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Observation Point to Silverleaves

Gippsland West Coastal Processes Studies

Department of Energy, Environment, and Climate Action

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EXECUTIVE SUMMARY

This study focuses on the approximately 2 km stretch of the Silverleaves coastline, west of Coghlan Road, encompassing a broader geomorphological unit that includes East Cowes Beach and the sandy spit extending to Observation Point. The objectives of this project were to assess the impacts and effectiveness of existing coastal protection structures along the East Cowes foreshore adjacent to Silverleaves, evaluate the coastal dynamics and processes affecting the East Cowes and Silverleaves shoreline, assess coastal hazards, and determine the likelihood of erosion leading to breaches as well as temporary inundation during regular and extreme events.

Key findings indicate that the shoreline position along East Cowes and Silverleaves is influenced by various anthropogenic interventions as well as naturally occurring and locally modified coastal processes. This dynamic shoreline was formed by sand supplied from Bass Strait into Western Port and along Northern Phillip Island over geological timescales. This sand supply, which varies seasonally and temporally, continues to provide sediment to many beaches on Phillip Island, including East Cowes and the Cowes Bank.

East Cowes is heavily modified by coastal protection structures, such as groynes and revetments, which shape much of this shoreline and influence both sediment transport and shoreline dynamics. Terminal erosion at the eastern most revetment (near Silverleaves) that was constructed in 1977 has led in the decades since its construction to erosion, scouring, and reorientation of the shoreline at Silverleaves. Aerial imagery analysis indicates that the shoreline has eroded at an accelerated rate especially in recent years (since 2022), where shoreline setback of up to 8 m/year has been observed. Numerical model results suggest that the altered shoreline orientation at Silverleaves that has resulted from this long term erosion may now be enhancing sand scour during strong tidal circulations or wave activity, contributing to the increased local erosion rate recently observed.

Current patterns and survey data analysis indicate that upstream revetments and previous timber seawalls have contributed to scour in the nearshore area, likely due to wave reflection, pushing sediment to the outer bank, where it is possibly carried east. This appears to result in some sediment bypassing Silverleaves, likely due to the combined effects of shoreline orientation and flow separation. The analysis suggests that the sediment pathway reattaches to the Silverleaves shoreline further downstream at central and eastern Silverleaves, where both historic and recent shoreline accretion is observed. We note that historic sand scraping may also be a contributing factor.

Recent beach nourishment efforts have proven to be sacrificial and are not considered a sustainable long-term solution for mitigating this erosion. Further analysis indicates that existing interventions like groynes, while preserving beach amenity and retaining sand locally at East Cowes, impedes natural sediment supply to downstream areas such as Silverleaves. This is particularly relevant directly in front of the recently constructed pattern placed rock revetment where the newly upgrade/installed groynes are relatively inefficient.

Substantial erosion of the Silverleaves shoreline can be expected within the immediate planning horizon. It is important to note that Silverleaves is also subject to inundation hazards within the current planning horizon. Inundation from Rhyll Inlet is beyond the scope of this assessment but has been shown in past assessments to be a critical hazard and thus it will be a key consideration for adaption planning at Silverleaves.

The key recommendation from this study is that there is a critical need to develop sustainable, long-term adaptation pathway and coastal protection strategies for Silverleaves encompassing inundation hazards from Rhyll Inlet.

A key gap identified in this study is the lack of comprehensive time-series validation of current patterns. Numerical models used in such shallow, complex environments may produce erroneous

results. Therefore, we recommend collecting both current and wave data on Cowes Bank to confirm these results, particularly along the shoreline to validate the predicted flow separations. Such validation data could be obtained once the an endorsed adaptation pathway has been identified (if required).

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1 INTRODUCTION

1.1 Scope and Context

FSC Range was engaged to undertake a detailed coastal processes study at East Cowes to Silverleaves area, which is located 60 km southeast of Melbourne on the northern coast of Phillip Island (Figure 1-1).

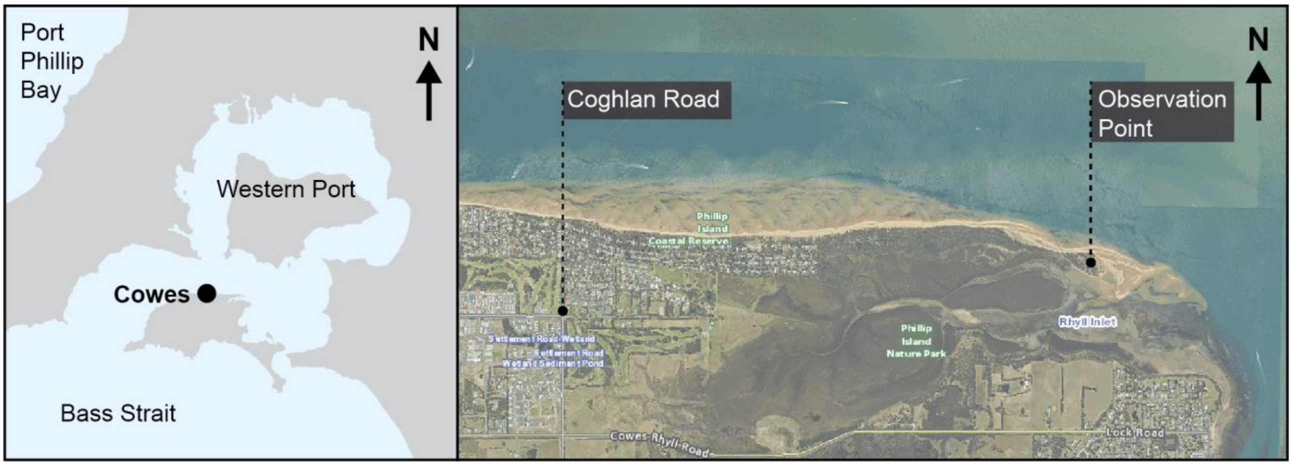

Figure 1-1: Site locality and context
(left) The location of the site in relation to Western Port. (right) Aerial view of study area (CoastKit, 2024).

The East Cowes to Silverleaves shoreline is located on the northern side of Phillip Island. This side of Phillip Island is within Western Port, and thus the coastal processes along these shorelines are affected by the dynamics of both Bass Strait and Western Port. These dynamics are discussed in this report.

East Cowes refers to the area along which many anthropogenic interventions have occurred over many decades. Currently, a groyne field extends from Erehwon Point to the boundary of Silverleaves and varies in its functional effectiveness. These groynes primarily aim to maintain beach amenity along this section of coastline. At the back of the beach is an existing rock revetment-type structure, which is a primary erosion (and possibly inundation) defence structure. Further along the coastline is a new pattern placement rock revetment, which then transitions to an older rubble rock revetment.

Figure 1-2: Key features of East Cowes Beach
Much of the shoreline has coastal management interventions, which include an extensive timber groyne field and both pattern placed and rock rubble revetments (CoastKit, 2024).

Silverleaves approximately begins at the end of the rubble rock revetment. The shoreline here takes a sharp inward change in direction. This sharp change in direction is an erosional feature that has been present for several decades, which has increased in its rate of recession. Silverleaves in particular faces coastal erosion challenges, which poses threats to public and private assets. Foreshore protection structures were once located along this shoreline, but these have now aged and are no longer effective; all are buried or have been removed. Further east, the shoreline forms a large crescent bay where the narrow western beaches slowly transition to relatively wide beaches to the east.

Figure 1-3: Key features of Silverleaves

There is a noticeable shift in the shoreline orientation at the end of the revetment with a narrow beach that slowly widens to the east (CoastKit, 2024).

1.2 Aim of this Assessment

The focus of this project is the approximate 2 km of Silverleaves coastline, east of Coghlan Road. However, to provide context and enable a comprehensive analysis of the coastal processes, the study includes the broader geomorphological unit within which Silverleaves lies, which includes East Cowes Beach. This section of coastline is noted for the many coastal protection structures that have been installed over the decades as well as the sandy spit that extends eastward to Observation Point.

The aims of this study were to:

1. Evaluate the coastal dynamics along the Cowes and Silverleaves shoreline and how these dynamics are affected by coastal processes prevalent along this shoreline.

2. Assess the impacts and effectiveness of existing coastal protection structures along this shoreline.

3. Assess coastal hazards along the Silverleaves shoreline.

4. Determine if erosion of Silverleaves foreshore is likely to result in a breach and possibly temporary inundation during regular and/or extreme events.

The methodology adopted is described in the relevant subsections.

2 PREVIOUS STUDIES

Coastal processes within Western Port and areas nearby Silverleaves have been the subject of several studies in recent history. Hence, to establish a baseline understanding of coastal processes at the site, a review of available literature and data was completed.

The Problem of Beach Erosion on the North Coast of Phillip Island, 1987 (PICS 1987)

This study by the Phillip Island Conservation Society with Eric Bird covered the entire north coast of Phillip Island, providing detailed information on geomorphology, coastal processes, and the history of erosion and erosion management practices. The study considered several options for erosion protection at East Cowes. Beach renourishment was recommended, although it was noted that the sand on Cowes Bank is too fine for nourishment, necessitating sourcing sand from elsewhere, with dredging of shipping channels being a suggested source. Two other options were also considered feasible, including maintenance and extension of existing coastal protection structures on eroding sections of the coastline (sea walls, boulder ramparts, and groynes) and/or no further extension of structures until private property or public facilities are directly threatened.

Western Port Local Coastal Hazard Assessment: Report 6 (R06) - Review of Representative Locations, 2014 (Water Technology, 2014)

The report by Water Technology for Melbourne Water involved a detailed study of coastal processes throughout Western Port. The East Cowes area (Erehwon Point to Observation Point) was selected as a representative area for erosion and inundation hazard mapping, considering current conditions and the impacts of climate change. The report includes detailed overview of the coastal geomorphology of Rhyll Inlet and Silverleaves study area and details the key erosion hazard mechanisms and interactions relevant to Silverleaves. Erosion mechanisms and magnitudes include:

- **Backshore Sand Lobe Migration**
  The report suggests that the shoreline in the area is influenced by the formation of eastward migrating backshore sand lobes. It is believed that these may stem from occasional sand injections past Erehwon Point, alongside intricate sediment dynamics and interactions with Cowes Bank. Multiple sediment sources and transport processes likely contribute to the significant shoreline variability observed over various timeframes. The report indicates that net (eastward) longshore transport rates could increase by approximately 50% under the 2100 +0.8m sea level rise scenario. The predicted increased sediment transport rates are attributed to the greater depths across Cowes Bank which allows larger waves to impact the spit shoreline. They conclude that precise estimates of the extent of future impacts from backshore sand lobe migration and associated longshore sediment transport processes is not possible. Uncertainty in this estimate mainly stems from 1) historical variability in alignment of the shoreline and successive spit landforms and 2) the coastline's history of coastal protection measures, making past trends unreliable for projecting long-term changes. We note that a fundamental assumption that underpins the increased sediment transport rate is the supply of sand to be transported.

- **Equilibrium Profile Recession (due to SLR)**
  The sandy spit shoreline types in Western Port pose challenges for applying the Bruun model to estimate equilibrium profile recession distances. The dynamic Cowes Bank, with its wide and shallow nature, continuously transports and mobilizes sediment, intermittently supplying the shoreline. As a result, there isn't a conventional sediment closure depth for the current spit shoreline, which is required for application of the Bruun rule. Further, the evolving spit landforms in the study area, possibly influenced by relative sea level fall in the mid-Holocene, make it challenging to ascertain the impact of mean sea level on the current spit alignment and its potential sensitivity to projected sea level rise in this century. The report concludes that a relatively high Bruun rule factor of 100 (i.e. the shoreline will retreat by 100 times the rise in sea level) should be applied as this location shows evidence of significant change and sensitivity to historical sea level variations.

- **Loss of Coastal Wetlands**
  The extensive mangrove and saltmarsh fringed shorelines of Rhyll Inlet are likely to face significant impacts from changes in inundation regime and depths due to sea level rise. The unique western end of Rhyll Inlet, unlike other parts of Western Port, lacks bluffs or Cranbourne Sands backing, potentially allowing the vegetation communities to migrate inland in response to sea level rise.

- **Bluff Reactivation**
  The bluffs along the southern margin of Rhyll Inlet consist of poorly to weakly consolidated formations, prone to slope instabilities if over-steepened by wave impacts due to the loss of fringing vegetation from sea level rise. Given the historical occurrence of major slope failures in cliffs with similar geology in Western Port, and the sudden nature of such failures, a conservative hazard zone is recommended for slope failures along these bluffs. Bluff reactivation is expected where the MHWS tidal plane intersects the base of the bluffs. In response, the hazard extent due to potential slope instabilities is projected to extend landward from the base of the bluff by a factor of 5 times the bluff's height along these shorelines, resulting in a final failure slope of approximately 11 degrees where they are susceptible to reactivation due to sea level rise.

While specific recommendations for erosion management were not provided, the report does identify inundation hazards for the area. Findings include potential vulnerability around Dunsmore Road, and the coast near Coghlan Road which (at the time of the assessment) has an elevation below the 1% AEP storm tide level. Inundation hazards are expected to mainly originate from Rhyll Inlet, with storm tides propagating with minimal attenuation into the area and along low-lying land formations toward the study area's contemporary spit shoreline.

East Cowes Foreshore: Erosion Management Options (Water Technology 2018)

Water Technology (2018) was engaged by the Bass Coast Shire Council to undertake an investigation into management options to mitigate shoreline erosion and storm tide inundation hazards under existing and future conditions between Erehwon Point and Observation Point. The report was initially published in August 2011 and focused on East Cowes Foreshore between Erehwon Point and Sanders Road, then was subsequently revised in August 2018 to extend the study to Observation Point.

This study provides a good background on the area’s coastal geomorphology and offers insights into erosion processes. It was estimated in this this study that the mean rate of net annual longshore sediment transport is approximately:

- 12,000 m^3/year along the nearshore/beach toward the east
- 40,000 m^3/year toward the east on the outer bank

However, it was also noted that the longshore transport varies considerably and the underlying variability in the shoreline position is affected by the migration of backshore sand lobes and the formation of spits (observed over the historical photographic record) that migrate eastward along the shore.

The report highlights that continued infilling of the Silverleaves Bight is apparent, however, shoreline protection works constructed to the west have resulted in acute terminal erosion impacts in this area. The maximum extent of shoreline variability observed over the photographic period (1968 through 2009) was approximately 50 m.

The study recommends various protection options, including nourishment, seawalls, and groynes, relevant to Silverleaves' coastal management.

East Cowes Foreshore Erosion Protection Functional Design (2020)

BMT (2020) were engaged by the Bass Coast Shire Council to review previous erosion management options, recommend a suitable approach, and develop a functional design to address erosion at East Cowes foreshore between Rose Avenue and Coghlan Road. The recommended erosion protection measures for East Cowes Beach include removing the deteriorating timber groynes and seawall, constructing a new 330 m rock revetment with pedestrian access points. They also recommended installing six new timber groynes in front of the revetment along with beach nourishment via beach scraping to fill groyne compartments as each groyne is completed. They note that groyne construction in this area is to add beach amenity, adding that the revetment can be constructed independently however the beach in front of the revetment may lower consequently reducing beach amenity. They further recommended that existing timber groynes 14 and 15 to be repaired, with optional upgrades include reinforcing the rock revetment in front of the Scotch College Boat shed and replacing groynes 14 and 15 if necessary.

Silverleaves Beach Nourishment Design Advice (BMT, 2023)

This report details advice for the nourishment campaign at Silverleaves, including:

- identification of appropriate sand borrow area via sediment sampling analysis,
- production of design nourished beach profile, and
- description of potential environmental impacts of the proposed nourishment.

This beach nourishment was implemented at the end of August, 2023. Photos of the nourishment were provided for reference.

3 GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

3.1.1 Regional Setting

Marsden and Mallet (1975) summarised the development of Western Port over geological timescales:

- Western Port is crossed by seismically active fault lines. The bay itself was formed by downfaulting in the Quaternary period, essentially a geological process that results in the subsistence of the land. In addition to the sunkland that was created between South Gippsland and the Mornington Peninsular, these geological faults also created areas of uplift, which today are Phillip Island and French Island.
- During the interglacial periods in the Pleistocene (when the sea level was high), extensive fluvial and lacustrine deposition occurred within Western Port. These depositions emerged during the last glacial phase (when the sea level was low) and deep valleys were formed within the bay as Western Port drained out onto the Bass Strait plain.
- When the last glacial phase ended (approx. 18,000 years ago), the sea level increased rapidly in the early Holocene and by about 10,000 years ago Western Port was again submerged. During the mid Holocene, sea levels locally were about 1.5 m higher than today, and it was around this time that the eastern entrance to Western Port at San Remo is thought to have been created.
- Around 3,000 years ago the sea level fell to the approximate levels observed over contemporary geological time.

Today, the bay has a semidiurnal tidal regime and experiences an average tidal range of approximately 2.2 m. Sea water is primarily exchanged with the Bass Strait at the western entrance with only about 15% of the volume entering Western Port via the Eastern Entrance during any given tidal cycle (Hinwood, 1970). The hydrodynamic complexity of the bay is influenced by the presence of both French Island and Phillip Island, however in general the flow is split into the north and east arms around French Island (Figure 3-1).

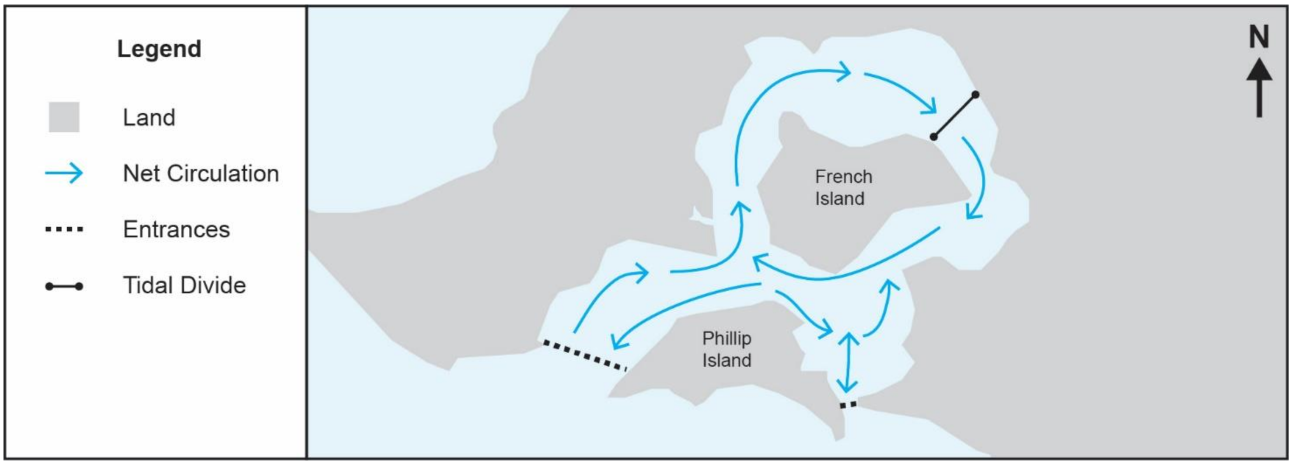

Figure 3-1: Conceptual model of the Western Port net circulations patterns.
The net circulation patterns within Western Port as described by Harris et al. (1979). There is a clockwise circulation within Western Port.

