Final Report

Inverloch Region Coastal Hazard Assessment – Adaptation Action Technical Assessment

Department of Environment, Land, Water and Planning

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1 INTRODUCTION

1.1 Overview

In 2020 the Inverloch Regional and Strategic Partnership (RaSP) was established, comprising nine agencies and the Bunurong Land Council Aboriginal Corporation, working together to address the problem of erosion and inundation at Inverloch and the surrounding coast. The Department of Environment, Land, Water and Planning (DELWP) is leading the RaSP.

The RaSP's project is called the Cape to Cape Resilience Project, and a key piece of work is the Inverloch Region Coastal Hazard Assessment (CHA), which is an assessment of coastal hazards for the stretch of coast between Cape Paterson and Cape Liptrap, including Inverloch, Anderson Inlet and Venus Bay.

Water Technology has been commissioned by DELWP to undertake the Inverloch Region CHA.

This report does not aim to assess all coastal hazards across the Cape to Cape region. This report is focussed on the technical feasibility of a suite of **coastal erosion** hazard adaptation actions for the Inverloch foreshore **between Flat Rocks and Point Norman only**. The assessment focuses on this stretch of the coastline, the erosion hazard and how engineering actions could be used to address coastal erosion hazards. Modelling and multi criteria analysis have been used to consider the suitability of different actions along this coastline.

The adaptation actions have been primarily considered to address coastal erosion hazard in the short term as a key driver of the Inverloch Region Coastal Hazard Assessment has been the erosion of the beach between Flat Rocks and Surf Beach, and the community desire to see a plan to address the hazards facing the area now, as well as into the future. The suitability and adaptability of engineered actions for the longer term is considered, and structures could be designed to ensure future adaptability over time as sea levels rise and beaches evolve.

The analysis and recommendations from this assessment will be used alongside consideration of other adaptation actions (including planning and nature based actions) to inform adaptation pathway planning for the Cape to Cape Resilience Plan.

The adaptation actions have been developed based on the results of technical assessments completed for the CHA. This has included assessment of coastal processes which result in coastal erosion hazard and coastal and catchment flooding processes which result in coastal inundation hazard. The assessment of adaptation actions is the final stage of the CHA (Figure 1-1).

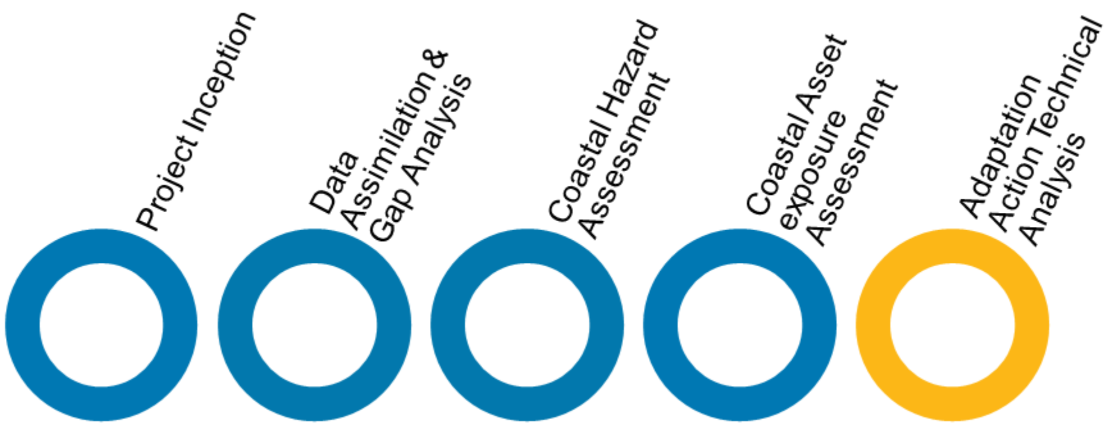


Figure 1-1 Inverloch CHA Project Phases

1.2 Study Area

The project study area extends from the eastern end of Cape Paterson's most eastern beach "Undertow Bay" to the eastern end of Morgan Beach, located just west of Cape Liptrap. The CHA project includes the shorelines of Venus Bay and Anderson Inlet, as presented in Figure 1-2.

The adaptation action analysis has been limited to the Inverloch coastline between Flat Rocks and Townsend Bluff (shown in yellow and green in Figure 1-2). Other assets and values outside of the Inverloch area have been identified as at risk to future coastal hazards, however adaptation to manage or mitigate these risks will be reviewed in later projects of the Inverloch RaSP.

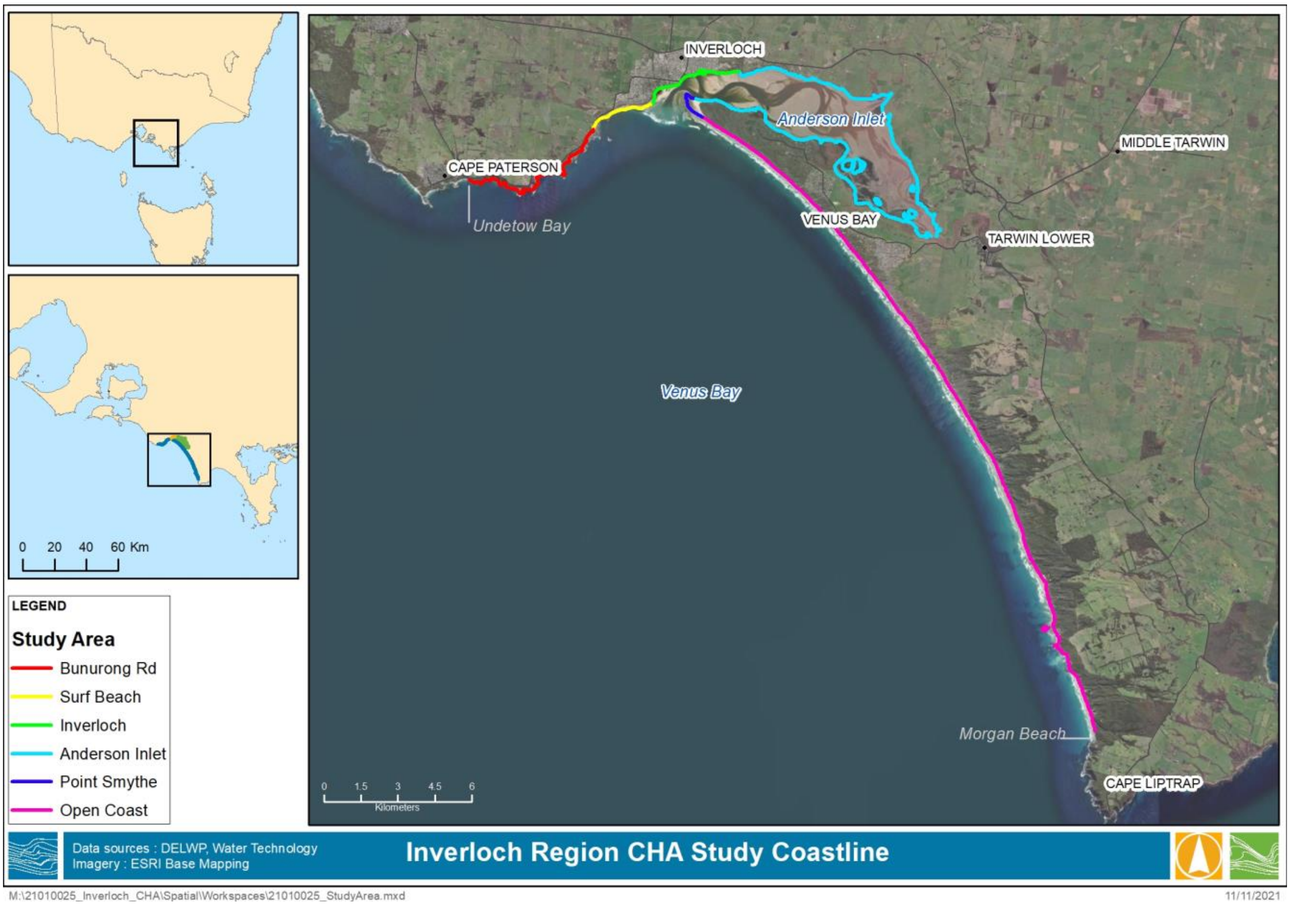


Figure 1-2 Study Area Coastline

1.3 Reporting

This report describes the methodology for the different aspects of the technical works required:

- Section 1 **introduces the project** and outlines the scope of work,
- Section 2 provides context to **coastal management** in Victoria and the adaptation pathways approach to be implemented.
- Section 3 describes the **coastal hazard exposure** and identifies areas where coastal hazards pose the highest level of **risk**.
- Section 4 details the **Multi Criteria Analysis** used to identify adaptation actions to assess.

- Section 5 explores the **technical effectiveness**, the coastal response and the risks associated with each adaptation action assessed.
- Section 6 **summarises** the Adaptation Assessment and provides **recommendations** for further work or assessment.

This document is Report 7 of a series of reports produced as part of the Inverloch Region Coastal Hazard Assessment project. It should be read in conjunction with the following:

- Report 1: Project Summary Report
- Report 2: Data Assimilation and Gap Analysis
- Report 3: Technical Methodology
- Report 4: Coastal Processes & Coastal Erosion Hazards
- Report 5: Coastal Inundation Hazards
- Report 6: Coastal Asset Exposure Assessment
- **Report 7: Adaptation Action Technical Assessment**

2 COASTAL MANAGEMENT CONTEXT

2.1 Policy Context

Coastal management along Victoria's coast is supported by the planning and management tools within the Marine and Coastal Act 2018, including the Marine and Coastal Policy (2020), the Marine and Coastal Strategy (2021) and the soon to be released *Pilot Guidelines – Victoria's Resilient Coast – Adapting for 2100+* (DELWP, 2022).

Figure 2-1 presents the "Planning and Decision Pathway" from the Marine and Coastal Policy (2020) and describes the steps required when planning for adaptation along the Victorian coastline. The technical assessment completed for the Inverloch CHA (described in Report 3 through 5) have been undertaken in conjunction with stakeholder and community engagement through community surveys, project updates, Fact Sheets, webinars, and online and in person presentation of coastal hazard processes and zones. Details are provided in Appendix A.

Figure 2-1 Planning and Decision Pathway (Marine and Coastal Policy, 2020)

2.2 Adaptation Context

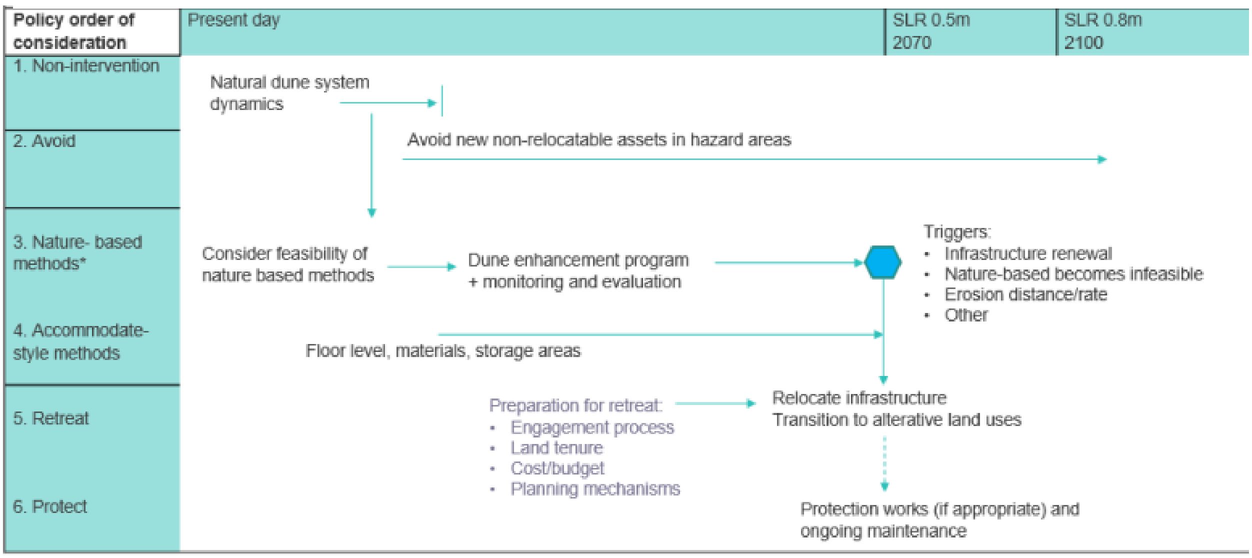
A key objective of the Marine and Coastal Policy is to enhance resilience to coastal hazards. Resilience is not limited to resilience of constructed assets such as roads and houses, and extends to the *capacity of social, economic and environmental systems* to cope with coastal hazards (DELWP, 2022).

In addition to the decision pathways presented in Figure 2-1, key aspects to managing coastal risks, especially in the Cape to Cape region are:

- Respect for natural coastal processes
- Strengthening of resilience to climate change
- Application of an adaption pathway approach
- Consideration of adaptation in the following order:
  - Non-intervention
  - Avoid
  - Nature Based Methods
  - Accommodate
  - Retreat
  - Protection

Consideration of the adaptation options above does not mean each of these steps is required at all points along the coastline, rather the approach to adaptation planning is to generate a pathway which recognises coastal processes and climate change will result in the evolution to the coast and thus the management over time will need to adapt to these changes.

A pathways approach is a decision-making strategy made up of a sequence of manageable steps or decision points over time (an example of a coastal adaptation pathway is provided in Figure 2-2. It looks at all options and identifies thresholds or triggers for when new action/s will need to be taken. It is a forward looking and adaptive approach that recognises the changing nature of climate change impacts and aims to ensure the most effective management tools are used at the most appropriate time.



*Nature-based methods use the creation or restoration of coastal habitats for hazard risk reduction (Morris RL, et al. 2021).

Figure 2-2 Example Coastal Adaptation Pathway (DELWP, 2022)

3 COASTAL HAZARD EXPOSURE

3.1 Coastal Hazard Mapping

To understand the areas along the coastline where adaptation is required, the likelihood of coastal hazard exposure was determined through a detailed technical coastal hazard assessment (Water Technology 2022a, 2022b, 2022c and 2022d). The resultant coastal erosion hazard and coastal inundation hazard zones were presented in Report 4 (2022b) and 5 (2022c) respectively and are available in GIS format and PDF's on the project webpage ((https://www.marineandcoasts.vic.gov.au/coastal-programs/cape-to-cape-resilience-project) and on the CoastKit (link).

