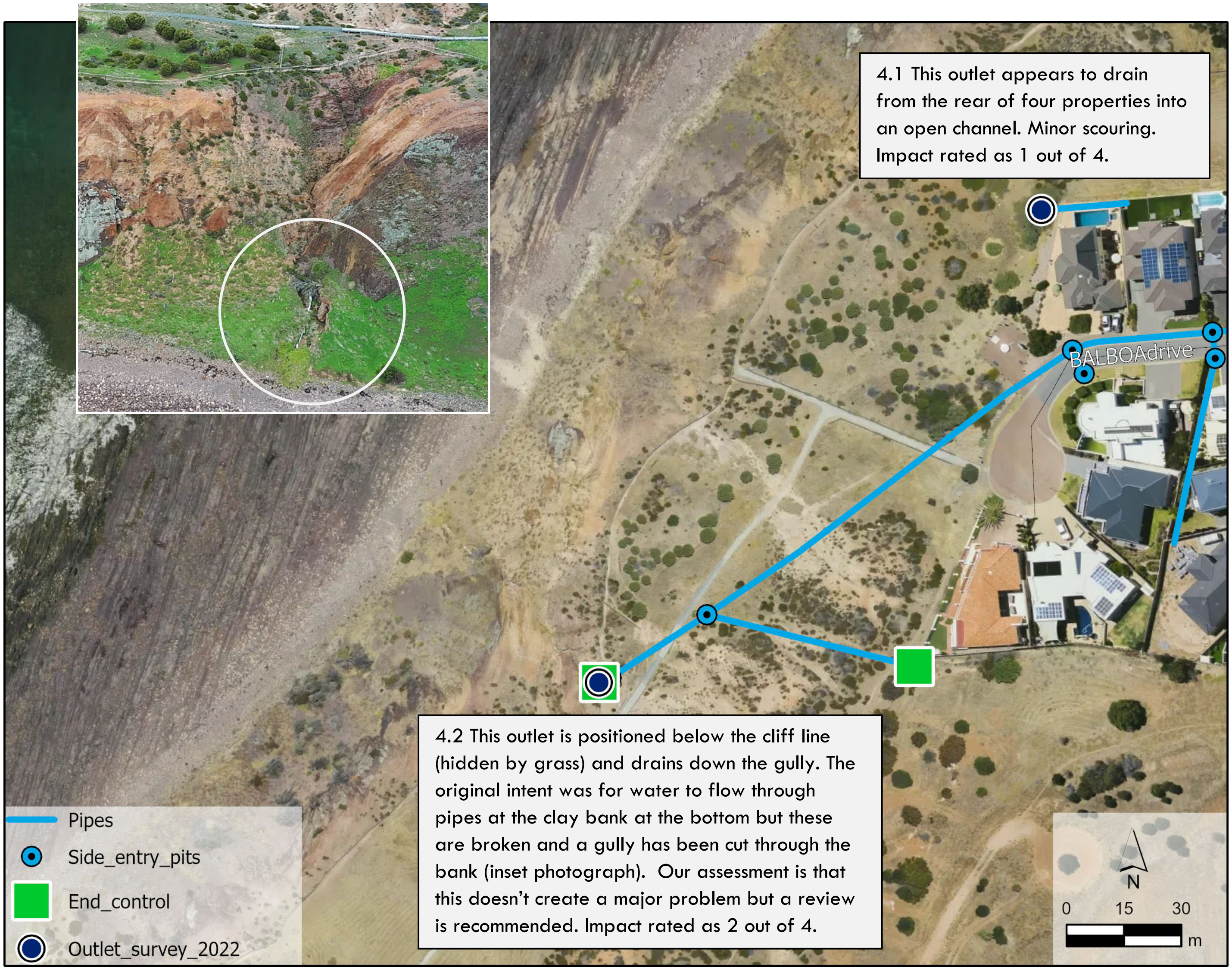


6. Storm water runoff from urban settlement

Summary of findings

Three basic questions were assessed in this project[15]:

1. Does Council manage the flow of storm water from urban settlement so that it does not flow uncontrolled over coastal backshores and dunes?

