Robe Coastline Monitoring Roadmap

Prepared for the

Robe District Council

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1 Introduction

1.1. Overview

The Robe Coastline (like many coastal locations is the southeast), has been increasingly subject to erosion hazards which will only be exacerbated by climate change and associated sea level rise in the future. There have been a number of technical studies undertaken previously to understand and assess these hazards and many have provided recommendations for monitoring to manage any associated risks.

In order to action these recommendations, Robe District Council requires a robust monitoring plan (the 'Roadmaps') to determine a specific cost-effective priority monitoring pathway moving forward. The Roadmaps clarify what different coastal monitoring tools can and cannot do, where and why they should be used and the expected frequency they should be applied in order to reduce risks to Council assets and public safety. Where necessary, specific short-term actions to address urgent risks are identified.

The roadmaps aim to be robust and cost-effective, supporting decision making and risk management for Council over the next 5 years.

1.2. Framework of the Roadmaps

The framework for the monitoring roadmaps is focused around the physical characteristics of the coastline (the coastal units) and is based on the general concept of information gathering; Why, What, Where, When, Who and How.

1.2.1. Coastal units

A monitoring Roadmap has been developed for each of the 17 coastal units defined along the Robe coastline (Figure 1). Each unit represents a predominant geomorphic type (sandy beaches, soft rock cliffs, engineered), and has identified hazards and may have specific assets (Council and private) at risk. Along the coastline between West Beach and Cape Dombey two localised coastal units (the Southern Carpark and the Blow Hole) have been included as they are previously identified high risk locations. Further information on each of the coastal units is provided in the accompanying technical note (Appendix A).

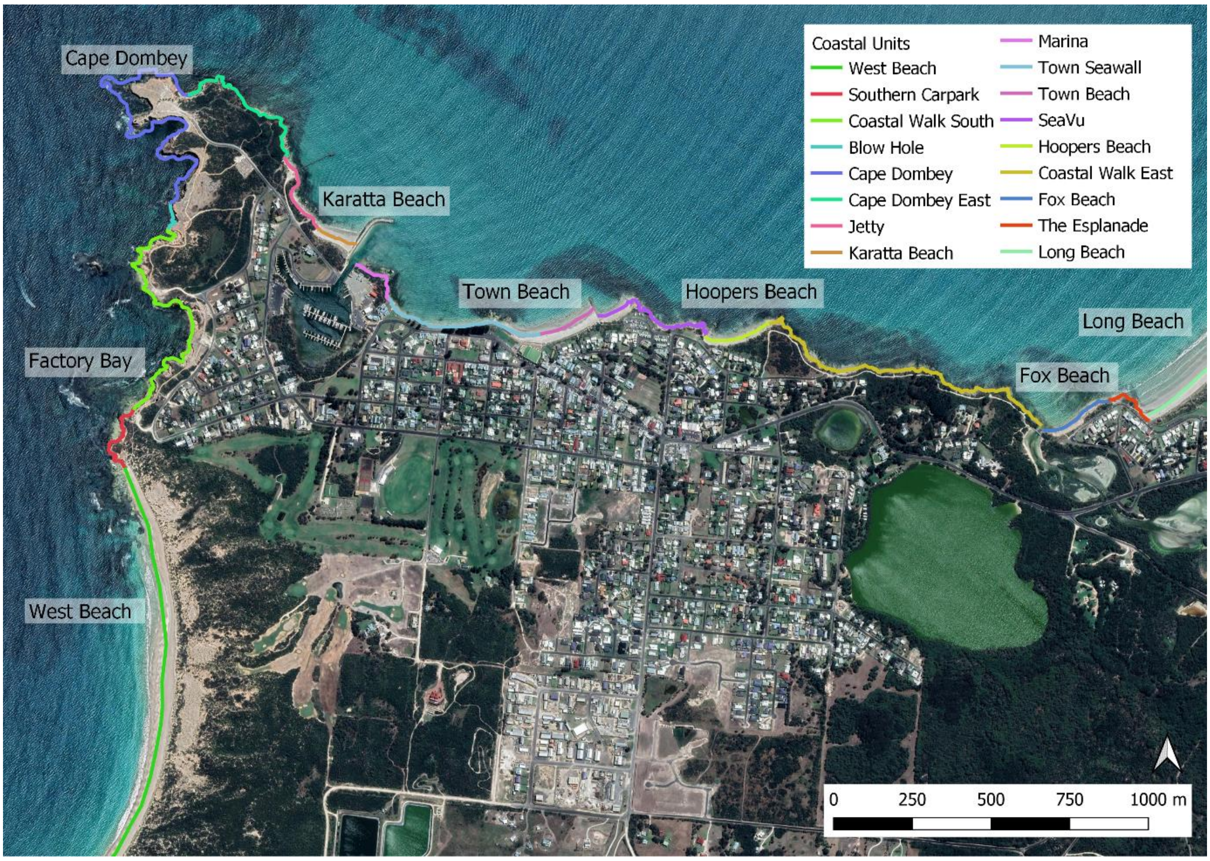

Figure 1: Coastal units defined for the Robe coastline

1.2.2. Why monitor?

Coastal monitoring allows evidenced based decision making, allowing Council to address the current issues and opportunities for action. To be effective there must be a clear purpose or 'why' to the monitoring.

The purpose of any coastal monitoring plan may include:

- Establishing a baseline condition (the context)
- Tracking progress towards an objective or trigger (the trends)
- Identifying the need for and measuring the effectiveness of management actions (assessing hazards)
- Planning for future change including prioritising of resources (defining trends and hazards)
- Assessing the current condition perhaps in response to a failure event or identified risk (for active management)

Within each roadmap a generalised 'why' or purpose has been defined, which has then been combined with an assessment of risk to the public or infrastructure to designate an appropriate minimum monitoring level, as shown in Table 1. This has been adapted from Damara (2015a & b).

The risk level is based on current understanding of the coastal erosion hazard within each coastal unit and the presence, proximity and expected value of assets or infrastructure (Council and private) located within a nominal 50 m of the coastline. Alternatively, where a detailed risk assessment has been completed for a coastal unit this has been used to define the risk level.

Table 1: Monitoring purpose and level

Monitoring Purpose	Risk Level	Monitoring Level	Type of Monitoring	Intended Use
Context	Low	0	Qualitative & Quantitative	Supports a wider understanding of coastal processes and to enable validation of future analysis or modelling
Trend	Low	1	Qualitative & Quantitative	Supports forecast of failure/erosion frequency and therefore the time available before a change in coastal management is required
Hazard	Medium	2	Quantitative	Supports estimation of likelihood of failure/erosion events requiring management action
Active Management	High	3	Quantitative	Supports decision making for active management, such as stabilisation or exclusion works

1.2.3. What and where?

What and where to monitor has been defined for each roadmap based on the method being used (the how), and the knowledge gap or hazard being assessed. This may include specific locations or the full extent of the coastal unit. The review of previous studies and recommendations as well as recent observations of change (Appendix A) has been used as the basis of what and where to monitoring for each roadmap.

1.2.4. How do we monitor?

How monitoring is undertaken will depend on a variety of factors including the available budget, the level of accuracy required, current technology, resources required and whether factors such as weather conditions need to be considered.

Additionally, on-going technology changes in data collection methods, such as the use of drones mean that how we monitor will continue to develop. To enable Council to take advantage of new technologies for data capture (the how), what to monitor has been defined in terms of the outputs required. How it is then captured can be varied over time.

A general description of currently available monitoring techniques is provided in Section 3.

1.2.5. When and how often should we monitor?

The frequency of any monitoring method relates to the overall purpose of the monitoring and how the data collected meets that purpose.

For each monitoring method identified within a coastal unit a specific monitoring frequency has been defined. This ranges from one-off data collection to address a specific knowledge gap to regularly monthly monitoring for deriving context and identification of trends.

1.2.6. Who does the monitoring?

Who does the monitoring may depend on available Council resources, the ability to engage the community through Citizen Science programs, and the technology necessary for a specific monitoring method. Within each roadmap guidance is provided on what resources could be used for the different monitoring methods.

It may be possible to resource the recommended monitoring through grants or research programs, however an assessment of funding options is beyond the scope of this study.

1.3. Evaluating the results

Monitoring doesn't stop once the data is collected. It must be evaluated and then stored for future reference. This proposed monitoring program covers a 5-year period and over that time a range of data will be collected.

Advice is provided on the analysis and reporting requirements associated with the different monitoring methods. Council will also need to develop a strategy for management of this data to ensure the full investment in data collection is realised.

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2 Roadmaps

An independent monitoring roadmap has been developed for each of the 17 coastal units along the Robe coastline. These roadmaps are summarised in the following sections. Some aspects of the monitoring program may be similar across multiple coastal units and the overall program of actions is summarised in Section **Error! Reference source not found.**. For a more detailed description of monitoring methods, refer to Section 3.

The gaps and limitations of previous studies and their recommendations with regards to monitoring have been used to developed this program. The review is provided in Appendix A.

2.1. West Beach

Coastal Unit	West Beach
Minimum Monitoring	Level 0
Monitoring Purpose	To establish a baseline for the assessment of coastal erosion hazards including responses to future sea level rise and allow quantitative assessment of adaption options and pathways.
Monitoring Program	
Photo monitoring (drone oblique imagery)	A qualitative method to assess beach change. **Extent:** the full length of the beach. This beach was not covered in the previous drone imagery. **Frequency:** Bi-Annually **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	None

2.2. Southern Carpark

Coastal Unit	Southern Carpark
Minimum Monitoring	Level 3
Monitoring Purpose	To confirm the extent of the area at risk due to failure of the large undercut feature, and define exclusion zone for public access.
Monitoring Program & Actions	
3D survey	A detailed 3D survey to allow the quantitative geotechnical analysis of likelihood and potential extent of failure associated with the large undercut cliff section. **Extent:** full extent of the undercut feature at the southern end of the carpark to establish the length and depth of the undercut and overall size of the feature. Also includes the ground surface above the undercut. **Frequency:** initial one-off to inform failure analysis and risk assessment, repeat survey in 5 years if significant change occurs. **Resources:** Commercial contract
Rock material properties	Field sampling and laboratory analysis of rock materials to determine their strength parameters which when combined with the 3D survey data to inform our understanding of the likelihood of failure of cliff undercuts. **Extent:** samples collected from rockfall debris at the base of the cliff. **Frequency:** one-off to inform failure analysis and risk assessment. **Resources:** Commercial contract
Vertical aerial survey	A high-resolution georeferenced aerial survey of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit. **Frequency:** Annual. **Resources:** Commercial contract.
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. To be reviewed against previous surveys. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of signage to warn against cliff collapse risk due to undercut failures. Warning signs at the carpark and on the beach (if accessible) Additional fencing and signage may be required once the full extent of the undercut risk area is determined from the 3D survey.

2.3. Coastal Walk South

Coastal Unit	Coastal Walk South
Minimum Monitoring	Level 2
Monitoring Purpose	To improve estimation of likelihood of failure/erosion events and identify changes that may require management action.
Monitoring Program & Actions	
Vertical aerial survey	A high-resolution georeferenced aerial survey of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit. **Frequency:** Annual. **Resources:** Commercial contract
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. To be reviewed against previous surveys. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of additional warning signs at carpark for cliff hazard and failure.

2.4. Blow Hole

Coastal Unit	Blow Hole
Minimum Monitoring	Level 3
Monitoring Purpose	To confirm the extent of the area at risk due to failure of the blowhole feature, and define exclusion zone for public access.
Monitoring Program & Actions	
High-resolution imagery / 3D model survey	High resolution imagery captured within the blowhole to quantify the extent landward of the feature. It may be possible to lower a 360-degree camera and lighting rig into the blowhole via the opening above or have a drone with lighting capture imagery through the entrance. The aim is to enable a quantitative assessment of the size of the cavity. **Extent:** blowhole cavity. **Frequency:** initial one-off to inform failure analysis and risk assessment, repeat survey in 5 years. **Resources:** Commercial contract.
Rock material properties	Field sampling and laboratory analysis of rock materials to determine their strength parameters which when combined with the 3D survey data to inform our understanding of the likelihood of failure of cliff undercuts. **Extent:** samples collected from rockfall debris at the base of the cliff. **Frequency:** one-off to inform failure analysis and risk assessment. **Resources:** Commercial contract
Vertical aerial survey	A high-resolution georeferenced aerial survey of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative assessment of changes to the area above the blow hole noting changes in the size of the existing surface features. An inspection template should be developed. **Extent:** full extent of coastal unit **Frequency:** Annual **Resources:** Commercial contract.
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. **Extent:** the full length of the unit. **Frequency:** Annually **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of additional fencing to exclude people from accessing the blowhole area (Figure 2) until the 3D survey has been completed and the full risk extent determined. Warning signs on existing and new fencing.

Figure 2: Locations for additional exclusion fencing and warning signs

2.5. Cape Dombey

Coastal Unit	Cape Dombey
Minimum Monitoring	Level 3
Monitoring Purpose	To confirm the extent of the area at risk due to failure of the large undercut features particularly those near the carpark and Obelisk, and define exclusion zone for public access. To improve estimation of likelihood of failure/erosion events and identify changes that may require management action.
Monitoring Program & Actions	
3D survey	A detailed survey to allow the quantitative geotechnical analysis of likelihood and potential extent of failure associated with the large undercut cliff section. **Extent:** full extent of the unit with focus on establishing the length, depth and extent of the specific undercut features at Points of Interest (POI) (Figure 4). Could be limited to POIs only depending on costs. **Frequency:** initial one-off to inform failure analysis and risk assessment, repeat survey in 5 years. Could focus on undercut features and area adjacent to the carpark to reduce initial survey costs. **Resources:** Commercial contract.
Rock material properties	Field sampling and laboratory analysis of rock materials to determine their strength parameters when combined with the 3D survey data to inform our understanding of the likelihood of failure of cliff undercuts. **Extent:** samples collected from rockfall debris at the base of the cliff. **Frequency:** one-off to inform failure analysis and risk assessment, **Resources:** Commercial contract.
Vertical aerial survey	A high-resolution georeferenced aerial imagery of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit **Frequency:** Annual. **Resources:** Commercial contract
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of additional fencing to exclude people from accessing the POIs area (Figure 4) until the 3D survey has been completed and the risk extent determined. Warning signs on fencing.