Coastal erosion and inundation hazard zones associated with a 1% AEP event under current and future conditions are presented in Figure 3-1 and Figure 3-2 for the Inverloch town coastline. The coastal erosion hazard is most significant along the Inverloch foreshore, especially between Flat Rocks and Surf Beach, the sand dunes encompassing the lagoon at Ayr Creek and at Point Smythe. Coastal inundation hazard is more extensive, with large parts of the Anderson Inlet floodplain vulnerable this century to increased coastal water levels. Urban flooding coincident with elevated storm tides also poses an inundation hazard to the Inverloch area, especially adjacent to Wreck Creek and Screw Creek.

The processes which drive coastal erosion and inundation are described in Report 4 and Report 5 (Water Technology, 2022) respectively.

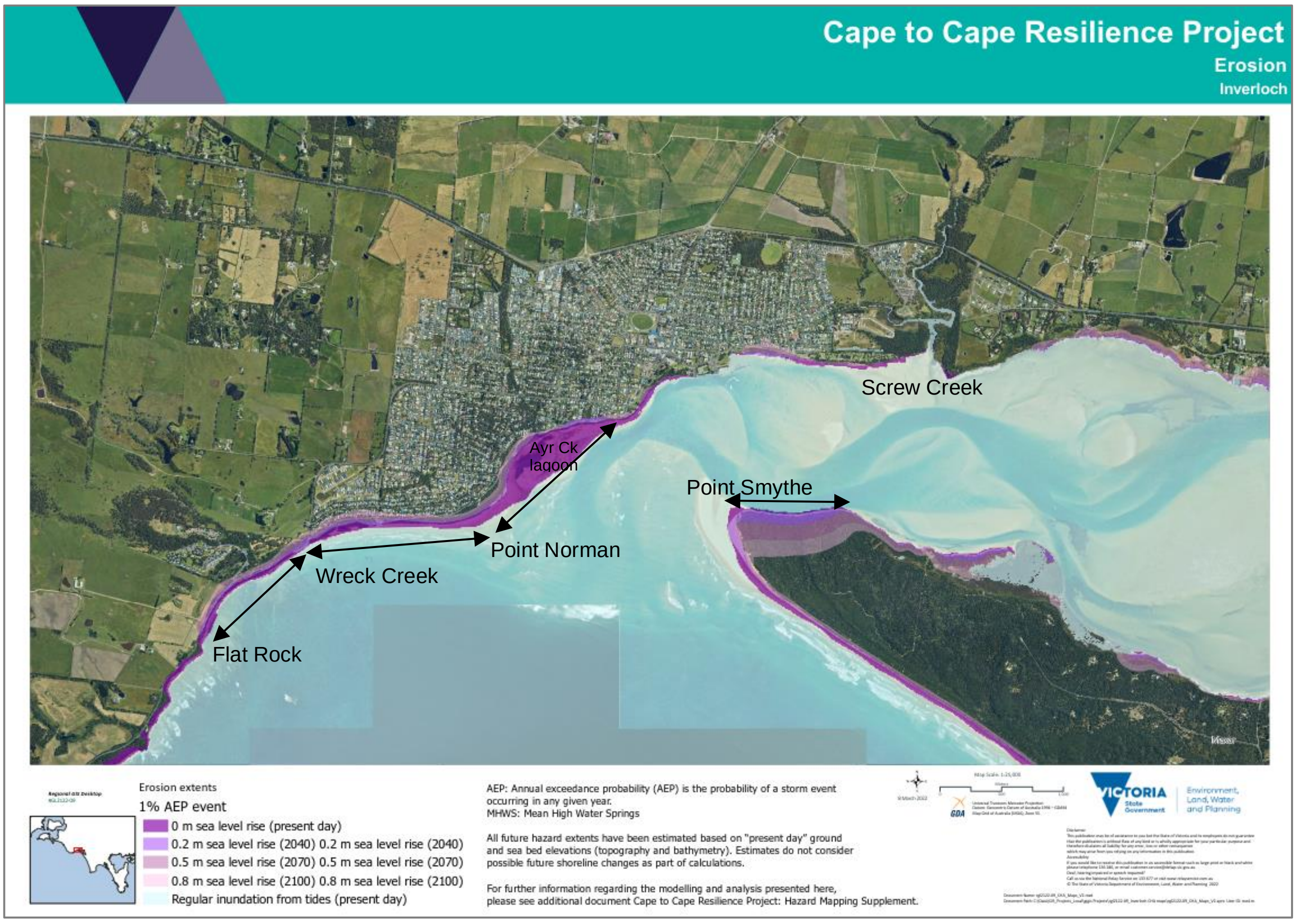


Figure 3-1 Inverloch Coastal Erosion Hazard Zone

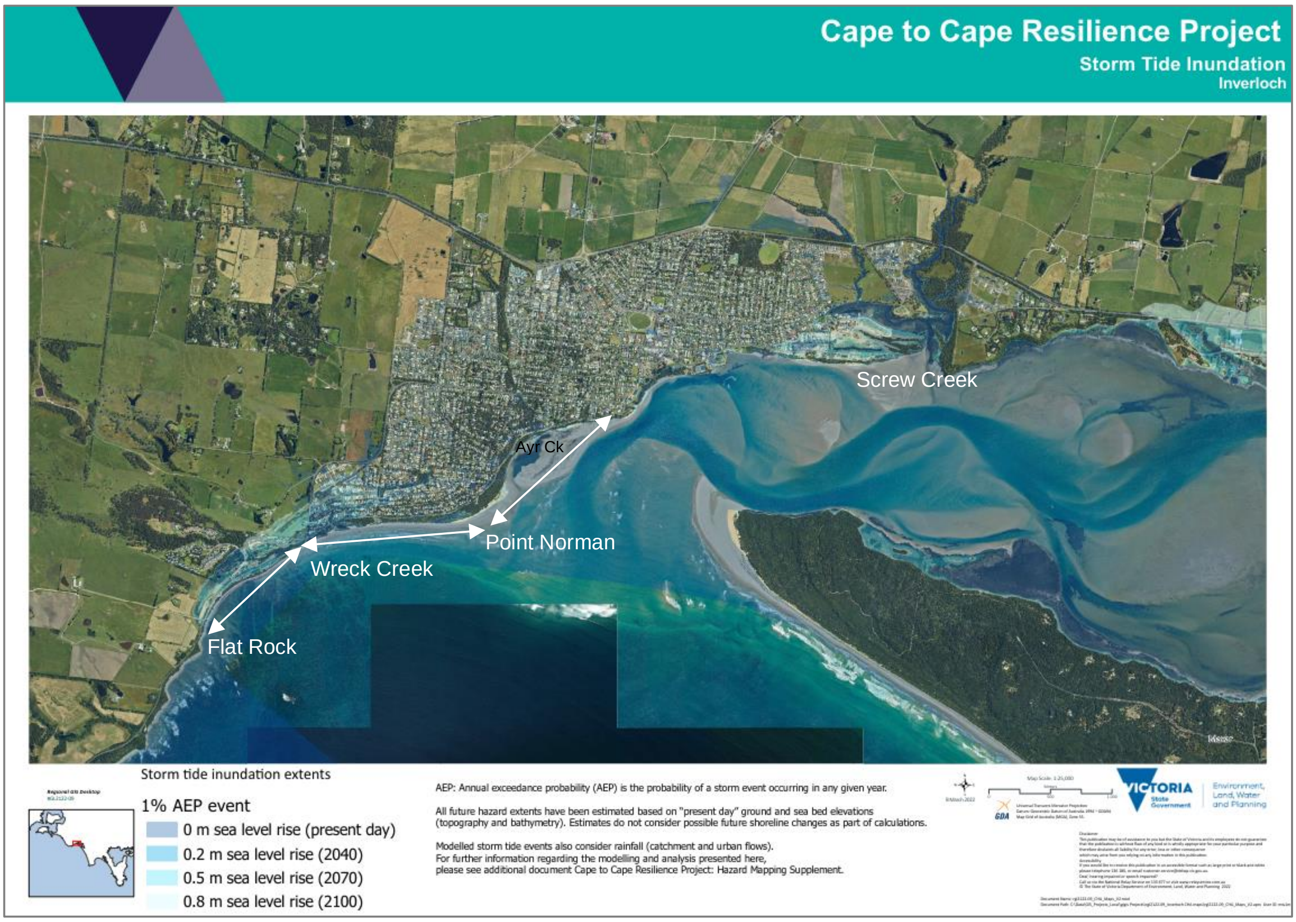


Figure 3-2 Inverloch Coastal Inundation Hazard Zone (1% AEP storm tide and wave conditions combined with 10% AEP catchment and 20% AEP urban flooding)

3.2 Coastal Asset and Values Risk Assessment

Using the coastal hazard zones it is possible to identify assets and values within the Study Area which may be impacted at different planning horizons. The exposure, and the consequence of the exposure of these assets to these hazards has been used to generate coastal hazard **risks profiles** for the Study Area. The coastal hazard risks are described in Alluviums Risk and Vulnerability Assessment report (Alluvium, 2022).

Inverloch was identified as having a high-risk profile, as a result of both the level of exposure and the more significant consequence of the hazard exposure to assets and values in the town. Key areas with high risk profiles within Inverloch are at Bunurong Road, Wreck Creek and Surf Beach as shown in Figure 3-3 and Figure 3-4 respectively.

Figure 3-3 Inverloch Coastal Erosion Hazard Risk – Bunurong Road

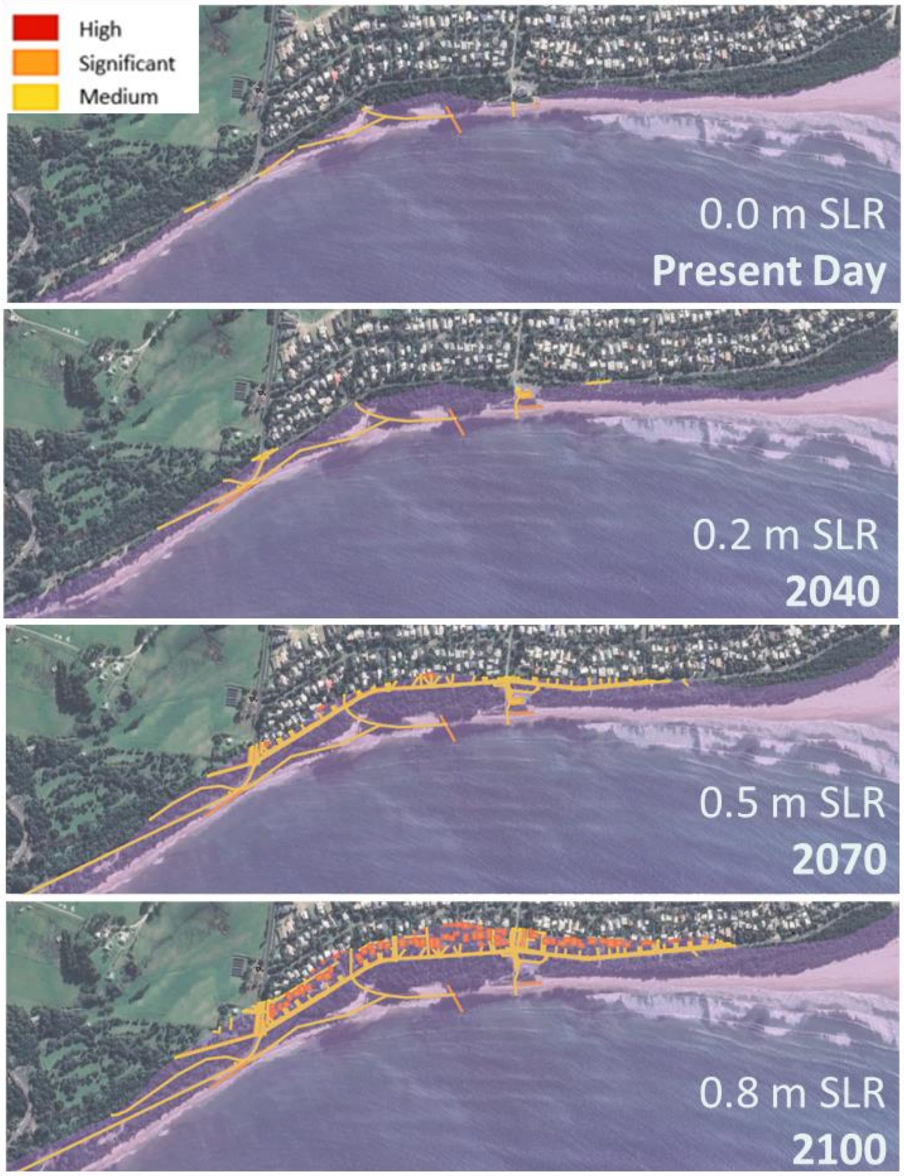


Figure 3-4 Inverloch Coastal Erosion Hazard Risk – Wreck Creek / Surf Beach residential area

The adaptation actions investigated in this report have been tailored to respond to these areas of high risk and provide information to support adaptation pathways planning and allow the community and stakeholders to manage these risks into the future.

Risk profiles of the assets along Bunurong Road and Surf Beach are presented below in Table 3-1. Risks are rated as Low, Medium, Significant and High for the different planning horizons and are described in further detail in Alluvium, 2022. Risk differs from coastal hazard exposure as risk considers both the likelihood of exposure and the consequence of that exposure for an asset or value. DELWP's risk management guidelines require it to manage risks on DELPW land or to DELWP assets which are rated as Medium or above, and to take action for any risks identified as Significant to High to reduce the existing risk to Medium or below.