The storm water scheme for Cell 4 is structured so that the vast majority flows into the Field River catchment. Exceptions are in Cell 4.3 where stormwater flows from four houses in Petrel Close to the upper slopes (no impact observed) and into a gully south of Balboa Drive (no impact on upper slope or gully but has cut a channel through the clay embankment at the base of the cliff).

2. What impact is occurring on the beach or backshore due to storm water runoff?

A gully has been cut through clay embankment at the base of cliff south of Balboa Drive. Our assessment after the rainstorms in June 2022 was that the impact on the beach was minimal and in this coastal context (remote, hard rock shore platform) the overall impact is rated as 2 out of 4 (moderate).

3. Do any storm water outlets require review?

A review of outlet 4.2 (GIS reference) is required to ascertain whether new storm water infrastructure is required at the base of the cliff and whether the gully should be filled. The only issue to be considered for the latter of these two is if seas rise as projected, then seawater will enter this gully. However, it is likely if seas rise as projected that the clay slopes at the base of these cliffs will be eroded away as has occurred in other locations along this section of coast.

Figures (a) and (b). The storm water infrastructure was likely under engineered in the first instance due to the remote location. The pipes have broken, and gully formed from storm water flows from Balboa Drive.

[15] In some coastal locations whether a confluence of rain events and sea storm events could create potential for increased flooding would be considered. This cell is elevated above any risk of confluence of events.

7. HAZARD IMPACTS AND RISKS

The purpose of this section of work is to consider the inputs from the first part of the study and undertake an assessment of hazard impacts and risks within this cell. We undertake this in two steps:

1. Assign an inherent hazard rating,
2. Conduct a risk assessment utilising the risk framework of City of Marion.

7. Hazard impacts and risks

Methodology

South Australian Coast Protection Board considers three main coastal hazards: inundation, erosion, and sand drift. Only the first two are under consideration in this project as there are no assets at risk from sand drift. The assessment of hazard impacts and risks is undertaken in two main steps.

1. Assign an inherent hazard rating

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 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. A coastal fabric of granite is less at risk from erosion than a coast backed by sand dunes. In some locations the natural fabric of the coast has been altered by human intervention. For example, the Adelaide metropolitan beaches were once backed by sand dunes, but installation of rock revetment has changed the nature of the fabric to rock.

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. This assessment takes into consideration the following elements and has meaning (context) in relation to all South Australian coasts:

- The geological layout
- Sediment supply/ balance
- The erodibility of beach and backshores
- The historical analysis as to how the coastline has performed over time
- The exposure (set by Nature Maps)
- Whether any human intervention has altered the nature of the coastline.

The risk assignments range from 'low' to 'very high' and may include a 'no risk' category. For example, coastal land that is elevated above any inundation risk will be assigned 'no risk'. A dotted circle to the right of the main assignment indicates that the risk assignment requires intensifying due to unique factors, or to indicate a higher risk that does not qualify for an overall higher rating (Example, Figure a).

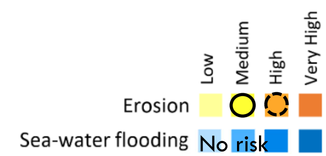


Figure a. Example of inherent risk output

7. Hazard impacts and risks

2. Conduct a risk assessment using the risk framework of City of Marion.

In this study we are primarily concerned with the way that coastal hazards may impact urban settlements over the coming century. How inundation and erosion impact human settlement will vary according to location. For example, at Hallett Cove Beach public assets are positioned in the immediate backshore, whereas at Field River some private assets directly adjoin the beach. Additionally, if seas rise as projected then seawater may flow further inland in low-lying areas and change the ecology. To evaluate public safety, how easily people may be able to retreat to a safe place is considered.