Figure 3: Cape Dombey undercut features possibly extending beneath adjacent carpark

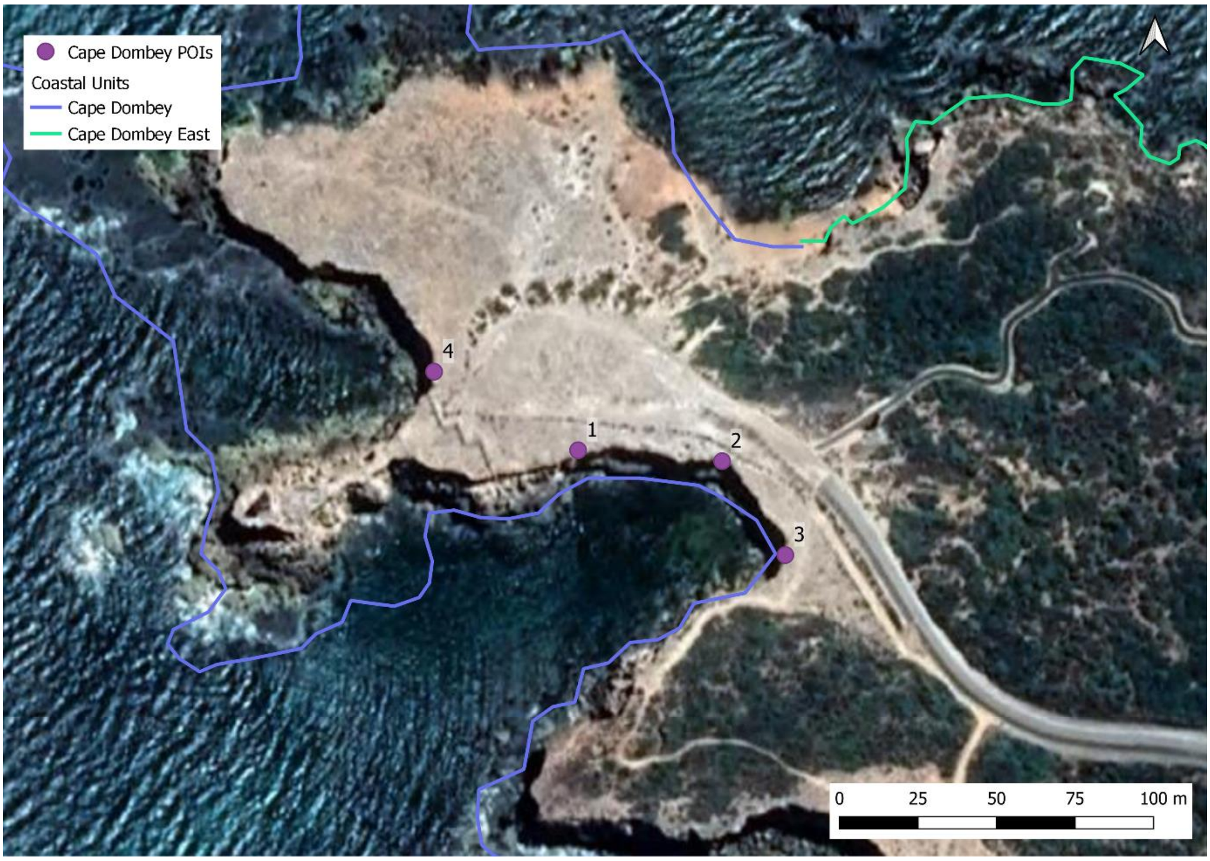


Figure 4: Locations of main points of interest (POIs) along Cape Dombey coastal unit

2.6. Cape Dombey East

Coastal Unit	Cape Dombey East
Minimum Monitoring	Level 2
Monitoring Purpose	To improve estimation of likelihood of failure/erosion events and identify changes that may require management action.
Monitoring Program & Actions	
Vertical aerial survey	A high-resolution georeferenced aerial imagery of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit. **Frequency:** Annual. **Resources:** Council staff, with inspection by geotechnical engineer every 5^{th} year (if issues raised).
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of warning signs along coastal walk for cliff hazard and failure

2.7. Jetty

Coastal Unit	Jetty
Minimum Monitoring	Level 1
Monitoring Purpose	To assess the stability and condition of the revetment structure and inform maintenance decisions.
Monitoring Program & Actions	
Visual inspection	Inspection of existing revetment structures to identify defects or damage that requires additional works to maintain its function. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in Year 5 or earlier as required. **Resources:** Coastal engineer.
Photo monitoring (drone oblique imagery)	A qualitative method to assess change and identify damage to the structure. Identification of damage may trigger an ad-hoc visual inspection by a coastal engineer. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	None

2.8. Karatta Beach

Coastal Unit	Karatta Beach
Minimum Monitoring	Level 0
Monitoring Purpose	To establish an understanding of the rate of longshore transport and volume of sand trapped by the breakwater.
Monitoring Program & Actions	
Photo monitoring (drone oblique imagery)	A qualitative method to assess beach change. **Extent:** the full length of the unit. **Frequency:** Annually (as part of wider coastline capture). **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	None

2.9. Marina

Coastal Unit	Marina
Minimum Monitoring	Level 0
Monitoring Purpose	To assist in the understanding of cliff stability and failure mechanisms. To assess the stability and condition of the sheet pile wall structure and inform maintenance decisions.
Monitoring Program & Actions	
Visual inspection	Inspection of existing sheet pile wall structure to identify defects or damage that requires additional works to maintain its function. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in Year 5 or earlier as required. **Resources:** Coastal engineer.
Photo monitoring (drone oblique imagery)	A qualitative method to assess change in the cliff form including location and frequency of any failures. **Extent:** the full length of the unit. **Frequency:** Annual (as part of wider coastline capture). **Resources:** Council staff / Flinders University.
Immediate Actions	None

2.10. Town Seawall

Coastal Unit	Town Seawall
Minimum Monitoring	Level 1
Monitoring Purpose	To assess the stability and condition of the seawall and revetment structures and inform maintenance decisions.
Monitoring Program & Actions	
Visual inspection	Inspection of existing revetment structures to identify defects or damage that requires additional works to maintain its function. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in Year 5 or earlier as required. **Resources:** Coastal engineer.
Photo monitoring (drone oblique imagery)	A qualitative method to assess change and identify damage to the structure. Identification of damage may trigger an ad-hoc visual inspection by a coastal engineer. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University
Immediate Actions	None

2.11. Town Beach

Coastal Unit	Town Beach
Minimum Monitoring	Level 1
Monitoring Purpose	To establish an understanding of the rate of longshore transport and volume of sand trapped by the groyne. To establish a trigger for future beach nourishment to maintain the amenity of the beach.
Monitoring Program & Actions	
Photo monitoring (drone oblique imagery)	A qualitative method to assess beach change. **Extent:** the full length of the unit. **Frequency:** Annual (as part of wider coastline capture). **Resources:** Council staff / Flinders University.
Visual inspection	Inspection of groyne structures to identify defects or damage that requires additional works to maintain the its function. **Extent:** length of groyne. **Frequency:** every 5 years, commencing in Year 5 or earlier as required **Resources:** Coastal engineer.
Review of beach profile monitoring (existing DEW profiles)	A quantitative measure of nearshore and beach change. **Extent:** existing profiles. **Frequency:** Five yearly. **Resources:** Flinders University to review data.
Immediate Actions	None

2.12. SeaVu

Coastal Unit	SeaVu
Minimum Monitoring	Level 2
Monitoring Purpose	To improve estimation of likelihood of failure/erosion events and identify changes that may require management action
Monitoring Program & Actions	
Vertical aerial survey	A high-resolution georeferenced aerial survey of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** 5 years. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit **Frequency:** Annual. **Resources:** Commercial contract
Photo monitoring (drone oblique imagery)	A qualitative method to assess beach change. **Extent:** the full length of the unit. **Frequency:** Annual (as part of wider coastline capture). **Resources:** Council staff / Flinders University.
Immediate Actions	None

2.13. Hoopers Beach

Coastal Unit	Hoopers Beach
Minimum Monitoring	Level 1
Monitoring Purpose	To establish a baseline for the assessment of coastal erosion hazards including responses to future sea level rise and allow definition of planning and action triggers.
Monitoring Program & Actions	
Photo monitoring	A qualitative method to asses beach change and assist in identifying planning or action triggers. **Extent:** 2 monitoring locations per beach to be selected to reflect stress points for the assessment of management triggers. **Frequency:** Quarterly, then increased to monthly during winter storm periods. **Resources:** local community groups.
Vertical aerial survey	A quantitative method to assess beach change. **Extent:** the full length of the beach. **Frequency:** Annual. The recommended frequency of vertical survey is dependent on the beach nourishment program for the beach. Often beach surveys are captures in summer and winter to look at the impacts of seasonal factors on sand volumes or pre and post storm events to assess specific volume loss of material and calibrate storm erosion models. The on-going beach nourishment makes estimation of natural losses and gains of sand from the beach from the survey alone more complicated as the volume of sand placed on the beach must be taken into account. Given these complexities an annual survey at the same time of year (e.g. end of winter or start of summer) will provide as a minimum a generalised understanding of annual changes at the beach. If this survey is undertaken the beach profile monitoring frequency can be reduced to five yearly. **Resources:** Commercial contract.
Beach profile monitoring	A quantitative measure of nearshore and beach change. Establish 1 new profile at Hoopers Beach then monitor annually. **Extent:** 1 per beach **Frequency:** Annually, given high risk to private and public assets. **Resources:** DEW to capture with Flinders University to review.
Immediate Actions	Re-establishment of dune vegetation and sand drift fencing following recent nourishment. Improve condition of fencing at the western end and extend fencing to ramp access to prevent informal access and reinstate vegetation.

2.14. Coastal Walk South

Coastal Unit	Coastal Walk East
Minimum Monitoring	Level 2
Monitoring Purpose	To confirm the extent of the area at risk due to failure of the undercut feature near the end of McIntyre St, and define exclusion zone for public access if necessary. To improve estimation of likelihood of failure/erosion events and identify changes that may require management action.
Monitoring Program & Actions	
3D survey	A detailed survey to allow the quantitative geotechnical analysis of likelihood and potential extent of failure associated with the undercut adjacent to McIntyre St. **Extent:** measurement of the extent of the large cavity at McIntyre St turning area to establish the length, depth and extent of the specific undercut features for risk assessment, Point of Interest CW2 (Figure 5). **Frequency:** initial one-off to inform failure analysis and risk assessment. **Resources:** Commercial contract.
Vertical aerial survey	A high-resolution georeferenced aerial imagery of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit. **Frequency:** Annual. **Resources:** Commercial contract.
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	Installation of warning signs along coastal walk for cliff hazard and failure Installation of fencing at McIntyre St turning area to limit access to the cliff edge.

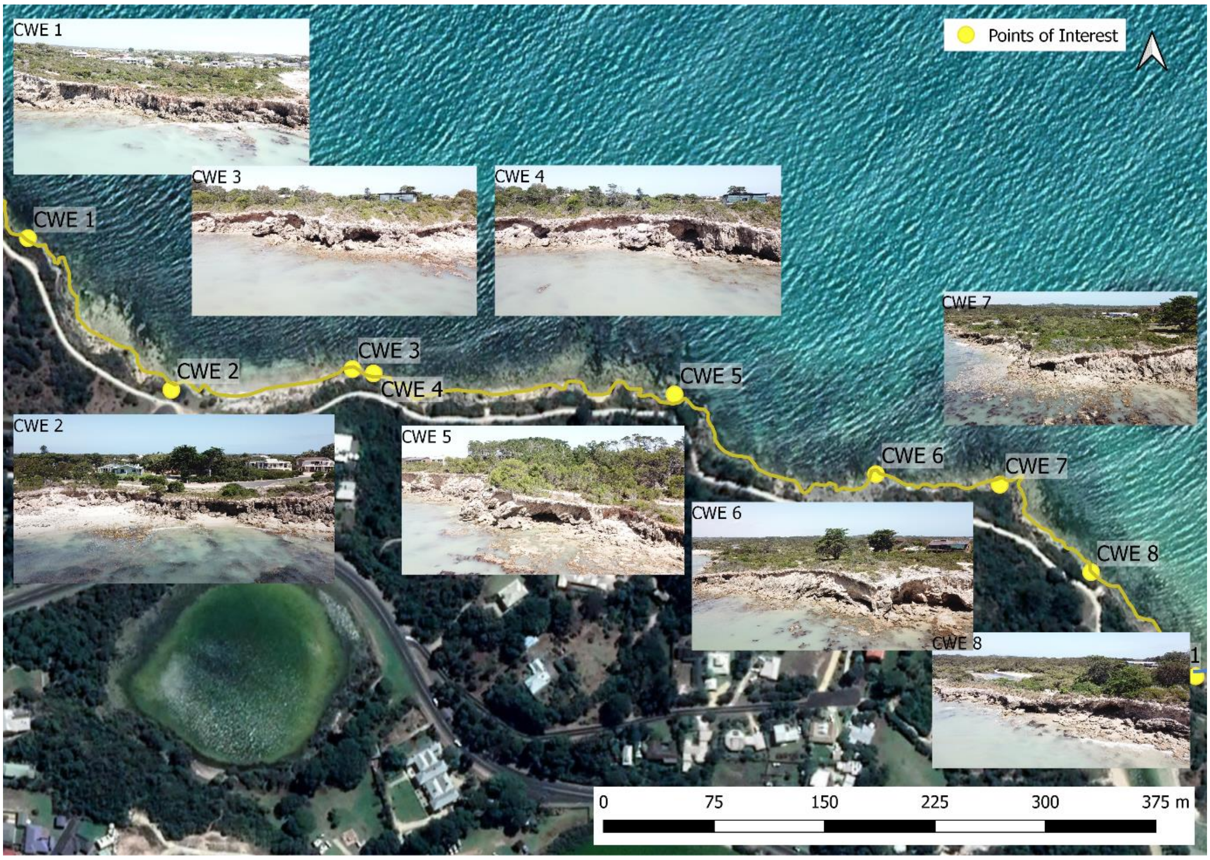


Figure 5: Points of interest (POIs) along the Coastal Walk South coastal unit

2.15. Fox Beach

Coastal Unit	Fox Beach
Minimum Monitoring	Level 1
Monitoring Purpose	To establish a baseline for the assessment of coastal erosion hazards including responses to future sea level rise and allow definition of planning and action triggers.
Monitoring Program & Actions	
Photo monitoring	A qualitative method to asses beach change and assist in identifying planning or action triggers. **Extent:** 2 monitoring locations per beach to be selected to reflect stress points for the assessment of management triggers. **Frequency:** Quarterly, then increased to monthly during winter storm periods. **Resources:** local community groups.
Vertical aerial survey	A quantitative method to assess beach change. **Extent:** the full length of the beach. **Frequency:** Annual. The recommended frequency of vertical survey is dependent on the beach nourishment program for the beach. Often beach surveys are captures in summer and winter to look at the impacts of seasonal factors on sand volumes or pre and post storm events to assess specific volume loss of material and calibrate storm erosion models. The on-going beach nourishment makes estimation of natural losses and gains of sand from the beach from the survey alone more complicated as the volume of sand placed on the beach must be taken into account. Given these complexities an annual survey at the same time of year (e.g. end of winter or start of summer) will provide as a minimum a generalised understanding of annual changes at the beach. If this survey is undertaken the beach profile monitoring frequency can be reduced to five yearly. **Resources:** Commercial contract.
Beach profile monitoring	A quantitative measure of nearshore and beach change. Establish 1 new profile at Fox Beach then monitor annually. **Extent:** 1 per beach **Frequency:** Annually, given high risk to private and public assets. **Resources:** DEW to capture with Flinders University to review.
Immediate Actions	Re-establishment of dune vegetation and fencing following recent nourishment Replace older fencing on western end and extend newer fencing on eastern end to prevent informal access.

2.16. The Esplanade

Coastal Unit	The Esplanade
Minimum Monitoring	Level 2
Monitoring Purpose	To improve estimation of likelihood of failure/erosion events and identify changes that may require management action.
Monitoring Program & Actions	
Photo monitoring (fixed points)	A qualitative method to assess changes to the southern cliff section adjacent to the roadway and assist in understanding the frequency of failures. **Extent:** 3 monitoring locations selected to reflect existing photo points used for the initial risk assessment. **Frequency:** Six monthly. **Resources:** local community groups / Council.
3D survey	A detailed survey to allow the quantitative geotechnical analysis of likelihood and potential extent of failure associated with the undercut cliff section at the point. **Extent:** full extent of the undercut features to establish the length of the undercut and overall size of the feature. **Frequency:** initial one-off to inform failure analysis and risk assessment. **Resources:** Commercial contract.
Rock material properties	Field sampling and laboratory analysis of rock materials to determine their strength parameters when combined with the 3D survey data to inform our understanding of the likelihood of failure of cliff undercuts. **Extent:** samples collected from rockfall debris at the base of the cliff. **Frequency:** one-off to inform failure analysis and risk assessment. **Resources:** Commercial contract.
Vertical aerial survey	A high-resolution georeferenced aerial imagery of the coastline to allow quantitative comparison of the cliff edge and rates of change. **Extent:** full extent of coastal unit. **Frequency:** every 5 years, commencing in year 3 of this program. **Resources:** Commercial contract.
Visual inspection	A qualitative and quantitative assessment of the cliff top / slope crest where there is safe access noting GPS locations of any tension cracks and/or slumping, and accumulated fresh debris (if visible). An inspection template should be developed. **Extent:** full extent of coastal unit. **Frequency:** Annual. **Resources:** Council staff, with inspection by geotechnical engineer every 5th year (if issues raised).
Photo monitoring (drone oblique imagery)	A qualitative method to assess cliff change and failure frequency particularly for the undercut cliff sections at the point. **Extent:** the full length of the unit. **Frequency:** Annual. **Resources:** Council staff / Flinders University.
Immediate Actions	Installation of warning signs along for cliff hazard and failure on beach and bluff.