Table 3-1 Inverloch Coastal Hazard Risk Profile

Asset / Hazard	Existing	2040	2070	2100
Bunurong Road (Flat Rocks to Wreck Creek)				
Coastal Erosion	Medium*	Medium	Significant**	Significant
Coastal Inundation	Medium*	Medium*	Medium	Medium
Tidal Inundation	Low	Low	Low	Low
Wreck Creek dunes (Wreck Creek to Ozone St)				
Coastal Erosion	Medium*	Medium	Significant	High
Coastal Inundation	Low	Medium*	Medium	Medium
Tidal Inundation	Low	Low	Low	Low
Toys Backwater				
Coastal Erosion	Medium*	Medium*	Medium	Significant
Coastal Inundation	Low	Medium*	Medium*	Medium
Tidal Inundation	Low	Low	Low	Low
Broadbeach Estate / Screw Creek				
Coastal Erosion	Low	Low	Low	Low
Coastal Inundation	Medium*	Medium*	Medium	Medium*
Tidal Inundation	Low	Medium*	Medium*	Significant*

* At some locations within the area

** Assumes presence of coastal protection structures. In absence of structures, risk rating would increase.

4 ADAPTATION OPTIONS

4.1 Guiding Principals

As noted in Section 2.2, when planning for coastal adaptation, there are there are a number of strategic approaches and a hierarchy of considerations, as detailed in Table 4-1.

Table 4-1 Strategic Adaptation Approach Order of Consideration (after Marine and Coastal Policy (2020))

Strategic Approaches Order	Marine and Coastal Policy (2020) definitions	Planning considerations / types of actions
1. Non intervention	Allow marine and coastal processes, and the hazards they may pose, to occur.	Triggers (event, timing, other) can be identified for when additional action may commence.
2. Avoid	Locate new uses, development and redevelopment away from areas that are or will be negatively impacted by coastal hazards.	This option typically applies for all coastal hazard areas.
3. Nature-based methods	Enhancing or restoring natural features to mitigate coastal hazard risk.	This may include dune or beach nourishment, wetland restoration, enabling landward migration of habitat, and potential hybrid nature based and engineering approaches (e.g. living shorelines).
4. Accommodate	Structures can be designed to reduce the exposure to, or decrease the impact of, coastal hazard risk, thus 'accommodating' the risk.	This may include movable infrastructure (e.g. life-saving towers, stairs/ramps) flood resilient building design, use of resilient materials.
5. Retreat	Existing structures, assets or uses may be decommissioned or relocated away from areas that are, or will be, negatively impacted by coastal hazards.	This may apply locally or more broadly as part of the adaptation planning process.
6. Protect (major engineering works)	Existing physical barriers are enhanced, or new ones constructed, to mitigate the impact of coastal hazards. Protect is an option of last resort; it is often expensive, its benefits tend to be very localised, and it frequently transfers the problem to nearby areas.	This may include a commitment to ongoing beach nourishment, construction of seawalls or other physical barriers/structures or interventions (groynes, breakwaters) that are likely to have significant impact on natural coastal processes.

4.2 Adaptation Actions

4.2.1 Functional Types

Within the *Pilot Guidelines – Victoria's Resilient Coast – Adapting for 2100+* (DELWP, 2022), adaptation options are the strategic approaches listed in Table 4-1. The range of tools, decision and physical works used to create the adaptation pathways such as planning scheme amendments, dune protection or tidal gates (for example) are considered adaptation actions. This report adopts this terminology.

Adaptation actions can be considered as falling into three functional types:

- Land management planning and design
- Nature based approaches (including hybrid)
- Coastal engineering

Each of these functional types is very broad, and adaptation actions across or within functional types can be combined to provide the optimum solution. The Pilot Guidelines (DELWP, 2022) provides a compendium of potential adaptation actions to consider.

4.2.2 Land Management and Nature Based Actions

In general, the **Land Management Planning and Design** actions are likely to apply in a range of ways for short and long-term adaptation at different locations. This includes relocation readily moveable assets, upgrades with resilient material and design approaches, and longer term planning of r how eth land is used in the future (overlays, planning scheme amendments, tenure). These options and actions are informed by the hazard assessments, risk and economic studies, strategic planning and engagement, as adaptation pathways are developed.

Nature based actions use the creation or restoration of coastal habitats for hazard risk reduction. This includes a suite of options associated with coastal wetland/ecosystem restoration, dune ecosystems, and hybrid engineering approaches (e.g. shellfish reefs). Nature based actions often require specific environmental conditions to be successful, and may require active management / ongoing action over shorter timeframes (e.g. regular dune protection activities). Nature based actions may be appropriate as part of an adaptation pathway based on site specific objectives, and often assist with retaining natural site values while mitigating hazard impacts.

Adaptation actions such as kelp forests are not appropriate around Inverloch due to the high wave energy on the open coastline and the shallow sandy bed adjacent to Toys Backwater and Screw Creek. Likewise planting of mangrove is unlikely to be successful on the open coast due to the wave energy, however this could be a potential adaptation action within the broader Anderson Inlet (not discussed here).

Shellfish reefs may be infrequently inundated near Screw Creek and exposed to too much wave energy on the open coast to make them viable.

Other actions such as dune protection, nourishment and the use of on-site materials are suitable to be built into adaptation pathways in conjunction with engineering approaches. The inclusion of nature based approaches for each place-based context should be part of strategic adaptation pathways planning and informed by the range of site objectives, values and specialist studies as required.

4.2.3 Engineering Actions

A first pass review of the appropriateness of engineering adaptation actions detailed within the VRC compendium has been considered for the coastal erosion at the coastline at the focus of this assessment (i.e. Flat Rocks to Point Norman). The first pass assessment is presented in Table 4-2.

Adaptation actions have been considered as:

- appropriate for future adaptation pathway (Pathway)
- not relevant to the coastal hazard (Not relevant)

- not appropriate for the coastal environment (Not appropriate), or
- an action to be shortlisted (Shortlist) for further consideration in a multicriteria analysis, especially where there are a number of potential actions which can be implemented as the first step in the pathway.

Further review of several **coastal engineering** actions to respond to the coastal hazards whilst adaptation pathway actions are established is considered warranted for a number of the actions from the VRC compendium (2022). Those not considered appropriate for further consideration included sand-bypassing for the open beaches or entrance due to the very high expense involved combined with the dynamic morphology of the entrance channels which could result in a lack of sand available for sand bypassing at the pump station. Likewise, the highly dynamic natural morphology of the entrance channels poses the risk that the response of the entrance to channel management could be unexpected, or outside the bounds of the expected response causing significant issues elsewhere.

The engineering actions identified in Table 4-2 as suitable for short-listing along the coastline from Flat Rocks to Point Norman have then been assessed using the project-specific Multi Criteria Analysis which is described further in Section 4.3.

Table 4-2 Suitability of Engineering Adaptation Actions

Functional Type / Sub-category	Action	Flat Rocks – Wreck Ck	Wreck Ck – Pt Norman
Beach nourishment	Beach scraping	Shortlist	Shortlist
	Cart and place, dredge and pump	Shortlist	Shortlist
	Sand by-pass system	Not appropriate	Not appropriate
Dredging	Management of channels / dynamics	Not appropriate	Not appropriate
Seawalls	Geobag revetment / walls	Shortlist	Shortlist
	Rock revetment	Shortlist	Shortlist
	Vertical seawall	Shortlist	Shortlist
Groynes	Rock	Shortlist	Shortlist
	Geobag	Shortlist	Shortlist
	Timber	Shortlist	Shortlist
Breakwaters	Offshore	Not appropriate	Shortlist
	Nearshore	Shortlist	Shortlist
Flood / tidal barriers	Levees / dykes	Shortlist	Shortlist
	Tidal /surge barriers	Shortlist	Shortlist
	Tidal gates	Shortlist	Shortlist
	Saline groundwater intrusion barriers	Not relevant	Not relevant
Drainage network	Pipes, valves (size, function)	Not relevant	Pathway

4.3 Multi Criteria Analysis of Adaptation Actions

A Multi Criteria Analysis (MCA) has been developed for the project and carried out to compare alternative actions and selected key assessment criteria.

The objective of the MCA is to apply a semi-qualitative and quantitative approach to compare alternative actions. The MCA in this assessment is used to shortlist engineering actions for detailed technical assessment. The MCA also provides a decision-making tool for complex situations where there may be conflicting objectives.

The MCA has been used to assess engineering adaptation actions identified in Table 4-2 which will result in a change in the coastal environment. This includes some nature based actions such as beach nourishment.

For the purposes of comparison, the MCA has assessed the adaptation actions based on a minimum design life of around 15-20 years in recognition of the community desire for short term action in response to recent erosion. The magnitude of coastal hazards defined at the 2040 planning horizon have been used to establish the level of protection required. For some of the engineering structures, a longer term design life and criteria could be more cost effective if proceeding with design and construction.

4.3.1 Criteria Themes

The five 'criteria themes' – environmental, legislative, social, technical and financial –relevant to the decision-making process for the project are weighted, based on the relative importance of the theme in achieving the project objectives.

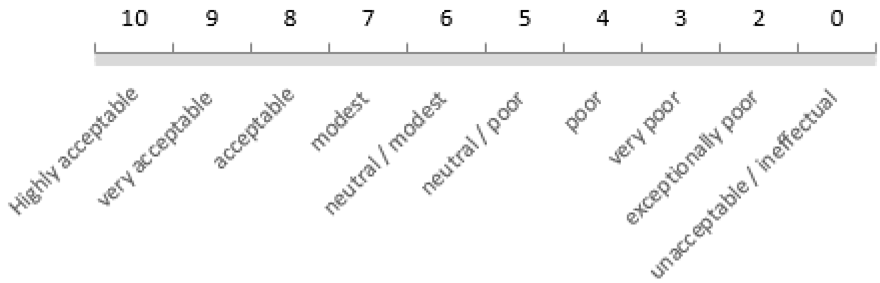
With the exception of the social theme, the criteria themes and assessment criteria are largely objective, and could be considered without thought given to the location and culture of the area at risk. However, to enable the community and stakeholder voice to be included in the MCA, the 5 criteria themes are given a project specific weighting. The weightings are relative to each other, i.e. they add up to 100%, and are derived from extensive stakeholder and community engagement undertaken by Alluvium Consulting as well as Traditional Owner consultation for the project (BLCAC's Cultural Values Assessment, 2021).

The relative weighting of each criteria theme in the assessment of actions are presented in Figure 4-1. Details of the consultation and the community values which have been used to define the criteria weighting can be found in Alluvium 2022a and Alluvium 2022b.

4.3.2 Assessment Criteria & Success Score

Within each criteria theme, there are assessment criteria which each adaptation action can be given a direct success score. The assessment criteria are weighted based on technical direction, consultation and previous experience. The weighting for each assessment criteria in each theme is presented in Figure 4-1, and additional detail regarding each assessment and criteria in Table 4-3.

The higher the score, the more appropriate or desirable is the action's outcome. Success and the interpretation of how acceptable an action is in achieving the criteria assessment objective is presented below.



The total sum product of the success score, the assessment criteria weighting, and the criteria theme weighting provides a score for each action which can be used to identify preferred actions. Where an action is completely unsuccessful in achieving the project objectives (e.g., will not work to prevent erosion), a success score of 0 is given and the action will not generate a positive score and will be ranked last (or equal last) of the actions assessed.

The actions identified as being suitable for *shortlisting* in Table 4-2 have been assessed using the MCA. These are presented in Sections 4.4 and 4.5 below.