3.1.2 Northern Phillip Island

The area between Cowes and Rhyll (often referred to as East Cowes) was initially an open embayment. This embayment formed during the mid-Holocene (approximately 7,000 years ago) and was backed by a cliffed shoreline. These cliffs existed at the interface between the mid-Holocene shoreline that had developed and the Older Volcanics Basalt that characterised what is now Phillip Island. A beach-ridge systems subsequently developed and the orientation of these ridge systems suggest west to east longshore transport. The calcareous sand that supplied this longshore transport is thought to originate from the Bass Strait seafloor, which was/is transported into Western Port by swell waves.

As the sea level fell, sediment supplied from the west to this shoreline generated several prograding sand spits that extended in an easterly direction from the Older Volcanic Basalt Headland at Erehwon Point. Evidence of this process is preserved in the morphology of the area and indicates that at least three stages of spit evolution has occurred, the earliest spit being approximately 3.0 km long. The conditions that led to the formation of the various spit development stages are not known. However, Marsden and Mallet (1975) suggest that the opening of the eastern entrance to Western Port at San Remo resulted in changes to the tidal flow dynamics within Western Port and an increase in the magnitude of the easterly flood tide current. This may have increased the rate of sediment supply along the northern coastline of Phillip Island. Other factors that may have (and possibly continue to have) impacted the development of the shoreline here include changes to sediment supply into Western Port as well as variation in sea levels. Ultimately, the marine influences within the tidal inlets that developed behind these spits slowly reduced as mangroves and saltmarsh trapped and consolidated sediments, which filled in much of these inlets.

This coastline here is thus historically highly dynamic over geological timescales and its position has fluctuated substantially. However, it is worth pointing out that anthropogenic changes to the shoreline throughout the area will strongly affect the capacity of the shoreline position to fluctuate in the future.

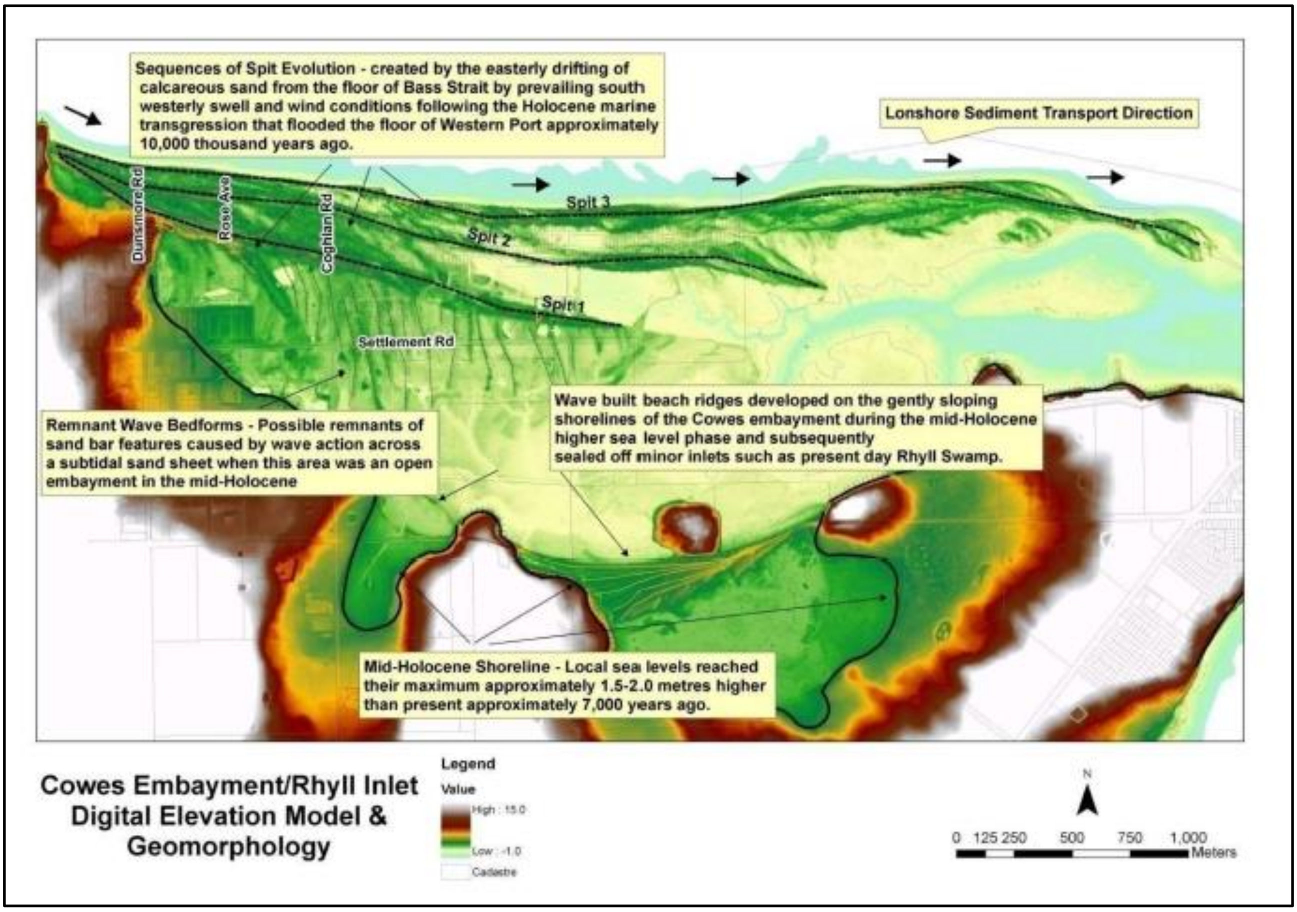

Figure 3-2: Evolution of East Cowes and Silverleaves
Reproduced from Water Technology (2011).

3.1.3 Cowes Bank

Cowes Bank, which is 400 meters wide and 5 kilometres long, is visible at low tide and increases in width toward the east. Aerial imagery analysis shows the presence of sand waves along the bank, which are oriented northeast though East Cowes and northwest through Silverleaves. These undulating bars and troughs are formed from medium to fine sand, and although were noted in the work by PICS (1987), it was concluded that little is known about their dynamics. Fundamentally, however, the pattern of the sand waves indicate a net easterly transport, with sediment migrating around Erehwon Point. Seagrass formations are also observed in the lee of these sand bars / waves, which indicates that these formations are relatively stable and slow moving. We discuss the role of this bank to regional sediment transport in section 5.6.

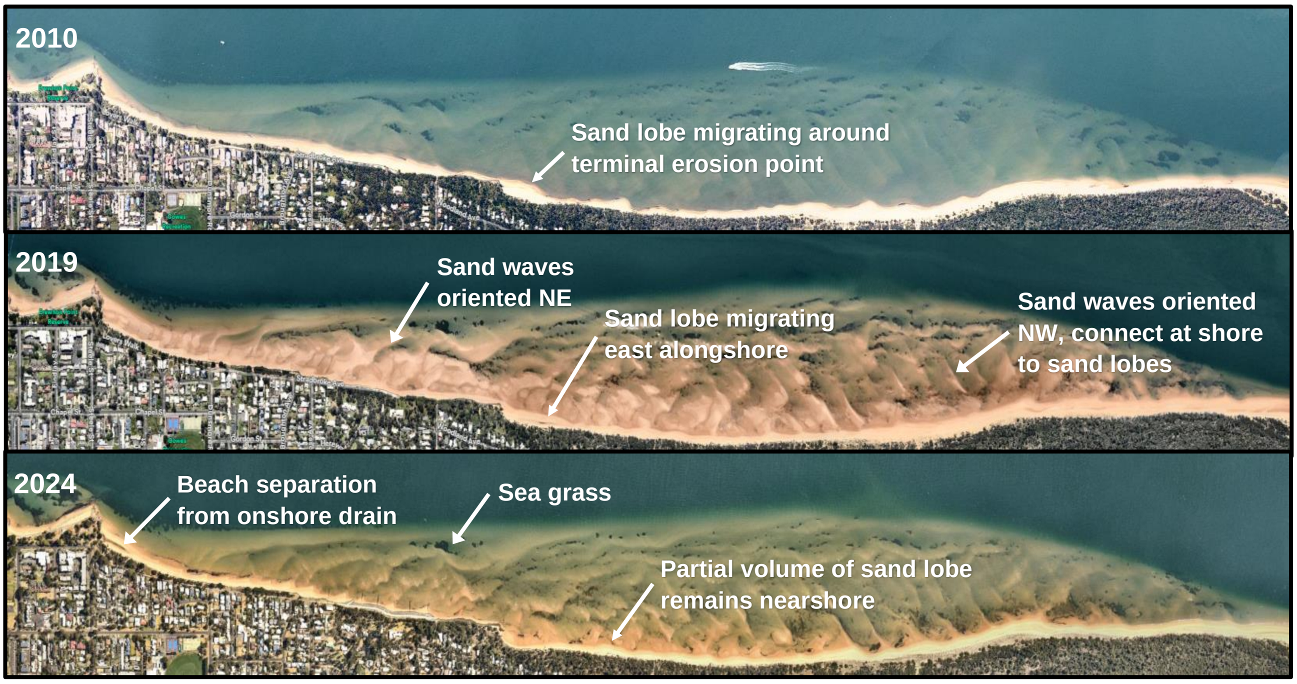

Figure 3-3: Features observed along Cowes Bank
Aerial Imagery from VCMP (Jan 30, 2024).

3.1.4 Silverleaves

The settlements at Silverleaves today are located on what are historical spits that have developed over geological timescales (section 3). Much of the surface is composed of sandy sediments that have migrated along the shoreline from the west. This is evident in the marine habitat classes around this area (Figure 3-4), which is mostly characterized by littoral and sublittoral sand. The episodic injections of calcerous sand that continue past Erehwon can either 'drip feed' the beach, arrive as lobes of sand that propagate along the shoreline resulting in patterns of erosion and accretion, or are deposited within the Cowes Bank. The sand that is deposited in the bank then travels as sand waves across the bank approximately parallel to the shoreline and reattaches to the shoreline at various locations. The morphology indicates that the configuration of the coastline has been very dynamic over relatively recent decadal but also geological timescale and thus suggests that the coastline is sensitive to both sea level and sediment supply.

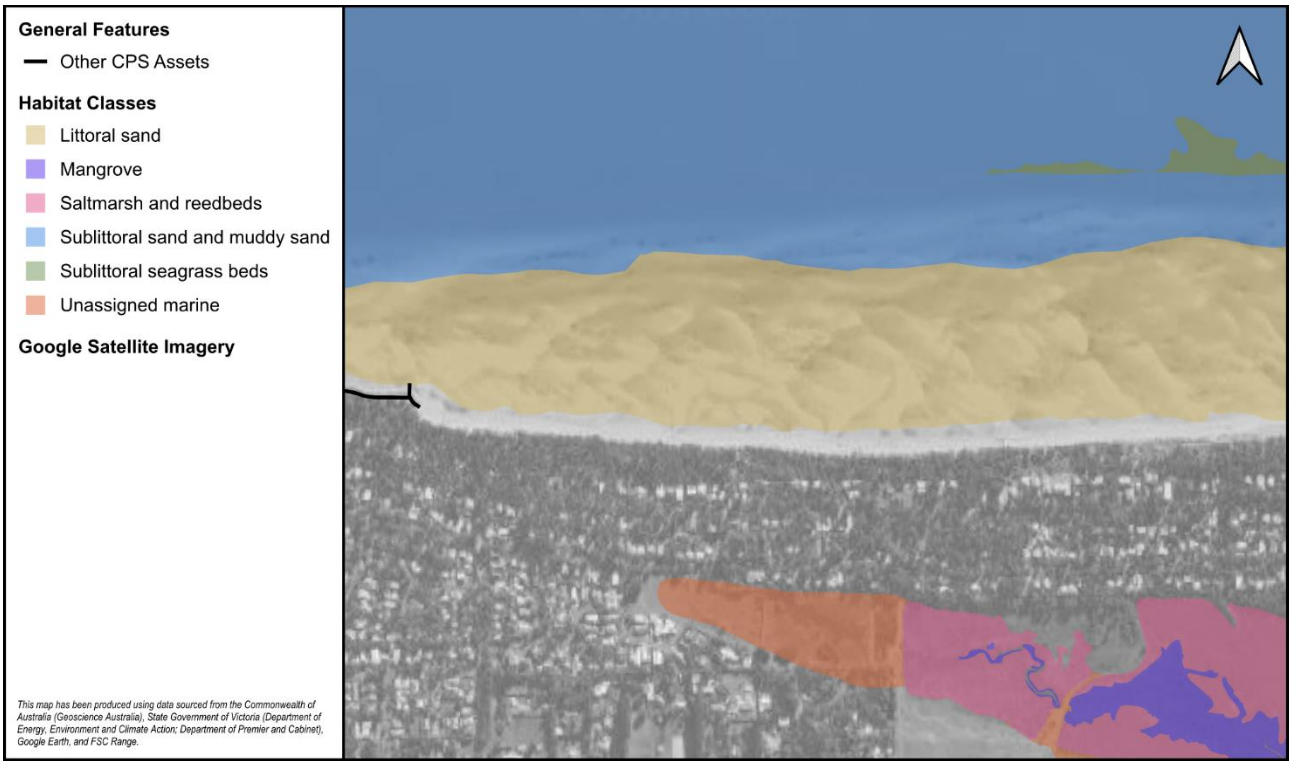

Figure 3-4: Marine habitat classes at Silverleaves

Shows the Statewide Marine Habitat (Appendix B).

4 SHORELINE POSITION

4.1 Contemporary Variability

The available dataset on historical shoreline position for the area is shown in Figure 4-1 and Figure 4-2 (DEA Coastlines, 2023). The dataset indicates that the shoreline position (as defined by the land-water interface) has generally fluctuated over annual timescales. However, the shallow nature of Cowes Bank makes this interface difficult to define. Consequently, we believe at this location the data is somewhat unreliable.

Reanalysis aerial imagery and survey data reveals that the shoreline position along the northern coastline of Phillip Island has varied substantially since at least 1953 (date of first survey available) and 1968 (date of the first aerial image available). To assess contemporary changes to the coastline and update the analysis conducted in the PICS (1987) and Water Technology (2018) studies, a compilation and thorough review of aerial imagery was undertaken. All images and datasets were georeferenced and plotted on a common scale. The data utilized for analysis includes historic and recent high-resolution images sourced from VCMP via Propeller, Google Earth Engine, and Nearmap (2024). The area is regularly monitored by VCMP via drone survey every 6 to 8 weeks since Aug 2018, with some gaps.

Figure 4-1: Map of shoreline position nearby CPS – East Cowes

Extracted from DEA Coastlines (2023), showing the net shoreline movement and historical shoreline position. The historical shoreline position is defined by the annual tidally corrected land-water interface (Bishop-Taylor et al., 2021).

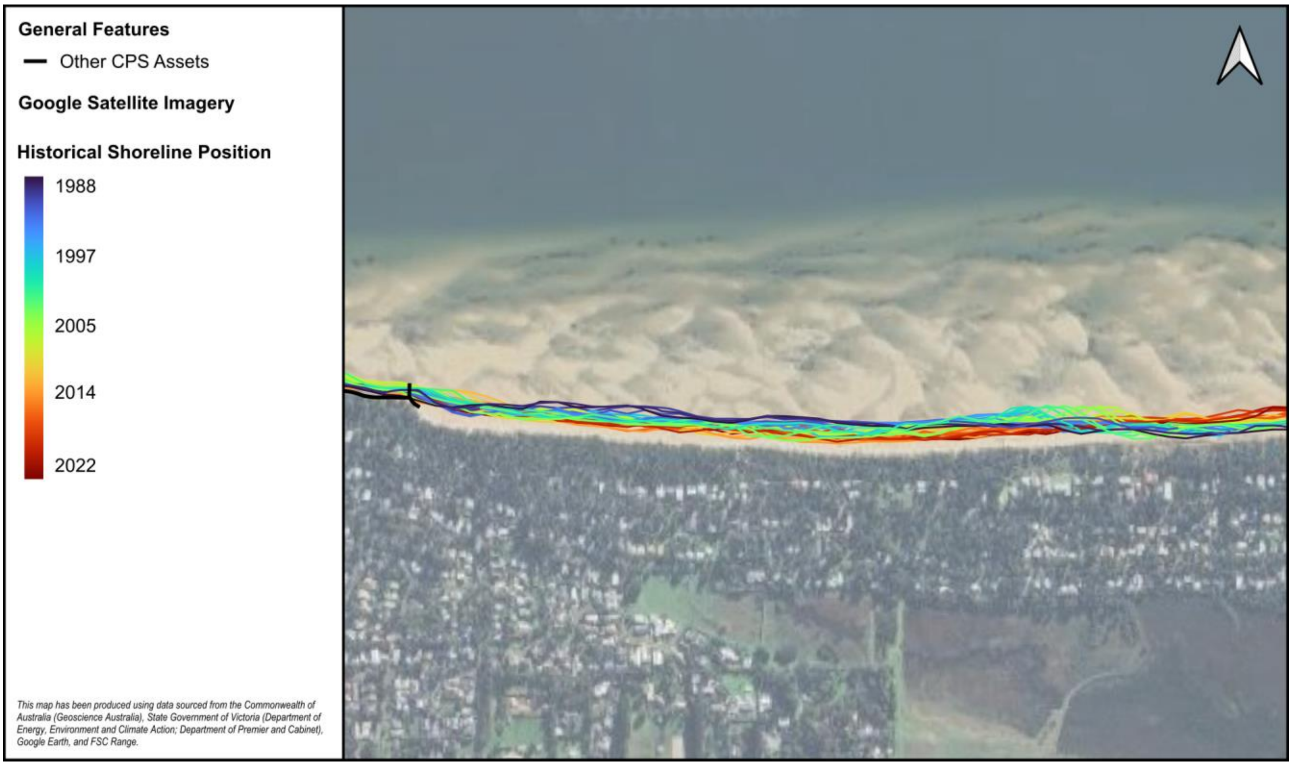

Figure 4-2: Map of shoreline position nearby CPS – Silverleaves

Extracted from DEA Coastlines (2023), showing the net shoreline movement and historical shoreline position. The historical shoreline position is defined by the annual tidally corrected land-water interface (Bishop-Taylor et al., 2021).