Coastal Unit	The Esplanade
	Installation of fencing at two access points on bluff to prevent vehicle access

2.17. Long Beach

Coastal Unit	Long Beach
Minimum Monitoring	Level 0
Monitoring Purpose	To establish a baseline for the assessment of coastal erosion hazards including responses to future sea level rise and allow quantitative assessment of adaption options and pathways.
Monitoring Program & Actions	
Photo monitoring (drone oblique imagery)	A qualitative method to assess beach change. **Extent:** southern end of Long Beach to just beyond the Surf Life Saving Club. **Frequency:** Bi-Annually. **Resources:** Council staff / Flinders University / Contractor
Immediate Actions	None

3 Monitoring Methods

There are a range of methods available that will provide the required monitoring data outputs. The selection of a given method comes down to the level of accurate or detail required, the cost of the capture method, and the resources required for capture and analysis. The following table provides a general outline of the different methods recommended in the roadmaps. The method adopted may change over time as technology advances and the costs of higher-accuracy techniques reduces.

Table 2: Overview of monitoring methods

Data Required	Description	Monitoring Method	Comments
Photo monitoring (fixed points)	Repetitive photos taken over time at set locations with set fields of view to enable visual comparison of coastline state. Generally collected by community members.	Citizen science to support coastal management. Examples include: • Coastsnap (NSW) • Photomon (WA) • Fluker posts (Vic) Photos uploaded to website or app for standard data management	• Simple for local community to be involved in capture • Illustrates changes on short- and longer-term time scales • Minimum photo quality specs required • Qualitative data only (trend) • Costs involved in setup and on-going data storage
Oblique Aerial Imagery	Photographs taken from an elevated position over water, at an angle (not directly perpendicular) to the coast.	Aerial video and imagery capture using drones	• Enables a qualitative assessment of changes to the coast over time • Identification of changes used to estimate frequency of failure for risk assessments • Each capture should use the same flight path, with specific imagery points at the identified points of interest. Same camera orientation required at each POI and ideally additional close ups captured. • Imagery should be captured at low tide, calm sea conditions and preferably lightly overcast to reduced shadowing
3D survey	An accurate representation in 3D of complex surfaces such as cliff faces including undercuts. Measurements of failure features such as block sizes.	Surveyor using a total station	• High accuracy but reduced detail compared to other methods • Able to capture information for features that may be hidden from view but access may be limited due to safety constraints
		LiDAR (aerial or ground based)	• High accuracy, provides fine detail of coastal features • Expensive equipment

Data Required	Description	Monitoring Method	Comments
			• Specialist operator for capture and processing • Consultants generally required for analysis and interpretation of results
		Photogrammetry (aerial or ground based)	• High accuracy, provides fine detail of coastal features • Lower cost and faster than LiDAR • Requires ground control for accuracy • Specialist operator for capture and processing • Consultants generally required for analysis and interpretation of results
Vertical Aerial Survey	Vertical aerial survey is captured from above looking vertically downward. A survey accurate (+/-0.15m) 3D surface model is the main output	LiDAR or Photogrammetry (aerial or ground based)	• Same approaches appreciable as for 3D survey but focussed on broader scale data capture with reduced detail for vertical features such as cliffs • Cannot resolve undercuts, cavities etc • Photogrammetry accuracy reduced in areas of dense vegetation • Photogrammetry it typically cheaper and faster
Profile Monitoring	Repeated profiles of the nearshore, beach and dune collected to monitor long term change	Surveyor (DEW)	Profiles can also be extracted from vertical aerial surveys to supplement these long-term monitoring profiles. Coastal practitioner required to analysis and interpret results, however could be undertaken at Flinders University by students under supervision.
Rock Material Properties	Collection and analysis of field samples of rock to determine their strength and material properties	Geotechnical engineer / Laboratory	Could potentially be completed by Flinders University
Visual condition assessment	A qualitative and quantitative assessment of the cliff top / slope crest noting GPS locations of any tension cracks and/or	Coastal or geotechnical engineer / Council staff (with training)	An inspection template should be developed for consistency of inspection parameters, to document the assessment and to allow comparison between assessment. A geotechnical

Data Required	Description	Monitoring Method	Comments
	slumping, and accumulated fresh debris (if visible).		engineer should review the results.

For further information on coastal monitoring methods a selection of references and websites are provided below:

- DELWP (2019) Monitoring sandy coasts in south west Victoria
- Damara (2015a & b) Peron-Naturaliste Partnership Coastal Monitoring Guidelines
- CONSCIENCE. 2007. Inventory of coastal monitoring methods and overview of predictive models for coastal evolution. Concepts and Science for Coastal Erosion Management. European Community Sixth Framework Programme for European Research and Technological Development. 49p.
- Matthew, et al (2018). Cost-effective erosion monitoring of coastal cliffs, Coastal Engineering 138, p152-164
- Coastal imaging http://ci.wrl.unsw.edu.au/
- Coastal monitoring shoreline position: https://www.griffith.edu.au/__data/assets/pdf_file/0020/213374/Coastal-Monitoring_Shoreline-Position.pdf

4 Evaluation and data storage

4.1. One-off data capture

4.1.1. 3D surveys

3D survey of specific locations within the Southern Carpark, Blow Hole Cape Dombey, Coastal Walk East and The Esplanade coastal units will require review and interpretation.

The purpose of the data capture at these sites is to confirm the extent of specific cliff undercut features to allow Council to provide adequate fencing and signage to reduce the risks to the public from cliff failures.

The survey supplier should provide Council will a short report outlining the survey methodology, along with drawings/maps or other outputs which will allow Council to interpret the survey results. Council may wish to engage an engineer to assist with this.

All 3D data should be supplied to Council in electronic form to allow use of the information for future assessments. This information provides the baseline for assessing failure and risk at these locations.

4.1.2. Rock Material properties

The determination of rock strength information along with porosity/density properties is recommended to assist with quantifying the risks associated with cliff failure along the soft rock cliff coastline at Robe.

This sample collection would need to conducted by a geotechnical engineer and samples analysed in laboratory. The rock samples should be representative of the cliff material, relatively unaltered or weathered by marine exposure and the samples original *in situ* orientation should be identifiable.

Parameters to be measured include:

- Rock properties: porosity, particle density, bulk volume
- Rock strength: tensile strength and unconfined compressive strength

The collection of this information will allow the estimation of the critical length of any overhangs and assist in the assessment of failure risk for locations along the Robe coastline.

It can be combined with the 3D surveys of specific overhangs to assist with understanding the likelihood of failure of these features. The location of all samples collected should be recorded. Council would need to engage a geotechnical engineer to assist with this interpretation.

4.2. Regular (quarterly) monitoring

This regular quarterly photo monitoring could be provided within the large-scale research program. It was noted in the ARC Linkage project presentation by Flinders University that Coastsnap and video monitoring were to be included.

4.3. Annual monitoring

Annual monitoring activities include:

- Oblique aerial imagery capture (full coastline)
- Vertical aerial survey of Hoopers Beach and Fox Beach
- Visual geotechnical inspections

4.3.1. Oblique aerial imagery and survey capture

The oblique aerial imagery should be captured for the whole Robe coastline annually. This data should then be reviewed by a coastal engineer with specific comparison to previously identified points of interest. The comparison of the 2018 and 2020 imagery is provided in Appendix A.

Vertical aerial surveys of Hoopers Beach and Fox Beach should be compared with the previous datasets to provide a quantitative analysis of change. Due to the on-going nourishment program for these beaches, care much be taken in the interpretation of the data and for its use for further modelling or analysis.

4.3.2. *Visual geotechnical inspections*

Records should be kept during scheduled monitoring including photographing cliff faces. Council staff could undertake the inspection with training however a geotechnical engineer is recommended.

Inspection of the cliff face should take particular note of vertical cracks, fresh scars where material has detached recently and fresh debris at the cliff base. Any widening of cracks may suggest imminent failure at that location.

4.3.3. *Annual reporting*

Each year an annual monitoring report should be produced, summarising monitoring completed each year with comparison to the previously collected data. Any changes in erosion conditions should be clearly identified, especially where immediate actions to address potential or realised risks are required.

The monitoring report should also review the overall plan and document any changes to monitoring program including methods utilised. It is recommended this annual analysis and reporting be completed by a coastal/geotechnical engineer.

4.4. Five yearly monitoring

4.4.1. *Vertical aerial survey*

The monitoring roadmaps have specified vertical aerial survey of sections of the soft rock cliff coastline at 5 yearly intervals. This is currently scheduled for Year 3.

The vertical aerial survey will produce an accurate map of the coastline in these locations which can be compared to the 2018 coastal LiDAR dataset and the earlier analysis by Fotheringham (2009) to produced updated estimates of the rate of recession of these shorelines.

The analysis and reporting should be undertaken by a coastal engineer. This information will then inform risk assessments and assist in adaptation planning along these shorelines.

4.4.2. *Coastal structure condition assessment*

All coastal structures should be inspected every 5 years by a coastal engineer to assess their structural integrity and on-going performance. The current inspection schedule of these structures is unknown and therefore the 5 yearly inspection has been nominally specified for year 5 of the program.

A short condition assessment report is required, highlighting any issues and remediation requirements.

4.5. Data storage

A key component of coastal monitoring is ensuring that the data is suitably stored and maintained to support future use. Factors to consider include:

- Physical and electronic storage of data
- Database/storage administration
- Provision of data accessibility, and
- Maintenance of data quality records

These factors become increasingly significant for information-heavy datasets, such as LiDAR or Photogrammetry surveys. For example, the annual monitoring imagery and survey capture may generate datasets in the 100’s of gigabytes in size.

5 Summary

A summary of the proposed monitoring roadmaps and the overall 5-year monitoring plan for the Robe Coastline is provided in Table 3. This sets out the for each coastal unit the different monitoring methods and their proposed frequency of monitoring

Table 3: 5-year Monitoring Plan for the Robe Coastline

Coastal Unit	Urgent Actions			Year 1						Year 2						Year 3						Year 4						Year 5							One-offs
	Fencing	Signage	Dune revegetation / signage	Photo Monitoring (fixed points)	Photo Monitoring (oblique imagery)	3D survey	Beach Profiles	Vertical aerial survey	Visual Inspection (geotechnical)	Photo Monitoring (fixed points)	Photo Monitoring (oblique imagery)	3D survey	Beach Profiles	Vertical aerial survey	Visual Inspection (geotechnical)	Photo Monitoring (fixed points)	Photo Monitoring (oblique imagery)	3D survey	Beach Profiles	Vertical aerial survey	Visual Inspection (geotechnical)	Photo Monitoring (fixed points)	Photo Monitoring (oblique imagery)	3D survey	Beach Profiles	Vertical aerial survey	Visual Inspection (geotechnical)	Visual inspection (coastal structures)	Photo Monitoring (fixed points)	Photo Monitoring (oblique imagery)	3D survey	Beach Profiles	Vertical aerial survey	Visual Inspection (geotechnical)	Rock material properties
West Beach					2												2													2					
Southern Carpark		1			A	1			A		A				A		A			5	A		A				A			A				A	1
Coastal Walk South		1			A				A		A				A		A			5	A		A				A			A				A	
Blowhole	1	1			A	1			A		A				A		A			5	A		A				A			A				A	1
Cape Dombey	1	1			A	1			A		A				A		A			5	A		A				A			A				A	1
Cape Dombey East		1			A				A		A				A		A			5	A		A				A			A				A	
Jetty					A						A						A						A					5		A					
Karatta Beach					A						A						A						A							A					
Marina					A						A						A						A					5		A					
Town Seawall					A						A						A						A					5		A					
Town Beach					A						A						A						A					5		A		D			
SeaVu					A				A		A				A		A			5	A		A				A			A				A	
Hoopers Beach			1	Q	A		D	A		Q	A		D	A		Q	A		D	A		Q	A		D	A			Q	A		D	A		
Coastal Walk East	1	1			A	1			A		A				A		A			5	A		A				A			A				A	
Fox Beach			1	Q	A		D	A		Q	A		D	A		Q	A		D	A		Q	A		D	A			Q	A		D	A		
The Esplanade	1	1		6	A	1			A	6	A				A	6	A			5	A	6	A				A		6	A				A	1
Long Beach					2						A						2						A							2					

1	One-off
A	Annually
2	Every 2 years
Q	Quarterly
6	Sixth Monthly
D	DEW capture
5	Every 5 years

6 References

Coastal imaging http://ci.wrl.unsw.edu.au/

Coastal monitoring shoreline position: https://www.griffith.edu.au/__data/assets/pdf_file/0020/213374/Coastal-Monitoring_Shoreline-Position.pdf

CONSCIENCE. 2007. Inventory of coastal monitoring methods and overview of predictive models for coastal evolution. Concepts and Science for Coastal Erosion Management. European Community Sixth Framework Programme for European Research and Technological Development. 49p.

Damara (2015a). Coastal Monitoring Action Plan, Peron Naturaliste Partnership Region Coastal Monitoring Program

Damara (2015b). Coastal Monitoring Guidelines, Peron Naturaliste Partnership Region Coastal Monitoring Program

DELWP (2019) Monitoring sandy coasts in south west Victoria, Department of Environment, Land Water and Planning, State of Victoria

Matthew, et al (2018). Cost-effective erosion monitoring of coastal cliffs, Coastal Engineering 138, p152-164

Appendix A: Technical Note

Technical Note

Date: 14/07/2020

Client: Robe District Council

Subject: Coastline Assessment Review

1 Introduction

The Robe Coastline (like many coastal locations is the southeast), has been increasingly subject to erosion hazards which will only be exacerbated by climate change and associated sea level rise in the future. There have been a number of technical studies undertaken previously to understand and assess these hazards and many have provided recommendations for monitoring to manage any associated risks.

In order to action these recommendations, Robe District Council requires a robust monitoring plan to determine a specific cost-effective priority monitoring pathway moving forward. The plan clarifies what different coastal monitoring tools can and cannot do, where and why they should be used and the expected frequency they should be applied in order to reduce risks to Council assets and public safety. Where necessary, specific short-term actions to address urgent risks are identified.

To aid the development of the monitoring plan, a detailed reviewed of previous studies has been completed and with an assessment of current coastal conditions both of which are documented within this technical note.