Direct risks

In summary, while the impact of sea level rise may be somewhat uniform on a coastal region, the impact will be felt differently in the context of human experience. To bring appropriate focus, hazard impacts are described within four main receiving environments:

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

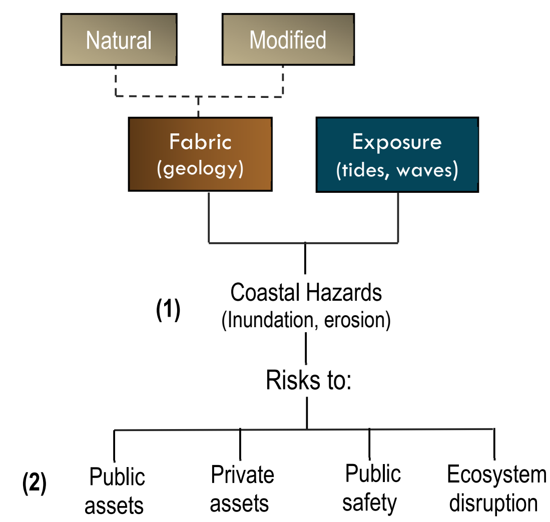
Note, the term ecosystem disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt the entire ecological system, for example seawater flooding into freshwater ecologies.

Indirect risks

To provide focus and contain variables, this risk assessment is confined to direct impacts upon physical receiving environments. Indirect impacts may arise because of these direct impacts. For example, the loss of a beach in some coastal locations may cause indirect impacts – loss of tourism resulting in a declining economy, and may also diminish social well-being and community pride.

This assessment utilises the Council's risk assessment framework and 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. This is a long-term frame, but infrastructure such as houses and roads, have long lifespans.

The overall risk assessment strategy is summarised in the diagram below (Figure a).



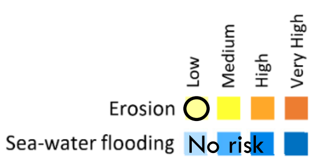
7-1 Inherent hazard risk assessment (SA)

Inherent risk assessment:

Inherent risk assessments are established using set criteria outlined above that apply to the whole State of South Australia[1].

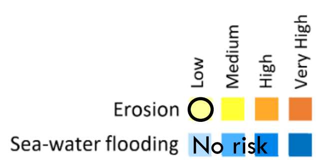
Albatross Walk (Cell 4.1)

Predominantly hard rock sloping shores that are resistant to erosion at the base, dominated by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. Elevated backshore is at no risk from inundation.



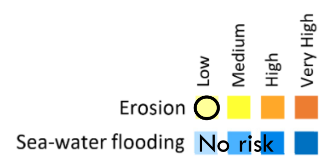
Petrel Close (Cell 4.2)

Predominantly hard rock sloping shores that are resistant to erosion at the base, dominated by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. Elevated backshore is at no risk from inundation.



Balboa Drive (Cell 4.3)

Predominantly hard rock sloping shores that are resistant to erosion at the base, dominated by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. Storm water discharges directly down the cliff at end of Balboa Drive. Elevated backshore is at no risk from inundation.



[1] Worksheets that underpin the evaluation are available from Integrated Coasts.

7-2 Risk assessment using Council's risk framework

Risk assessment on receiving environments:

The following pages contain the risk assessments for Hallett Cove Cliffs (South):

- Albatross Walk (Cell 4.1)
- Petrel Close (Cell 4.2)
- Balboa Drive (Cell 4.3)

The risk assessment template draws on City of Marion risk framework, Policy RM-PRO-1.01 (v8.0) dated 25/02/2020.

Location: Albatross Walk (Cell 4.1)

Erosion

Risk assessment using Council's risk framework

Coastal setting	Predominantly hard rock sloping shores that are resistant to erosion at the base. Domintaed by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. This impact is observed in a minor way with storm water impacts on the walking trail. Private assets are located within 20m from the clifftop but this location is resistant Brachina Formation. A walking trail traverses the top of the cliff.

Risk identification: No immediate risks identified. If seas rise as projected then seawater will interact more frequently with the base of the cliff.