4.1.1 East Cowes

At East Cowes there has been notable variability in the shoreline position over the last 55 years, however, there has been little to no landward recession over the assessed period. This appears to be in due to several different factors including:

- A 'drip' supply of sand to the beach from around Erehwon Point, which continues to supply sand to this section of coast.
- Large volumes of sand that bypass Erehwon Point periodically, which dramatically increases the amount of sand that is available to be transported along the shoreline (also refilling any depleted groyne compartments). These injections have sometimes been characterized as sediment lobes, but may also simply include large volumes of sand, or sand that is initially detached from the shoreline due to the presence of a creek at the far west of the shoreline.
- Substantial anthropogenic interventions along the entire extent of the shoreline. Groynes have historically captured sand to create beach amenity. Revetments also exist along the back beach for almost the entire extent of the shoreline. These assets prevent landward recession of the shoreline during erosive periods.

It is worth noting that the groyne field has varied in function over the assessed period but was probably mostly functional in the late 1960's and early 1970's. By the 1990's the groynes to the west offered little function, probably due to their deteriorating condition.

Figure 4-3: Evolution of East Cowes (selected imagery shown)

Groynes have been a central feature of this shoreline with reduced effectiveness in over recent decades. Natural sand supply to the shoreline has varied over decadal timescales. Imagery extracted from VCMP (2024), CPS History from PICS (1987), Water Technology (2018), BMT (2020).

*Note some discontinuities exist between aerial imagery and reported construction dates.

4.1.2 Silverleaves

In contrast to East Cowes, the shoreline at Silverleaves has exhibited substantial change over the same period. Recent shorelines were inferred from the visible vegetation line, which is a conventional reference interface to monitor long term shoreline change. A representative shoreline from March 2024 was delineated and superimposed onto the earlier photos to illustrate the changes to the shoreline over contemporary history (Figure 4-4).

Perhaps most striking is the development of the terminal erosion at the end of the rock revetment This appears to have become visible somewhere in the late 1980's, around the same time that the groyne that was once here was removed (sometime between 1985 and 1989). Whilst it could at first be assumed that the removal of this groyne may have triggered this response, our analysis of the shoreline position over several decades reveals that the shoreline at Silverleaves already exhibited recession over much of the shoreline extent prior to the removal of the groyne. This is also consistent with the assessment by PICS (1987), which also noted ongoing erosion at Silverleaves as well as some infilling further to the east.

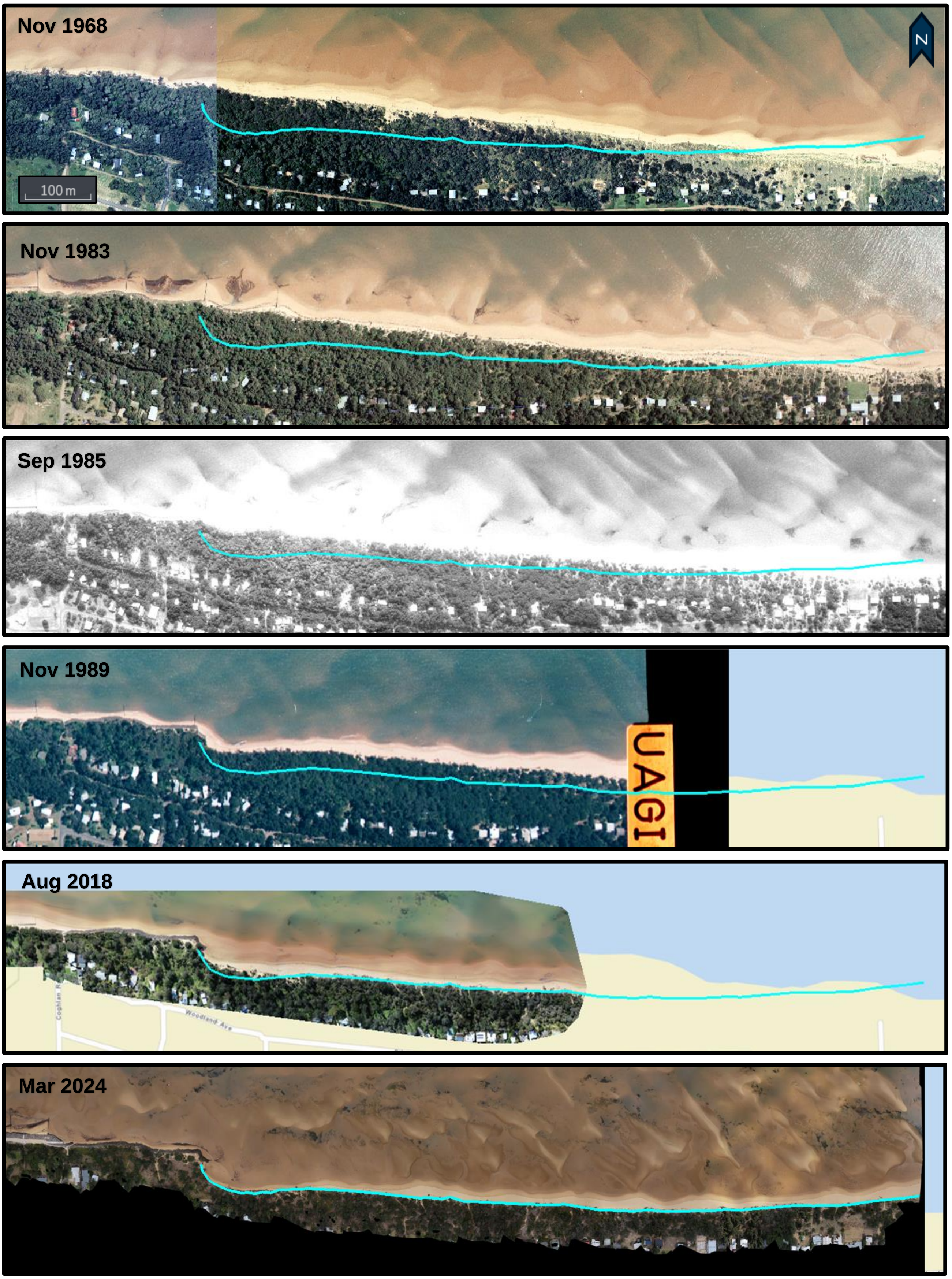

Figure 4-4: Aerial Imagery and shoreline change throughout Silverleaves
March 2024 shoreline shown in teal. Aerial Imagery provided by VCMP (2024)

4.2 Erosion Rates at Silverleaves

A historical survey record provided during the site visit documents previous surveys in the area that measure the distance from the original northern boundary of the freehold land to the High Water Mark (HWM) or the edge of the bank, also called the coastal buffer zone, at four points along the Cowes/Silverleaves shoreline. The 1953 and 1987 surveyed coastal buffer widths for the property seaward from Sanders Road were compared to the historic and recent widths measured from high-resolution imagery (Table 4-1). This analysis indicates:

- The shoreline in this area has receded by approximately 77 m since 1953,
- Erosion appears to have accelerated after construction of the revetment in 1977 and removal of the groyne field in this area sometime between 1985 and 1989, and
- In recent years (since 2022) erosion in this localised area appears accelerated. Near Sanders Road, the shoreline has retreated by 12 m over the span of just two years, and the maximum recession measured in the area was 16 m over two years (Figure 4-5).

Recession at this location has been prevalent for some time and documented in several of the recent studies. It is most likely attributed to terminal erosion from the adjacent revetment, combined with diminished sand supply due to both natural causes and upstream anthropogenic interventions (such as groynes and revetments) that have modified the rate and magnitude of sediment transport along the shoreline over several decades.

4.3 Summary

Whilst there has been much work undertaken to monitor the shoreline at East Cowes and Silverleaves, a definitive explanation as to possible future extents of the erosion observed at Silverleaves as well the coastal processes that may be contributing to the accelerated erosion is unknown and was therefore investigated in this assessment.

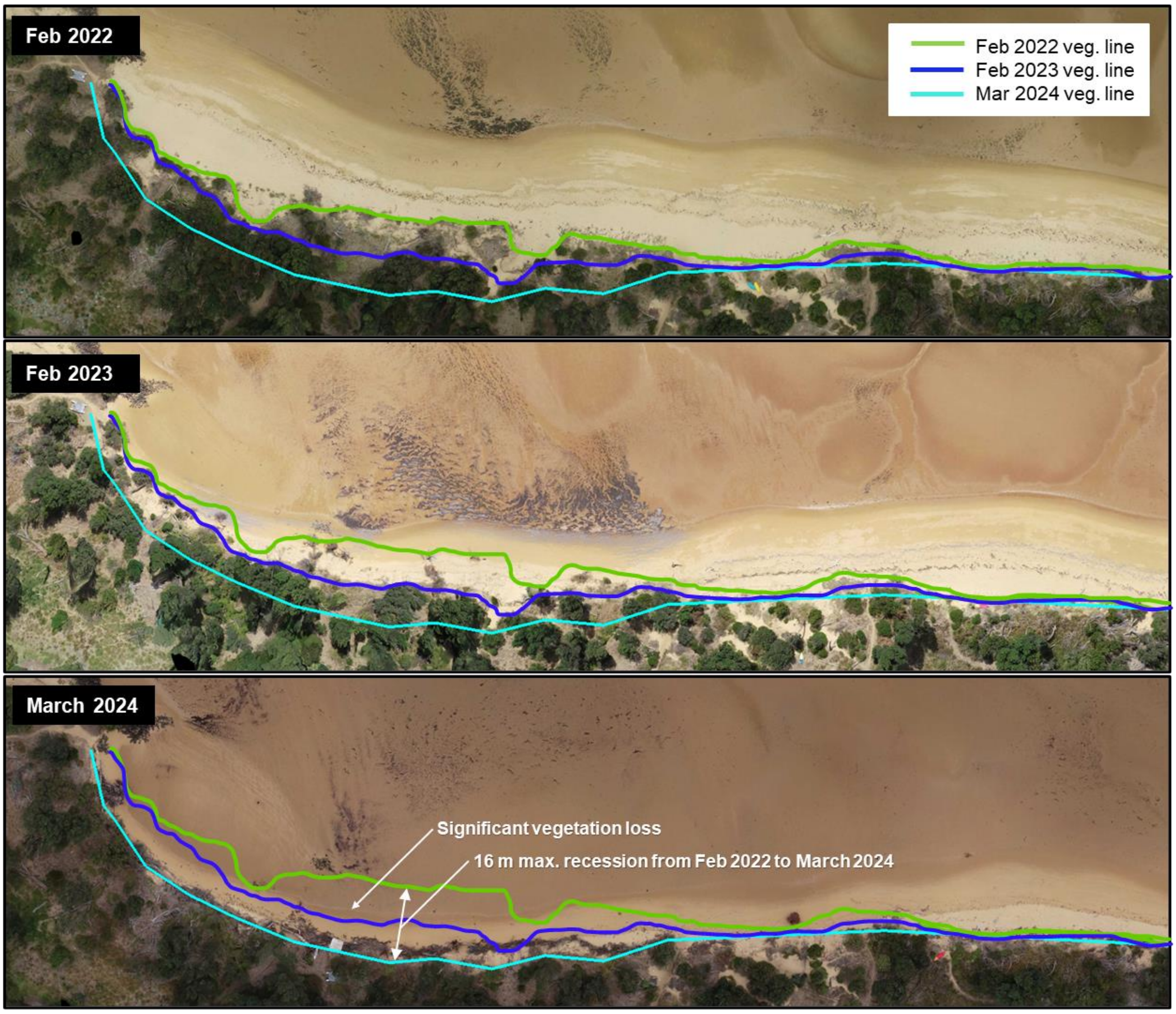

Figure 4-5: Aerial Imagery and shoreline change at the end of the rock revetment
Aerial Imagery provided by VCMP (2024)

Table 4-1: Measured Coastal Buffer Width
Measured as the distance from freehold land boundary to High Water Mark at point seaward from Sanders Road

Year	Coastal Buffer Width	Recession rate
1953	123 m	Unknown, no data prior to 1953 available
1974	120 m*	0.15 m/year avg. Between 1953-1974*
1987	92 m	2.15 m/year avg. between 1974-1987**
2018	65 m	0.9 m/year avg. between 1987-2018
2022	57 m	1.8 m/year avg. between 2018-2022
2024	45 m	**6.0 m/year avg. between 2022-2024**

Source: W. Richardson 1953, CPO CPO Field Notes PO5368; J. Jansson 1987; FSC Range, 2024, measured from historical aerial imagery from Feb, 1974 and high resolution orthorectified images from Aug 2018, Feb 2022, and March 2024 (VCMP, 2024).
*Note: Measurement is approximate due to image clarity, assumed error +/- 5m (or +/- 0.2 m/year).
**Note significant anthropogenic interventions occurred during this period: Revetment constructed upstream in 1977, and groynes in this area were removed between 1985 and 1989.

5 COASTAL PROCESSES

To understand the coastal processes responsible for shoreline change along East Cowes beach and Silverleaves, we used a combination of data driven analysis and numerical modelling.

5.1 Methodology

5.1.1 Data driven analysis

High-resolution Structure from Motion point cloud data was sourced from the Victorian Coastal Monitoring Program (VCMP). Structure from Motion derives 3D spatial data from dense high resolution imagery. The area has been regularly monitored by the VCMP via drone survey every 6 to 8 weeks since August 2018, with some gaps. Using this data, we quantified the differences in the bathymetry both spatially and temporally. Whilst there is likely to be some error associated with the use of Structure from Motion imagery, in the absence of other data we believe that the data, and especially the trends derived from the data, are reasonable for the purposes of this analysis.

We prepared difference plots throughout the area as well as within sub-sections to quantify patterns of sediment movement both at the shoreline as well as on Cowes Bank.

5.1.2 Numerical Modelling

A primary objective of this study was to develop a foundational numerical model of Western Port and Phillip Island to evaluate coastal processes at East Cowes and Silverleaves, serving as a basis for assessing coastal infrastructure and management strategies. Due to the complex nature of shoreline dynamics in this area, a single numerical model cannot encompass all relevant processes. Thus, a comprehensive suite of numerical models was used. This section outlines the development and calibration of both regional and local-scale hydrodynamic and wave models, aimed at replicating regional circulation and nearshore processes, and introduces the shoreline process model.

Modelling Approach

The modelling strategy employs a scenario-based approach to optimize run times, given the impracticality of continuous modelling over extended periods due to the complexity of the process-based model systems. However, the short-term simulation results can be scaled to predict longer-term impacts. Both seasonal and extreme scenarios were modelled based on long-term climatic data.

Modelling Software

For hydrodynamic and wave modelling in Western Port and Phillip Island, we employed coupled Hydrodynamic (Delft3D) and Spectral Wave (SWAN) models. Delft3D, developed by Deltares (2019) is an industry-standard integrated modelling suite capable of simulating two-dimensional and three-dimensional flow, sediment transport, morphology, waves, water quality, and ecology, while managing interactions among these processes.

The Delft3D-FLOW module simulates hydrodynamics under tidal and meteorological forcing within the model domain. Delft3D-FLOW is a multi-dimensional hydrodynamic simulation program that calculates non-steady flow and transport phenomena on rectilinear or curvilinear boundary-fitted grids.

Available metocean data indicates that offshore wave conditions occasionally influence circulations within Western Port. To account for this, wave conditions are integrated into the simulations using the Delft3D-WAVE module. This integration allows for the direct coupling of wave and current forces. The WAVE module utilizes the SWAN wave model, a third-generation spectral wave model developed at Delft University of Technology, which calculates random, short-crested wind-generated waves in coastal regions and inland waters (Deltares, 2019). SWAN incorporates the following physical processes:

- Wave propagation, shoaling, refraction due to current and depth, and frequency shifting due to currents and non-stationary depth
- Wave generation by wind
- Wave interaction
- Whitecapping, bottom friction, and depth-induced breaking
- Dissipation due to aquatic vegetation and turbulent flow
- Wave-induced set-up

Domain

The flow model domain encompasses the entire Western Port and extends offshore to capture broader tidal dynamics. The mesh resolution varies, becoming finer towards the project site with a minimum local resolution of 5 meters. This high-resolution area ensures detailed modeling of local hydrodynamic processes, such as local smaller scale flow patterns and influence of the coastal protection structures. The functional groyne CPSs were included in the model.

5.1.3 Available Data

Existing data that were available and used in the analysis are summarised in Table 5-1.

Table 5-1: Data used in this assessment.

Relevant data that were identified for use in this assessment are summarised. There are many other data sources available that could also be used. These have not been listed.

Data	Source	Comment
Bathymetry/Topography		
VCMP DEM 2018-2024	Victorian Coastal Management Program (VCMP) via Propellor	Localized high resolution Orthophotos and DEM from UAV photogrammetric survey from approx. Erehwhen Point to Silverleaves. Survey data dated 30 January 2024 were used to resolve local bathymetry and topography for numerical models. Other VCMP surveys dated from 2018 to 2024 were used for aerial shoreline change mapping and volume calculations.
5m DEM 2020	GeoScience Australia	Land cover dataset used to define land boundaries and topography.
10m VicCoast DEM 2021	Government of Victoria	Data used to resolve regional bathymetry for numerical models.
250m DEM	GeoScience Australia	Used to resolve offshore bathymetry for numerical models. Only used offshore in areas not covered by VicCoast DEM.
Shoreline		
DEA Shorelines	GeoScience Australia	1988 to present was used to assess medium and long-term shoreline position variability.
Characteristics	FSC Range site inspection	On-ground assessment of beach composition, shape, and characteristics for erosion mapping.
Water Level Data		
Tidal Planes	Stony Point Tidal Guage (AusTides, 2021)	Used to define the tidal planes.
Sea Level Rise	Local Coastal Hazard Assessment by Water Technology (2014)	Aligns with Marine and Coastal Policy (2020)
Storm Tide	Local Coastal Hazard Assessment by Water Technology (2014)	Storm tide water level includes the contribution of astronomical tide and atmospheric storm surge.
Wind and Wave Data		
Hindcast Wind and Wave Conditions	Hindcast data from WaveWatch III numerical models via CoastKit	Timeseries of hindcast data probabilistically analysed to define extreme event incident wind and wave conditions for numerical models.
Wave Setup	CSIRO CANUTE 3	1% AEP wave setup estimated and cross-compared with wave setup calculated by the numerical models.
Other Data		
Asset Data	Aerial Mapping (Google Earth Engine / Nearmap / LandSat / Sentential / Maxar)	Cross-referenced on site during site inspection.
Sediment Sampling Data	BMT, 2014	BMT completed sediment sampling near Silverleaves for beach nourishment design.