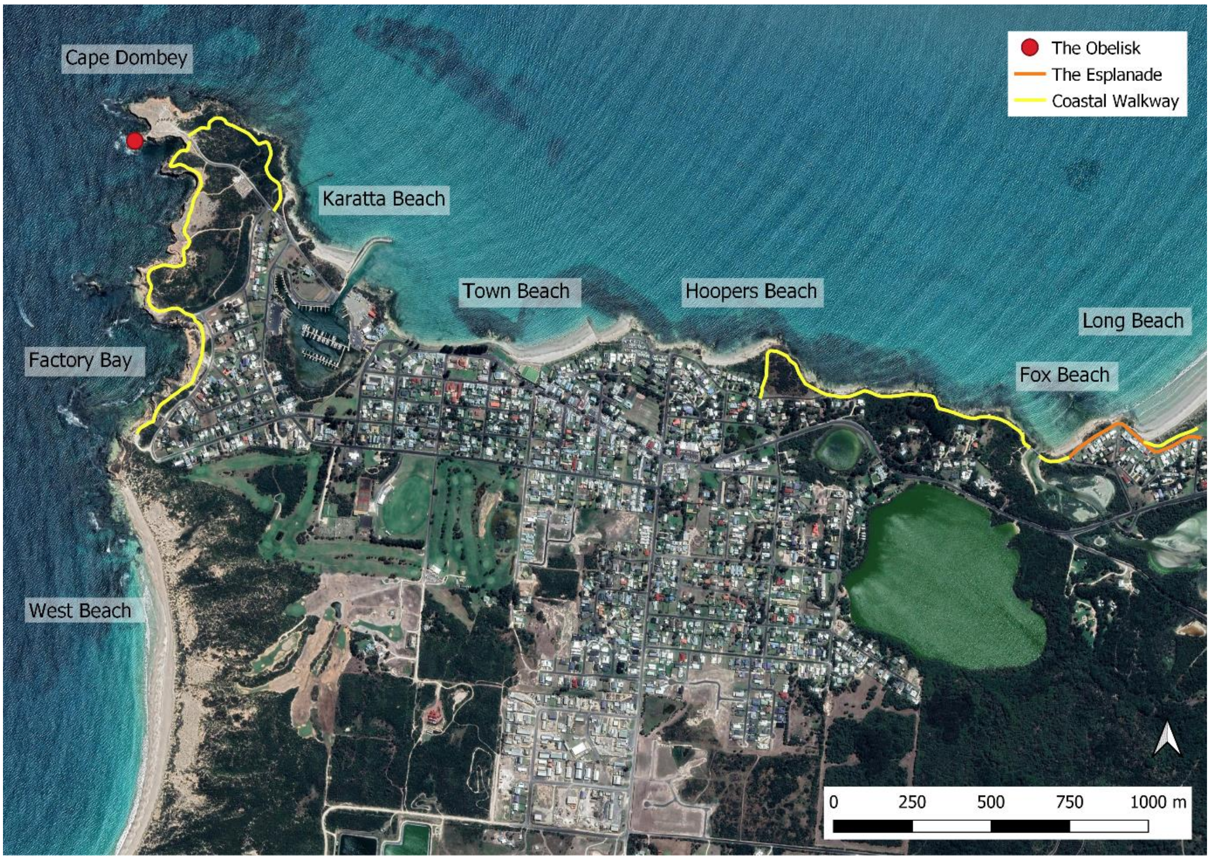


Figure 1 Study extent

The review and consolidation of previous studies and data has focused on evaluation of their recommendations particularly around monitoring.

The assessment of current conditions is set out as a geomorphic review incorporating:

- Delineation of the coast into 17 coastal units, which set the framework for the accompanying monitoring plan.
- A description of the erosion processes and observed conditions for each coastal unit based on the information and data available from previous studies, aerial drone video captured in February 2020, and a site visit undertaken by a Wavelength coastal engineer in the 11-12th May 2020.

2 Previous Studies

2.1. Overview

A range of coastal studies have been completed for different sections of the Robe coastline to address different specific purposes or concerns. Each of these reports has provided Council with recommendations for future work. As the scope and focus of the reports differs, Council requires the information to be reviewed and consolidated in order to support any future planning, works or monitoring actions. The aim of this review of previous studies has therefore been to bring together the previous information for specific sections of the coastline, and provide a clear evaluation of the various recommendations in order to inform the monitoring process and plan presented in Monitoring Roadmap.

2.2. Review and Evaluation

Table 1 provides a brief overview of previous coastal erosion and related studies that have been completed for some or all of the Robe coastline. Recommendations within each report relating to future monitoring have been identified in **Bold**.

The recommendations from each report have been reviewed and evaluated in terms of the robustness of outcomes and the ability of the proposed monitoring to translate the data collected into actionable insights for Council. This review is summarised within the table.

2.3. Gaps and Limitations

In general, the previous studies provide a good basis for the management of the Robe coastline in the future. Overall, the main gaps and limitations of the work to date can be summarised below:

- Future monitoring recommendations are sound, for example the review of erosion rates based on additional erosion monitoring. However, they are limited by the lack of clear purpose. Each monitoring recommendation would benefit from the provision of a clear purpose e.g. to allow refinement of the proposed buffer zone or comparison of erosion extent to long-term action trigger(s).

- A range of monitoring techniques are discussed without detail on why, how, or where each technique should be applied. For example, the repeat drone footage at Cape Dombey provides a visual assessment of change, but unless the video/imagery is collected at the same angles, same locations and under the same tide conditions it is difficult to accurate assess changes. The information also needs to link back to physical measurements where possible to enable risks to be quantified.

- None of the recommended monitoring addresses how the data is to be evaluated and the results used to provide evidence-based decision making.

- For the coastal cliffs, quantitative assessment of recession rates measured to date (e.g. Fotheringham, 2009; Hesp and DaSilva, 2020) could be applied to other areas of similar coastal morphology. However, measuring change in the position of the cliff edge does not provide a complete assessment of the potential hazard or the associated risk. These soft rock cliffs typically comprise erodible lower layers capped by a more resistant layer (see Section 3) leading to undercuts and overhangs. The existing cliff recession rates do not account for this and potentially underestimate changes below the cliff line that could induce failure.

These gaps and limitations have been considered in the development of the monitoring process and plan.

Table 1: Summary of previous studies and monitoring recommendations

Study Area	Reference	Synopsis	Recommendations	Evaluation of Recommendations
Hoopers Beach	Civil and Environmental Solutions, October 2018	The study assessment identified that recent accelerated erosion at Hoopers Beach is likely the result of several factors including: • The large 2016 storm event and subsequent high coastal water level events interacting directly with the coastal dunes at the back of the beach, causing dune failure and loss of sand volume from the beach. • Additional dune erosion has occurred from uncontrolled pedestrian access points Medium to long term recession estimates indicate likely on-going erosion which will likely impact private dwellings and public infrastructure by 2050. Short- and long-term management options to address the risks associated with coastal erosion were presented.	• Identify suitable sand borrow sources for beach nourishment • Erect fencing and unstable cliff warning signs at the back of the dune • Close of uncontrolled beach access points and revegetate • **Develop and implement a detailed monitoring program including methodology and trigger levels in consultation with CMB which could include installation of sand movement monitoring galvanised or marine grade stainless steel poles at the toe of dune and front of beach at sixty metre intervals along the beach to annually survey changes in beach level and toe position and inform triggers for longer term management options** • Undertake initial and annual beach nourishment • Install a trial shore normal groyne at east end of the beach • **Should the top of dune erosion line get closer than 3m from to the northern title boundary of the western most dwelling, then consider installation one of the long-term management options identified**.	A generally robust analysis of the coastal erosion hazard at Hoopers Beach with identification of short- and long-term actions which could be implemented to address potential risks to assets including monitoring to support their implementation. A limitation of the proposed monitoring is the lack of clear purpose for the monitoring to support the implementation of the proposed actions. Council's overall adaptation strategy should confirm what the future planning and action triggers are in order to establish what type or form of monitoring is required, at what frequency, and how it will be used to inform long term adaptation actions.
Fox Beach	Civil and Environmental Solutions, November 2018	The study assessment identified that recent accelerated erosion at Fox Beach is likely the result of several factors including: • The large 2016 storm event and subsequent high coastal water level events interacting directly with the coastal dunes at the back of the beach, causing dune failure and loss of sand volume from the beach. • Additional dune erosion has occurred from uncontrolled pedestrian access points	• Identify suitable sand borrow sources for beach nourishment • Erect fencing and unstable cliff warning signs at the back of the dune & entrance to rocky undercut zones • **Develop and implement a detailed monitoring program including methodology and trigger levels in consultation with CMB which could include installation of sand movement monitoring galvanised or marine grade stainless steel poles at the toe of dune and front of beach at sixty metre intervals along the beach to annually survey changes**	A generally robust analysis of the coastal erosion hazard at Fox Beach with identification of short- and long-term actions which could be implemented to address potential risks to assets including monitoring to support their implementation. The erosion hazard lines should be truncated at the limits of the sandy beach section (approx. opposite 4 The Esplanade) where the more resistant underlying rock

Study Area	Reference	Synopsis	Recommendations	Evaluation of Recommendations
		Medium to long term recession estimates indicate likely on-going erosion which will likely impact private dwellings and public infrastructure by 2050. Short- and long-term management options to address the risks associated with coastal erosion were presented.	**in beach level and toe position and inform triggers for longer term management options** • Undertake initial and annual beach nourishment • **Should the top of dune erosion line get closer than 2m from to the northern seal of the Esplanade or northern edge of the coastal path, then consider installation one of the long-term management options identified**. • Include works for management of rock undercuts in any long-term measures.	material which forms the adjacent headland outcrops and which will limit the rate of coastal recession. As for Hoopers Beach, planning and action triggers and a clear adaptation strategy are also required to define the extent of future monitoring requirements.
The Esplanade	Tonkin Consulting, 2017	A brief report outlining a Landslide Risk Assessment for a section of The Esplanade, where cliff stability and the potential for erosion to impact the adjacent roadway is a concern. Three cliff undercuts were assessed, with limited survey of the undercut extents completed. The general block failure characteristics were also estimated based on measurements of existing debris at the base of the cliffs.	• Installation of fencing (or physical barrier) along the length of the access ramp and walkway. • Signage at regular intervals including at beach access points. • **Photographs of the cliff at regular intervals to understand frequency of failures and how general erosive actions are affecting the cliff.** • Council should consider closing this section of the Esplanade to vehicular traffic and align the shared path and fence line so that these are several metres further from the crest of the cliffs.	As the analysis is based on limited data with no quantitative evaluation of cliff stability, the risk analysis outcomes and recommendation are considered conservative. The hazard extent, along with the likelihood and frequency of the potential cliff failures could be more robustly defined through collection of baseline data and on-going monitoring, The evaluation of options to manage the potential risk of cliff failure also does not consider physical works to stabilise the undercuts, which could eliminate the need to close the adjacent roadway.
SeaVu Caravan Park	GHD, 2016	This report provides a desktop risk assessment associated with the coastal cliffs and slopes adjacent to the SeaVu Caravan Park. Field observation were made of the cliffs to characterise the cliff height, level of vegetation, presence of undercutting, recent rockfall activity, presence of talus and high tide impacts. This information was used to provide an evaluation of the perceived level of	Recommendations were provided for five sections of the cliff line along the front of the caravan park site, and included the following: • Warning signage (all sections) • **Monitor the crest and top of slope including progression of undercutting** (all sections) • **Monitor tension cracking and/or slumping of crest line** (all sections)	Although the report purports to be a risk assessment of coastal cliff and slope stability no actual risk assessment was undertaken. The field observations appear sound and do support the site-specific recommendations presented in Section 7.5. These recommendations are generally good;

Study Area	Reference	Synopsis	Recommendations	Evaluation of Recommendations
		risk along the cliff line and to support recommendations for risk treatments.	• **Monitor accumulated fresh debris from landslides and rockfalls** (all sections) • Revegetation of upper slope to deter public access (sections 2 and 3) • Excavate the existing crest line and reprofile slope to remove undercutting hazard (section 2) The report also provides a detailed general monitoring strategy, from annual to regular monitoring using a broad range of techniques.	however, they relate to the perceived level of risk rather actual risks to life or property. The general monitoring strategy is very broad and ranges from the collection of baseline data to regular safety checks. A range of monitoring techniques are also presented without detail on why, how, or where each technique should be applied. The purpose of the different monitoring options and how the monitoring data would be used in the future are not clear.
The Obelisk	Coffey Geotechnics 2015	The report outlines a limited geotechnical assessment of the access and area around the Obelisk undertaken to determine safety risks associated with proposed maintenance works.	• Maintenance access to the site is considered high risk. • Risks could be reduced by using a crane to move personnel to/from the site. • Personnel must be skilled in high ropes access, and maintain a fall arrest system throughout.	The assessment addresses a very limited scope and does not provide any recommendations in relation to future monitoring.
Cape Dombey	Fotheringham, 2009	The author compared the cliff line location at Cape Dombey between an 1896 survey and a detailed survey collected in 1987 to assess change. Cliff position was compared at 48 sites, with 33 recording erosion between surveys. The maximum erosion was 26m, and the average was 5.9m. Undercutting (within weaker calcarenite) and eventual collapse of the cliffs (probably caves, cutbacks, overhangs and long spanning undercuts) appears to be the main mechanism of cliff retreat.	• For future planning purposes potentially 30m of erosion should be planned or along the exposed coast. This is derived from the maximum recorded erosion of 26m with additional 4m to accommodate the effects of sea level rise. • **The cliff edge at Cape Dombey should be resurveyed to detect change since 1987.** • Assuming a 30m buffer from the cliff line, several locations where assets are located are potentially at long term risk. **The cliffs along these sections should be inspected for undercutting** and a strategy developed for managing cliff erosion. • **Given uncertainty in predicting future erosion rates, this should be reviewed in 10 years (i.e. 2019).** • **The cliff top between Robe and Long Beach is surveyed for future erosion monitoring.**	A comprehensive assessment of erosion through analysis of change in the location of the cliff line at Cape Dombey over a 100-year period. The recommended coastal hazard buffer zone (30m) is based on a 'worst case' erosion scenario and is considered potentially conservative for many locations. Future monitoring recommendations are sound, particularly the review of erosion rates based on additional erosion monitoring. However, it would benefit from providing a specific purpose for the monitoring; e.g. to allow refinement of the proposed buffer zone.

Study Area	Reference	Synopsis	Recommendations	Evaluation of Recommendations
			• Public visitation areas are appropriately managed to minimise a cliff fall risk.	
The Obelisk & Cape Dombey	Tonkin, 2018	Based on a field assessment, including drone video footage along the coast from Cape Dombey for 2.3km along the coastal walking trail, 15 sites of long-term stability concern were identified. Each site of concern was ranked from high to low depending on an assessment of likely action required by Council to ensure public safety. Structural integrity of the cliff was not determined, and the ranking was based on visual assessment only.	*Main Obelisk Car Park* • Council should control public access to the present Obelisk carpark, with a 10m buffer from the cliff edge. • Restrict large/heavy vehicle access where possible. • If the extent of undercutting can be determined, it may be possible to reduce the proposed buffer extent. • **Further assessment/monitoring should be undertaken to confirm suitable long-term actions**. • **Frequent (at least annual) monitoring of the Obelisk cliff around the carpark to ensure public safety is minimised**. • Design of the future carpark to ensure it is not trafficable by vehicle. *Obelisk Nature Walk – Blow Hole* • Prevent public access to the area of the sinkholes • **Monitor the ground stability around the areas of concern and monitor any further movement or loss of ground strength in the area.** • Introduce signage *Southern Carpark* • Prevent public access to walking areas over the arch • Introduce signage *Obelisk Nature Walk – Chainage 825* • **Undertake additional inspections to ensure long-term stability** • Prevent public access • Introduce signage *Cape Dombey - General* • **Undertake frequent drone surveys to provide Council with information to asset in assessing rate of erosion**	The report presents a visual assessment of erosion susceptibility and inferred risk to life and property as a result of the instability of coastal cliffs at Cape Dombey. No quantitative geotechnical assessment was undertaken. Drone surveys are recommended for assessing rates of erosion; however, video comparisons will not provide a quantitative measure. They can assist in understanding the frequency of failures and support other monitoring approaches.

Study Area	Reference	Synopsis	Recommendations	Evaluation of Recommendations
			of the cliffs and rate at which they are receding/collapsing. • **Compare historic footage to determine rate of coastal recession**. • Undertaken informed risk assessment of current areas of concern.	
All	Flinders University, 2020	The study examines the historical changes to beaches and cliffs in and around Robe. Historical aerial imagery comparison along with analysis of DEW coastal profiles have been used to estimate rates of change along different sections of the coast.	• Cape Dombey and the adjacent cliffs are eroding at rates of between 0.33mm/year to 0.24 m/year. • Town Beach, Hoopers Beach and Fox Beach are all experiencing erosion. • **A new topographic/bathymetric survey line (profile) should be established for Hoopers Beach to monitor future changes**. • Long Beach appears stable to slightly accretionary. • Town Beach, Hoopers Beach and Fox Beach will require regular nourishment to maintain their sandy beach systems.	The erosion rate estimates for Cape Dombey should be considered as part of any future risk assessment for this coastline. The analysis supports the previous erosion assessment for Hoopers and Fox Beach.