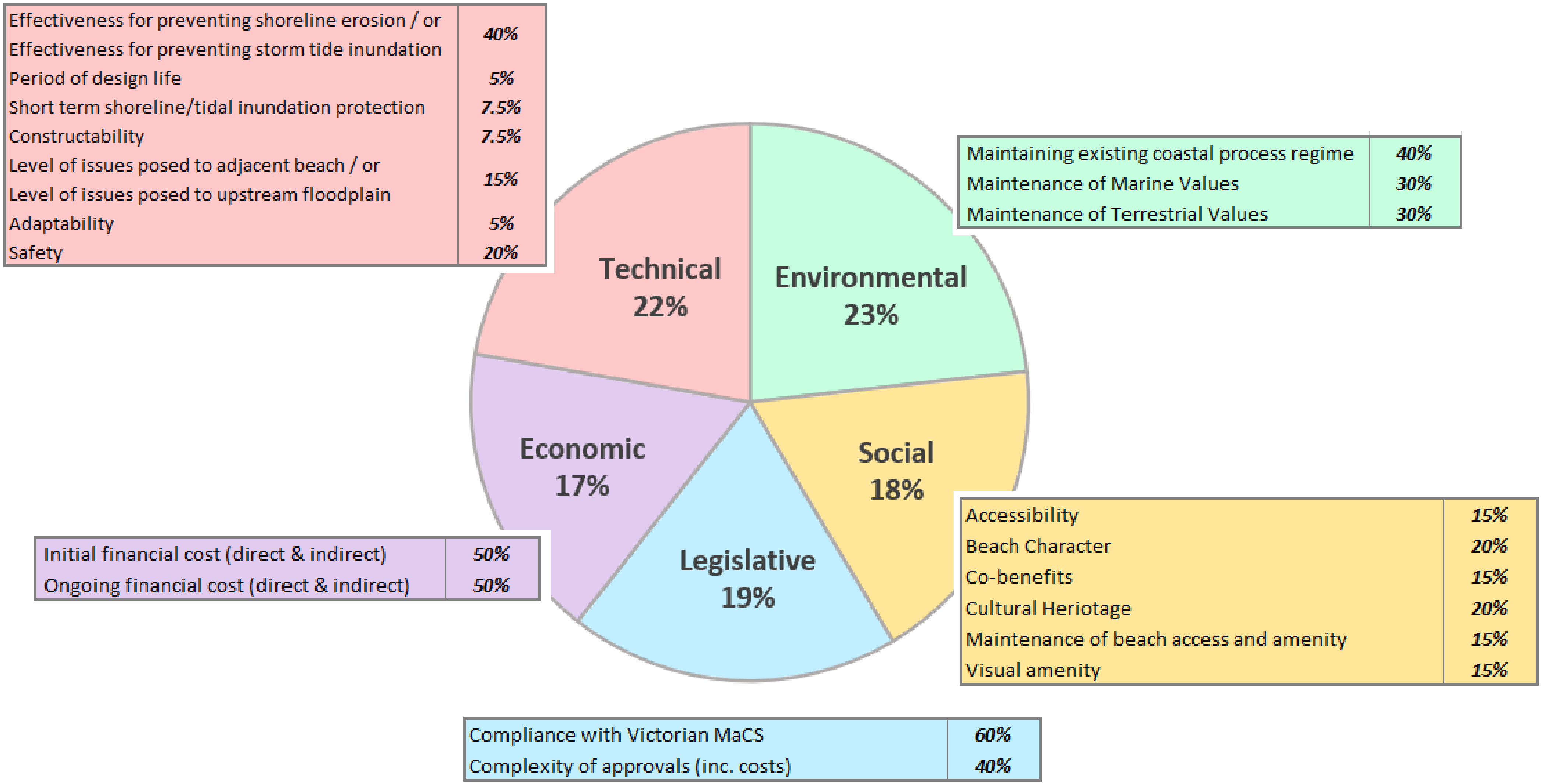


Figure 4-1 Criteria Theme Weighting

Table 4-3 Assessment Criteria Detail

Criteria Theme	Assessment Criteria	Detail
Environmental values	The importance of biological diversity and ecological integrity of the local coastal environment. The maintenance of these values can be achieved by appropriate avoidance or management of adverse impacts.	
	Maintenance of coastal process regime	how effectively the action allows the existing sediment transport regime from west to east, and on-shore offshore transport to continue
	Maintenance of marine values	the effect to which the action poses any impact on the marine environment, e.g., additional sand imported may bury rock reefs and associated habitats
	Maintenance of terrestrial values	the impact of the action on the dune environment, e.g., rock wall may result in loss of vegetation on the dune
Legislative	To ensure that actions are consistent with planning and legislative requirements of Commonwealth, State and Local governments it is necessary to have appropriate regard for the full range of legislation that controls activities in the coastal zone. The extent to which such strategies comply with such requirements varies and is an important consideration when selecting the preferred action.	
	Complexity of approvals	will the action require additional assessment due to local, state or federal regulations; will the action require additional assessments, for instance marine ecology or navigation review
	Compliance with Victorian Marine and Coastal Strategy	how does the action rate within the framework of the VMaCS
Social	The concept of social values has a very broad definition, but in the context of the Inverloch region it encompasses the sense of community; connectedness; along with the personal and community health and wellbeing felt by all beach users and the local community. The criteria in this section may be very subjective, as observed during the community and stakeholder consultation sessions and assessment exercises.	
	Accessibility	the ability to maintain and improve all ability access to the beach and coastline is considered to retain and enhance the enjoyment of our coastline
	Beach character	preserving the community perception and feel of their beach (very subjective)
	Co-benefits	the action results in multiple benefits. In addition to its primary intended outcome – e.g. hazard reduction combined with habitat improvement, or with amenity/recreation
	Cultural Heritage	protection and sensitive management of cultural heritage assets and values is required when assessing coastal actions.

Criteria Theme	Assessment Criteria	Detail
	Maintenance of beach access and amenity	ability for the community to continue with their preferred method of interaction with the coastline and the surrounding coastline. Common themes identified through consultation include activities such as walking, sunbathing, child beach play, water based recreation (swimming, surfing, fishing), cultural heritage, tourism, education, etc
	Visual amenity	preserving the existing vistas provided at Inverloch
Economic	Implementation of actions will invariably involve financial implications.	
	Capital costs	The initial financial costs of the project, including design, construction material and plant and necessary approvals and work required to gain approvals (also linked to legislative)
	Operating Costs	Ongoing financial costs of the project, including maintenance works' frequency and complexity
Technical	The technical aspects of the solution and the likelihood of success.	
	Effectiveness	will the action prevent further erosion of the coastline or inundation of the land until the long-term adaptation pathway actions can be implemented
	Design life	how long will the action provide effective coastline protection
	Short term protection	does the action offer a temporary halt to the coastal hazard (predominantly erosion)
	Constructability	how difficult and complex will construction be, are specialist contractors required, also related to social impact and interruption of social values during construction
	Adjacent beach issues	will the protection result in more significant terminal scour at the adjacent beach
	Adaptability	ability of action to adapt with the continued change of the coastal environment
	Safety	the ability of the action to provide ongoing safety of the community and visitors to the coastline

4.4 Bunurong Road (Flat Rocks to Wreck Creek)

Bunurong Road is an important asset facilitating connection between Cape Paterson and Inverloch as well as to the many beaches and sites visited, and properties accessed by the road. The portion of the road impacted by coastal erosion hazard is shown in Figure 3-3. The engineering adaptation actions identified as potentially appropriate for managing coastal erosion hazards along the Bunurong Road coastline are explored in Table 4-4.

Beach nourishment – one off and ongoing – were identified as the highest ranked actions (rated 1 and 2) for reducing the coastal erosion hazard along Bunurong Road. However, the risks associated with relying on a single nourishment to protect the coastline until the 2040 planning horizon are considerable and ongoing beach nourishment, assisted by dune protection and revegetation is considered a more technically feasible solution, albeit potentially with higher ongoing costs.

Engineering actions such as construction of a seawall (constructed of either geotextile bags or rock) were rated next highest ranked (3 and 4), with a higher technical effectiveness score than nourishment but with greater impact on the existing coastal processes, marine and terrestrial values than nourishment.

As noted, this report assesses the technical feasibility of actions to adapt to short term erosion. Resilience to storm tide inundation can be achieved across the short term planning horizon assessed (i.e. to 2040) through the use of storm tide barriers or tidal gates at Wreck Creek and the Flat Rocks road culvert. Construction of a permanent storm tide barrier may result in drainage issues following a catchment flood event and is not recommended. The impact of coastal protection actions on drainage and inundation should be considered during detailed design of any future works.

Based on these outcomes, a technical feasibility assessment of beach nourishment options and a seawall option have been completed for the Bunurong Road – Wreck Creek section of the coastline.

Table 4-4 Bunurong Road Coastal Erosion Adaptation Actions

Bunurong Road (Flat Rocks to Wreck Ck)

Engineering Actions

Category	Category weighting	Assessment Criteria	Criteria weighting	Beach nourishment (single event)	Beach nourishment (ongoing management)	Geotextile bag seawall	Rock revetment	Vertical seawall	Living seawall	Groyne field	Long groynes	Nearshore breakwater
Environmental	0.23	Maintaining existing coastal process regime	0.4	7	7	4	4	4	4	3	2	4
		Maintenance of Marine Values	0.3	8	8	4	4	3	3	5	4	3
		Maintenance of Terrestrial Values	0.3	9	9	5	5	5	5	7	6	7
Legislative	0.19	Compliance with Victorian MaCS	0.6	8	7	2	2	2	3	3	2	2
		Complexity of approvals (inc. costs)	0.4	9	9	5	5	5	5	5	3	3
Social	0.18	Accessibility	0.15	6	10	5	4	3	3	7	5	5
		Beach Character	0.2	6	8	4	4	3	3	3	4	5
		Co-benefits	0.15	5	7	5	5	5	6	5	5	5
		Cultural Heritage	0.2	5	5	6	6	6	6	5	5	5
		Maintenance of beach access and amenity	0.15	5	8	5	5	4	4	5	5	5
		Visual amenity	0.15	6	9	5	5	4	4	5	6	6
Economic	0.17	Initial financial cost (direct & indirect)	0.5	6	6	7	7	6	5	7	2	3
		Ongoing financial cost (direct & indirect)	0.5	10	4	9	9	8	7	9	8	7
Technical	0.22	Effectiveness for preventing shoreline erosion (~20y)	0.4	2	10	10	10	10	10	5	4	5
		Period of design life	0.05	2	10	10	10	10	10	10	10	7
		Short term shoreline/tidal inundation protection	0.075	5	10	10	10	10	10	5	4	5
		Constructability	0.075	5	5	6	9	6	5	4	3	3
		Level of issues posed to adjacent beach	0.15	8	8	3	3	2	2	2	2	3
		Adaptability	0.05	2	10	8	7	5	5	7	7	4
		Safety	0.2	8	8	3	3	2	2	2	2	3
		TOTAL SCORE		6.8	6.8	4.9	4.9	4.4	4.4	4.5	3.4	3.7
		Ranking		2	1	4	3	6	7	5	9	8

4.5 Surf Beach

The Surf Beach dunes and beach area have been identified as an important social asset to the community and there are significant public services, i.e. roads, water, gas, sewer, communication, power, and residential homes at risk from future coastal erosion hazard.

The extent of exposure to coastal erosion hazard is shown in Figure 3-4. The exposure to coastal erosion and the processes which drive coastal recession along the beach are complex and are discussed in detail in Report 4. Engineering adaptation actions identified as potentially appropriate for managing coastal erosion hazards along the Surf Beach are explored in Table 4-5.

Consistent with the Bunurong Road section of this coastline, the highest ranked adaptation option is beach nourishment. Despite the high rank however, it is unlikely that a single beach nourishment project alone will be sufficient to prevent coastal erosion for a planning horizon of 2040, as noted by a low technical score for this option. Ongoing beach nourishment and management are the second highest ranked action to provide coastal erosion protection, however it is noted that there will be a significant ongoing cost and potential impacts to the environmental values of the location where the sand is sourced from and also from the constant movement of sand across the beach.

A groyne field assessed in the MCA was considered to occur in combination with beach nourishment, and provided a notably lower, but still acceptable score in the MCA.

Geotextile sandbag and rock seawalls have a similar weighted score, however score low in the environmental, legislative and social categories, and more notably, will result in significant change to the “natural coastal” beach amenity, inconsistent community sentiment (Alluvium, 2022).

Other types of seawalls score lower in the MCA and also do not meet community objectives in terms of natural coastal beach amenity.

A single long groyne at Point Norman and nearshore breakwaters score low on the MCA, however are actions which have been discussed in the community both prior to and during the CHA project.

Based on this, technical feasibility of a series of groynes, a single long groyne at Point Norman, and a series of nearshore breakwaters have been assessed for the Wreck Creek to Flat Rocks section of the coastline.

Table 4-5 Surf Beach Coastal Erosion Adaptation Actions

Surf Beach (Wreck Ck to Pt Norman)

Category	Category weighting	Assessment Criteria	Criteria weighting	Beach nourishment (single event)	Beach nourishment (ongoing management)	Geotextile bag seawall	Rock revetment	Vertical seawall	Living seawall	Groyne field	Long groynes	Nearshore breakwater
				Engineering Actions								
Environmental	*0.23*	Maintaining existing coastal process regime	*0.4*	8	7	4	4	3	4	3	2	4
		Maintenance of Marine Values	*0.3*	8	8	4	4	3	3	5	4	3
		Maintenance of Terrestrial Values	*0.3*	9	9	5	5	5	5	7	6	7
Legislative	*0.19*	Compliance with Victorian MaCS	*0.6*	8	6	2	2	2	3	3	2	2
		Complexity of approvals (inc. costs)	*0.4*	9	9	5	5	5	5	5	3	3
Social	*0.18*	Accessibility	*0.15*	7	10	5	4	4	4	7	5	4
		Beach Character	*0.2*	8	9	4	3	3	4	5	2	3
		Co-benefits	*0.15*	8	9	5	5	5	6	5	5	5
		Cultural Heriotage	*0.2*	6	6	6	6	4	4	7	8	8
		Maintenance of beach access and amenity	*0.15*	8	8	6	6	4	4	7	6	8
		Visual amenity	*0.15*	8	8	6	6	4	4	7	3	3
Economic	*0.17*	Initial financial cost (direct & indirect)	*0.5*	7	7	7	7	5	4	7	3	4
		Ongoing financial cost (direct & indirect)	*0.5*	10	4	9	9	8	7	9	8	7
Technical	*0.22*	Effectiveness for preventing shoreline erosion	*0.4*	2	10	10	10	10	10	8	4	5
		Period of design life	*0.05*	5	10	10	10	10	10	10	10	7
		Short term shoreline/tidal inundation protection	*0.075*	9	10	10	10	10	10	8	4	5
		Constructability	*0.075*	7	6	8	8	6	5	5	2	2
		Level of issues posed to adjacent beach	*0.15*	8	8	2	2	2	2	2	2	3
		Adaptability	*0.05*	2	8	8	7	5	5	7	7	4
		Safety	*0.2*	8	8	2	2	2	2	2	2	3
		TOTAL SCORE		**7.4**	**7.6**	**5.4**	**5.4**	**4.7**	**4.8**	**5.6**	**3.9**	**4.3**
		Ranking		**2**	**1**	**4**	**5**	**7**	**6**	**3**	**9**	**8**

5 TECHNICAL ASSESSMENT

The following engineering adaptation actions have been selected to further assess their potential effectiveness, performance and risks if applied to the coastline:

1. Beach nourishment to provide a sacrificial buffer to coastal erosion along the Bunurong Road between Flat Rocks and Wreck Creek seawall
2. A seawall to prevent erosion of the Bunurong Road between Flat Rocks and Wreck Creek seawall
3. A number of smaller groynes to reduce alongshore transport losses along Surf Beach
4. A large groyne to build up a wide beach and prevent loss of sediment from Surf Beach
5. Nearshore breakwaters to prevent loss of sediment from Surf Beach and reduce the incoming wave energy

The technical assessment of these actions has been designed to provide an overview of the general effectiveness, performance and risk to the adjacent shoreline. Within each action there are a suite of variations which can be further assessed to optimise the success and minimise the risks of the action. These additional investigations should be undertaken during detailed design phase when further information regarding the available budget can be used to tailor the solution.

5.1 Design & Investigation

5.1.1 Numerical Modelling

The detailed coastal processes assessments and numerical modelling used for this Technical Assessment were developed as part of the CHA and are reported upon in Report 3 and 4 (Water Technology 2022).

The alongshore transport modelling package LITPAK has been used to provide a 40 year hindcast of sediment transport potential along Surf Beach. The LITPAK model used a wave hindcast generated by the University of Melbourne (Liu, 2022) for the Victorian Coastal Monitoring Program. The 40 year numerical model hindcast was transformed inshore to Surf Beach to provide higher resolution wave climate data, however it is noted that this transformation has not been calibrated to locally measured inshore wave data, an action recommended prior to any detailed design investigation.

5.1.2 Design Conditions

This analysis provides a high-level technical feasibility assessment of the proposed actions. The analysis does not constitute a detailed assessment nor a detailed design investigation from which construction plans can be developed.

The proposed design life of the engineering actions is short, to 2040, in acknowledgement that these actions have been assessed in response to the community desire to address the short term erosion hazard along the Flat Rocks to Point Norman stretch of the coast, and that these actions may be part of an adaptation pathway in the longer term (Table 4-1). For some of the engineering structures, a longer-term design life and criteria may be more feasible and should be optimised during detailed design works.