5.2 Water Levels

5.2.1 Astronomical Tide

The nearest tidal station is located at Stony Point approximately 20 km southwest of the East Cowes/Silverleaves area. The latest astronomical tides as defined by this tidal station are shown in Table 5-2. The tide here is semi-diurnal with a spring tide range greater than 2 m.

Table 5-2: Astronomical tides associated with Stony Point
Extracted from Australian National Tide Tables 2024 NTM Edition 25 (Commonwealth of Australia, 2023).

Tide	Australian Height Datum (m AHD)	Chart Datum (m CD)
Highest Astronomical Tide (HAT)	+1.62	+3.40
Mean Higher Water Springs (MHWS)	+1.12	+2.90
Mean High Water Neaps (MHWN)	+0.62	+2.40
Mean Sea Level (MSL)	+0.00	+1.78
Mean Low Water Neaps (MLWN)	-0.68	+1.10
Mean Low Water Springs (MLWS)	-1.08	+0.70
Chart and Prediction Datum	-1.78	+0.00

5.3 Wind

The nearest weather station is at Rhyll and indicates that incident winds from the north typically have the greatest occurrence and magnitude relative to other directions incident to the measurement site. The maximum wind speed is usually less than 15 m s^{-1}, but higher recordings have been made. Winds from the east are typically less frequent.

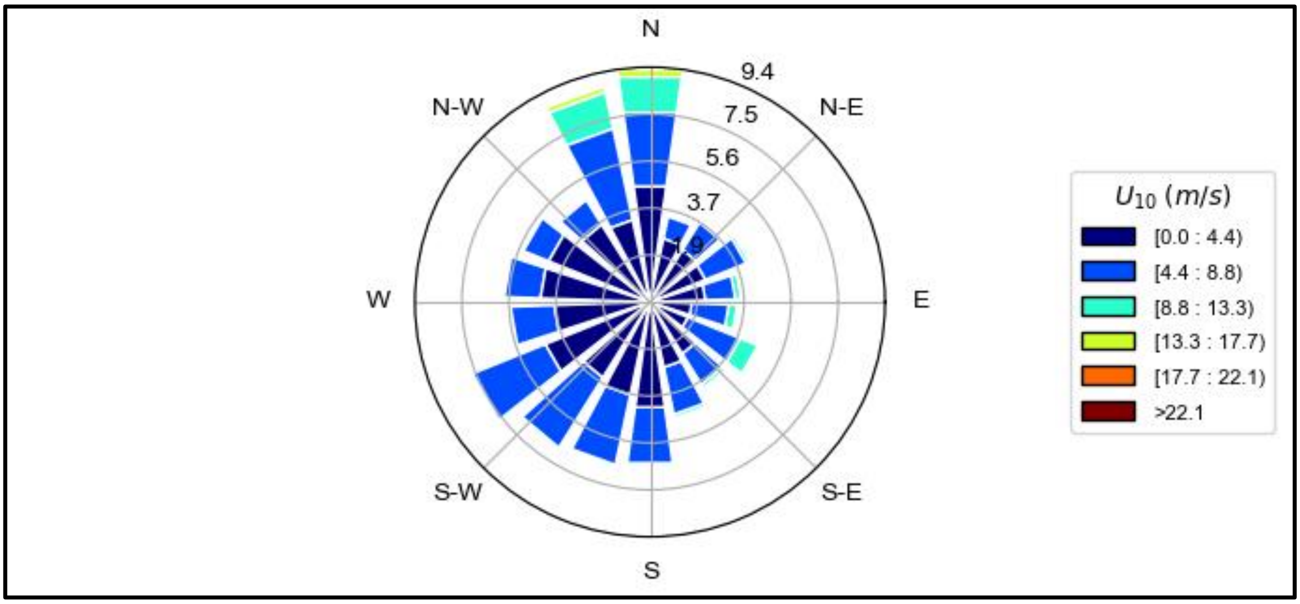

Figure 5-1 Wind climate history at Rhyll
The weathers station at Rhyll, which is located approximately 4.5 km south east of the site. Data range is from 1991 to 2024 and was sourced from the Australian Bureau of Meteorology.

The wind station at Rhyll is not necessarily representative of the wind climate offshore of Cowes Bank, which is protected from the south by Phillip Island and more exposed to westerly winds. Re-analysis of wind data in the WWIII model by Liu et al (2022) approximately 1 km offshore of the shoreline reveals that prevalence of north-westerly winds, which can be expected to play a role in the generation of much of the waves that impact the area as well as generate alongshore currents.

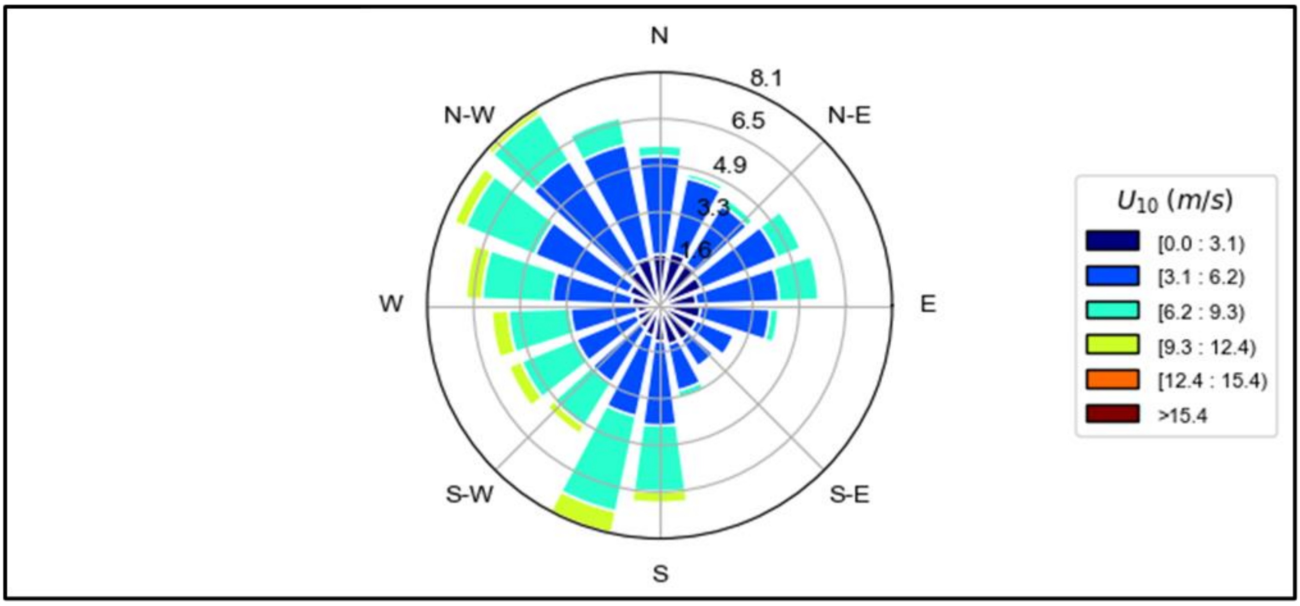

Figure 5-2 Wind climate history approximately 1 km offshore of the Cowes Bank

This model derived wind data spans from 1981 to 2020 and has been extracted from the Victorian WWIII model (Liu et al., 2022).

5.4 Wave Climate

The wave climate across the East Cowes and Silverleaves foreshore region is characterized by two predominant wave types:

- Wind Waves generated within Western Port
- Long Period Ocean Swell Waves that propagate into Western Port from Bass Strait.

Vessels may frequent the area however vessel wake is not anticipated to be of significance when compared to swell and wind waves.

5.4.1 Wind Waves

Low energy, fetch-limited wind waves are generated locally within the Eastern and Western Arms of Western Port. During winter, wind and waves are predominantly from the northwest. Conversely, in the summer months, winds blow primarily from the southwest to southeast and wind wave energy diminishes due to the area's northerly orientation. The more substantial and persistent waves originate from the northwest during winter, in contrast to the relatively smaller waves in summer, are believed to significantly influence the observed eastward sediment drift. These waves can be as large as 0.8 m on the Cowes Bank. Predominant south-easterly winds in summer create calmer conditions for the north side of Phillip Island, which typically characterise the wave climate as much as 80% of the time.

5.4.2 Long Period Ocean Swell Waves

These waves enter Western Port from the western entrance and refract around Phillip Island into the study area. By the time they reach East Cowes and Silverleaves, these waves are typically small in height. Swell waves are likely a significant driver of sediment transport further to the west of the site due to their long periods, persistent occurrence, and oblique approach. Analysis of the hindcast wave data indicates that swell waves near the centre of the channel offshore of Cowes Bank (Figure 5-3) reach up to 2.3 m during the 10% AEP (10-year) event, and up to 2.5 m during the 1% AEP (100-year) event. These waves almost exclusively come from the south southwest, and hence are attenuated and diminish as they propagate to and refract toward the East Cowes and Silverleaves shorelines.

Further, wave conditions in Western Port are modulated by the tidal current that flows through the Western Entrance. During ebb tide, the currents flow in the opposite direction to the waves, leading to wave-current blocking and refraction, a scenario where wave energy is partially counteracted by the opposing currents. This interaction often results in a reduction in wave heights and energy during ebb tide compared to flood tide conditions.

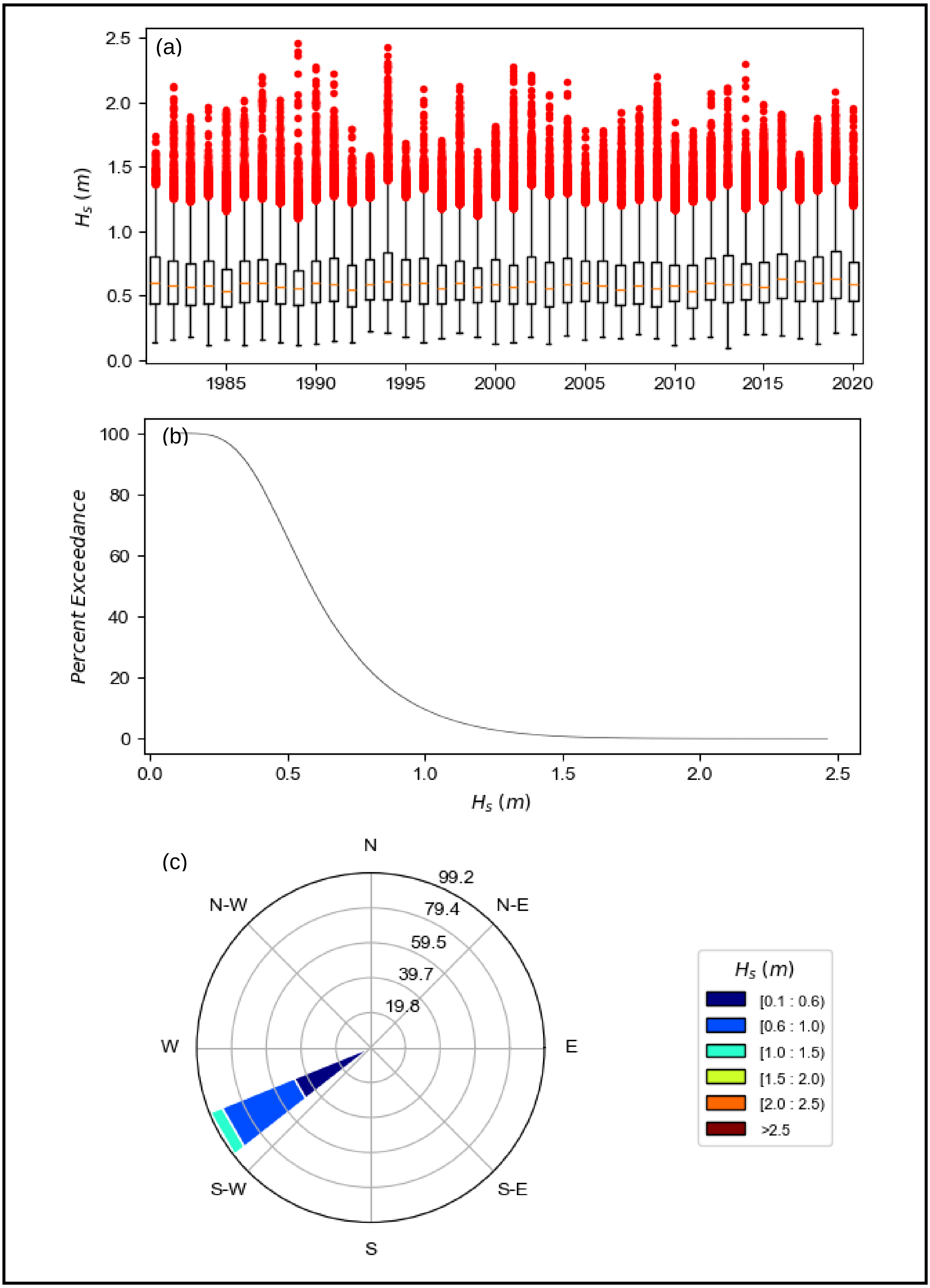

Figure 5-3 Swell wave climate approximately 1 km offshore of Cowes Bank

(a) Summary of the annual wave climate, (b) Wave height exceedance plot and (c) direction of incident waves. This model data spans from 1981 to 2020 and has been extracted from the Victorian WWIII model (Liu et al., 2022).

5.5 Currents

There are no insitu measurements available on the Cowes Bank or along the northern Phillip Island coastline, however spot estimations by PICS (1987) are available. These estimations are consistent with the numerical modelling of the bank and shoreline undertaken in this study. Our recent modelling however reveals that complex nearshore current patterns characterise this area. The spot current estimations by PICS (1987) are not suitable to verify presence of magnitude of these circulations but do provide confidence that the overall current dynamics are correctly simulated.

5.5.1 Tidal Currents

It is well established that the tidal currents propagate to the east during flood (rising) tide, and then turn and flow to the west during ebb (falling) tide. Whilst this oscillating tidal flow is fairly uniform offshore of the Cowes Bank, these currents do interact with the bathymetry and coastline structure resulting in the generation of complex flow fields in the nearshore.

During flood tide, two different flow patterns emerge at Silverleaves. The first flow patten involves west-east currents directed alongshore. As these currents pass by the end of the last revetment, there is a notable reduction in the velocity and perhaps more importantly a slightly onshore directed flow develops approximately 400 m along the shoreline (Figure 5-4). This shore-oblique to normal flow may contribute to the cross-shore transport of sand from Cowes Bank back to the Silverleaves shoreline albeit at relatively slow propagation rates, but could be enhanced if waves are also present during this tidal phase. Our analysis suggests that these flood tide currents are generally low, in the order of 0.1 m/s, which is consistent with the estimates by PICS (1987) that suggest tidal current rates of about 0.12-0.2 m/s. During spring tidal phases the currents can as high at 0.6 m/s.

When the flood current flows past the revetment, it separates from the main flow path, creating regions of low pressure behind the structure, which lead to the formation of vortices or eddies (Figure 5-5). Formation of an eddy during the transition from flood tide to ebb tide is also observed. As the tidal flow reverses direction at the erosion hotspot, a rotating current is generated. This eddy subsequently migrates towards the channel, moving with the ebb tide. Whilst the magnitude of these eddies appears to be relatively low, it is possible that they may result in two processes that affect the shoreline. The first process is the continual bypass of sand transported along Cowes Bank (i.e. sand is transported past this location). The second process that may occur is for conditions where this eddy intensifies, such as during high water levels or where waves or surface wind driven currents supplement the tidal flow, this eddy may scour out sediment and transport it slight offshore where it is transported by the tidal flow. These observed current patterns are also consistent with erosion observed during low-wave events by local residents as well as the observed accretion at eastern Silverleaves.

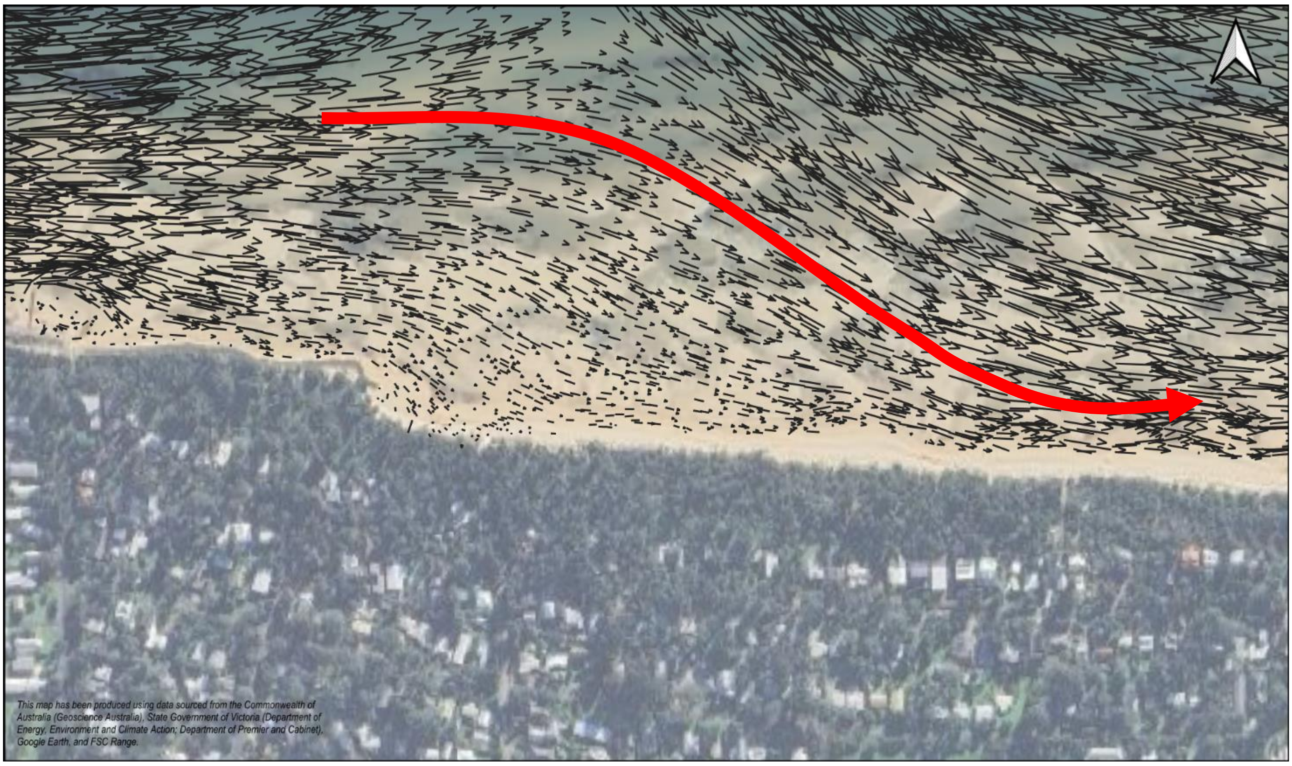

Figure 5-4 Tidal current flow vectors – initial flood tide phase

During flood tide the flow is approximately alongshore parallel but appears to reduce in front of the erosion hotspot before reattaching approximately 400 m beyond the end of the revetment.