3 Geomorphic Review

3.1. Overview

This section summarises a geomorphic review of the coastline, including a description of the erosion processes and current conditions based on the information and data available from previous studies, aerial drone video captured in February 2020, and a site visit undertaken by a Wavelength coastal engineer in the 11-12th May 2020. The Southeast Coastline LiDAR DEM (2018) for the Robe area was also sourced from the Department of Environment and Water.

3.2. Coastal Units

To assist with the review and inform the monitoring plan, the Robe coastline has been separated into 17 coastal units (Figure 2). Each unit represents a predominant geomorphic type and coastal processes, has identified hazards as described by previous studies or identified in this review, and may have specific assets (Council and private) at risk. Along the coastline between West Beach and Cape Dombey two localised coastal units (the Southern Carpark and the Blow Hole) have been included as they are previously identified high risk locations.

The coastline in Figure 2 is defined along the approximate 0.5m AHD contour as assessed from the Coastal LiDAR. This has been used as an indication of the coastline position for the purpose of identifying the coastal units only.

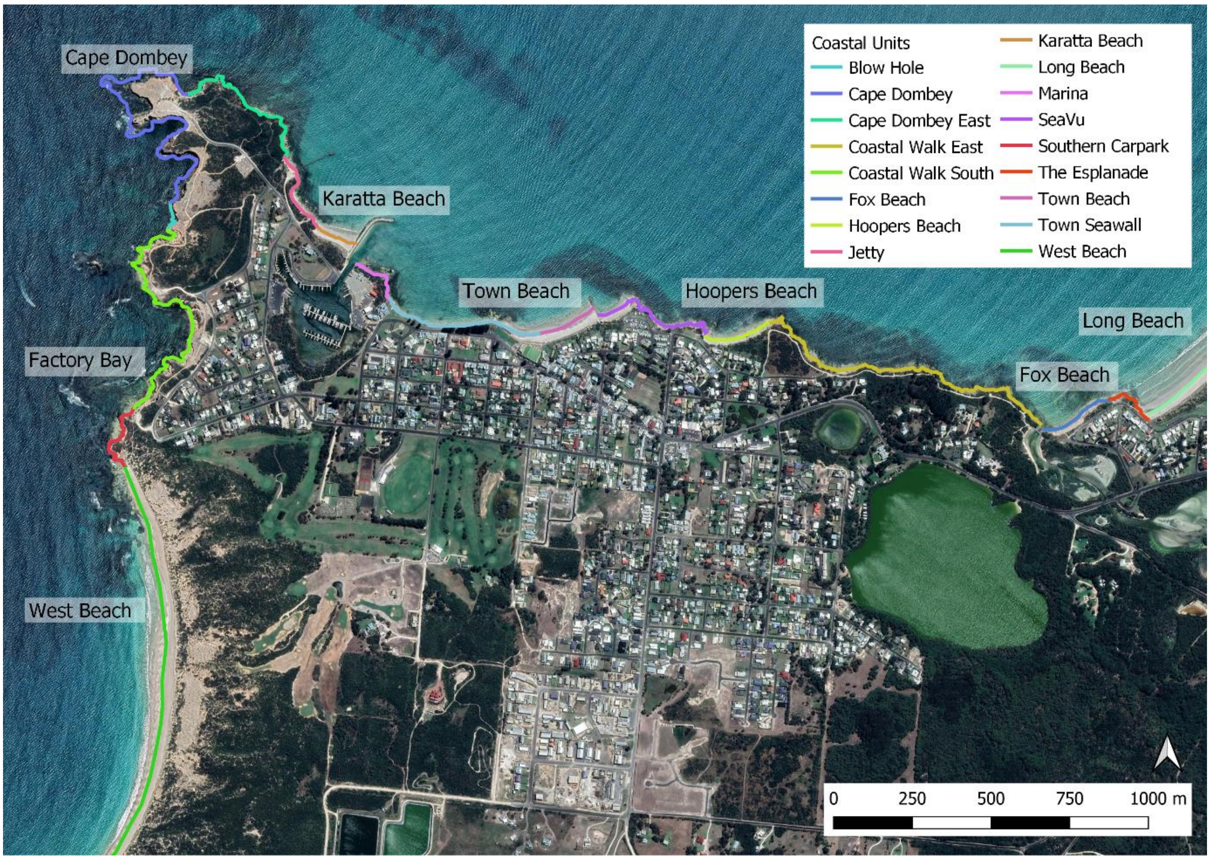


Figure 2: Coastal units defined for the Robe coastline

3.3. Geomorphic Types and Erosion Processes

The Robe coastline comprises three broad geomorphic types; sandy beaches, soft rock cliffs, and engineered coast. The erosion processes will be different depending on the geomorphic type.

A general description of each geomorphic type and the associated coastal erosion processes are summarised in the following sections.

3.3.1.Sandy Beaches

There are six sandy beaches along the Robe coastline, Figure 3. They range from the high energy exposed beach with steep backshore dunes at West Beach, to Long Beach in Guichen Bay with a series of small pocket beaches separated by rocky limestone headlands in between.

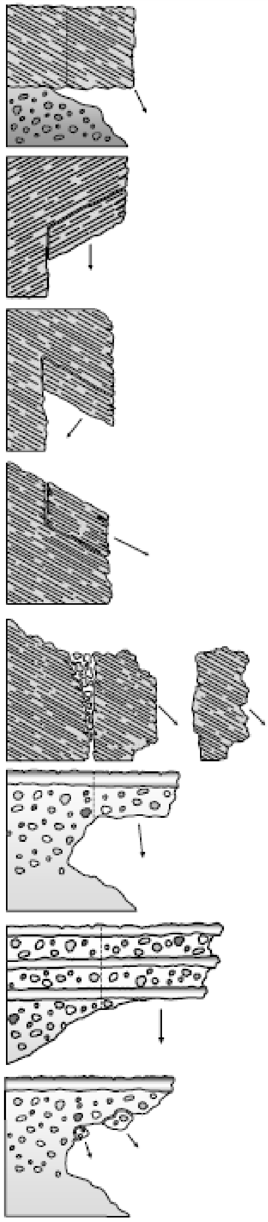
Erosion of these beaches can occur as a result of storm events (short-term erosion), through a long-term deficit of sand into the beach system (long-term erosion), and as a result of shoreline response to sea level rise. Additionally, at West Beach the formation of a dune blow out through disturbance of the vegetation could also trigger erosion.

Figure 3: Sandy Beaches

3.3.2.Soft Rock Cliffs

Tonkin (2018) describe the cliffs in the vicinity of Cape Dombey as "comprising of variable limestone with a relatively strong cap of calcrete overlying weaker and more erodible rock". The differential strength of the rock allows for weaker layers to be readily removed and eroded which facilitates the undercutting and weathering of the cliffs. Wave cut notches, caves and blowholes are common (Hesp and DaSilva, 2020).

The erosional processes for these types of material are shown in Figure 4 which is from Muller et al (2006). This rock failure classification is based on similar landforms found at The Bluff at Barwon Heads in Victoria, and which are analogous to the soft rock sections of the Robe coastline.



Type 1
Tensile failures of undercut aeolian calcarenite at the base of the cliff. Block sizes vary but are generally large (>1 m^3) to very large (>5 m^3). Blocks drop vertically, or rotate during fall with very short trajectory paths.

Type 2
Tensile failures along bedding planes of undercut aeolian calcarenite, where the beds dip into the slope face. Failed blocks are generally elongate slabs or wedge shaped. Trajectory paths vary according to the elevation at which the failure occurs and the downslope morphology, but can be longer distances.

Type 3
Tensile failure along bedding planes of undercut aeolian calcarenite, where the beds dip out of the slope face. Failed blocks are generally small (<0.3 m^3) to medium sized (<1 m^3) elongate shapes. Blocks often rotate during fall and trajectory paths are usually short to very short.

Type 4
Planar (shear) failure along bedding planes of aeolian calcarenite where beds dip out of the slope. Blocks are mostly small to medium sized and break apart on impact. Trajectory paths vary with the elevation at which the slope occurs and the morphology of the down slope cliff.

Type 5
Toppling failures of large to very large blocks with sufficient height to width ratio. Failure can be promoted by wedging of rockfall debris into sub-vertical defects, and basal undercutting by wave action. Very short trajectory paths and blocks can break apart on impact.

Type 6
Tensile failures of calcrete overhangs, where the failure occurs through intact rock, or along a defect, or a combination of both. Elongated slabby blocks often break apart on impact, resulting in small to medium sized pieces. Trajectory paths can be quite long, since the failures occur in the upper cliff face.

Type 7
Tensile failures of calcrete overhangs where the failure occurs through several layers. Failures can involve large to very large elongated slabs which rotate during fall and come to rest on the upper slopes, creating an ongoing hazard. Medium sized and smaller sized failures may break apart on impact and the trajectory of the debris may extend from the upper cliff to the beach.

Type 8
Tensile failures of smaller irregular blocks of calcrete from the underside of overhangs. Trajectory paths can be longest (uppermost cliff to beach), although the fall debris most often contributes to the development of scree slopes.

Figure 4: Rockfall classification based on models of failure (Muller et al, 2006)

Fotheringham (2009) provides a quantitative comparison between the cliff line at Cape Dombey from an 1896 survey and a repeat survey in 1987. The measured erosion of the cliff line at different locations is shown in Figure 5. The numbers refer to the measurement sites in Table 1 of Fotheringham (2009). The locations are indicative, the spatial references for each measurement location have been requested from DEW.

These measurements provide an indication of the long-term rate of change of the cliff line, with a maximum recession rate of 0.26m/year. As the author notes, it is important to consider the landform characteristics (embayment, promontory, straight) and wave exposure and the wide variation in erosion rates reflects these differences along with the variable resistance of the rock material. The presence of a reef at the base of the cliff also provides local protection and reduces the wave impacts at the toe.

The highest erosion rates were noted at sites 20 and 22, near Doorway Rock.

Figure 5: Measured cliff top erosion between 1986 and 1987 (Fotheringham, 2009)

3.3.3.Engineered Structures

Engineered structures along the Robe coastline include the marina breakwater and sheet pile entrance wall (Figure 6), revetments like at the jetty (Figure 7), seawalls such north of Town Beach and groynes.

Revetments, seawalls and groynes are generally installed for erosion protection and indicate previous erosion issues in those locations. For the purpose of this assessment, the location of these structures within or defining a coastal unit has been identified and recommendations are provided as to their monitoring requirements in the accompanying plan.

An assessment of the current condition and structural integrity of the engineered structures along the Robe coastline is beyond the scope of this study.

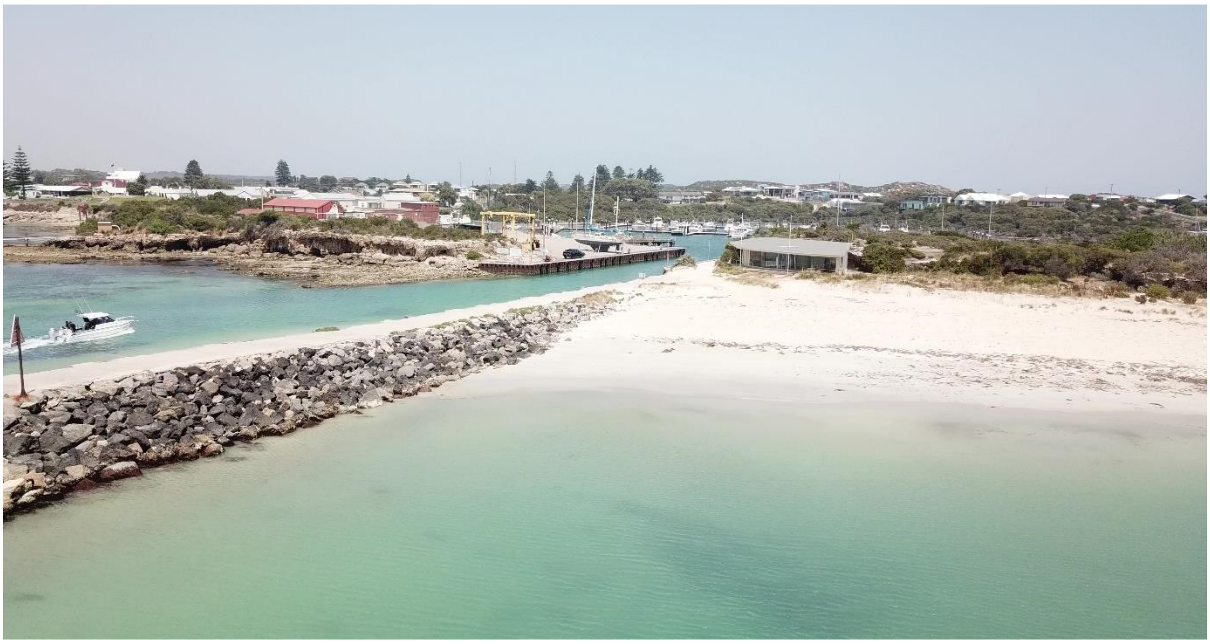


Figure 6: Engineered coastline with a view of the marina breakwater and sheet pile entrance wall

Figure 7: Rock revetment at the jetty access

3.4. Observations of Change

The following sections summarise observations of change for each coastal unit starting from West Beach through to Long Beach. Where there is repeat drone imagery or other data this has been used to inform the observations. In locations east of Cape Dombey there is no previous drone footage available and the observations are based on drone imagery captured in February 2020, the site visit in June 2020 and previous studies.

A comparison of the 2018 to 2020 drone imagery at the 14 locations identified by Tonkin (2018) is provided in Appendix A.

The repeat drone imagery provides a visual record with which to assess change over time, and give an indication of the frequency of failures. Unfortunately, there are no measurements available to quantify the size (depth, length, thickness) of overhangs or undercuts or previous failure features so it is not possible to quantify the risk of failure of such features.

3.4.1.West Beach

West Beach comprises a high energy sand and reef dominated surfzone, back by a steep foredune along with vegetated and active transgressive dunes and blowouts (Hesp and DaSilva, 2020). This steep profile can be seen in Figure 8, where two cross-shore profiles extracted from the coastal LiDAR are plotted. The location of the profiles is shown in Figure 9.

Also included in the plots is the 1% AEP storm tide levels under current and future conditions (from Civil and Environmental Solutions, 2018). A sea level rise increment of +0.3m by 2050 and +1.0m by 210 has been assumed. The maximum water levels shown include wave setup and wave runup of an additional 0.5m above the peak storm tide level.

Over the longer term, West Beach has been generally stable, with the shoreline mapping of Hesp and DaSilbva (2020) showing West Beach has been stable to slightly accretionary over the period 1946 to 2019. This is likely the result of the increasing level of vegetation cover across the transgressive dune system.

The February 2020 drone footage did not extend to West Beach.