Within this 10 to 20 year design life a number of design events were reviewed to determine the most appropriate level of protection to design to. The 2% AEP storm event was considered the most practical level, providing a balance between probability – an 18 to 33% chance of a design storm occurring within the design life respectively (Table 5-1), and the additional level of intrusion and cost associated with adopting a larger design storm.

It is important to note the probability of the design storm occurring in the next 20 years is 33%, or in the next 10 years is 18%, and whilst these events are considered "*about as likely as not*" or "*unlikely*" to occur, is not impossible they will occur and a response plan should be developed in conjunction with any coastal adaptation action constructed.

Table 5-1 Storm Events to consider and annual likelihood of occurring for a given exceedance probability

Annual Exceedance Probability (AEP) ***(Average Recurrence Interval, ARI)***	**Likelihood of Event occurring within**					
	1 year	**5 years**	**10 years**	**20 years**	**50 years**	**100 years**
(1 year)	0.63	0.99	1.00	1.00	1.00	1.00
20% *(5 year)*	0.18	0.63	0.86	0.98	1.00	1.00
10% *(10 year)*	0.10	0.39	0.63	0.86	0.99	1.00
2% *(50 year)*	0.02	0.10	0.18	0.33	0.63	0.86
1% *(100 year)*	0.01	0.05	0.10	0.18	0.39	0.63
0.1% *(1000 year)*	0.00	0.00	0.01	0.02	0.05	0.10

5.2 Bunurong Road Beach Nourishment

Beach nourishment was identified as the most preferred adaptation action for Bunurong Road to minimise coastal erosion risks. Design of beach nourishment is complicated by the unpredictable nature of coastal erosion. A design storm may occur the day after nourishment or may not occur at all within the nourishment design life.

The MCA identifies the need for continual beach nourishment to maintain the coastal protection. Thus, this technical assessment includes conceptual design of the volume of sand required to protect the shoreline from the 2% AEP storm, and estimation of the annual volume of sediment which, likely as a minimum, would need to be provided or returned to the coastal section.

5.2.1 Technical Effectiveness

5.2.1.1 Sacrificial storm protection

The design wave conditions impacting the shoreline from Flat Rocks to Wreck Creek have been established from a 40 year offshore hindcast which has been transformed inshore. The inshore wave climate has not been calibrated to measured data and wave conditions at the shoreline may be more or less impacted by the rock platform and refraction and diffraction around Cape Paterson than presented. Sensitivity testing of the incoming wave height was completed to assess the range in storm demand with wave condition. A variance of +/-20% of the wave height was found to result in a variation of -5% to +10% of storm demand, acceptable for a conceptual assessment of the sacrificial storm protection.

SBEACH modelling was used to determine the existing storm demand along Bunurong Road for the 2% AEP storm event. For consistency with the hazard mapping, a "double" storm was simulated where two 2% AEP events occurred in succession with no recovery of the beach in between storms. The beach profile was adjusted to represent nourishment with this volume and the design storm simulated to ensure the existing dune was protected.

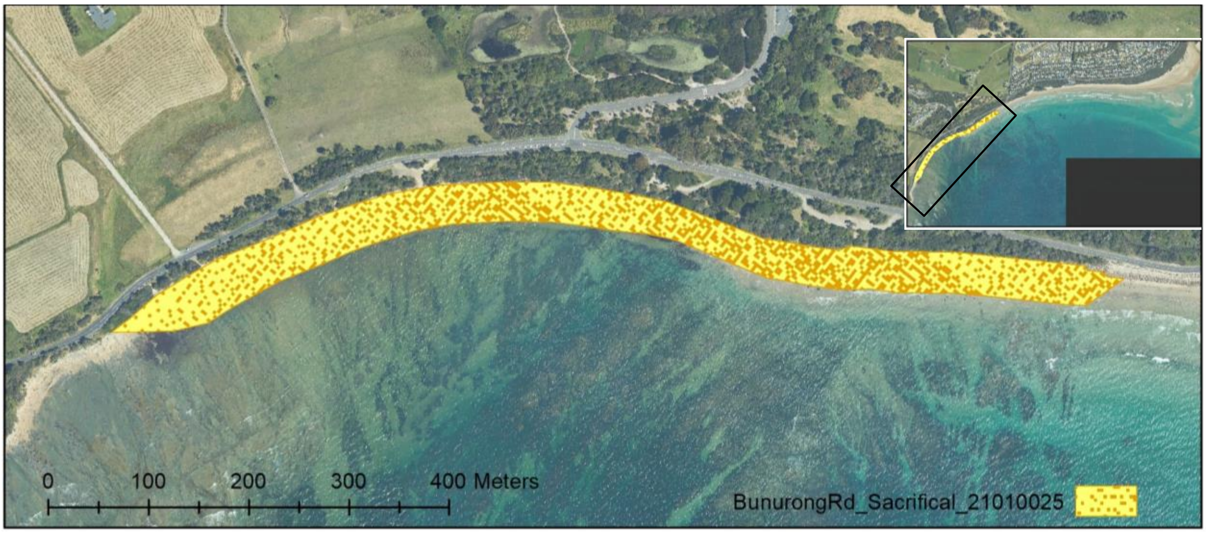
The volume of beach nourishment required to prevent erosion of the existing dune during the 2% AEP was in the order of 75 – 100m^3 per meter width of beach, at a crest level of 2.5m AHD and a width of around 40m. This is a considerable volume of material and would represent an initial nourishment volume of 75,000m^3 to 100,000m^3. The scale of the crest of the initial nourishment at 2.5m AHD on the existing beach is presented in Figure 5-1.

For comparison, the volume of recent beach nourishment projects completed by DELWP and Parks Victoria are noted in Table 5-2. Beach nourishment works within Port Phillip Bay were completed using a nearshore cutter suction dredge to pump material offshore onto the coast where it was spread by onshore plant. Works at Inverloch along the Bunurong Road/Surf Beach coast over the past 3 years have been completed using onshore plant to transport sand from Point Norman and the Ayr Creek lagoon dunes to the erosion sites. A combination of works would likely be required to nourish this stretch of beach given the large volume of material required and the shallow platform along the coast which would limit the ability of nearshore vessels.

Table 5-2 Recent Beach Nourishment in Victoria

Beach	Completion	Volume (m^3)	Cost (AUD)	Works Duration	Rate (per m^3)
St Leonards, Bellarine Peninsula	2021	24,000	$ 1.4 M	4 months (over approx. 2 y)	$58.33
Mt Martha, Mornington Peninsula	2021	25,000	$ 1.2 M	2 months	$34.83*
Tootgarook, Mornington Peninsula	2022	35,000	$ 890,000	2 months	
Bunurong Road seawall	2022	2,500	$ 48,000	6 days	$19.20
Inverloch SLSC seawall	2021	500 x 2	$ 16,000 (x2)	3 – 5 (each)	$32.00
Surf Beach (SLSC & Bunurong Rd)	2019	2,000 x 2	$ 60,000 (x2)	~ 10 days (each)	$30.00

* Mobilisation and demobilisation costs for beach nourishment at Mount Martha and Tootgarook were shared. A unit cost is shown based on the combined total cost and total volume nourished during the two projects



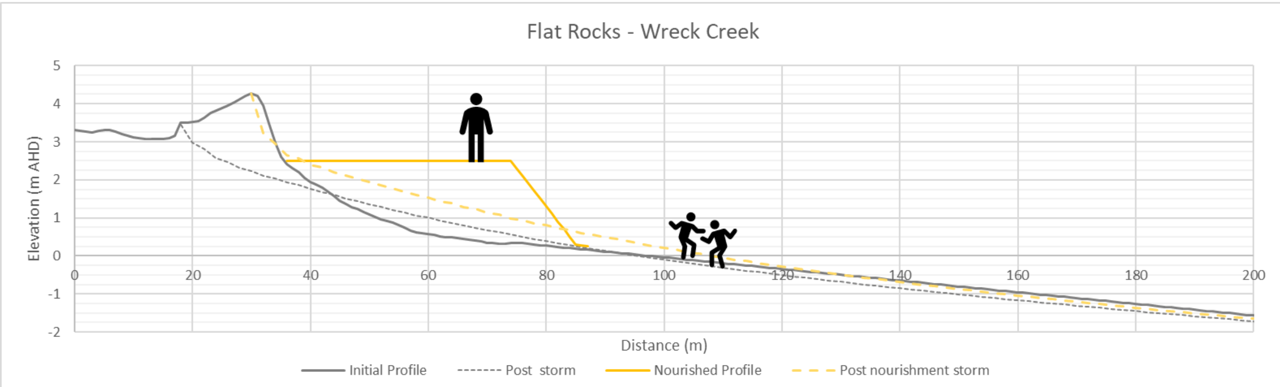


Figure 5-1 Conceptual extent of Sacrificial Beach Nourishment (NB. Profile horizontal and vertical scales not even)

5.2.1.2 Beach Management

To maintain the required beach volume for storm protection, regular top up or management of the material placed for nourishment would be required. Alongshore transport has been modelled using the numerical model LITPAK, described in Report 4. The net sediment transport along this stretch of the coast is eastward, with very little westward transport.

Reshaping of the sacrificial nourishment over time from the design profile (i.e. a wide, high crest) would result in sediment being available within the nearshore zone for transport away from the beach. As per the SBEACH modelling, there is no available measured data to calibrate the inshore wave model and the change in wave conditions across Flat Rocks. Alongshore transport rates determined by the model should be considered being in an order of magnitude scale.

The results of the LITPAK modelling indicate average annual net sediment transport potential of 150,000 – 250,000m^3 along the Flat Rocks coast. This represents sediment transport *potential*, and the transport is currently limited by the supply of material across the beach profile. As for the calculation of storm demand, the inshore wave climate has not been calibrated to measured data and wave conditions at the shoreline may be more or less impacted by the rock platform and refraction and diffraction around Cape Paterson than presented.

Modelling indicates around 40% of the predicted sediment transport potential occurs above the -0.5m AHD contour and thus a significant amount of the nourished beach could be expected to be lost over a 12 month period. To maintain the sacrificial storm demand beach, considerable, and ongoing, renourishment to provide ongoing protection to the 2% AEP event would be required – potentially replacing the full volume of the sacrificial beach on an annual basis.

5.2.2 Coastal Response

The effect on the neighbouring beaches from nourishment would be an influx of sediment as it is transported east. Surf Beach, between Wreck Creek and Point Norman, would benefit from the additional sand from a coastal hazard risk perspective. Under the existing beach environment, the sand would be expected to continue to migrate east across Surf Beach into the entrance.

The influx of this nourishment volume (potentially the full 75,000 to 100,000m^3) annually into the entrance may change the entrance dynamics. Whilst it is possible some material can be transported back to the Flat Rocks to Wreck Creek beach for renourishment, a greater amount in the nearshore zone would be available to enter the entrance, potentially changing the sediment balance within the entrance.

5.2.3 Risks

The influx of sediment into the Anderson Inlet entrance area is a key risk of large scale, and continual nourishment of the beach at Flat Rocks to Wreck Creek would be necessary to maintain dune protection. The complex dynamics of the entrance make prediction of the impact difficult to quantify and there are a wide range of potential responses. Examples of potential responses are:

- Increase in sediment from the west results in a migration of the entrance channel to the centre of the current entrance bar and an increased migration of the channel could result in increased erosion hazards along the Inverloch township foreshore.
- Increase of sediment results in a more significant shift of the entrance channel towards Point Smythe, eroding the point and creating a shorter entrance channel which bypasses the Inverloch coastline.

In addition to the potential risk to the entrance dynamics, loss of habitat across Flat Rocks is a concern with such a large influx of sediment which will be dispersed across the intertidal area.

Risks associated with construction of the nourishment and regular re-nourishment are as follows:

- Construction works
  - Some loss of dune vegetation could be expected along the beach during nourishment as machinery accesses the beach.
  - Significant truck movements, or pipe and dredge pumps would be required to place the material, posing a safety risk to beach users.
  - Ongoing management would result in more truck movement across the beach, impacting beach users and posing a safety hazard.
  - A suitable source of sand is required for ongoing nourishment and beach management. A sand supply of this magnitude may be difficult to find and multiple sources may be required for land based supply. A large dredge, capable of delivering sand inshore would be required for offshore sand supply. A suitable sand supply would need to be identified and the risks associated with removing the sand from the borrow site fully assessed.
- Inundation

    - Nourishment would required for protection from storm tide inundation from the sea, however the high dune would also prevent free drainage of the catchment and would result in extended (both in duration and extent) flooding of the low lying area landward of the road.
- Amenity
    - Construction of a 40m wide beach at 2.5m AHD elevation would change the amenity of the beach, especially the interface between the beach and the rock platform. The wide flat beach would initially be replaced by a high beach and steep face, then a wider flatter beach as the profile adjusts to the environment.

5.3 Bunurong Road Seawall

A seawall along the Bunurong Road coastline from Flat Rocks to the bridge over Wreck Creek would prevent structural failure of the road, and loss or damages to the services located in the road reserve through erosion of the coastal sand dune which currently provides a buffer between the road and the ocean wave and tidal forces.

The extent of a seawall to protect the road and services is presented in Figure 5-2. The wall would need to extent up to 1,000m along the coast to connect the higher land in the west with the existing Bunurong Road seawall.

Figure 5-2 Bunurong Road coastline, Flat Rocks – Wreck Creek Bridge

5.3.1 Technical Effectiveness

The objective of a seawall along the Bunurong Road would be to prevent the erosion of the sand dune buffer and maintain a stable footing for the road. Engineering design works can be used to achieve this for a short or long design life. Cost assessment would be required to establish the optimum level of design. Particular considerations for the design include:

- Toe design – toe of the seawall should be placed on bedrock where practical (i.e. if bedrock is not too deep). Closer to the Wreck Creek opening previous works have not encountered bed rock and as such the toe of the structure should be designed to be below the LAT to ensure scour of the beach adjacent to the seawall does not result in structural failure

- Material type / armour layer – the seawall would be exposed to direct wave action from the open coast. Wave energy would be tempered through diffraction and refraction across Flat Rocks and would be depth limited for much of the coastline due to the rock platform. However, significant wave energy, increasing towards Wreck Creek, could be encountered and engineering design should ensure suitably sized material is used to build a seawall.
- Overtopping
  - Drainage: at over +4.0m AHD, the crest of the existing Bunurong Road seawall is unlikely to be overtopped by wave setup during an existing or 2040 2% AEP design storm event. However, over wash may occur due to the elevated water level caused by an individual wave running up and over the structure. Depending on the exposure to the wave, including the dune and vegetation seaward of the wall, this runup could cause damage to the crest of the seawall and create unsafe traffic conditions during a storm event.