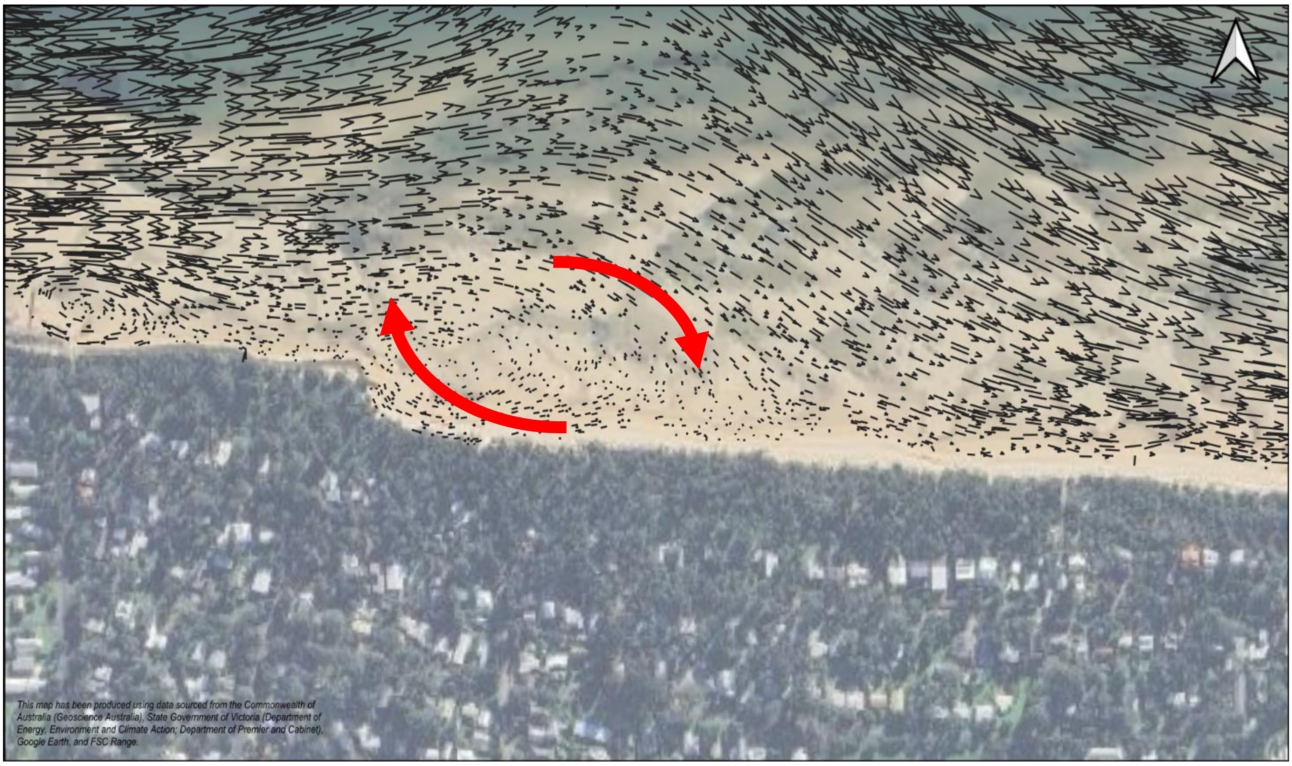

Figure 5-5 Tidal current flow vectors – later in the flood tide phase

As flood tide proceeds, a recirculation cell (eddy) develops at the location where the sustained terminal erosion is now observed.

During ebb tides, the alongshore currents are higher but mostly alongshore uniform (Figure 5-6). Our analysis suggests these currents can be as high as 0.3 m/s, but they do vary spatially and with time as the water depth reduces. This is consistent with the estimate by PICS (1987), which also suggested current of 0.33 m/s. Such currents may transport sediment in a westerly direction but unlike during the flood tide, due to the relatively uniform flow, this sediment is likely to remain closer to the shoreline.

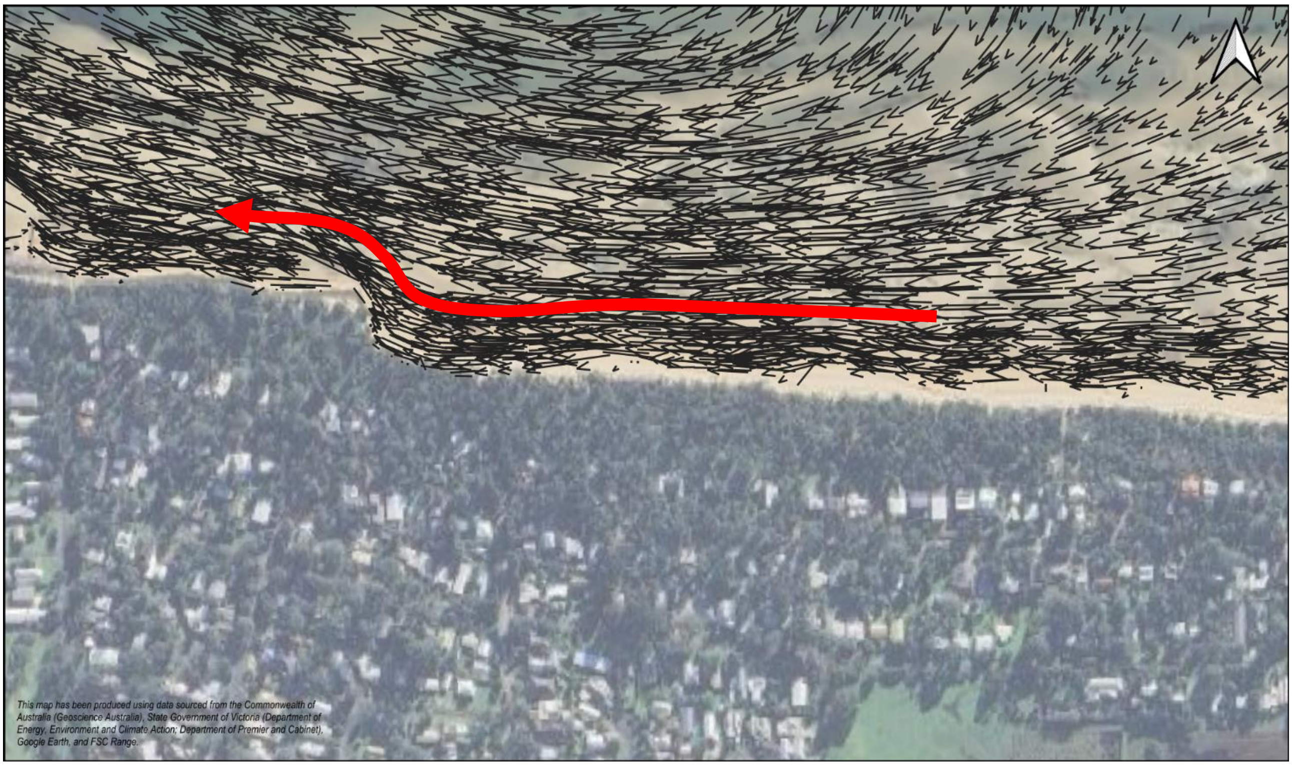

Figure 5-6 Tidal current flow vectors – ebb tide phase
During ebb tide the tidal current is faster but also alongshore parallel.

These current patterns suggest that, at least in part, the shoreline orientation at Silverleaves now generates a slight negative feedback, whereby the change in shoreline orientation may now be enhancing the scour of sand when tidal circulations are strong or when enhanced by waves. This may be at least a contributor to the increase in the rate of erosion observed locally.

We note that a key limitation of this study is comprehensive (timeseries) validation of these current patterns. See section 5.5.3 for limitations and recommended actions to fill these data gaps.

5.5.2 Wave-driven Currents

The shallow Cowes Bank controls the magnitude of the waves that propagate toward the shoreline. As a consequence, relatively large waves tend to break on the outer bank. This wave breaking process can drive flows onto the bank as well as mobilise sand. Closer to the shoreline, waves that arrive at an incident angle drive relatively weak alongshore flows, principally from west to east (Figure 5-7). Although if strong winds from the east occur, the opposite can also occur. Based on the metocean data offshore of this location, the principal waves are most likely to occur from the north or north west sector and thus a west-to-east wave transport of sediment along the shoreline is likely to prevail. This is also consistent with geological records, historical observations as well as contemporary accumulation of sediment within the existing groyne field that is functional.

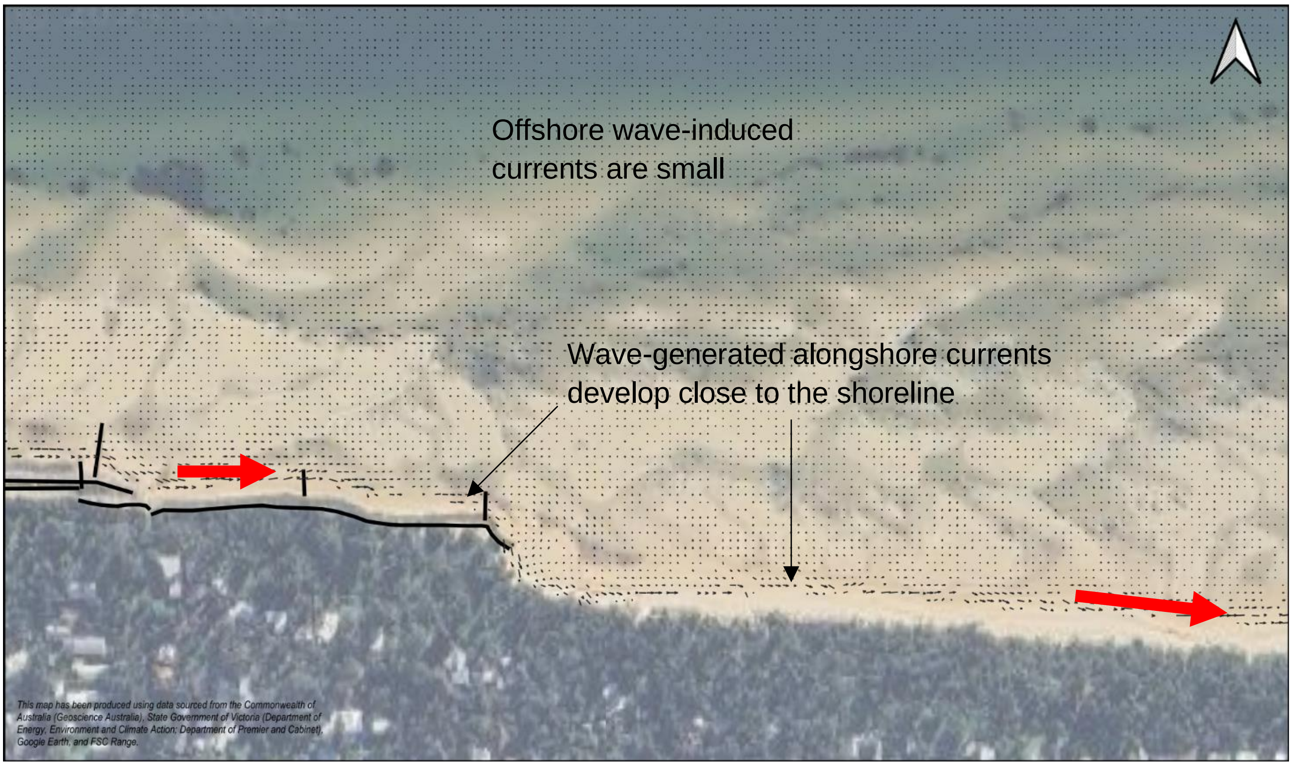

Figure 5-7 Alongshore wave-generated currents

Small near cross-shore orientated incident waves that propagate across Cowes Bank can generate a small but persistent alongshore current. This current can be expected to have a greater magnitude when incident waves are larger or more oblique to the shoreline.

5.5.3 Limitations

We note that a key gap is comprehensive (timeseries) validation of the model results. In such shallow complex environments, it is likely that numerical models such as the one used in this assessment may provide erroneous results. Depending on the selected adaptation pathway (beyond the scope of this assessment), validation of the numerical modelling may be required to further constraint the results. In such an instance, we recommend that both current and wave data be collected on Cowes Bank and particularly along the shoreline to validate the flow separations that have been predicted in the model. Recommended data measurement techniques for validation could include:

- **Wave and Current Gauges:** Deploy bottom mounted wave and current gauges over several months to capture tidal cycles and wave events at key locations on the bank.
- **Lagrangian Drifters**: Using Lagrangian drifters is a reliable method for tracking water movement. These drifters float with the currents, providing real-time data on flow patterns.
- **Manual Observation and Data Collection**: Regular monitoring and data collection using simple tools like floating biodegradable markers or dye releases can help validate model predictions and understand current patterns. These items are visible and can be tracked manually or via aerial surveys.
- **Hydrodynamic Models with Particle Tracking**: Combining hydrodynamic models with particle tracking modules, such as those using Lagrangian particle tracking, can simulate and predict the movement of particles in shallow water environments. This method allows for detailed analysis of current patterns and sediment transport.

5.6 Sediment Dynamics

The sediment dynamics at East Cowes and Silverleaves involves two separate sediment transport processes:

1. Sediment transported along Cowes Bank
2. Sediment transported along the shoreline

Both processes appear to operate somewhat independently and are typically thought to have little exchange, however this may not always be the case.

5.6.1 Cowes Bank

Bathymetric surveys from the VCMP were evaluated and compared over various timeframes (2018 to 2024 at 6 to 8 week intervals) to assess erosion/deposition patterns and potential sediment pathways. This analysis indicates substantial erosion and deposition patterns along Cowes Bank. In general, the bank from Erewhon Point to Rose Avenue has exhibited erosion since 2018, while the nearshore has accreted, mainly in the newly constructed (2015-2018) groyne compartments.

At the location where the new pattern placed rock revetment that was constructed in 2022 is located, erosion at mid bank and nearshore has been observed. This nearshore and mid-bank erosion is apparent year to year and may be attributed to several processes:

- Sand scraping activities undertaken in the area to reinforce the shoreline (prior to the construction of the new revetment) that lowered the seabed in this area, which may continue to be adjusting to the presence of the new revetment.
- Reflected waves off the new pattern placed rock revetment as well as the previous timber seawall. Whilst the lowering of the seabed by sand scraping activities may still be observed in the data, we note that the seabed in the area appears to have continued to lower since the construction of the revetment. It appears that at least some of the material eroded from the nearshore and mid bank is redistributed to the outer bank, which shows an accretion trend since 2018. Silverleaves has also exhibited accretion at the outer bank since 2018, and severe localized nearshore erosion.

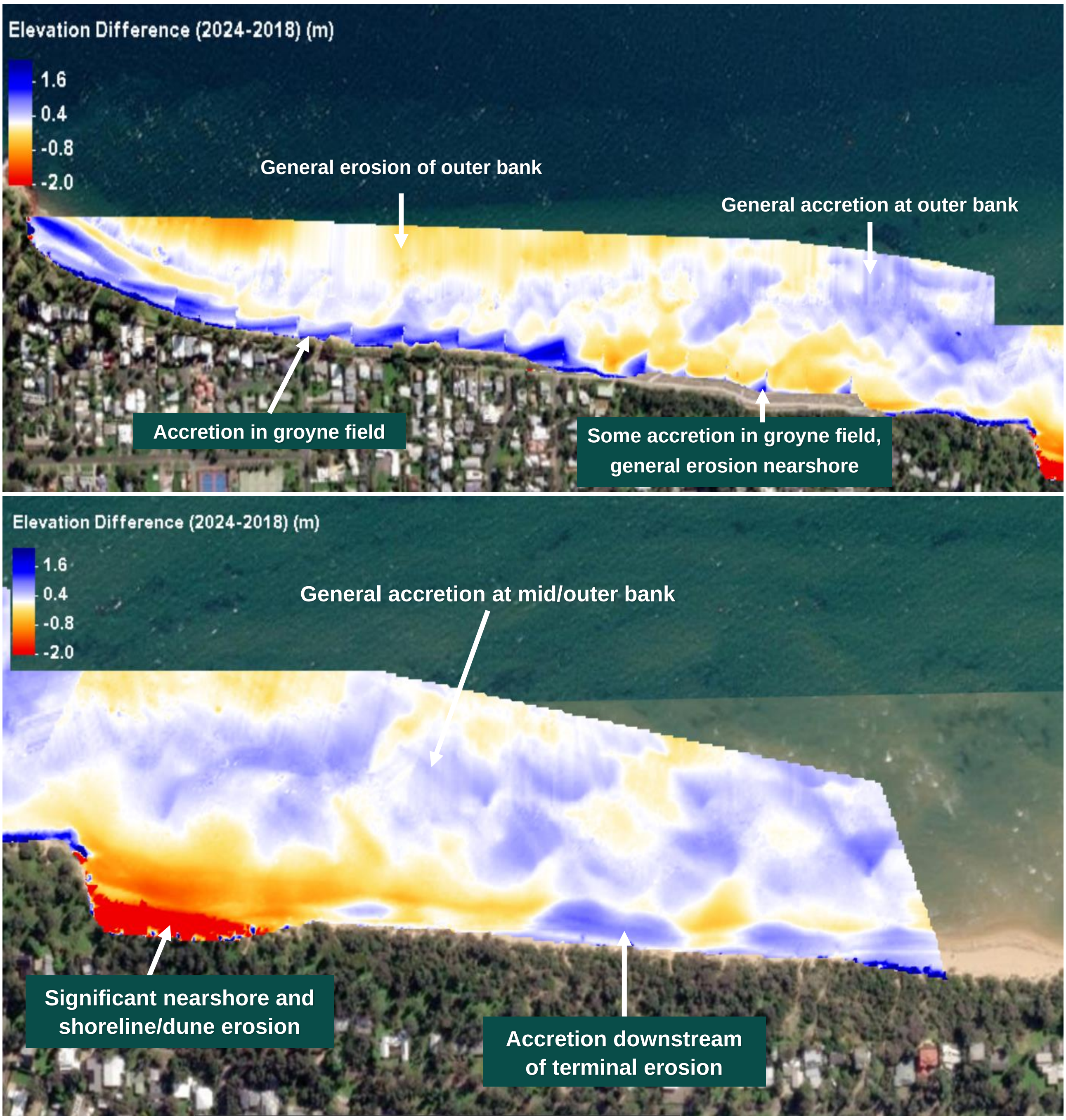

Figure 5-8: Erosion/deposition trends at Cowes (upper) and Silverleaves (lower).
Survey data from VCMP (March 2018 and Jan 2024)

Table 5-3: Volume eroded/accreted from 2018 to 2024

Area	Nearshore Net Volume Change	Overall Net Volume Change
East Cowes - Erewhon Pt Rose Ave	+8300 m^3	- 3800 m^3
East Cowes - Rose Ave to Coghlan Rd	-5200 m^3	+1200 m^3
Silverleaves	-9000 m^3	-2600 m^3

Survey data from VCMP (March 2018 and Jan 2024)

5.6.2 Along the Shoreline

It has long been proposed that sand lobe migration along this shoreline contributes to the variability of sediment supply to this shoreline. Indeed, there is evidence of the migration of large clumps of sediment that migrate along the shoreline from west to east. Water Technology (2018) suggests that these lobes originate from sediment transported into Western Port from Bass Strait. Historically before the shoreline was modified, it is thought that the entire shoreline would oscillate as these lobes progress along the coast (by as much as 50-100 m). Extensive interventions along this coast mean that such oscillation cannot occur and that terminal erosion points (such as near Silverleaves) now compensate for this historical variability. Based on our assessment, the rate of sediment transport along the shoreline is relatively low <10,000 m^3/year.