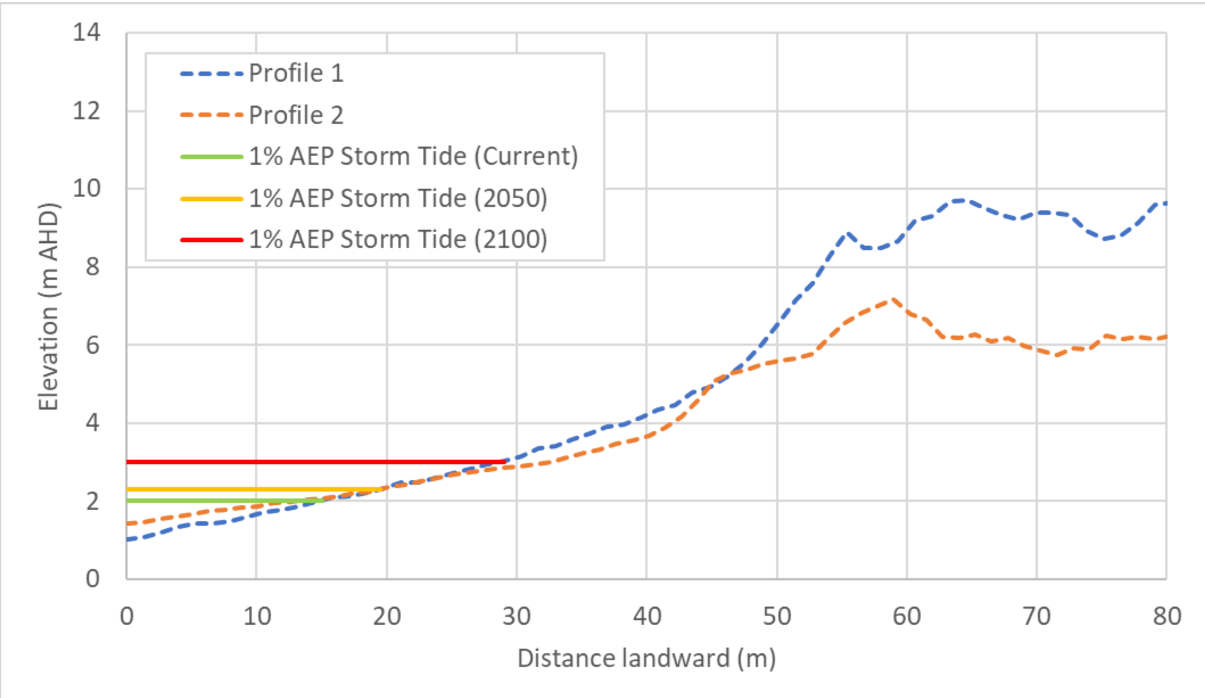


Figure 8: West Beach profiles including storm tide elevations

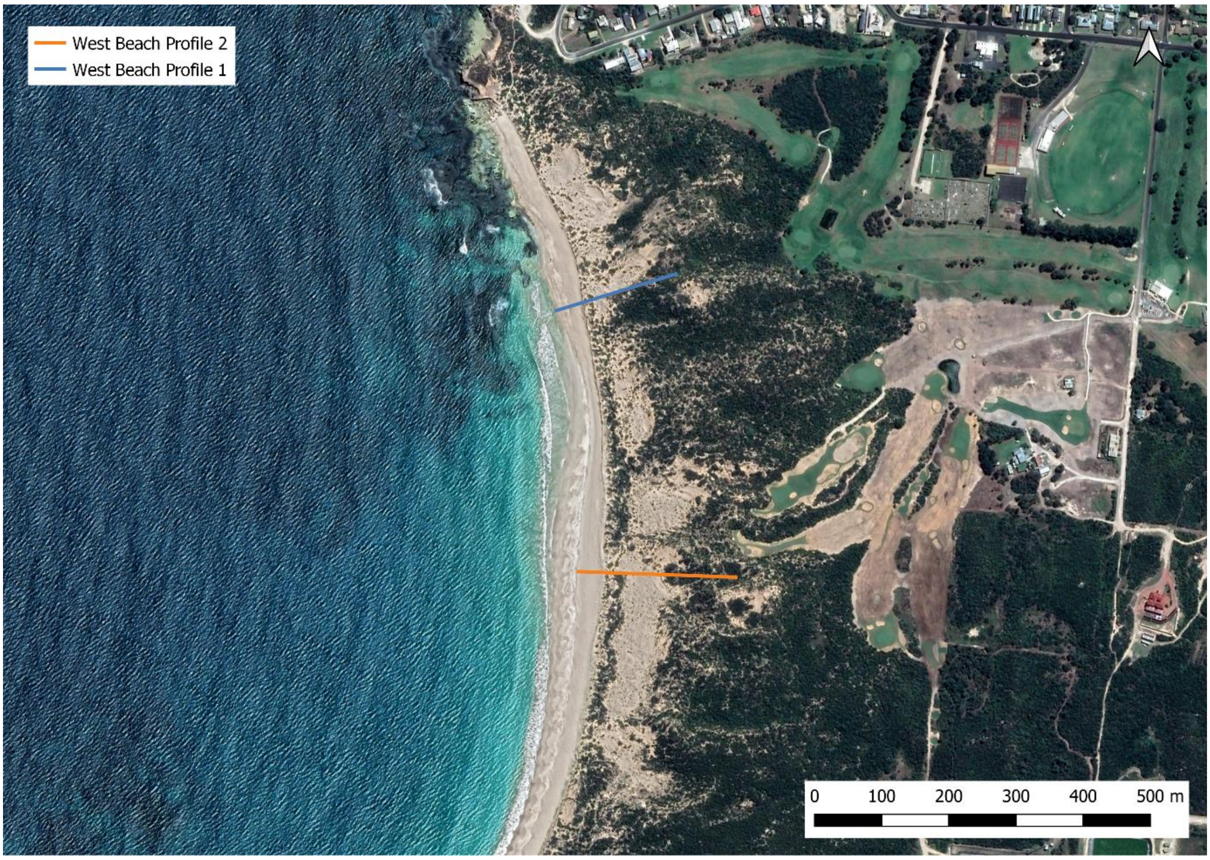


Figure 9: West Beach profile locations

3.4.2.Southern Carpark

The Southern Carpark coastal unit comprises a rock headland at the northern end of West Beach with a wide rocky shore platform at its base (Figure 10) which extends northwards to the southern carpark area of the coastal walk. The headland is characterised by undercut features the most notable being the undercut adjacent to the carpark area. This undercut was noted as a potential high-risk location by Tonkin (2018).

Figure 11 shows the location of a recent failure of sections of overhanging calcrete adjacent to the southern carpark. The height of the overhangs is around 6-7m above the beach below. Unfortunately, the dimensions of the failure blocks cannot be determined from the imagery.

The undercut extends some distance beneath the cliff edge and Tonkin (2018) estimated it could extend towards as far as the carpark although the exact extent is unknown. The recent failure confirms the weakness of thin remaining calcrete layer and the significant erosion hazard at this location.

Figure 10: Example of shore platform and undercut cliffs

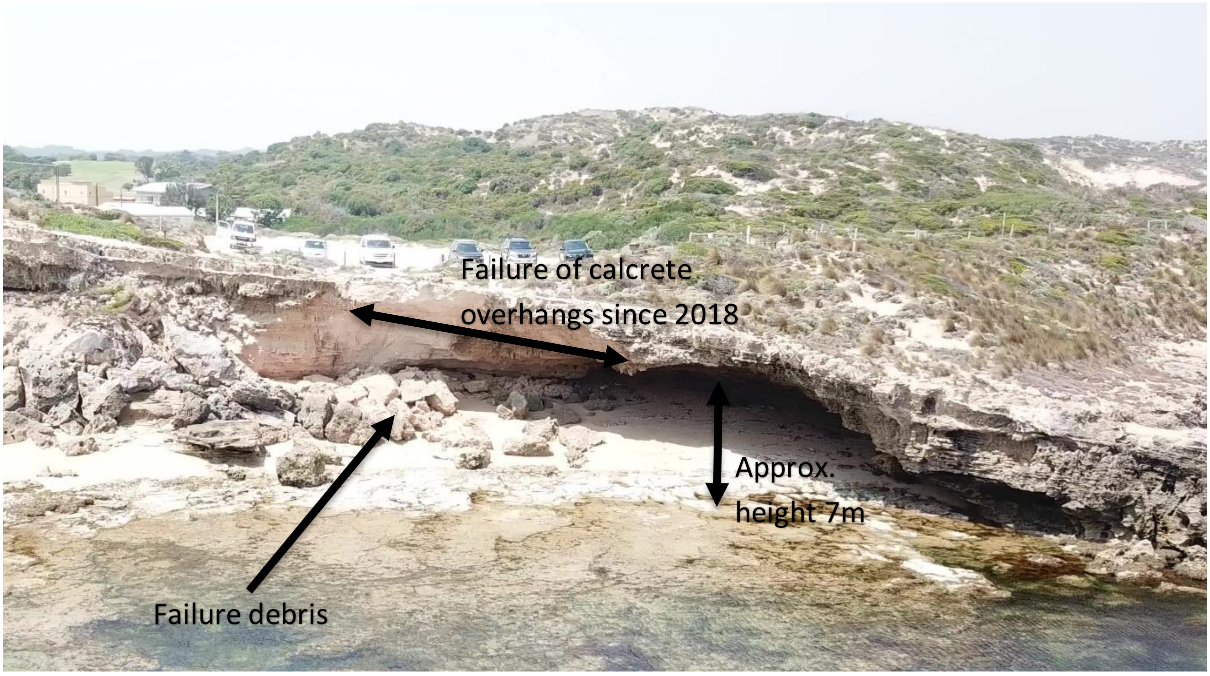


Figure 11: Large undercut cliff at the southern carpark

3.4.3.Coastal Walk South

The Coastal Walk South coastal unit extends from the southern carpark past the lighthouse, Glass Beach and around Doorway Rock. Comparison between the 2018 and 2020 drone imagery did not identify any significant changes along this coastal unit.

An undercut cliff section at the carpark at the end of Joy Terrace was observed, Figure 12. There is currently no signage or fencing to exclude people from this area. The cliff height is around 4-5m.

Figure 12: Carpark at the end of Joy Terrace with cliff undercut sections visible

Within the embayment adjacent to Doorway Rock, Figure 13 is location 20 from Figure 5 where Fotheringham (2009) recorded significant cliff line recession of 22.53m over the 100-year period.

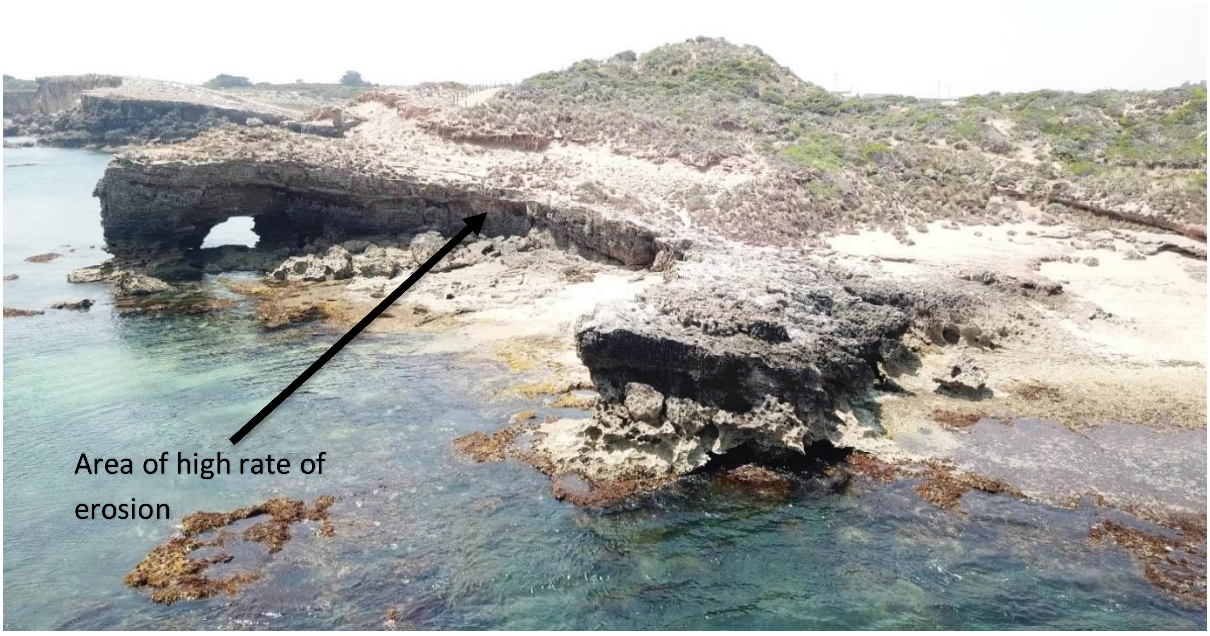


Figure 13: Doorway Rock

3.4.4.Blow Hole

The blowhole is located adjacent to the coastal walkway and is currently covered by a grate, Figure 14. As noted by Tonkin (2018), adjacent to the blow hole is an area of soft depressed ground which likely indicates a cavity under the ground. These features lie near the end of a large cavity in the adjacent cliff, Figure 15, as it is likely there is a connection between them.

No obvious visual changes have occurred between the 2018 and 2020 imagery of the cliff cavity feature. However, as noted by Tonkin (2018) if there is a large connected cavity between the cliff and the blow hole area a sinkhole could develop. Sinkholes tend to develop rapidly (seconds to minutes) and it is not possible to predict when a sinkhole will appear.

Figure 14: Blow Hole and adjacent depressed area

Figure 15: View of the cavity feature which likely links to the Blow Hole

3.4.5.Cape Dombey

The cliffs along the Cape Dombey section exhibit a wide range of configurations with archways, undercuts, overhangs, and caves visible. The report by Tonkin (2018) identified three locations around the Obelisk main carpark as potential high-risk locations due to the potential for failures of the adjacent cliffs to impact the carpark areas (locations 2, 3 and 4 as shown in Figure 16).

No changes in the condition of the cliffs was observed between the 2018 and 2020 imagery. It was not possible to determine any additional information on the size and depth of the undercut features in the 3 locations.

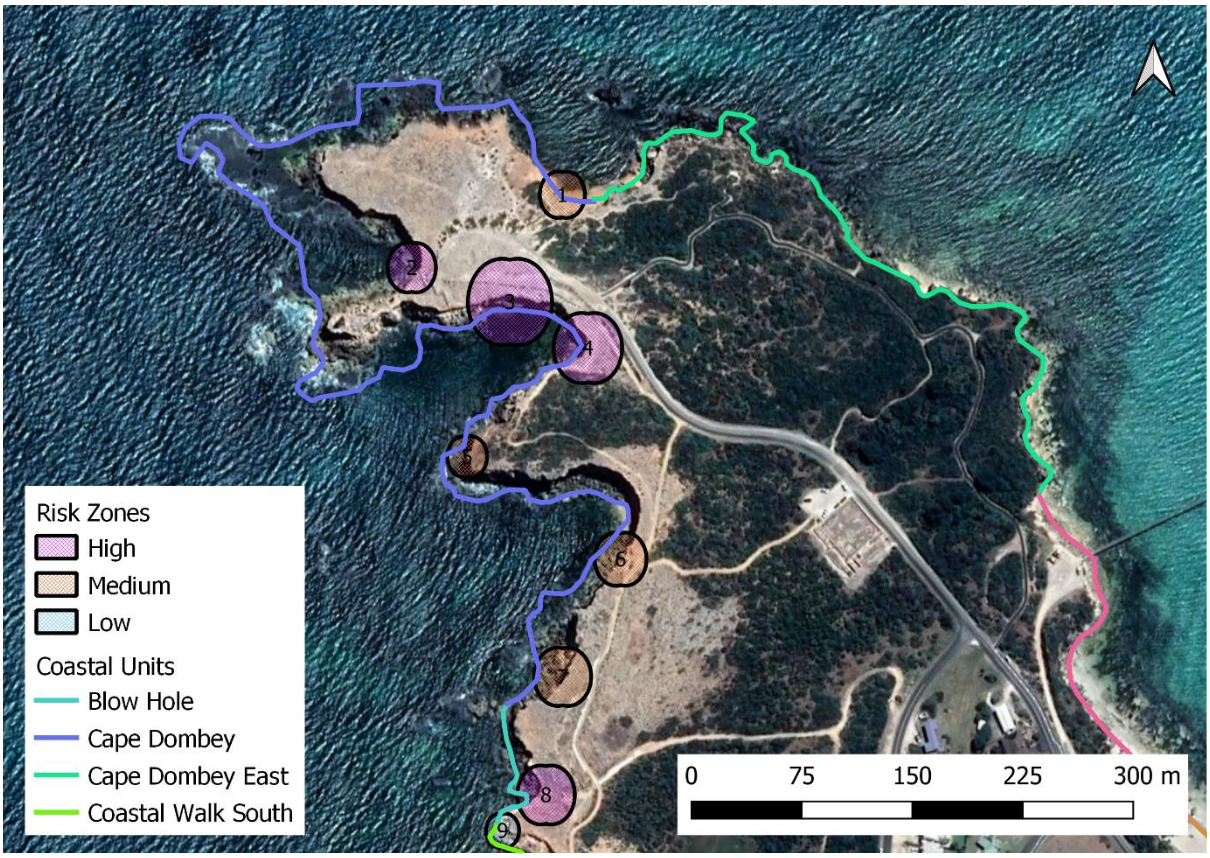


Figure 16: High risk locations at Cape Dombey from Tonkin (2018)

Figure 17: View of undercut at Risk Zone 3 adjacent to the carpark

3.4.6.Cape Dombey East

The Cape Dombey East coastal unit comprises similar geomorphic characteristics to the main Cape Dombey section. Along this section the main asset is the coastal walkway, which is generally located >10m from the cliff edge. There are informal tracks which lead towards the cliff edge in a few locations.