Current risk mitigation: Nil

Receiving environment	Risk description	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail. No impacts from the sea are possible. Storm water runoff can erode the cliffs and walking trail but observed impact is low.	2020	*possible*	*insignifcant*	low
		2100	*possible*	*insignifcant*	low
Private assets*	Private properties are situated ~20m from the cliff top, but in this location the cliff is comprised of resistant Brachina Formation.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk
Public safety	The public use the walking trail. This assessment relates to erosion risk and does not relate to the structural stability of the walking trail and assumes people remain on the trail. Increasing storm water may cause scouring of the walking trail.	2020	*unlikely*	*insignifcant*	Low
		2100	*unlikely*	*insignifcant*	low
Ecosystem disruption	The coastal setting is rocky beach and predominantly hard rock cliff backshores. Ecosystem disruption is not anticipated from rising sea levels.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk

Inherent hazard rating
How inherently vulnerable is the coastline

	low	medium	high	very high
Erosion	○			
Sea flooding	no risk			

Erosion hazard rating
Current Outlook 2022

	low	Medium	high	extreme
Public infrastructure	○			
Private assets	no risk			
Safety of people	○			
Eco-system disruption	no risk			

Erosion hazard rating
Future Outlook 2100

	low	Medium	high	extreme
Public infrastructure	○			
Private assets	no risk			
Safety of people	○			
Eco-system disruption	no risk			

Assumptions

Rain water events have not been assessed in this project.

The assignment of future risks assumes that seas rise as projected and that no adaptation responses are employed.

*Governments are not necessarily liable for private assets.

Location: Petrel Close (Cell 4.2) Erosion **Risk assessment using Council's risk framework**

Coastal setting	Predominantly hard rock sloping shores that are resistant to erosion at the base. Domintaed by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. This impact is observed in a minor way with storm water impacts on the walking trail. Private assets are set well back at ~ 90m from the clifftop. A walking trail traverses the top of the cliff.

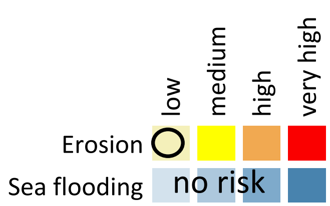
Risk identification: No immediate risks identified. If seas rise as projected then seawater will interact more frequently with the base of the cliff.

Current risk mitigation: Nil.

Receiving environment	Risk description	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail. No impacts from the sea are possible. Storm water runoff can erode the cliffs and walking trail but observed impact is low.	2020	*possible*	*insignifcant*	low
		2100	*possible*	*insignifcant*	low
Private assets*	Private properties are situated ~90m from the cliff-top.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk
Public safety	The public use the walking trail. This assessment relates to erosion risk and does not relate to the structural stability of the walking trail and assumes people remain on the trail. Increasing storm water may cause scouring of the walking trail.	2020	*unlikely*	*insignifcant*	low
		2100	*unlikely*	*insignifcant*	low
Ecosystem disruption	The coastal setting is rocky beach and predominantly hard rock cliff backshores. Ecosystem disruption is not anticipated from rising sea levels.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk

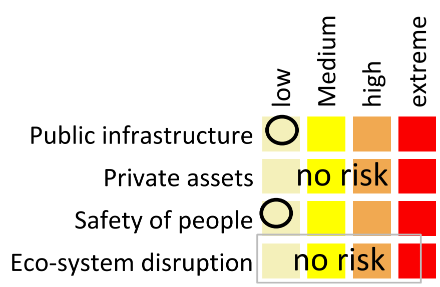
Inherent hazard rating

How inherently vulnerable is the coastline



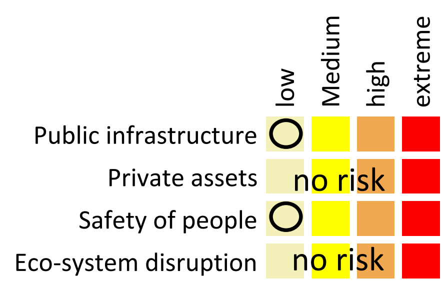
Erosion hazard rating

Current Outlook 2022



Erosion hazard rating

Future Outlook 2100



Assumptions

Rain water events have not been assessed in this project.