Whilst our review of aerial imagery does reveal some lobe-type features that propagate along the shoreline, this sedimentary feature is not necessarily regular. We believe what is perhaps a better description of the process is:

- Sand is transported around Erehwon Point and is separated by the outflow from the creek/drain at the western end of East Cowes beach.
- Eventually this sand spit-type feature begins propagating down the coastline where it may be either welded to the shoreline, pushed offshore, or both.
- Of the sand that does weld to the shoreline, it is either captured by the groyne field or bypasses it and slowly propagates east along the shoreline toward Silverleaves. This propagation is more evident east of Silverleaves where groynes have not been constructed. The timescale of this propagation appears to be in the order of 5 to 30 m/year.

5.7 Impact of Coastal Interventions

5.7.1 Influence of Groynes

The aerial imagery analysis reveals significant fluctuations in beach width along East Cowes Beach. Review of this imagery and survey data indicates that the first four timber groyne CPSs do not currently impact the transport of sediment and thus shoreline position or beach amenity. Several other groynes along East Cowes Beach are also not functional. A number of other groynes are functional and do have an impact on sediment transport and the shoreline position. These (more recently constructed) groynes appear to be retaining sand even during erosion episodes, resulting in the formation of small fillet beaches on the west sides of the groynes. Any sediment that is captured and held by these groyne structures will not be able to move downstream to replenish the beaches at Silverleaves, although when the compartments are filled bypassing appears to occur. Our analysis suggests that large volumes of sand can (at times) be stripped out of these groyne cells during storm events, which has implications for the dynamics of the whole coastline. Without proactive sand nourishment of the groyne fields following these erosive events, there will be limited natural bypassing of sediment during times when the natural sediment supply is low until these compartments refill.

A series of new timber groynes were installed in 2022 in front of the newly constructed pattern placed rock revetment. Notably, no sand was added to the compartments of these groynes during their construction. Consequently, it is reasonable to expect that these groyne compartment trap some (if not all) of the sediment transported along the shoreline. This most certainly will have reduced the amount of sand available further downstream, which not only was previously able to pass from East Cowes but would also have been stripped from the shoreline (now defended by the revetment) where the dilapidated timber seawall was located and transported alongshore to Silverleaves. We note that given gaps have formed under several of these groynes, at least some of the sand may be transported between compartments and potentially offshore too (section 5.7.2).

Figure 5-9: A functional groyne that retains sand to the west but allows bypassing around the tip to the east
Observed on site in February 2024.

5.7.2 Influence of Revetments

The East Cowes coastline is protected by revetments of varying structural condition. Terminal erosion of the eastern-most revetment, constructed in 1977, is particularly notable where the protective influence of the structure diminishes. This phenomenon often leads to accelerated erosion due to the re-establishment of unimpeded hydraulic forces on the shoreline, resulting in pronounced scouring and sediment displacement in the exposed region. Furthermore, the differential erosion rates have caused a reorientation of the shoreline, altering local coastal dynamics and may have now resulted in the creation of a negative feedback condition (Section 5.5).

In 2022 the timber seawall nearby Silverleaves was upgraded to form a pattern placement rock revetment with a groyne field in front. In the time since the new revetment was constructed, the shoreface has lowered and in some areas is now located below the bottom boards of the new timber groynes. It is worth noting that the nearshore had been subjected to sand scaping over several decades to harvest sand to protect the shoreline from erosion. Our analysis indicates that the shoreface has continued to lower since 2022. This is likely to be a consequence of the absence of sediment placement during construction and the relatively smooth surface associated with the pattern placement revetment. The smoother pattern rock placement results in wave reflections off the structure, which drive two-interrelated processes:

1. Lowering (scour) of the beach elevation by incident and reflected waves.
2. Enhanced offshore-shore transport due to increased near bed return flows.

These processes transport sediment offshore but would likely be reduced if a suitably designed sandy beach existed in front of the revetment.

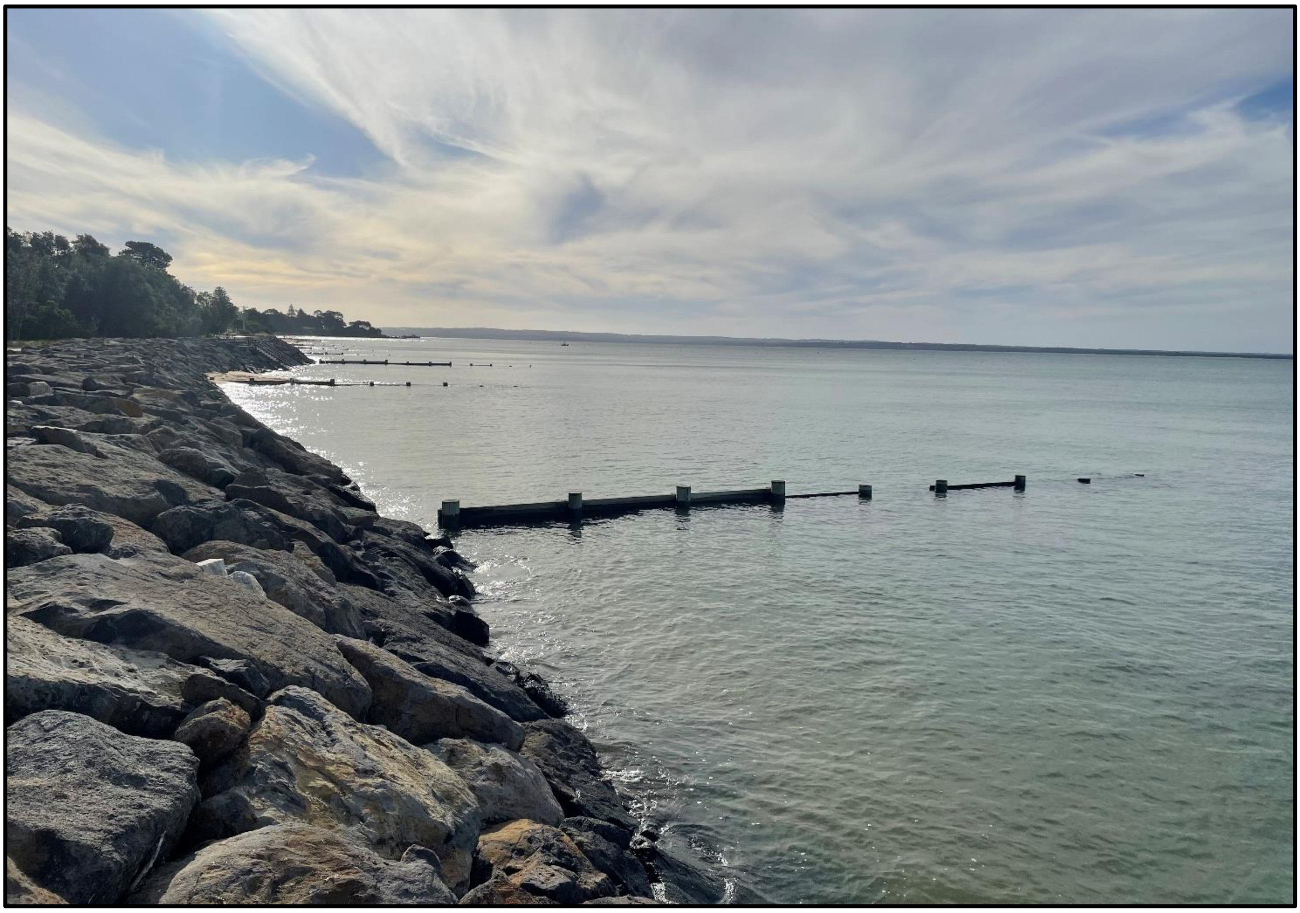

Figure 5-10: Shoreline submergence at the new pattern rock revetment during typical tidal conditions. Observed on site in February 2024.

The observed beach lowering at this location is not expected to impact the performance of the revetment itself, however, it does limit beach amenity which the groynes were designed to retain. Reanalysis of the Cowes Bank bathymetry also suggests that a notable offshore shift of the sediment deposited on the bank directly in front of the revetment structure has also occurred (Figure 5-11). Although we note that there is insufficient long term data to verify this to be a causal relationship. Nevertheless, from a first principles coastal physics perspective, this is possible.

The data suggest that the combined influences of these various processes and interventions may be causing sediment transported along Cowes Bank to bypass the area where the most significant erosion is observed at Silverleaves. This theory is supported by the relatively wider beach widths currently reported further east along Silverleaves. It is important to note that the absolute magnitude of sand exchange and the relative contribution of each of these to the erosion rate observed at Silverleaves are not fully understood. Other factors may also be contributing to these observed changes in sediment dynamics and beach morphology (such as overall sand supply).

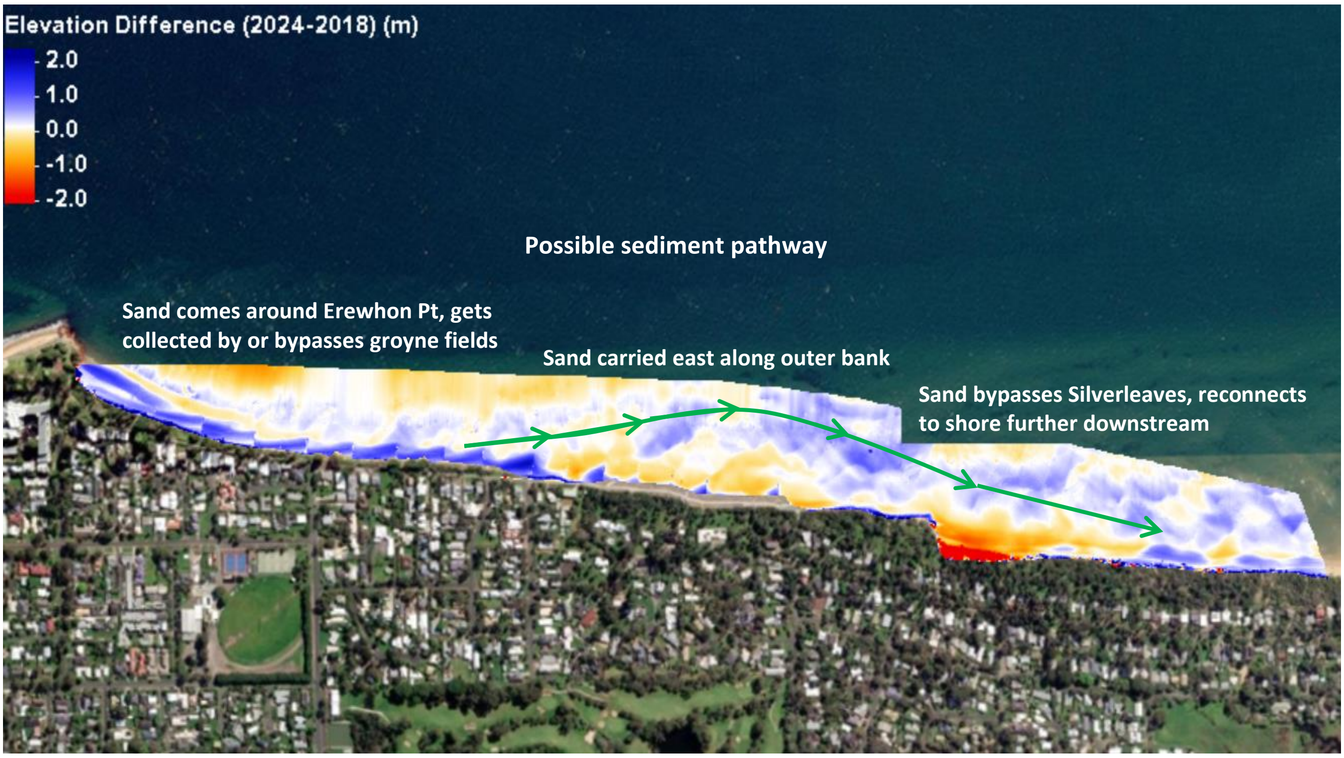

Figure 5-11 Possible nearshore-Cowes Bank sediment exchange

A notable shift in offshore sand depositions is observed in reanalysed bank bathymetry data. Survey data from VCMP (March 2018 and Jan 2024)

5.7.3 Effectiveness of recent nourishment

A recent beach scraping effort was conducted at Silverleaves to mitigate localized erosion. A survey taken on August 7, 2023 (pre-nourishment) was compared with another survey from October 6, 2023 (post-nourishment). The results indicate that 240 m^3 of sand was eroded from the nourished beach area, in addition to the 5110 m^3 initially placed, totalling 5350 m^3 of erosion over the approximately two-month period. An evaluation of the surrounding area, including the borrow area, suggests that up to 77% of the volume eroded from the nourished beach was redistributed across the adjacent downstream area. Subsequent surveys revealed continued erosion of the nourished area with accretion downstream, indicating that the sediment is unlikely to return to the eroded shoreline and is instead being transported further east.

The rapid erosion observed in this data highlights that beach nourishment is a sacrificial effort in mitigating erosion. While this nourishment may have reduced the potential extent of erosion in recent years, it is not considered a viable long-term solution for mitigating erosion risks. Continuous replenishment would be required to maintain beach integrity, making it an unsustainable strategy over the long term. Alternative solutions need to be explored to effectively address ongoing erosion challenges.

6 DRIVERS OF SHORELINE CHANGE

It is our assessment based on the data available that there are several factors and coastal processes that together result in the observed shoreline position along East Cowes and Silverleaves:

- At geological scales, the shoreline was relatively dynamic and formed as a consequence of the supply of sand from Bass Strait into Western Port and along Northern Phillip Island.

- This same supply process continues to provide sand to many of the beaches on Phillip Island, including at East Cowes and the Cowes Bank. The supply varies seasonally and temporally. When supply is high, substantial volumes of sand pass Erewhon Point and propagate as clumps of sand along the shoreline. Their migration is significantly affected by groyne fields along the East Cowes shoreline. On average, these clumps of sand (lobes) appear to propagate at 5 to 30 m/year.

- The sand supplied to East Cowes and the Cowes Bank is transported along the shoreline to Observation Point.
  - Some of this sand is transported along the shoreline by wave generated currents (alongshore currents), and can be trapped by groynes until there is sufficient sand within the groyne compartment to allow the sand to spill over and bypass downstream.

  - Some of the sand is transported across Cowes Bank by tidal currents during tidal cycles when currents are sufficiently high to mobilise and transport the sand either suspended in the water column or more likely as sand waves along the seabed. At other times, waves may be required to mobilise the sand.

  - At least some sand that was historically closer to the shoreline appears to be pushed to the outer Cowes Bank opposite the location of the new pattern placed rock revetment. This may be reducing the sand that is transported to Silverleaves by enabling this sand to bypass the terminal scour location and to reattach further east along the shoreline. Possible causes of this may be reflections off the revetment due to the relatively smooth form of this structure.

- The existing terminal erosion that has developed at Silverleaves over recent decades is now sufficiently large that it appears to affect several processes in this area. These include the bypassing of currents due to the abrupt change in shoreline position, the creation of nearshore eddies, and the acceleration of flows during ebb tide, which may be contributing to the accelerated scour that has been observed in recent years.

- Upstream groyne interventions retard the volume of sand that is propagated along the shoreline. When the associate groyne compartment is not sufficiently full of sand, sand propagating along the shoreline simply does not pass the structure. There are several groynes that continue to be functional along the East Cowes coastline and are important for beach amenity. Recently upgraded groynes (particularly in front of the new pattern placed rock revetment) with associated compartments that are currently not full of sand are reducing the sand reaching Silverleaves.

- Finally, at least some of the erosion observed at Silverleaves may have previously been mitigated by the propagation of clumps (lobes) of sand along the shoreline. There does not currently appear to be any substantial volumes of sediment currently propagating along the East Cowes shoreline currently or in the recent past.

7 COASTAL HAZARDS

Based on the history of the site as well as the contemporary coastal processes, several coastal hazards have been identified. The scope of this assessment principally focuses on a 5 to 10 year horizon, but we have noted hazards to 2100 where sufficient data is available.

7.1 Coastal Inundation

7.1.1 Sea Level Rise

The extent of land projected to be subject to permanent inundation due to various degrees of sea level rise (SLR) has been identified in Figure 7-1 and Figure 7-2. This dataset was extracted from the Victorian Coastal Inundation Dataset (2009), which was intended for assessments at a regional level. The latest projected SLR scenarios have been summarised in Table 7-1. These scenarios approximately align with the extent mapped below (Figure 7-1 and Figure 7-2), therefore these were used to evaluate extents of land subject to permanent inundation due to SLR.