The cliff recession analysis by Fotheringham (2009) did not identify significant recession along some of this coastal unit, however the assessment did not consider the presence of undercut features.

Five points of interest were identified from the drone imagery, as shown in Figure 29. These are locations where there is cave or an undercut feature that may be in the vicinity of an access track (formal or informal), although they are generally > 10m away.

These locations provide reference points for comparison with future drone survey to provide information on the frequency of failures.

Additional warning signage would be warranted along the coastal walk to encourage walkers to remain on the path and avoid walking near the cliff edge.

Figure 18: Points of interest Cape Dombey East coastal unit

3.4.7.Jetty

Figure 7 presented an image of the jetty revetment. The revetment appears in poor condition with slumping and missing rocks in various locations. A condition assessment by a coastal engineer to confirm the structural integrity of the revetment is recommended.

East of the jetty revetment the remainder of this coastal unit comprises soft rock cliffs ranging in height from 10m near the jetty to around 5m moving east towards Karatta Beach. The access path to the jetty runs behind the cliff edge and essentially limits public access to these areas. There are no other assets with 10m of the cliff edge.

Figure 19: Soft rock cliffs east of the jetty revetment

3.4.8.Karatta Beach

Karatta Beach is situated between the jetty and Robe marina breakwater. The construction of the marina breakwater has resulted in the build-up on sand on its western side leading to the general accretion and progradation of the beach. Excess sand from Karatta Beach has previously been used in nourishment of the other small beaches to the east (Hesp and DaSilva, 2020).

A view of the beach in February 2020 is shown in Figure 20. Excess sand was removed from beach in June 2020 for nourishment of Hoopers Beach and Fox Beach.

Figure 20: View of Karatta Beach in Feb 2020

3.4.9.Marina

The Marina coastal unit extends from the sheet pile around the point to the start of the Town Beach seawalls. It comprises a low soft rock cliff with a height of around 6m AHD. Figure 21 presents a view of these cliffs, which shows a series of low undercuts with a couple of more substantial cavities at the eastern end.

There are no formal pathways along this cliff section and the area around the cliff appears to be heavily vegetated which would limit access.

Figure 21: View along Marina coastal unit showing cliff undercuts and cavities

3.4.10. Town Seawall

The coastal unit termed Town Seawall has been highly modified over time, with the construction of a series of seawalls along its length. The condition of these structures has not been reviewed as part of this study. A view of the section of seawall opposite Morphett Street is shown in Figure 22.

Figure 22: View of a section of the seawall along the Town Seawall coastal unit

3.4.11. Town Beach

Town Beach has been defined as lying between the end of the seawall structure at the west and the groyne at its eastern extent. It is believed that sand nourishment has occurred at various times. The groyne at the eastern end of the beach appears to have stabilised the beach profile by restricted further eastward longshore sediment transport.

At the western end of the beach, private properties are within around 13m of the edge of the vegetation.

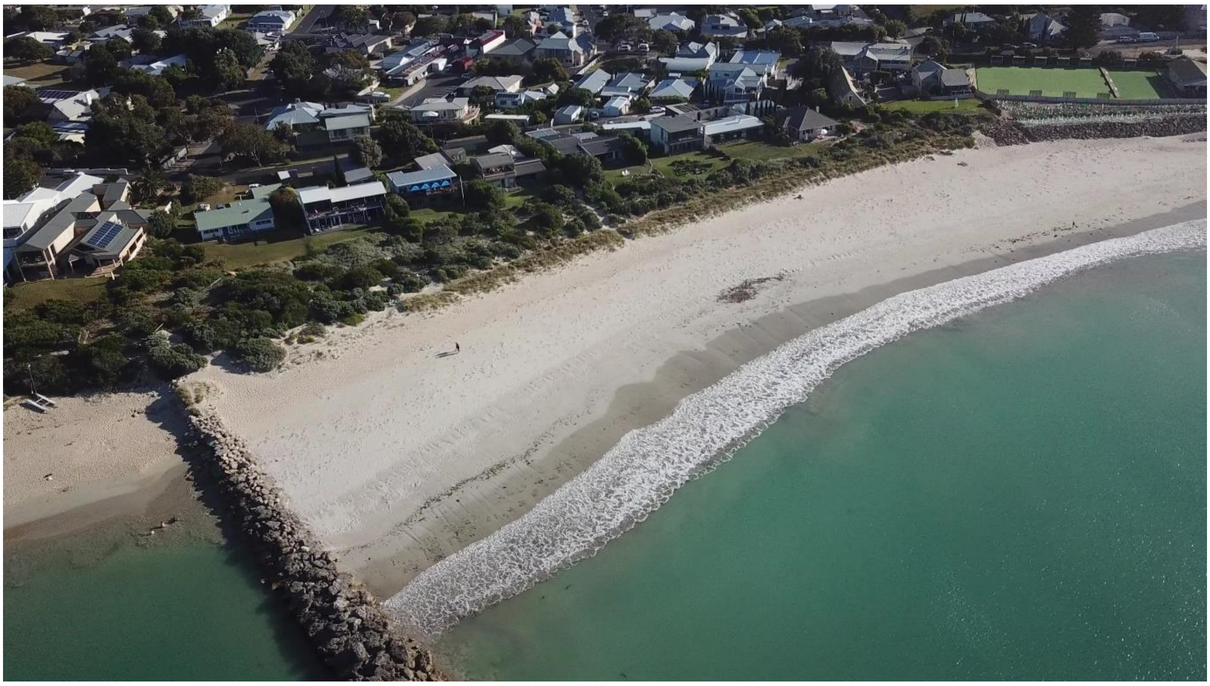


Figure 23: View of Town Beach looking west from the groyne towards the new seawall section

3.4.12. SeaVu

The stability of the cliffs around the SeaVu Caravan Park were visually assessed in the GHD (2016) report. The assessment indicated undercutting of the cliffs in some areas by up to 1.5m. A view of these cliff areas from the 2020 drone imagery is presented in Figure 24.

Figure 24: View of the cliffs at SeaVu Caravan Park

Although remedial works were recommended in the report, visual observations indicate these areas are fenced off and well outside the current fence line. The previous risk rating is likely therefore to be overly conservative.

Of more immediate interest is the cliff section to the east of the Caravan Park along Seafarers Crescent. Figure 25 shows the current undercut cliff sections. These areas are accessible by pedestrians and by vehicles in some areas. The cliff failures here appear to be the result of tensile failures of the calcrete overhangs (failure types 6-8, Figure 4), with failed sections still present along the face in some locations. It is unknown how far the current overhangs extend beneath the point.

Figure 25: Undercut cliff at Seafarers Crescent, east of Squires Drive

3.4.13. Hoopers Beach

Hoopers Beach is bounded by small rocky headlands at either end. Figure 26 shows a view of the beach looking east where the dune buffer narrows substantially and private assets as well as Seafarers Crescent are <15m of the beach. Erosion of the beach and dune areas occurs during storm events, and there is a long-term erosional trend at this beach. It is thought that this erosional trend may have been instigated by the construction of the marina breakwaters to the west (Hesp and DaSilva, 2020).

Beach nourishment was undertaken in June 2020 to increase the available sand buffer, Figure 27.

Figure 26: View looking west along Hoopers Beach showing the narrow dune barrier at Seafarers Cres

Figure 27: View looking east along Hoopers Beach showing the June 2020 renourishment

3.4.14. Coastal Walk East

The soft rock cliffs along Coastal Walk East (between Hoopers Beach and Fox Beach) have not previously been assessed. Along this section the main asset is the coastal walkway, which is generally located >10m from the cliff edge. The cliff heights vary from 4 to 12m.

Eight points of interest were identified from the drone imagery, as shown in Figure 29. These are locations where there is cave or an undercut feature that may be within 5-10m of the coastal path. The turning bay at the end of McIntyre Street is also approx. 10m from the cliff edge (CWE 2). The depth of the undercut feature cannot be determined from the aerial imagery.

Figure 28: Cliff undercut at the turning bay on McIntyre Street

These locations provide reference points for comparison with future drone survey to provide information on the frequency of failures.

Additional warning signage would be warranted along the coastal walk to encourage walkers to remain on the path and avoid walking near the cliff edge. Additional signage at McIntyre Street is also recommended.

Figure 29: Points of interest along the Coastal Walk East coastal unit

3.4.15. Fox Beach

Fox Beach is bounded by low limestone headlands at either end, and is adjacent to the outlet channel to Fox's Lake.

Like Hoopers Beach, Fox Beach exhibits a long-term erosional trend, which has been accelerated by a series of storm events since 2016. There is only a limited buffer between the dunes and adjacent roadway, Figure 30. Beach nourishment was completed in June 2020, Figure 31.

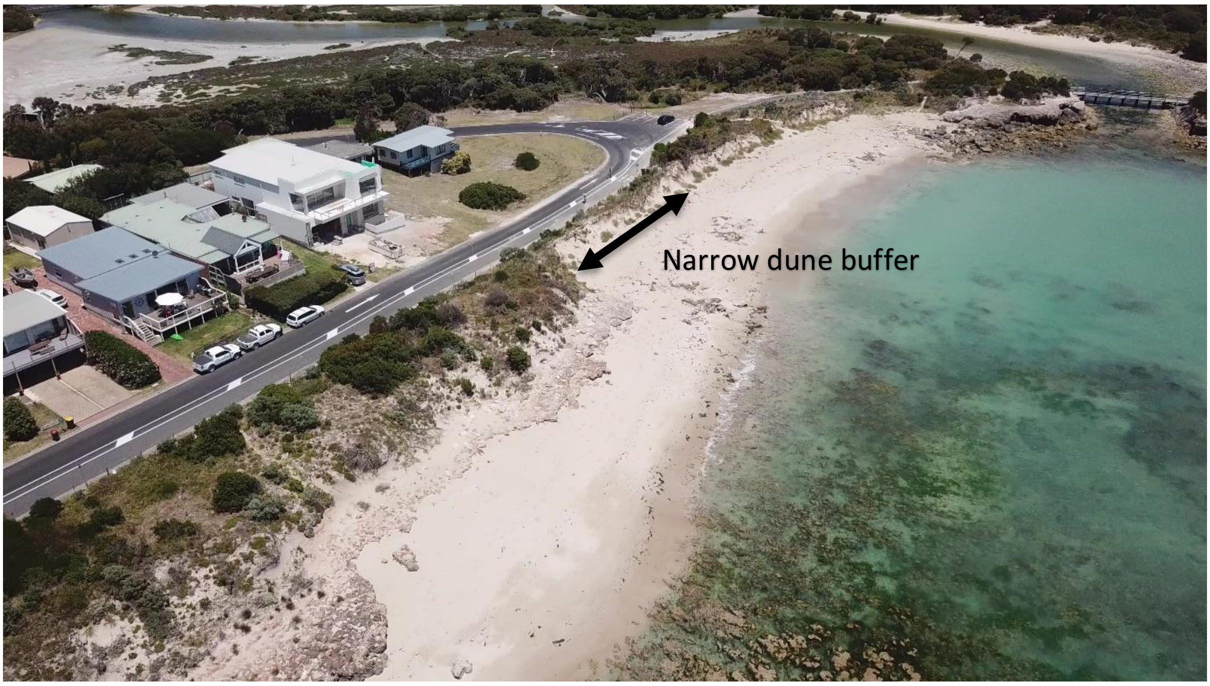


Figure 30: Aerial view of Fox Beach in February 2020 showing a limited dune buffer between the beach and adjacent roadway

Figure 31: View of Fox Beach from the outlet showing sand nourishment along approx. 110m of the beach

3.4.16. The Esplanade

The cliff height along The Esplanade varies from around 8.6m AHD at the eastern end near Park Terrace to 5.0m AHD at the headland west of the beach access near Gruschen Street. Based on the available LiDAR, the base of the cliffs and the adjacent beach is at around 1.45m AHD. This level is well above the predicted Highest Astronomical Tide (HAT) for Robe of +0.6m AHD, and indicates that wave action at the base of the cliffs is unlikely to be the main erosion driver. This is supported by the presence of established grass and vegetation along the base of the cliff. Subaerial processes such as the removal of weaker sediments by wind and possible surface or ground water infiltration are likely greater contributors to erosion.

Tonkin Consulting (2017) surveyed three of the cliff undercut sections located between the access ramp and No. 28 The Esplanade. The data indicated that at these three locations there was a buffer of between 0.15m to 1.5m between the face of the undercut and the fence line along the roadway. They also estimated based on the size of debris at the cliff toe that when failures occur the block size is typically around 1m thick by 2m long (along the cliff line) and 1m wide. Comparison of the images in Tonkin (2018) and those taken on the recent site visit in June (Figure 32 and Figure 33), would indicate erosion is occurring as a result of tensile failures of the undercut aeolian calcarenite (failure types 1-3, Figure 4).

As noted in Tonkin (2017) there is insufficient data to determine the rate at which undercuts may fail.

Interestingly, the previous analysis did not consider the risks associated with the sections of undercut cliff west of the access ramp, near Gruschen Street, shown in Figure 34. Although further from the roadway, the undercut cliffs extend some distance beneath the cliff edge. There are currently no warning signs or fencing to limit access to these areas.

The cliff failures here appear to be the result of tensile failures of the calcrete overhangs (failure types 6-8, Figure 4).