    Free drainage of this water, either landwards towards Wreck Creek, or back though the seawall should be included in detailed design.
  - Scour protection: in the event of over wash of the existing, extended or new seawall, scour protection may be required on the landward side to prevent erosion of material. The level and detail of scour protection should be determined in detailed design.
- Catchment drainage
  - The area landward of Bunurong Road is currently drained via a culvert at the western end of the road at Flat Rocks, or via Wreck Creek. Continued capacity of these drainage networks should be considered in detailed design.

5.3.2 Coastal Response

The construction of a seawall along an open coast introduces a reflective interface at the coast to the incoming wave energy. The generalised response of the coastline to a seawall is presented in Figure 5-3. The wave energy reflected off the face of the seawall leads to a loss of sand and lowering of the beach at the wall. The lower beach allows for higher waves and water levels at the wall, which spills over to the adjacent coastline, as does the lowering of the seabed. As the seabed lowers, the beach profile sets back to maintain the existing beach profile, resulting in terminal scour where the seawall is not in place.

Erosion of the seabed at the seawall would continue until the bedrock is encountered or the bed level is deep enough such that wave energy no longer reaches the bed of the seawall.

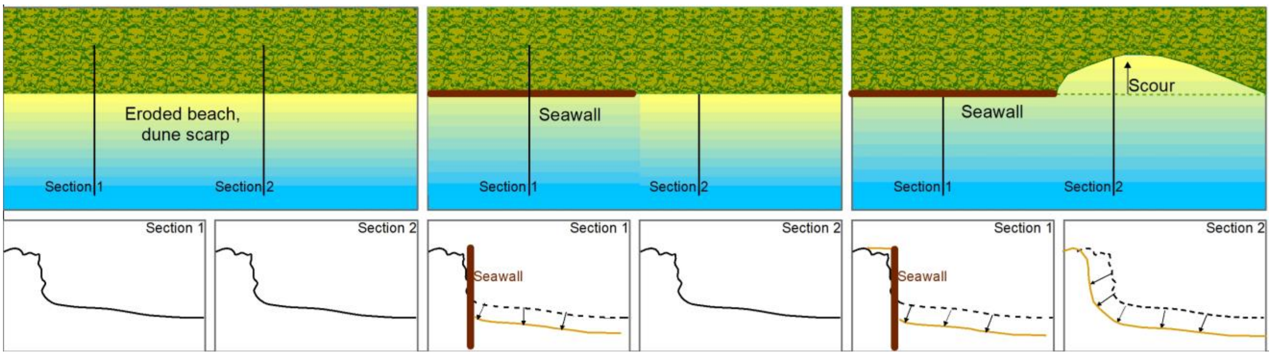


Figure 5-3 Coastal Response to Seawalls

In the initial period after construction of a wall, the strong longshore transport along the coastline would continue to push the existing beach material eastward towards the Wreck Creek mouth and Surf Beach.

However, following the exhaustion of the supply of sand, erosion, especially terminal scour would occur along the neighbouring coastline. Terminal scour at the end of a seawall can be observed at the Inverloch SLSC seawall. Terminal scour is caused by the lowering of the beach profile at the seawall which also lowers the profile directly adjacent to the seawall. This new beach profile drives the retreat of the unprotected dune landward. On flat beaches this point may be a significant distance from the seawall due to the low grade. An example of terminal scour at the Ocean Grove Main Beach is shown in Figure 5-4.

The distance of the terminal scour (both landward and along shore) is driven by a number of factors such as:

- Stable profile of beach at the seawall
- Height, volume and material (sediment and vegetation) within the natural dune
- Alongshore sediment transport, periods of "recovery" where sediment can be trapped within the terminal scour and help to rebuild the scour hole either temporarily or seasonally

The recent easterly conditions at Inverloch over summer have resulted in a reduction in terminal scour on the eastern end of the Inverloch SLSC seawall as material has accumulated in the scour hole. The western end of the wall, however, has experienced an increase in scour as sediment is not being supplied to this area.

Figure 5-4 Terminal Scour (Ocean Grove Main Beach, 2018)

5.3.3 Risks

Risk associated with construction of a seawall along the Bunurong Road area as follows:

- Construction works

  - A loss of dune, dune vegetation and beach could be expected along the seawall path during construction. Parts of the remaining dune are narrow and it is likely that in some parts dune could be lost completely with construction of the wall.
- Access
  - Access points may be limited due to the narrow zone available for construction of the wall.
- Inundation
  - Overtopping, backflow through Wreck Creek of catchment flows could lead to inundation of the low lying land behind the seawall. Drainage would be required through the wall.
- Terminal Scour
  - Erosion of the dune at the Wreck Creek bridge would result in the formation of a new mouth of Wreck Creek at the end of the seawall. This could impact the bridge foundations. Exposure of the bridge to direct wave energy during a storm event could also occur if terminal scour and the changing of the creek alignment widened the creek mouth at this point.
  - Erosion of the dune and vegetation adjacent to the wall would be expected.
- Amenity
  - Construction of a seawall would have a significant impact on the visual aesthetics of the beach from Flat Rocks to Wreck Creek
  - The lowering of the beach would have an impact on the availability of the beach and access to the beach area will be reduced as the lowered beach is increasingly inundated in high tide conditions.

5.4 Surf Beach Groynes and Nourishment

A series of short groynes and beach nourishment along the Inverloch Surf Beach from the Wreck Creek seawall east beyond the Inverloch SLSC would **reduce the rate of coastal recession** to the dunes which currently provide a buffer between the road, services (water, power, communications etc), residential areas and the ocean wave and tidal forces. The Surf Beach and Wreck Creek dunes and beach area are also highly valued by the community for their recreation and aesthetic values (Alluvium, 2022).

5.4.1 Technical Effectiveness

The objective of groynes and beach nourishment along the Surf Beach coastline is to prevent the erosion of the beach and sand dunes, whilst maintaining a vegetation buffer to the road. There are a range of variables which are to be considered in the design of a groyne field and nourishment program. These have been addressed in the following sections and an initial concept for groyne dimension and layout, as well as beach nourishment, provided.

The process of determining the length and spacing of groynes is presented conceptually in Figure 5-5. The following factors are considered, and the design of the groynes follows the practice described in CIRIA (2020):

- The volume of material to be used for beach nourishment
- The natural equilibrium or post-storm beach profile
- The depth and distance from the beach face where sediment will be lost through alongshore transport
- The spacing between the groynes which prevents erosion on the lee side of the groyne.

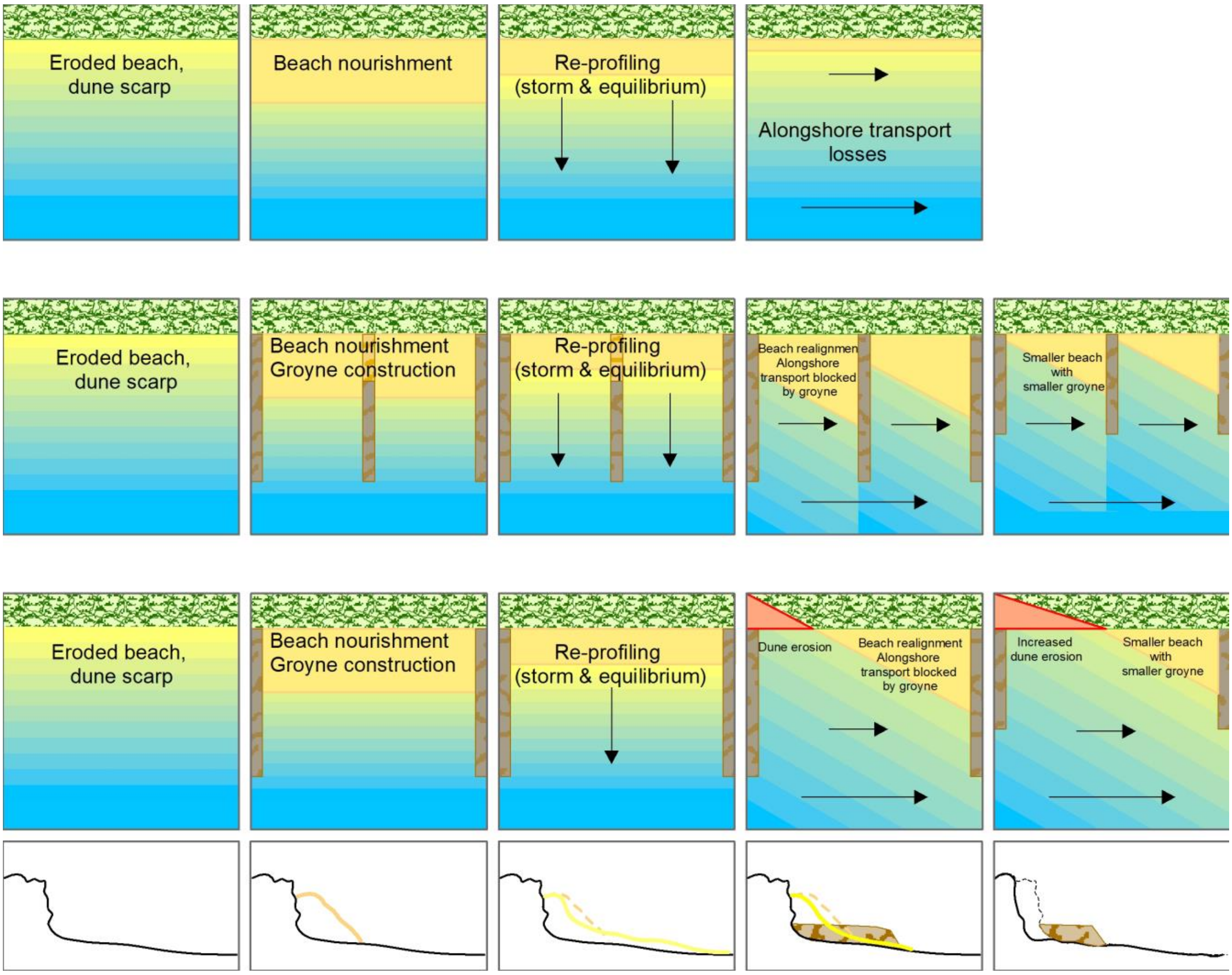


Figure 5-5 Considerations for determining groyne parameters

5.4.1.1 Groyne Length

The length of the groynes is driven by both the location/depth along the beach profile where the majority of the alongshore sediment transport occurs, and the balance between groyne length and groyne spacing to ensure groyne construction does not increase erosion of the dune on the lee side.

Typically, groynes are designed to ensure that the alongshore sediment transport which moves sediment along the coast is blocked by the groyne. The depth/offshore distance of the alongshore sediment transport is driven by the beach and nearshore profile and the wave climate. An exposed open beach is subject to larger waves which can drive sediment transport at greater depths than protected coastlines.

The LITPAK modelling indicates the sediment transport occurs primarily in depths less than -3m AHD along this coast. This is presented in the modelling results in Figure 5-6 which represents the transport potential just west of the SLSC. A negative sediment transport potential rate indicates transport to the east and a positive sediment transport potential indicates transport west. The net sediment transport is the positive (west) plus negative (east) transport. There is a strong net negative (east) transport potential over the 40 year hindcast with negligible westward (positive) transport potential.

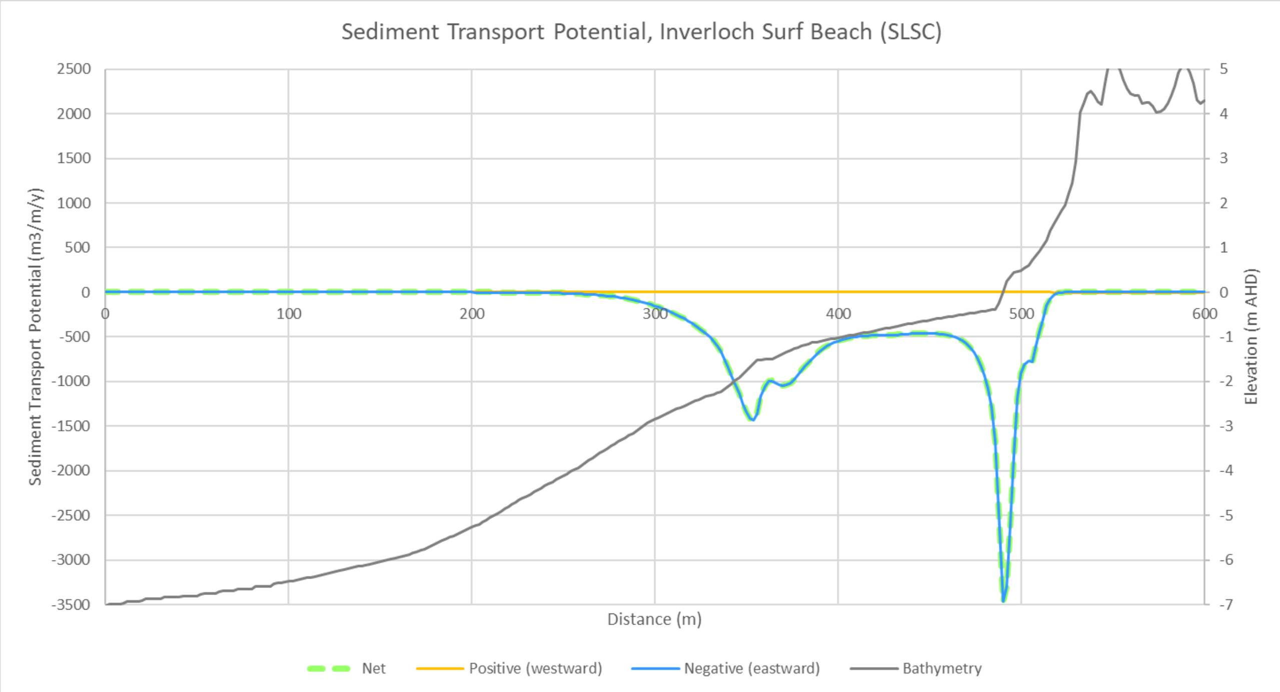


Figure 5-6 Sediment Transport Potential across the beach profile, P006

This net negative transport reduces in volume from west to east as the nearshore contours become more parallel to the incoming wave as shown in Figure 5-7 where the average annual net sediment transport across the depth profile is shown for profile 2 through 10, shown in the lower figure of Figure 5-7. The arrows on the figure illustrate the proportion of sediment transport potential at different depths to assist in designing the appropriate length of the groyne.