The assignment of future risks assumes that seas rise as projected and that no adaptation responses are employed.

*Governments are not necessarily liable for private assets.

Location: Balboa Drive (Cell 4.3) — Erosion — **Risk assessment using Council's risk framework**

Coastal setting	Predominantly hard rock sloping shores that are resistant to erosion at the base. Domintaed by low profile offshore reef and rocky beach platform. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. This impact is observed in a minor way with storm water impacts on the walking trail. Private assets are set well back at ~ 45m from the clifftop. A walking trail traverses the top of the cliff. Stormwater is discharged down the gully to the beach just to the south of Balbao Drive.

Risk identification: Actions of the sea currently have low interaction with the backshore. This interaction will increase if seas rise as projected.

Current risk mitigation: Nil.

Receiving environment	Risk description	Time	Likelihood	Consequence	Risk
Public infrastructure	Walking trail. No impacts from the sea are possible. Storm water runoff can erode the cliffs and walking trail but observed impact is low.	2020	*possible*	*insignifcant*	low
		2100	*possible*	*insignifcant*	low
Private assets*	Private properties are situated ~45m from the cliff-top.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk
Public safety	The public uses the walking trails. This assessment assumes that people remain on official walking surfaces. No increased risk due to erosion is foreseen.	2020	*unlikely*	*insignifcant*	low
		2100	*unlikely*	*insignifcant*	low
Ecosystem disruption	The coastal setting is rocky beach and predominantly hard rock cliff backshores. Ecosystem disruption is not anticipated from rising sea levels.	2020	*no risk*	*no risk*	no risk
		2100	*no risk*	*no risk*	no risk

Inherent hazard rating

Inherent vulnerability

	low	medium	high	very high
Erosion	◯			
Sea flooding	no risk			

Erosion hazard rating

Current Outlook 2022

	low	Medium	high	extreme
Public infrastructure	◯			
Private assets	no risk			
Safety of people	◯			
Eco-system disruption	no risk			

Erosion hazard rating

Future Outlook 2100

	low	Medium	high	extreme
Public infrastructure	◯			
Private assets	no risk			
Safety of people	◯			
Eco-system disruption	no risk			

Assumptions

Rain water events have not been assessed in this project.

The assignment of future risks assumes that seas rise as projected and that no adaptation responses are employed.

*Governments are not necessarily liable for private assets.

8. Cell summary and recommendations

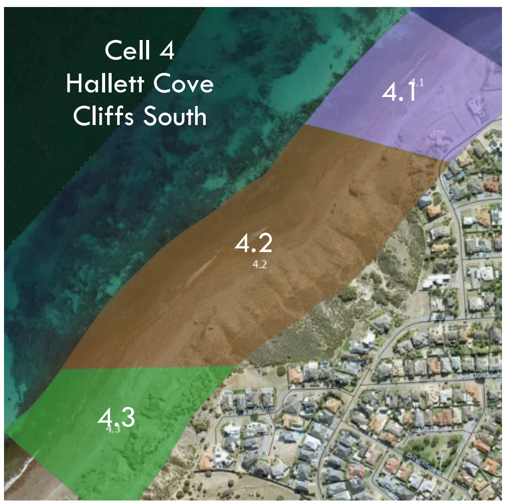
This cell report is designed to be reviewed and updated over time so that the baseline data is continually brought forward and modified to reflect any changes in the coastal system. This part of the report contains three main parts:

- Summary – a snapshot of the state of the coastal system at the date of writing.
- Overview of adaptation options and strategies.
- Recommendations – a review of recommendations from the prior study and a list of amended recommendations for the future.

8.1 Summary - Hallett Cove Cliffs South (Cell 4)

Coastal setting

Predominantly hard rock sloping shores that are resistant to erosion at the base, dominated by low profile offshore reef and rocky beach platform. Backshores are well-elevated and not vulnerable to inundation. Friable material is found in the upper cliff slopes which is vulnerable to stormwater runoff. Human interventions include a walking trail set close to the cliff crest and storm water disposed within the gully to the south. Residential development is set well back from the top of cliffs.