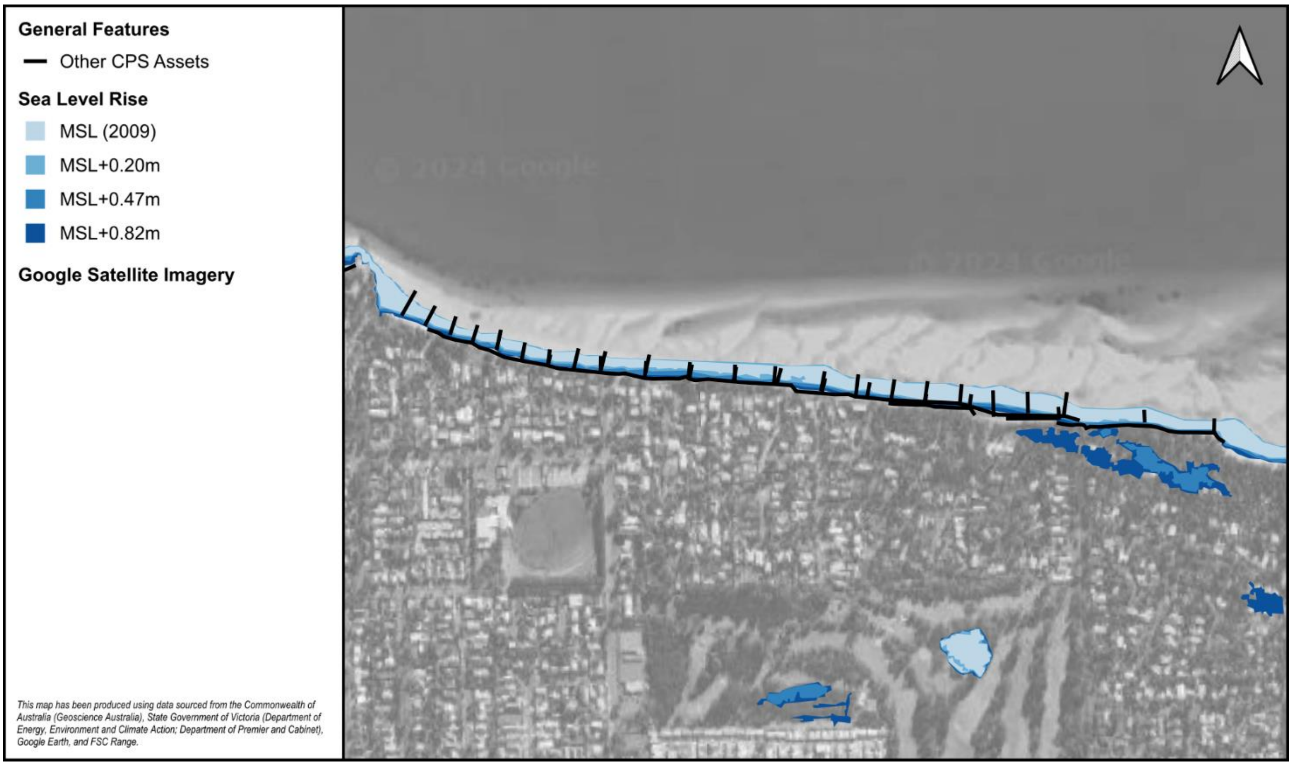

Figure 7-1: Map of projected sea level rise – East Cowes

Extracted from the Victorian Coastal Inundation Dataset (2009). This indicates the extent of permanent inundation due to various degrees of sea level rise.

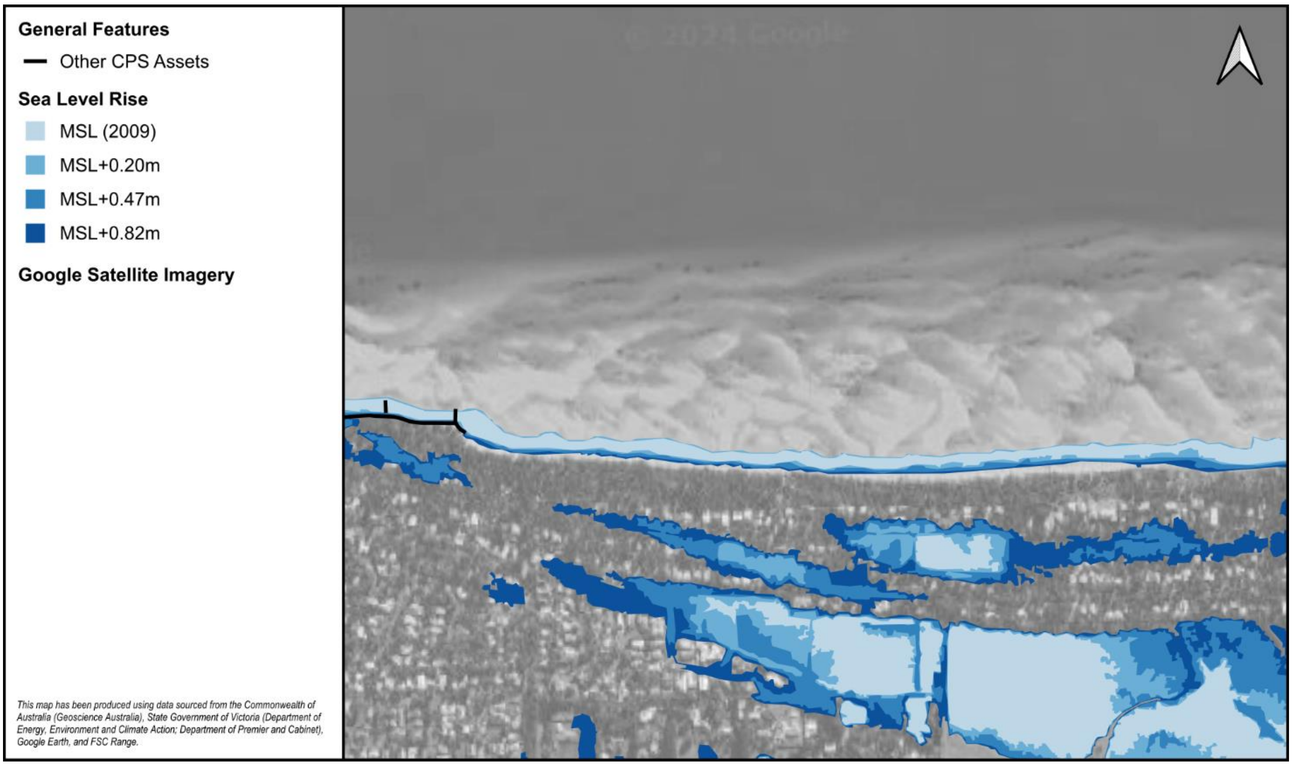

Figure 7-2: Map of projected sea level rise – Silverleaves
Extracted from the Victorian Coastal Inundation Dataset (2009). This indicates the extent of permanent inundation due to various degrees of sea level rise.

Table 7-1: Projected sea level rise scenarios
The current and short-term scenarios assume a Very High (RCP 8.5) Greenhouse Gas Emissions Scenario.

Planning Horizon	Year	SLR (m)	Source
Current	2025	0.11	CSIRO Canute 3
Immediate Term	2035	0.16	CSIRO Canute 3
Short Term	2050	0.26	CSIRO Canute 3
Long term	2100	0.80	Marine and Coastal Policy

Figure 7-1 shows that majority of East Cowes will not likely be subject to permanent inundation due to SLR. There is however a low lying area of land near the shore at Coghlan Road that may be vulnerable to SLR inundation beyond approximately 2070. At Silverleaves, a significant portion of the land is subject to permanent inundation from SLR, even for the shorter term planning horizons. Much of the potential permanent inundation hazard in this area are expected to originate from Rhyll Inlet. Future sea levels in Rhyll Inlet are likely to flood land with low elevations that accumulated between successive spit formations towards the contemporary spit shoreline of Silverleaves.

7.1.2 Storm Tide

Storm tides are elevated water levels caused by the combined effects of a storm surge and the normal tidal cycles. Table 7-2 presents different Annual Exceedance Probability (AEP) levels for storm tides from various sources.

Table 7-2: Storm Tide scenarios

AEP	Storm Tide (m AHD) (Canute, 2025 baseline)	Storm Tide (m AHD) (WT 2014 and BMT 2020)
100%	1.85	
10%	2.05	1.62
2%	2.19	
1%	2.25	2.2
0%	2.39	

The extent of land subject to temporary inundation due to sea level rise and storm tide has been identified in Figure 7-3 and Figure 7-4. This dataset was extracted from the Victorian Coastal Inundation Dataset (2009), which was intended for assessments at a regional level. These maps indicate a more pronounced extent of impact when compared to the maps extracted from the Western Port Local Coastal Hazard Assessment (2013) (Figure 7-3 and Figure 7-4).

While the anticipated extent of temporary inundation associated with the surrounding area varies, the data indicate that it is possible that temporary inundation will occur during extreme events even without considering future sea level rise. Low lying land near Coghlan Rd is expected to be inundated as it is below the current 1% AEP Storm Tide level. Although the revetment near this area has been upgraded since these assessments, it is unlikely to reduce the inundation hazard. This is because the adjacent revetment, which fronts most of the low-lying area, has not been upgraded and has a lower crest levels.

A significant portion of Silverleaves is within the hazard zone for temporary inundation. Hydrodynamic modelling (Water Technology, 2014) concluded that much of the potential inundation hazard to properties and infrastructure in this area is likely to originate from Rhyll Inlet. Storm tides can propagate with minimal attenuation into Rhyll Inlet and along the low fingers of land between the successive spit formations, extending towards Silverleaves shoreline.

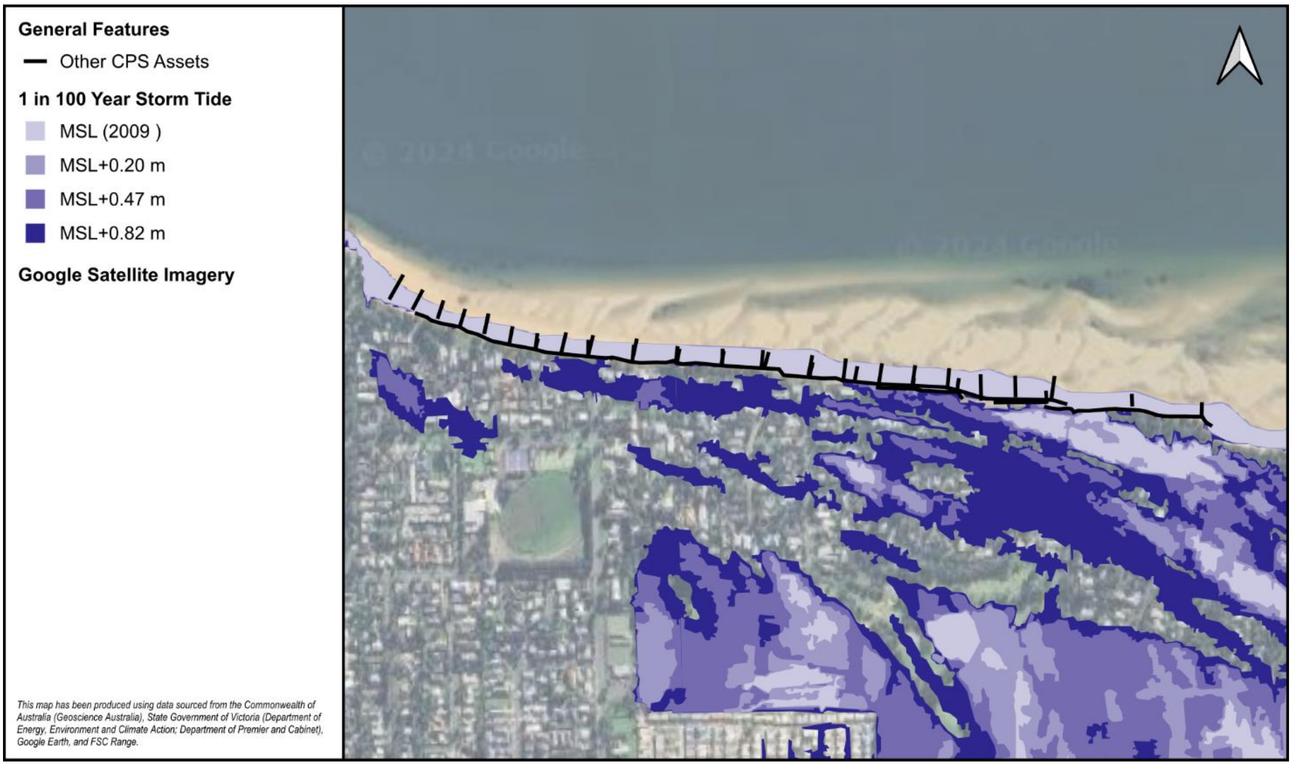

Figure 7-3: Primary map of storm tide - Cowes

Extracted from the Victorian Coastal Inundation Dataset (2009). Shows the extent of temporary inundation due to a 1-in-100-year storm tide with various degrees of sea level rise and added wind forcing.

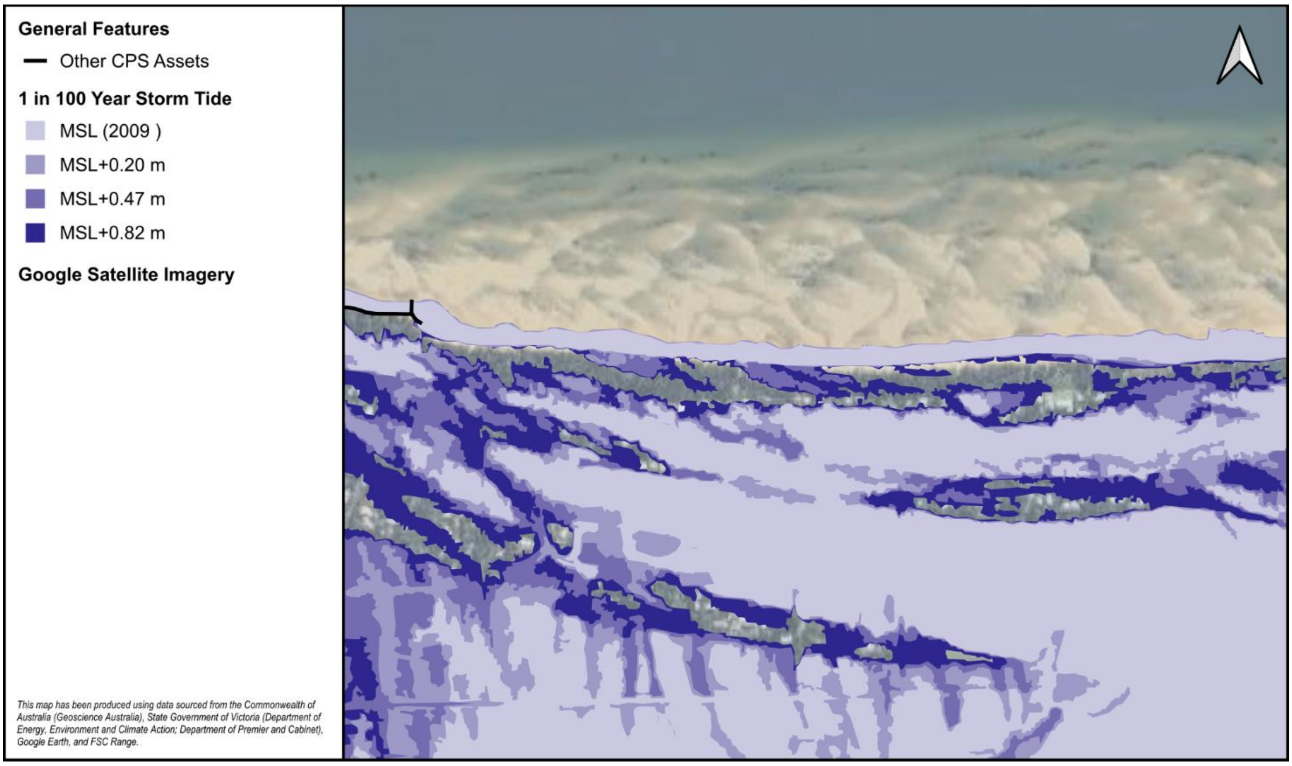

Figure 7-4: Map of storm tide – Silverleaves

Extracted from the Victorian Coastal Inundation Dataset (2009). Shows the extent of temporary inundation due to a 1-in-100-year storm tide with various degrees of sea level rise and added wind forcing

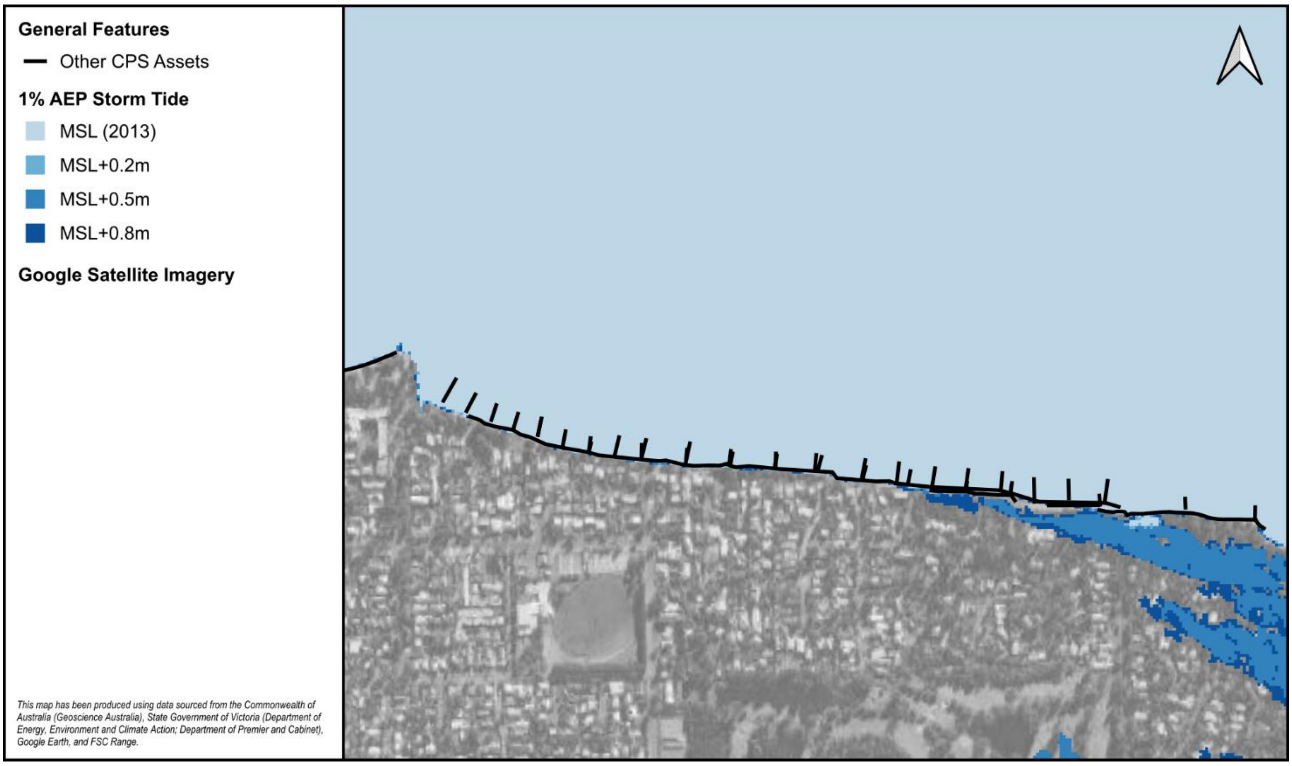

Figure 7-5: Secondary map of storm tide – East Cowes

Extracted from the Western Port Local Coastal Hazard Assessment (2013). Shows the extent of temporary inundation due to a 1% annual exceedance probability storm tide with various degrees of sea level rise