Although transport of sediment can occur beyond the -3m AHD contour, the majority of transport, i.e. 90%, occurs in depths shallower than -2m AHD whilst 60% occurs above the -1m AHD contour. To block 80% of the transport, the groyne needs to extend to around -1.5m AHD.

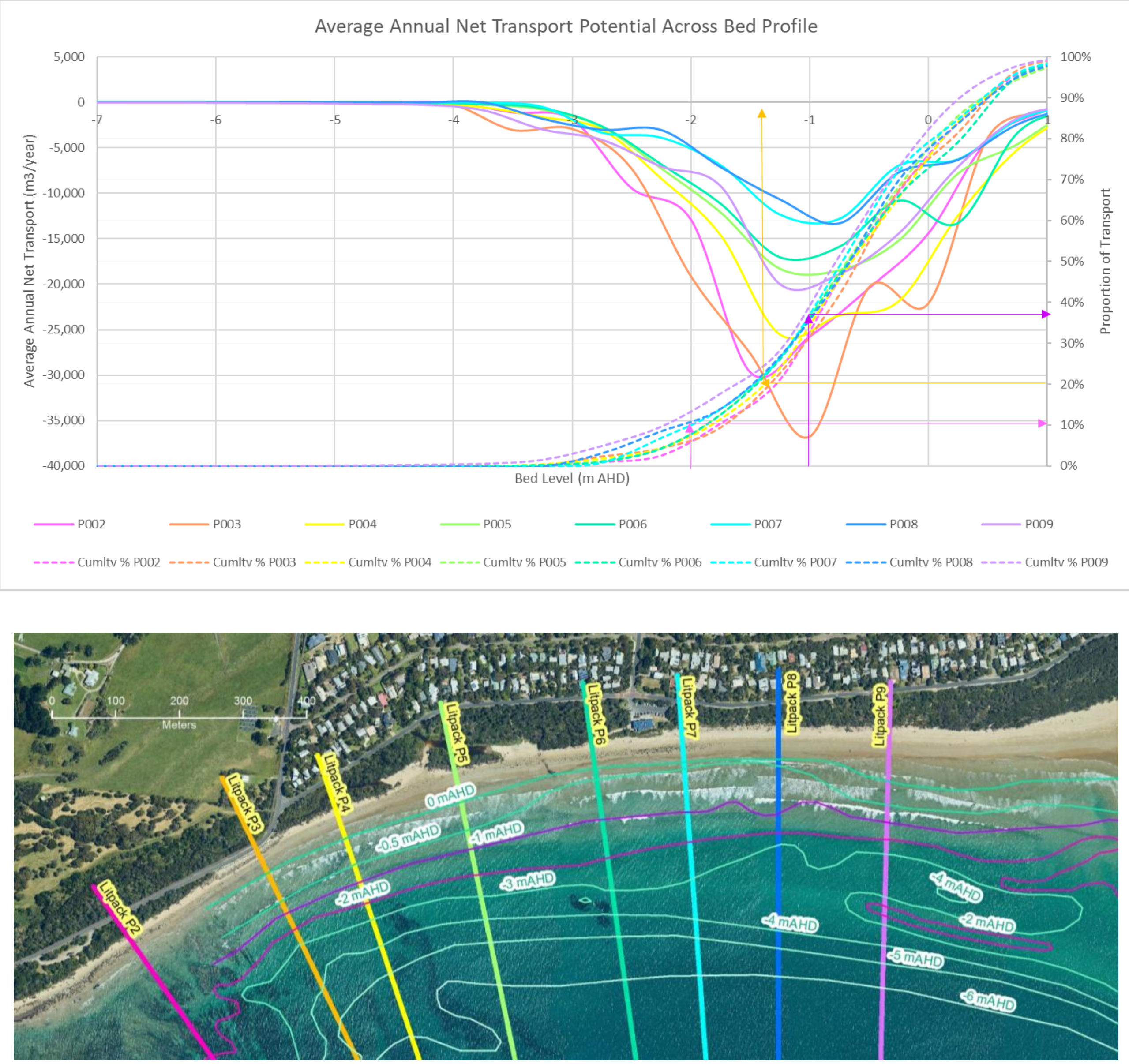


Figure 5-7 Net Sediment Transport Potential Surf Beach Profile (P007)

5.4.1.2 Sacrificial Beach Width

The SBEACH model has been used to assess the volume of sand required on the equilibrium beach to prevent erosion of the existing coastline in a 2% AEP storm. As noted in Section 5.1, the 2% AEP storm event is statistically *unlikely* to occur during the proposed design life (i.e. to 2040) of the groynes and beach nourishment and thus is considered a reasonable level to design to. It is important to note this does not mean the 2% AEP storm event will not occur immediately after construction and beach nourishment or in the design planning horizon, rather there is a low probability that it will. If a 2% AEP storm event occurs and removes the material designed to prevent erosion of the existing coastline, additional beach nourishment will be required.

The 2% AEP storm wave height and water level have been derived from a 40 year hindcast of wave and water levels, as described in Report 3 and Report 4. As with the modelling completed for the hazard mapping two consecutive 2% AEP storm events have been simulated to develop conceptual beach volume, to provide a conservative estimate of storm demand.

A number of different nourishment volumes were tested along the Surf Beach shoreline until the post-storm beach profile indicated the nourishment volume could protect the existing dune and coastline. Pre and post storm beach profiles for three profiles along the beach show the varying storm demand and beach nourishment required at the equilibrium beach to prevent erosion of the existing shoreline in Figure 5-8.

Beach widths required are in the order of 45 to 80m to provide a beach volume to balance storm demand between 75 and 100m^3/m.

The coastline nearest to the Bunurong Road/Wreck Creek bridge at Profile A is the most vulnerable to large storm events. The existing primary dune height of 3.3m AHD is below the total coastal water level under a 2% AEP storm event and it is difficult to generate an equilibrium beach which will prevent any damage to the primary dune. However, as shown in Profile A, Figure 5-8, whilst there may be some over wash of the dune into Wreck Creek, the modelling indicates the nourished beach profile will prevent retreat of the coastline during a 2% AEP storm event.

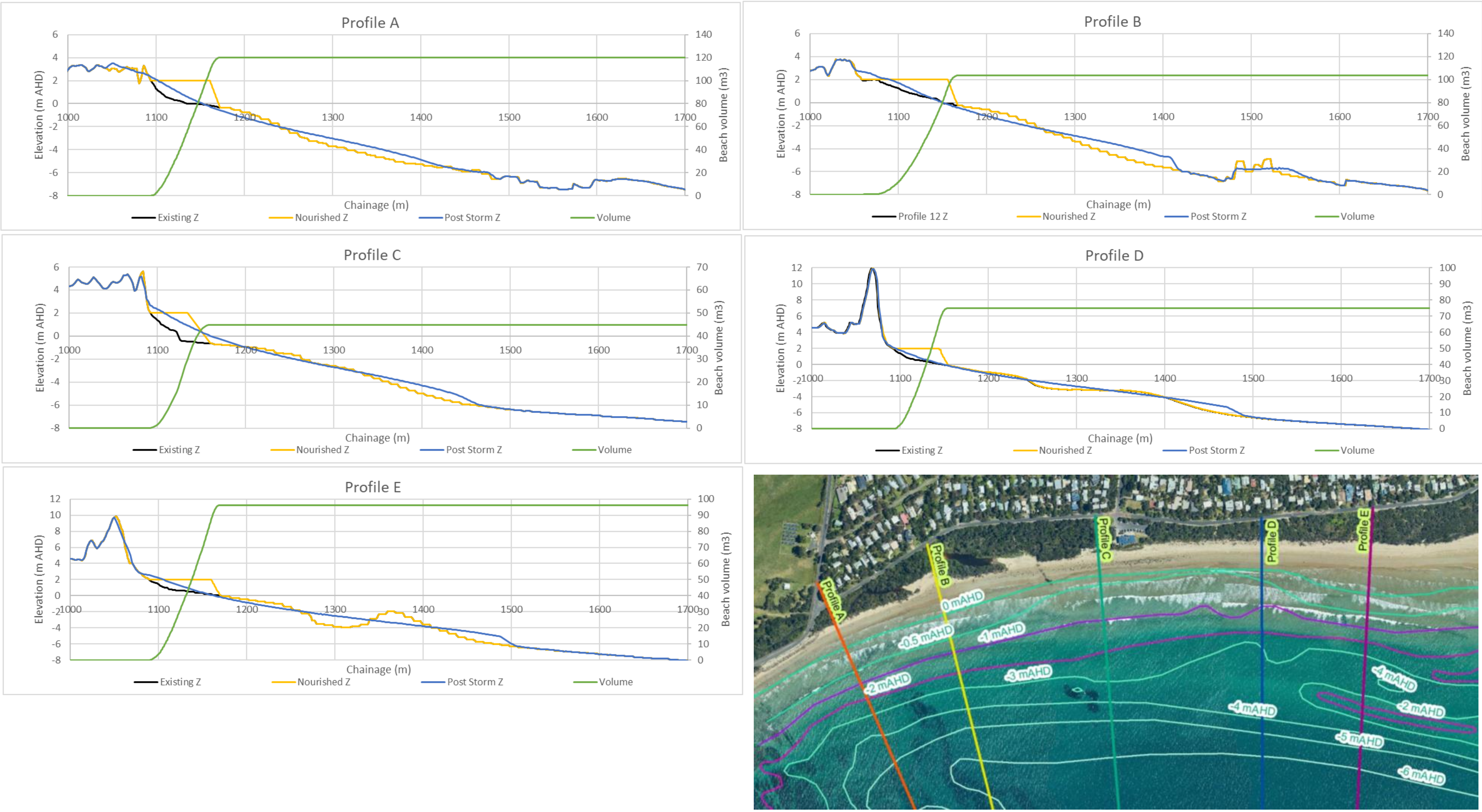


Figure 5-8 Pre- and post-storm beach profile

5.4.1.3 Groyne Spacing

The final element of groyne field design is to determine the spacing between the groynes. The construction of a sequence of groynes along the beach is completed to ensure that the realignment of the beach at the new groyne does not result in erosion along the adjacent coast (Figure 5-9). The distance between groynes is a function of the volume of sand used in beach nourishment and required on the equilibrium beach, the stable beach alignment (i.e. where the beaches and nearshore contours face the incoming wave energy and net sediment transport approaches zero) and the length of the groyne which in turn influences the capacity of the new beach to realign to the stable beach angle. A general rule of thumb is groyne spacing 2 to 4 times the length of the groyne (Van Rijn, 2004).

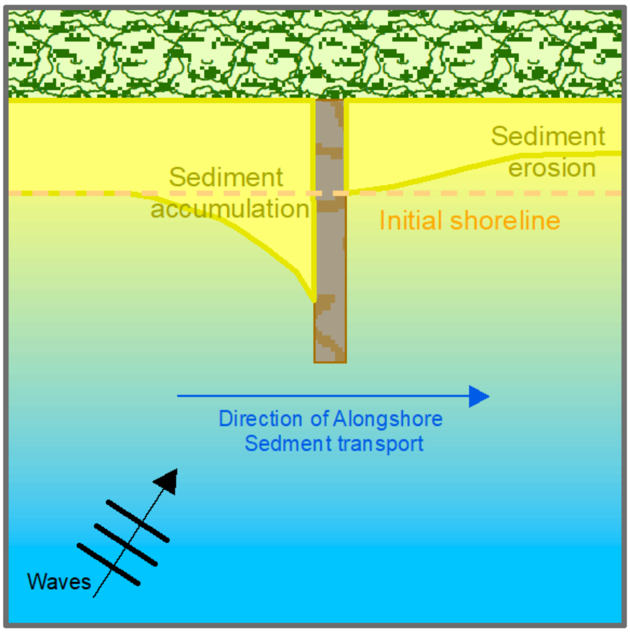


Figure 5-9 Erosion of adjacent shoreline due to groyne construction

The LIPTAK modelling has been used to provide additional information on the groyne spacing. The modelling has been used to establish the stable beach alignment along Surf Beach where the net sediment transport is zero (i.e. transport west is equal to transport east). The stable beach alignment along the coast ranges from 175 degrees (i.e. facing just east of south) at Wreck Creek to 195 degrees (facing west of south) towards Point Norman as a result of refraction of the incoming wave into Surf Beach. The stable (i.e. net zero transport) beach alignments are shown in the top image in Figure 5-11.

The refraction of the incoming wave has also been used to determine the alignment of nearshore contours from the dominant southwest (225 degree) wave. The nearshore contours help to determine the change in the bed profile with groynes, and the potential reduction in efficiency as the beach stabilises. The nearshore contours square with the incoming wave are presented in the middle figure in Figure 5-11.

Whilst the initial length of the groyne was proposed to terminate at -2m AHD to block 90% of the sediment transport (Figure 5-7), schematic development using the sacrificial beach width and the realigned depth contours indicated the depth contour at the end of the groyne may reduce to -1m AHD, allowing up to 60% of material to bypass. Groynes have thus been extended beyond the -1m AHD contour to the new -1.5m AHD contour to block up to 80% of the transport.

The lower image in Figure 5-11 shows the conceptual groyne design, stable beach and sacrificial beach to reduce the coastal erosion hazard along the Surf Beach to 2040.

This is a preliminary arrangement to explore the technical feasibility of a groyne field. Optimisation of groyne length and spacing should consider the inshore wave climate in more detail, specifically calibration of the transformation of the offshore wave climate inshore. Position and spacing of the groynes and beaches can be optimised through design work and consultation with key stakeholders (e.g. SLSC, local surf schools, beach users etc).