Coastal fabric – changes to beaches and backshores

Land base photography and aerial photography from 1949 indicate that there have been no changes to the beach and backshores over last one hundred years. This is due to the rocky nature of this section of coast and that generally actions of the sea are not interacting with backshores (apart from in locations of resistant rock).

Coastal exposure – sea level rise, storms, and projections.

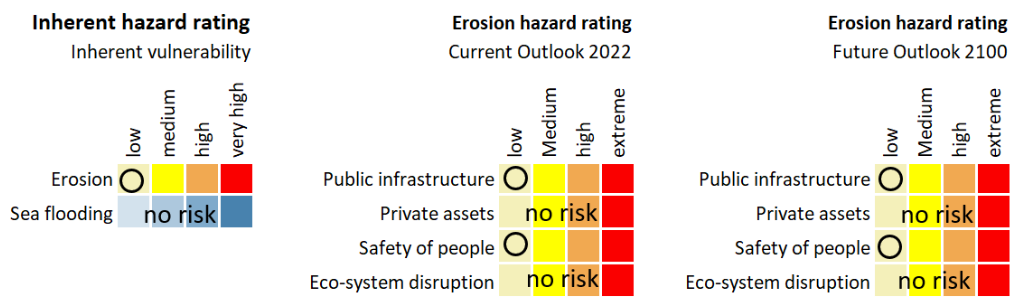
The rate of sea level rise remains relatively low at 3-4mm in this region. Monitoring of storms over the last two years shows that impact on backshores is low. Sea levels 0.3m higher than present projected for 2050 are unlikely to have a major erosion impact on beach and backshore. If seas rise as projected post 2050, routine high water may erode any clay within the escarpments at the base, but these are likely underpinned by rock.

Storm water runoff – impacts in the coastal zone

The storm water scheme is designed so that the majority flows into the Field River catchment. The exceptions are at Petrel Close where flows across upper slopes from four houses (no observed impact) and through a gully south of Balboa Drive (no impact in upper cliff, gully formed at base of cliff, minimal impact on beach).

Overview of Impacts and risk assessment

In the context of a rocky platform beach, offshore reef, and resistant rock in the backshore, and considering that most of these are not currently impacted by actions of the sea, impacts upon this coastal region are likely to be low over the coming century even if seas rise as projected.



8-2 Overview of adaptation options and strategies

Adaptation options and strategies

An overview of adaptation approaches is provided on this page to provide context to the recommendations. There are generally six categories of adaptation options:

1. **Avoidance** – Avoid the impacts of coastal hazards by ensuring that assets are not placed in vulnerable locations.
2. **Hold the line** – Install protection infrastructure that reduces the impact of coastal hazards or use environmental practices to strengthen natural protective forms such as dunes.
3. **Accommodate** – Accept some degree of hazard and conduct limited intervention to manage the hazard (for example, in areas that may be subject to inundation, raise houses on poles).
4. **Managed retreat** – Progressively move assets or services away from areas that could be impacted by coastal hazards now or in the future.
5. **Monitor** – monitor the coast and use the data to form future strategies.
6. **Loss acceptance** - Accept that coastal hazards will cause negative impacts on assets and services and when this occurs, they will not be replaced.

Adaptation responses

Within the adaptation options there are a range of potential adaptation responses.

Planning

Planning responses are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. For example, dwellings and sites required to be positioned at higher elevation or set back from the coastline.

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation.

Environmental management

Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support growth of habitat such as seagrasses. It may also include sand nourishment to replace sand that has been lost from the beach system.

Adaptation timing

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.

Adaptation strategy (Cell 4)

Due to the elevated and rocky nature of this section of coastline, the adaptation strategy will fall into options ***(1) Avoid*** and ***(5) Monitor*** with an incremental approach over time.

8-3 Recommendations – Hallett Cove Beach South

Recommended actions from 2018

The recommendations from the Coastal Adaptation Study of 2018 are listed below with reviews in the right-hand column.