Figure 32: View of the undercut cliff opposite no. 26 The Esplanade (similar location to Figure 8 in Tonkin, 2017)

Figure 33: View of the failure surface of the undercut cliff at The Esplanade

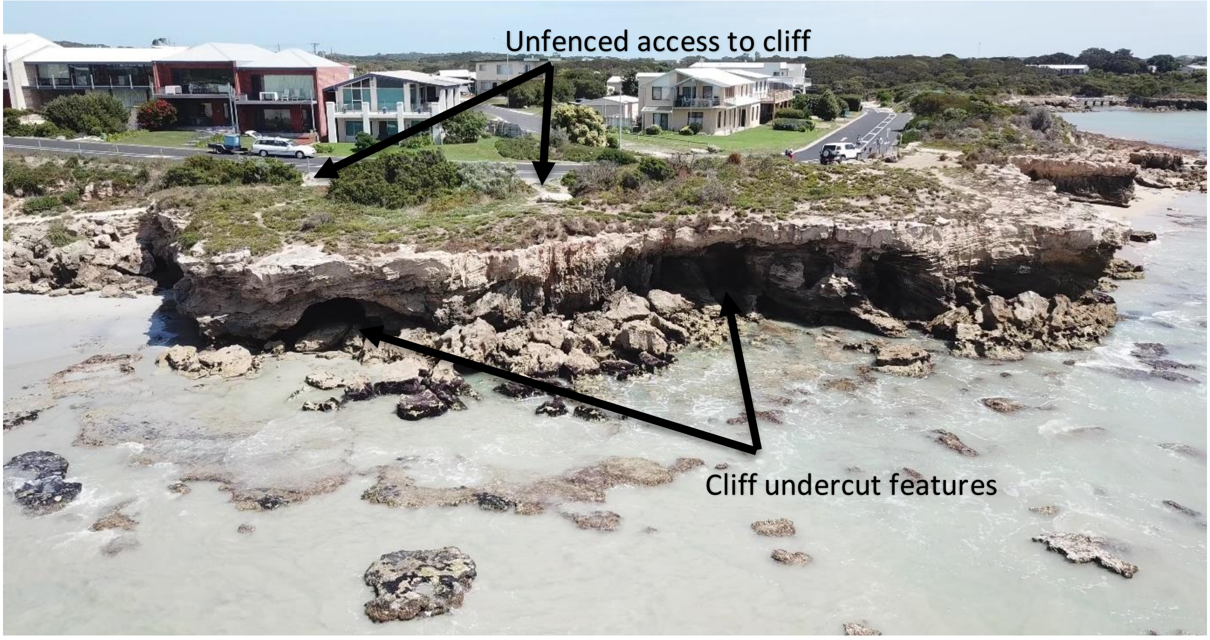


Figure 34: Coastal cliffs showing undercut sections on The Esplanade, opposite Gruschen Street

Additional warning signage and fencing is warranted from First Ramp to the start of Fox Beach to limit access to the cliff edge.

3.4.17. Long Beach

The beach and dune profile along Long Beach it much less steep than West Beach, reflecting the more protected position of the beach within Guichen Bay. Figure 35 shows the location of two profiles extracted from the coastal LiDAR at Long Beach. These are plotted in Figure 36 along with the 1% AEP storm tide levels under current and future conditions (from Civil and Environmental Solutions, 2018). A sea level rise increment of +0.3m by 2050 and +1.0m by 210 has been assumed. The maximum water levels shown include wave setup and wave runup of an additional 0.5m above the peak storm tide level.

At Long Beach Hesp and DaSilva (2020) used both historic aerial imagery and long-term profile analysis to assess long term change. Both assessments indicated that Long Beach ranges from stable to accretionary in the long term.

Figure 35: Long Beach profile locations

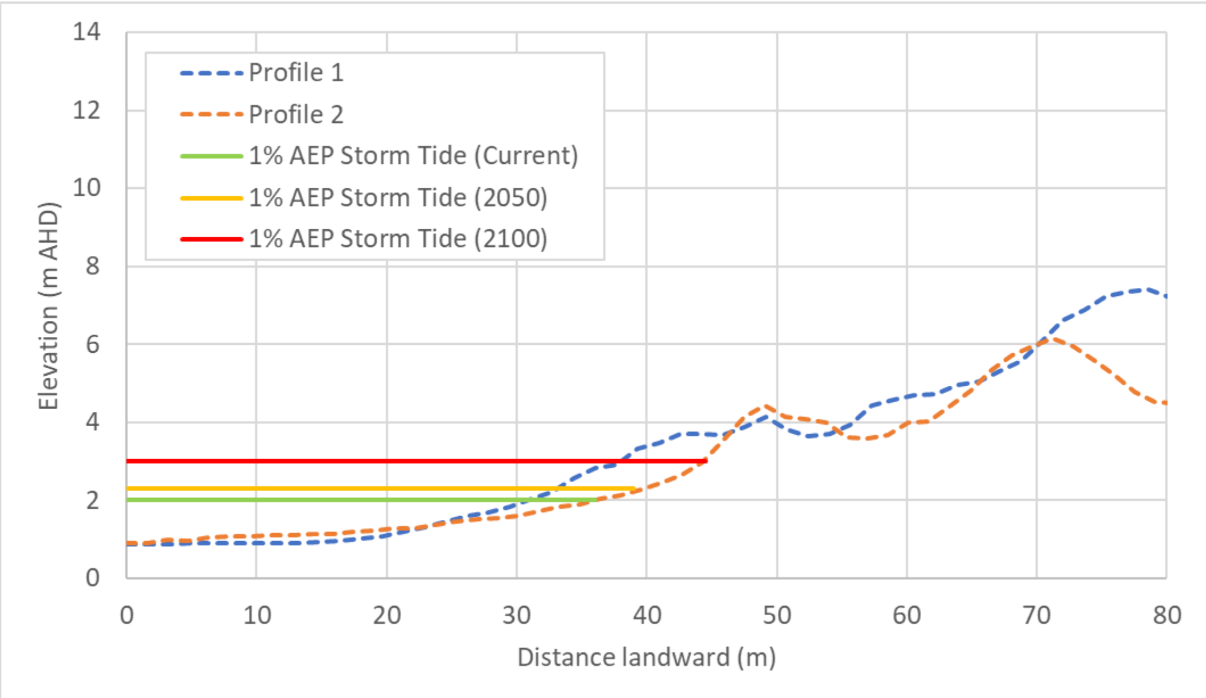


Figure 36: Long Beach profiles including storm tide elevations

The February 2020 drone footage did not extend to Long Beach.

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Appendix A Comparison of Drone Imagery 2018 - 2020

The following images are provided from the comparison of the Tonkin (2018) drone imagery and imagery capture in February 2020. The references are taken from the Tonkin (2018) report, with Zone 1 to 14 referring to the sites considered to have long term stability concerns as shown in Figure A-1. The size of each zone is taken to be the extent of the area of interest, as shown in the Tonkin report figures.

Figure A-1: Location of Risk Zones (from Tonkin, 2018)

Risk Zone 1 - Cliff Overhang (right side)

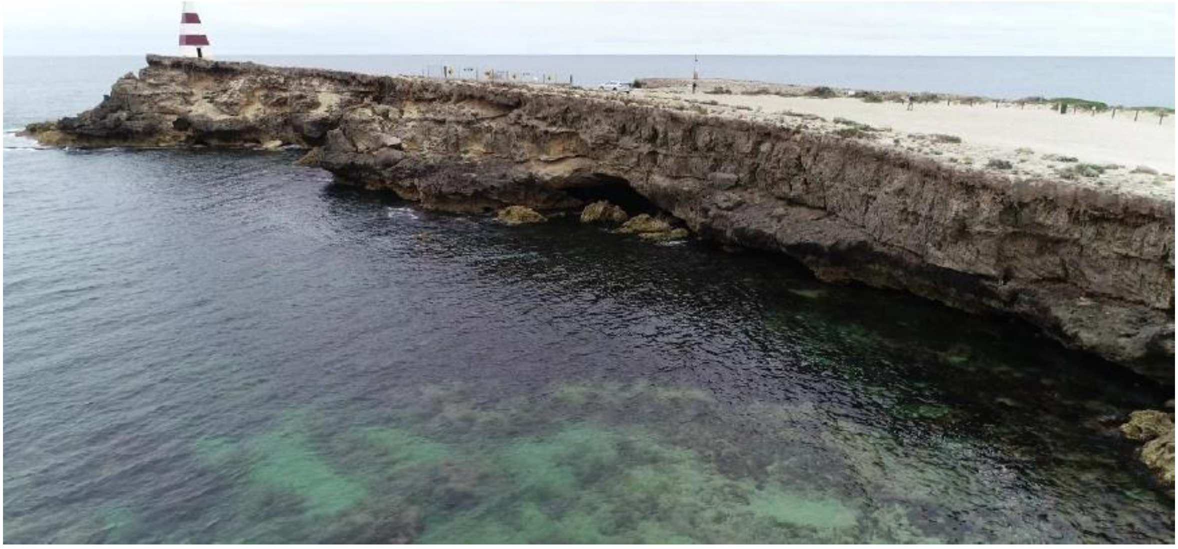
2018

2020

Risk Zone 2 - Obelisk Main Car Park North Side

2018

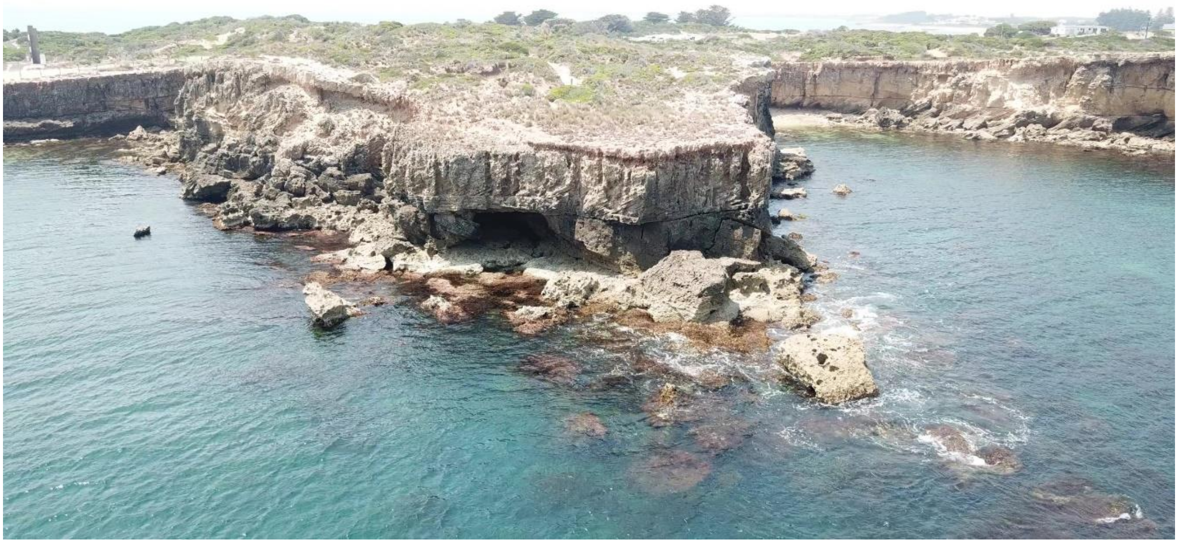
2020

Risk Zone 3 - Obelisk Main Carpark South Side
 2018
 2020

Risk Zone 4 - Obelisk Main Carpark Entrance

2018

2020

Risk Zone 5 - Cliff Undercutting
 2018
 2020

Risk Zone 6 - Cliff Undercutting (right side)

2018

2020

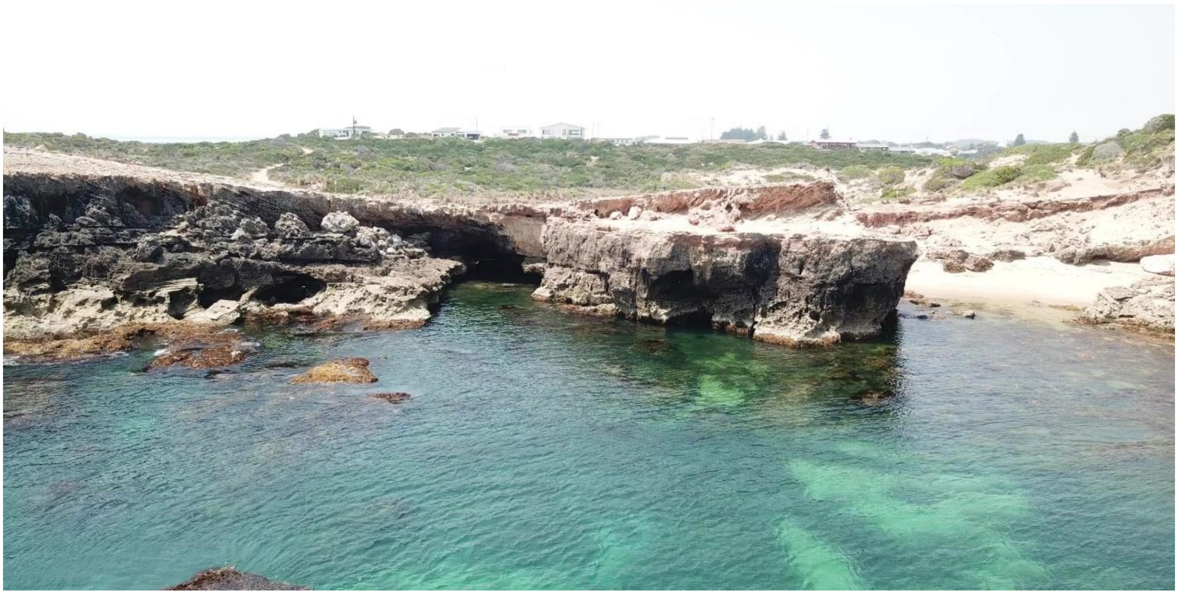
Risk Zone 7 - Cliff Overhang

2018

2020

Risk Zone 8 - Blow Hole Undercutting Cliff Face

2018

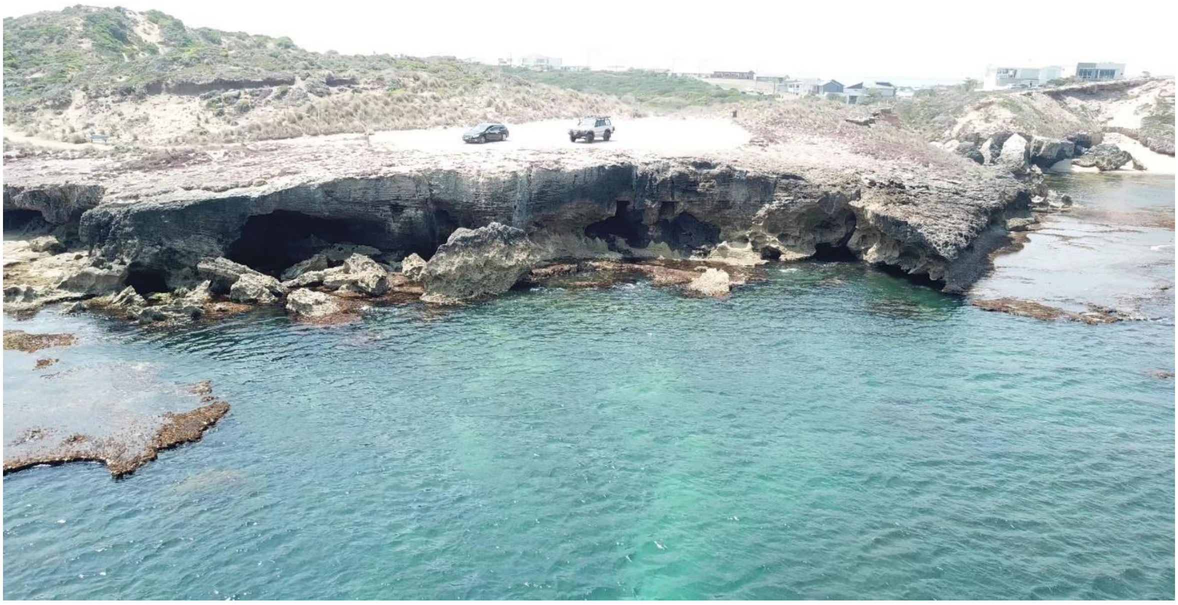


2020

Risk Zone 9 - Doorway Rock

2018

2020

Risk Zone 10 - Undercutting of Cliff (north side of carpark) Carpark 2
 2018
 2020

Risk Zone 11 - Undercut of Cliff Face with large soil mass above
 2018
 2020

Risk Zone 12 - Overhanging Cliff Face

2018

2020

Risk Zone 13 - Undercutting of Cliff

2018

2020

Risk Zone 14 - Obelisk Nature Walk Southern Carpark - Undercutting of Cliff
 2018
 2020