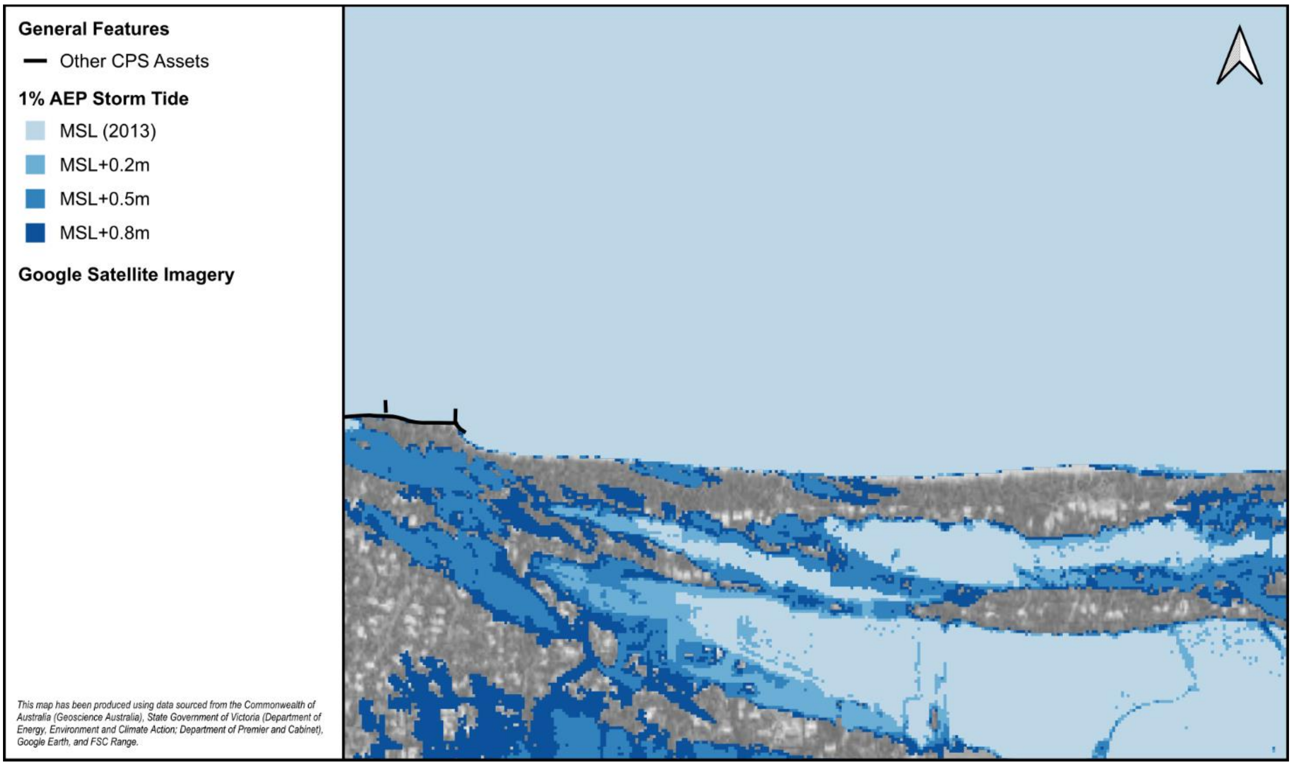

Figure 7-6: Secondary map of storm tide – Silverleaves

Extracted from the Western Port Local Coastal Hazard Assessment (2013). Shows the extent of temporary inundation due to a 1% annual exceedance probability storm tide with various degrees of sea level rise

7.1.3 Consequences

Permanent and temporary inundation are anticipated to affect the study area, particularly at Silverleaves. Inundation of private property and public assets can be expected even in the short-term planning horizons (i.e., 5 to 10 years). The mechanism of flooding from behind via Rhyll Inlet complicates the situation, as this hazard cannot be managed through CPSs along the coast. Instead, a broader understanding and comprehensive management plan for the entire area are required to effectively address this issue.

7.2 Coastal Erosion

The recession due to SLR alone as estimated by Water Technology (2018) is expected to result in substantial shoreline erosion. When combined with natural fluctuations due to sand lobe migration and storm events, it is possible that the sand-water interface of the beach may fluctuate substantially within the 5 to 10 years assessment horizon. We note however, that the entire East Cowes shoreline is backed by a rock revetment of varying quality. It is possible older sections of this revetment may be at risk of failure in the absence of beach sand, however an assessment of structural integrity of these CPSs is beyond the scope of this assessment. Thus, if the groyne CPSs were no longer functional, the risk is predominantly associated with loss of beach amenity.

Cowes Main Beach (located between Cowes Jetty and Mussell Rocks) has been subject to ongoing shoreline stabilisation works for several years. For example, sand renourishment works were recently undertaken in 2019 and 2023 to manage erosion. These works also included indigenous planting in 2020 to stabilize sand dunes. These ongoing shoreline stabilisation works were based on coastal process assessments by Atkins Maritime Engineering (2016) and Water Technology (2018); their impact on the foreshore area at the CPSs is not yet fully understood. Monitoring and evaluation of these works and their effectiveness can help inform future potential coastal management options at East Cowes and Silverleaves. For example, elevation and vegetation surveys may help determine if the works effectively mitigated erosion and if vegetation efforts were successful, which may inform management techniques for the broader coastline.

7.2.1 Probabilistic Assessment

To define the erosion hazard zone for Silverleaves (and specifically focusing on the erosion hotspot where the greatest erosion is occurring), a probabilistic approach was adopted that combined standard and well-tested deterministic or numerical approaches to estimate various erosion components. This approach recognises that there is inherent uncertainty associated with different physical processes and indeed with the methods used to quantify these processes. For erodible (i.e., sandy) coastlines, the coastal erosion components were assembled in a building block approach:

$$E = S + N \times L + SLR$$

Where:

E = erosion width (meters)
S = short term erosion for the design storm (meters)
N = planning period (years)
L = long term rate of erosion/accretion (meters per year)
SLR = recession due to sea level rise (meters)

Each of these erosion components are explained in the following sections. Probability distribution functions (pdfs) were defined for each component and were assembled as triangular distributions to approximate a normal distribution. The minimum, maximum and modal values for each pdf is described in the following sections and summarised in Table 7-3. Parameter values were randomly sampled from the pdfs and the extracted values were used to define a potential coastal erosion hazard zone distance. This process was repeated 10,000 times using a Monte Carlo technique to produce a probabilistic (forecast) distribution of the resultant coastal erosion hazard zone width.

Short-Term Erosion (S)

Short-term erosion applies to beaches where rebuilding by wave and aeolian processes follows periods of erosion. Short-term processes include storm erosion caused by singular or clusters of events, seasonal fluctuations in wave climate, or changes in sediment supply and demand. Short-term erosion can be assessed by analysis of: (1) anecdotal evidence of past erosion distances or geomorphological signatures; (2) statistical analysis of change in shoreline position obtained from aerial photographs or beach profile analysis; (3) simple geometric models for beach response or (4) assessment of storm erosion potential using semi process-based models.

Several of the studies undertaken to date have noted that cross-shore sediment transport occurs however none have quantified this precisely. This is likely due to the complexity of the bank and its role in the on and off-shore transport of sand. Antidotally, it is known that the beaches along the shoreline (especially at East Cowes) can be almost entirely stripped of sand during relatively moderate storms (once to twice per year). Our estimates using empirical cross-shore sediment transport formulations generally agree. It would be reasonable to assume that the entire beach may be eroded during a 1-in-10 year event at this location with the sand deposited onto the bank, where it will slowly migrate back toward the shoreline (albeit not necessary in the same location).

In this assessment we reanalysed aerial images obtained over the last 50 years to estimate the shoreline recession between different surveys. The underlying trend was subtracted from the data to determine an inter-survey erosion extent, which was then divided by the time between surveys to obtain a per year rate. This was then compared to frequent aerial images to validate the distribution parameters.

Long-Term Trends (L)

The long-term movement of the beach profile may be driven by changes in relative mean sea level, in coastal sediment supply, by anthropogenic influences, or associated with long-term climatic cycles. This combination of processes may result in erosion, accretion, or both. In this analysis, the long-term trends have been defined based on the average per year rate of change between the oldest and newest survey that was available.

Response to Sea Level Rise (SLR)

Geometric response models propose that as the sea level increases, the equilibrium profile is moved upward and landward conserving mass and original shape. The most well-known of these geometric response models is the Bruun Rule (Bruun, 1962, 1988) which proposes that with increased sea level, material is eroded from the upper beach and deposited offshore to a maximum depth, termed closure depth. The increase in seabed level is equivalent to the rise in sea level and results in landward recession of the shoreline. The model may be defined by the following equation:

$$R = \frac{L_*}{B + d_*} SLR$$

Where *R* is the landward retreat, *d** defines the depth of closure (maximum depth of sediment exchange), *L** is the horizontal distance from the shoreline to the offshore position of *d**, *B* is the height of the berm/dune crest within the eroded backshore and SLR is the relative sea level rise. We note that it is difficult to define the cross-shore active profile or the depth of closure at Silverleaves. Thus, we have adopted a simple 'Bruun Factor' approach. Water Technology (2018) suggested a factor of 100, which equates to sea level induced shoreline recession by as much as 20 m over the assessment horizon (5 to 10 years). That assessment noted, however, that there is a lot of uncertainty associated with this estimate. We believe that a comprehensive assessment of the entire bank including quantification of sand waves and field measurements would be required to constrain this value, which is beyond the scope of this assessment. However, we believe this estimate to be conservative and have thus used this as the upper distribution boundary. We have selected typical values for the other distribution parameters.

Table 7-3 Erosion Hazard Assessment Components and Distributions

The components assessed in the erosion hazard assessment are listed along with the lower, mode and upper values used to define the probability distribution function in the probabilistic assessment.

Parameter	Unit	Distribution			Comment
		Lower	Mode	Upper	
Short Term (ST)	m	2	6	10	Based on aerial shoreline data reanalysis
Long Term (LT)	m/yr	1 STD	1.5	1 STD	Trends from data analysis
Sea Level Rise (SLR)	m per m SLR	20	50	100	Bruun factor implies m setback per m SLR; applied for various SLR scenarios defined in Table 7-4

Based on our analysis, the estimated extent of coastal erosion that could be expected at the location of the terminal erosion point are summarised in Table 7-4. The erosion hazard results have been presented in a statistical format, providing a range of exceedance probabilities to illustrate potential erosion extents over various planning horizons. The 95% exceedance value indicates the erosion extent that has a 95% probability of being exceeded over the specified planning horizon. In contrast, the 5% exceedance value represents the erosion extent with a 5% probability of being exceeded, while the 50% exceedance value denotes a median scenario, where there is an equal probability (50%) of the erosion extent being exceeded or not. These statistical measures help in understanding the likelihood and potential severity of erosion, aiding in risk assessment and management planning. The possible (50% exceedance value) extents of shoreline erosion for various planning horizons were mapped at Silverleaves (Figure 7-7). We note that the erosion extents shown for the eastern side of Silverleaves are likely over conservative, however it is unknown how the shoreline will respond and reorient in the future. Therefore, a consistent setback distance was applied to the entire Silverleaves coast for conservatism.

Table 7-4: Possible extents of future coastal erosion at Silverleaves for various planning horizons

Refer to Table 7-1 for SLR sources

Planning Horizon	Year	SLR (m)	Shoreline Setback (m) Likelihood		
			95%	50%	5%
Current	2025	0.11	9	13	17
Immediate Term	2030	0.13	13	21	30
	2035	0.16	16	30	47
	2040	0.20	20	40	65
Short Term	2050	0.26	25	59	100
Long term	2100	0.80	65	165	290

Figure 7-7: Possible future shoreline setback extents for Silverleaves

7.2.2 Consequences

Shoreline Position

Erosion assessment results indicate that at Silverleaves, significant loss of private property, coastal reserve, and public assets is possible even in the relatively short-term planning horizon. The landward extent of shoreline erosion for most of East Cowes is not considered as the entire coast is protected by revetments; however, at the eastern end of East Cowes, terminal erosion of the revetment constructed in 1977 may propagate behind the structure, causing the revetment to fail enabling erosion of the shoreline.

Beach Shape and Amenity

Review of aerial imagery reveals that the older groyne CPSs along Cowes foreshore, including the first four timber groyne CPSs east of Erehwon Point and CPS S500907, are no longer functional and thus do not impact the shoreline position or beach amenity. Nearby groynes do, however, have an impact. The groynes constructed in 2022 in front of the new revetment were constructed to provide beach amenity (BMT, 2022), however were not nourished during construction and thus provide limited beach amenity while also making the beach difficult to walk across at low and high tide. While some of the more recently constructed functional groynes at East Cowes are anticipated to preserve the seasonal beach amenity and retain some sand during erosive conditions, they will likely inhibit sediment transport along the shoreline for some period of time as the compartments refill and thus will not be able to be transported downstream to replenish the beaches at Silverleaves. This means that without proactive sand nourishment of the groyne field, either after their initial construction, replacement, or following erosive events that deplete the sand within these compartments, there will be no natural bypassing of sediment during times when the natural sediment supply is low. The groynes require ongoing maintenance and sand replenishment to ensure both the retention of beach amenity at East Cowes and the continued supply of sediment to downstream beaches, particularly during periods of low sand supply.

7.3 Summary of Coastal Hazards

This coastal processes assessment has identified coastal hazards that are expected to be realised within the next 5 to 10 years (Table 7-5). We note that some hazards may exist that are unrelated to the purpose of the CPS, and to assess how best to manage these hazards is not within the scope of this assessment.

Table 7-5: Summary of coastal hazards

Based on Victoria's Resilient Coast – Adapting For 2100+ (DEECA, 2022). Some hazards have not been assessed because they do not relate to CPS. The third column indicates whether the coastal hazard is expected to be realised within the next 5 to 10 years.

Category	Process or Hazard	Relevant
Erosion	Short-term erosion – event-based erosion of sediment (storm-bite) and recovery.	Yes
	Long-term erosion – recession or progressive retreat of shoreline position over time.	Yes
Accretion	Short or long-term build-up of sediment in a localised area.	Yes
Inundation	Storm tide inundation – temporary event-based inundation.	Yes
	Permanent inundation – regular or persistent inundation by the regular tidal cycle.	Yes
Estuary dynamics	Changes in form and processes associated with estuarine and tidal areas.	Not Assessed
Off-shore sediment dynamics	Changes in the form and processes associated with offshore bathymetry and sediment transport.	Yes
Saline intrusion	Movement of saltwater into freshwater aquifers/groundwater.	Not Assessed

8 SUMMARY AND RECOMMENDATIONS

This study focused on the Silverleaves coastline, including the broader geomorphological unit within which Silverleaves lies, which incorporates East Cowes Beach and the sandy spit extending to Observation Point. The primary objectives were to assess the suitability of existing coastal protection structures, evaluate coastal dynamics and hazards, and determine the likelihood of erosion leading to breaches and temporary inundation.

Key Findings

1. **Shoreline Dynamics:**
   - The shoreline position is influenced by geological and seasonal sand supply from Bass Strait into Western Port and along Northern Phillip Island.
   - Sand supply to East Cowes and Silverleaves varies substantially due to natural and anthropogenic impacts, especially from groyne field along the East Cowes shoreline.

2. **Coastal Protection Structures:**
   - Notable terminal erosion observed at the easternmost revetment at East Cowes, constructed in 1977, has led to accelerated localized erosion, scouring, and reorientation of the shoreline. Erosion appears accelerated in recent years, since 2022 maximum shoreline retreat rates of 8 m/year were observed.
   - Revetments and historic timber seawalls are observed to scour the nearshore area and deposit sediment at the outer bank.
   - Groynes preserve beach amenity at East Cowes but can impede natural sediment bypassing to downstream areas, including Silverleaves.
   - Groyne fields require initial and ongoing sand replenishment to ensure sustained beach amenity and sediment supply downstream, particularly after erosive events that remove sand from the groyne compartments.

3. **Beach Nourishment:**
   - Analysis of recent nourishment efforts at Silverleaves show rapid erosion and redistribution of nourished sand. These efforts are deemed to be sacrificial and an unsustainable long-term solution to mitigate erosion at Silverleaves.

4. **Coastal Hazards:**
   - Significant erosion at Silverleaves could lead to property and asset loss even within the short-term planning horizon.
   - Inundation hazards could impact Silverleaves and a small area of East Cowes within the short-term planning horizon.
   - Inundation at Silverleaves mainly originates from Rhyll Inlet, requiring comprehensive area-wide hazard management strategies as well as adaptation planning.

5. **Current Patterns and Erosion Feedback:**
    - The altered shoreline orientation at Silverleaves may enhance sand scour during strong tidal or wave activity, contributing to increased local erosion rates.
    - Based on numerical model results and survey analysis of erosion/deposition patterns over various timescales, it is possible that at least some of the sediment that would have historically been transported to Silverleaves, now bypasses the local eroded area and reattaches to the shoreline further downstream at central/eastern Silverleaves. This is likely due to a combination of factors including the orientation of the eroded shoreline.

Recommendations

Short Term

- Undertake adaptation planning for Silverleaves coastline to address the identified short-term erosion hazards. We note it is important to recognise the coastline in its broader context.
- Adaptation planning for Silverleaves township is recommended to address the identified short-term inundation hazards. Permanent and temporary inundation are anticipated to affect the study area, particularly at Silverleaves.
- Implement ongoing maintenance and strategic nourishment to the groyne fields along this shoreline as well as design modifications of the groyne field directly in front of the new pattern placed rock revetment to aid sustained sediment supply downstream.

Medium to Long Term

- Develop sustainable, long-term adaptation pathway and coastal management strategies at Silverleaves beyond sacrificial beach nourishment efforts.
- Address long-term inundation hazards through comprehensive, area-wide management plans that consider both coastal and inland flooding risks.

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