	Action	Comments	Time Frame	Review 2022
1	Review nature of storm water outflows in 4.3 (Balboa Drive) and assess impacts	Undertake routine inspections of the outfall areas. Recommend that staff incorporate review of scouring impacts (use photography).	1-2 years	A two-year monitoring program was completed 2021-2022. Storm water impacts were reviewed using drone photography (2 rain events) and onsite inspection after rain events in June 2022.
2	Quantify more accurately the nature of routine and storm surge interaction with cliff base.	Monitor tidal regime for period of three months (winter). Monitor impact of storm surge events (if, and when they occur)	1-2 years	A two-year monitoring program (2021-2022) monitored five events along the coast. Seaweed strands were observed by drone photography after each event and seaweed strands were surveyed in the event of 17 September 2022. In the context of a review of the tide gauge data from Outer Harbor, these inputs were used to generate routine tidal monitoring to a higher degree of accuracy. This has quantified the nature of routine and storm surge interaction with the base of the cliff as of low impact.
3	Recapture digital model as basis for comparison.	Use appropriate software to quantify changes in the coastal environment.	3-5 years	This action is recommended for 2023.

8-3 Recommendations – Hallett Cove Beach South

Recommended actions 2022 to 2027 (five years)

This review and upgrade to the Coastal Adaptation Study (2018) and the City of Marion Coastal Monitoring Project provide the basis for the following recommendations in Cell 4. The summary at 8.1 above provides the immediate context for the recommendations.

	Action	**Rationale/ methodology**	**Time Frame**
1	Incorporate the findings of the CoM coastal monitoring program (2021-2022) into this report.	This report represents an upgrade from the Coastal Adaptation Study (2018) by including tasks that were not included in the 2018 project and an upgrade to the format. This has coincided with the conclusion of the first two years of the CoM coastal monitoring project. Some of the findings from the monitoring project inform this upgrade, but they have not been formally integrated with this report.	2023
2	Recapture the digital model as a basis for comparison with 2018 capture.	Use appropriate software to quantify changes in the coastal environment. This is likely to be the most effective way to assess changes in cliff environments.	2023
3	Monitor changes in beaches and backshores.	Use aerial photography obtained every three months by City of Marion to assess changes to beaches and backshores. This could be done as an annual operation using 4 captures. In particular, identify locations of any new rock falls, slumps or landslides.	Annual (ongoing) (2023-2027)
4	Monitor the impact of moderate storm events, either rain or sea storm (2-3 per year).	A flightpath has been established for a drone to capture photography of the coast at an oblique angle in relatively close range. For sea-storm events, monitor the location of seaweed strands in relation to the base of cliffs and any impacts to backshores. For rain events, monitor for any scouring of the backshores and beaches. For both events monitor for slumps, slides and falls in cliff environments.	Annual (ongoing) (2023-2027)
5	Assess the impact of any major sea storm.	Identify a suitable tidal benchmark at Outer Harbor to qualify as a major sea storm (for example, 1 in 2 year event). Inspect and survey the seaweed strands and update modelling parameters if required. Note, the proposals for task (4) and (5) simplify some of the current storm monitoring and therefore reduce cost, but still maintains the ability to track more significant storms which will be required in the context of rising sea levels.	As required (likely 3-5 in a five-year period).

	Action	Rationale/ methodology	Time Frame
6	Monitor the rate of sea level rise in Gulf St Vincent.	It is recognised that this action is not within the direct scope of City of Marion. However, periodic reviews are being done by others (e.g. Watson, 2020) and simple tools now exist at www.sealevel.info. It is recommended that when opportunities exist, City of Marion lobby for improved sea level monitoring in Gulf St Vincent (e.g. additional gauges, tracking vertical land movement). The reason for this action is that currently the rate of sea level rise is relatively low (3-4mm per year) whereas projections for the latter half of the century are high (10-15mm per year). An escalation in the rate at tide gauges will provide an early warning that these projections are being realised.	2023-2027