5.4.1.4 Groyne Height

Additional design considerations include determining the height of the groynes. The following aspects are assessed in design of groyne crest level (height):

- Safety
- Constructability
- Visual impact

Groynes are typically constructed with a crest above the high water level to ensure they do not pose a navigation hazard. Whilst a submerged groyne may provide a better visual outcome, they will provide a hazard to both boat users and those swimming and surfing in the nearshore waters.

The average annual peak water level, based on the 40 year numerical hindcast is in the order of 1.8m AHD offshore compared with the 2% AEP storm tide level for present day conditions of 2.15m AHD, indicating the minimum level for a groyne would need to be at least 1.8 to 2.0m AHD to minimise regular overtopping. It is important to note this represents the still water level, and waves may break over or onto a groyne at this level and detailed design works are required to establish the correct crest level of a groyne in the surf zone.

At an elevation of 2.0m AHD, the groyne would be 4m in height at the seaward end and (based on a typical slope of 1:1.5 and a crest of 2m wide) 14m wide. The groynes would have a **<u>significant</u>** visual impact across the beach, especially during low water. A scale conceptual cross section is provided in Figure 5-10.

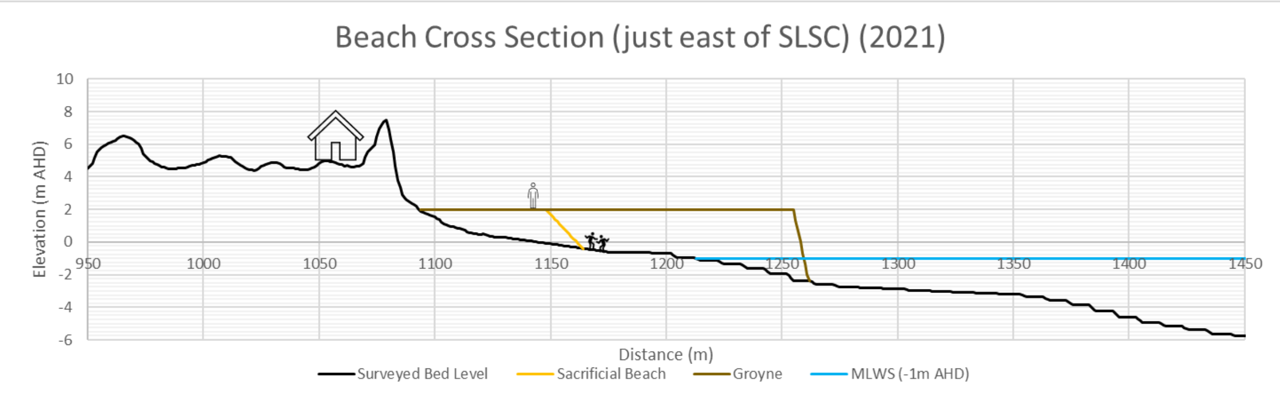


Figure 5-10 Conceptual Groyne Cross Section

5.4.1.5 Nourishment Volume

Beach nourishment will be required to allow realignment of the nearshore profiles and coastline to the sacrificial width required to protect the coastline as shown in Figure 5-11. An estimate of beach nourishment volume has been established by calculating the volume of sand required for the sacrificial beach plus an allowance for beach realignment as shown. The total volume of initial beach nourishment, and the volume per linear meter of the beach at nourishment for a level of +2m AHD is presented in Table 5-3. Beaches are denoted A through C from west at the Bunurong Road seawall (A) to east towards Point Norman (C).

Table 5-3 Beach nourishment required for multiple groynes

Beach	Volume required for sacrificial beach (m^3)	Additional volume to allow for realignment(m^3)	Total Initial Volume (m^3)	Volume per m beach (m^3/m)
A	20,000	15,000	35,000	125
B	30,000	35,000	65,000	140
C	20,000	15,000	35,000	100

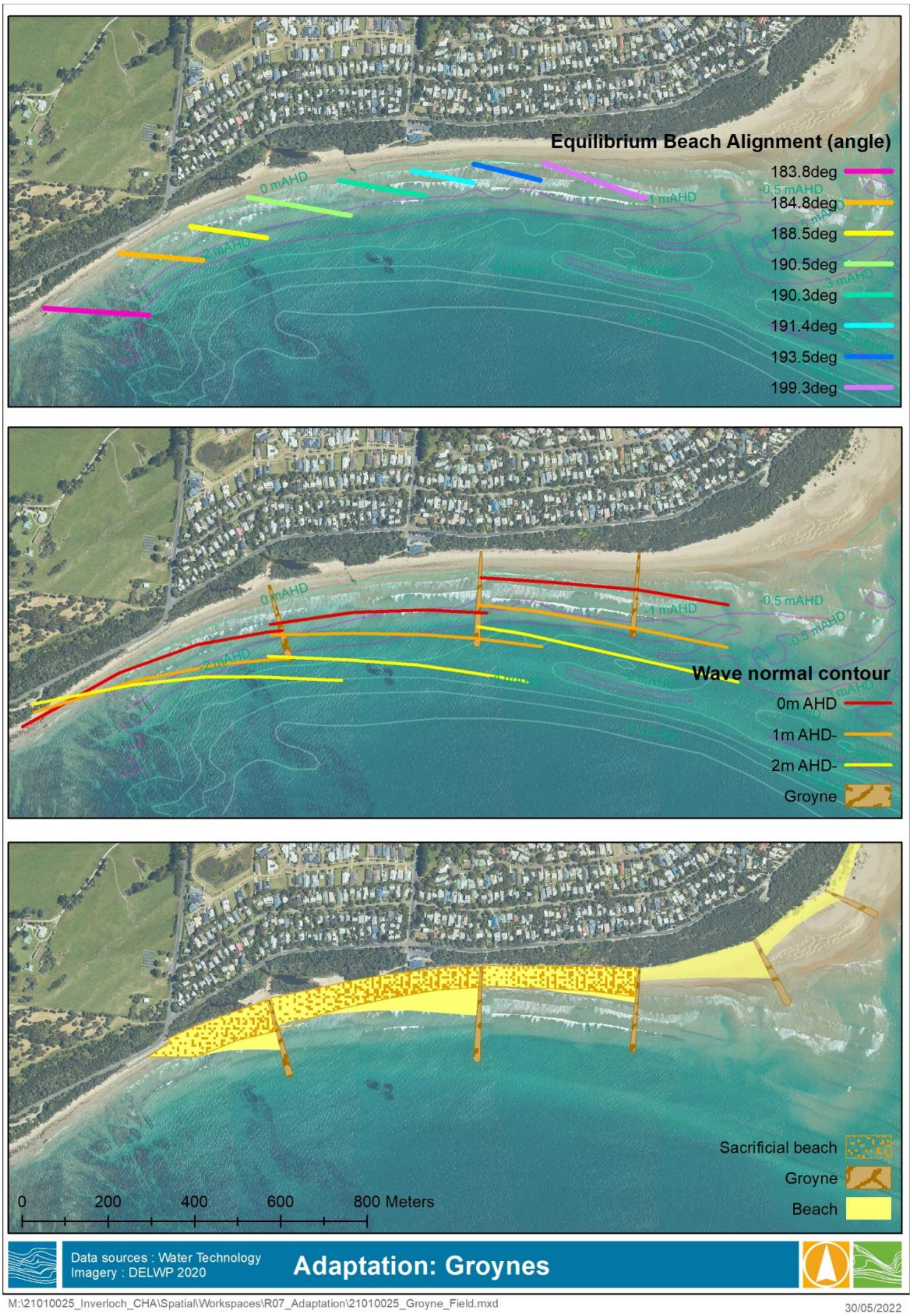


Figure 5-11 Conceptual groyne configuration

5.4.1.6 Alternative arrangements

The technical assessment described above has used the understanding developed in the coastal process investigation carried out for the Inverloch Region CHA to develop a solution which is most likely to be technically feasible. Groynes of this size and extent may differ from what is observed on other coastlines or thought to be a viable adaptation action. Common alternative proposals noted through the consultation, but not suitable for Surf Beach, are noted below:

- Short groynes
  - The recession at Surf Beach is driven by the combination of onshore-offshore movement of sand during calmer and stormier periods respectively and the strong net easterly alongshore transport. The alongshore transport peaks at depths of 1.5 – 3m of water so short groynes which do not interrupt this transport will not prevent the loss of beach and dune material.
  - An example of this is the negligible impact the (dilapidated) Wreck Creek training wall has on beach alignment.
- Apollo Bay has (relatively) shorter groynes at 70m to protect the Great Ocean Road
  - The groynes at Apollo Bay have been constructed in conjunction with a rock seawall to prevent the recession of the coast over a much longer planning horizon. A rock seawall is not proposed for Surf Beach.
  - As described above, alongshore sediment transport occurs in depths of 1.5 – 3.0m of water. At 70m long, groynes at Surf Beach will terminate at 0 to -0.5m AHD and not block alongshore sediment transport.
- Low timber groynes at Cowes
  - The low timber groynes at Cowes East on the northern coast of Phillip Island are not exposed to the ocean wave climate like Inverloch Surf Beach. Similar groynes at Inverloch would be damaged during storm events.
  - The groynes at Cowes appear to have been successful at trapping sand on the beach in the west, however this has starved the beach to the south and terminal scour is visible. Works are being completed at the western end including the construction of a rock seawall to prevent erosion of the coast (a feature not desired at Inverloch Surf Beach) and additional groynes to trap more sediment.

5.4.2 Coastal Response

The response of the coastline at Surf Beach to construction of beach groynes and beach nourishment is presented in Figure 5-11. To the west of the "Beach A" groyne, the existing Bunurong Road rock seawall would prevent any end scour effects, or over rotation of the Beach A to the first groyne.

However, at the eastern end of the groyne field, the response of the coastline is more complex and would be influenced by the changed sediment influx and the morphology of the entrance channel, which would be itself influenced by the changed sediment influx from the interruption posed by the groyne field.

The typical treatment at the end of a groyne field is to taper the groyne length and spacing to allow increased bypassing and a return to existing net sediment transport processes along an open coastline.

At and around Point Norman sediment transport is not only a product of the incoming wave energy, but also the ebb and flood tidal flows which shift sediment and result in erosion and accretion of the shoreline. The angle of the shoreline and depth and position of the ebb tide delta also impact the wave driven sediment transport around Point Norman. The response of the coastline around Point Norman during the design life of the groynes is thus difficult to define as these complex processes would vary local hydrodynamics and sediment processes.

5.4.3 Risks

Construction of a series of groynes, combined with beach nourishment, is a technically feasible option for protecting the shoreline at Surf Beach, however there are risks involved in the design, construction and implementation of a groyne field. The following provides an initial pass of potential risks to Surf Beach and the identified values to highlight the challenges posed by the action.

- Construction works
  - A loss of dune, dune vegetation and beach could be expected along the beach during construction with the movement of plant, and the excavation required to construct secure footings.
- Inundation
  - The nourished beaches will prevent the drainage of Wreck Creek across the beach surface.
    - The Creek could be trained along the edge of a groyne however this will reduce the effectiveness of coastline protection from beach nourishment.
  - The low dunes at the western most beach (Bunurong Road / Wreck Creek) are likely to be overtopped during a 2% AEP storm event. If this dune is overtopped dune material will be deposited into Wreck Creek and could cause the creek to have further reduced drainage capacity and result in inundation upstream.
- Beach nourishment
  - Nourishment has been designed to be sacrificial and it is assumed that the protection offered by beach nourishment will be lost or largely diminished following a 2% AEP storm event. Following a large storm renourishment will be required.
  - The volume of nourishment assumes the beach will realign to the long term wave angle and remain largely within the groyne cell. Loss of beach material without renourishment following storm events will over time result in a narrowing of the protective beach along the coastline.
  - A suitable source of sand is required for ongoing nourishment and beach management.
- Amenity
  - Construction of a series of groynes will have a significant impact on the visual aesthetics of the coast along Surf Beach.
  - The equilibrium alignment of the coastline is notably different to the current alignment. If the beach extended out to the stable alignment, the beach width would be significant in parts.
  - The nourishment (depending on nourished material) would likely result in a high dry beach followed by a steep slope at the water face to meet the existing flat beach, notably different to the existing wide flat beach.

In addition to risk to the Surf Beach coastline, there are significant “neighbouring beach” risks from the groyne construction. Specific responses to the groynes at Surf Beach could include:

- Erosion of the coastline eastward of the most eastern groyne as sediment would be blocked by the groyne field.
- Construction of the groynes around Point Norman to prevent this groyne-driven terminal scour may result in scour of the bed at the groynes as current shears off the channel alongside the groyne. This could cause a positive feedback and draw the main channel closer to the groyne as scour increases.
- Undercutting of groynes by the migrating channel could cause the structure to fail and collapse. This could lead to erosion of the adjacent shoreline.

- A change in sediment supply within the entrance and a migration of the entrance channel towards groyne-driven terminal scour could lead to scour of the dunes north of Point Norman and recession of the coastline towards Surf Parade and Veronica Street. Review of early aerial photography indicates the dune here was once much narrower (30m) and the channel closer to the residential area.
- The beach alignments are based on the long term wave climate. An extended deviation from the long term climate has been observed in more recent times contributing to the rapid recession of the Surf Beach coastline. A similar deviation from the long term wave climate could change the beach angle or distance offshore at which sediment transport occurs, resulting in a different response or equilibrium beach.

Additional groynes have been sketched to illustrate the potential need for extended coastal protection in response to groynes on Surf Beach in Figure 5-12. The groynes are presented on the aerial image from 2009 to highlight the shifted position of the channel along the Ayr Creek shoreline and the vulnerable nature of this coastline. The construction of groynes often results in the construction of more groynes until the full length of the coast is similarly protected.

From a technical standpoint, it is feasible to construct groynes and complete beach nourishment to prevent erosion of the existing shoreline. Three primary disadvantages are as follows:

- The groynes and beach nourishment will pose a significant change to the visual amenity and way Surf Beach is utilised.
- Ongoing commitment to and investment in beach monitoring and maintenance nourishment would be required to ensure the sacrificial beach is maintained to provide protection from a storm event.
- The impact on the coastline around Point Norman cannot be accurately resolved. Impact may be within the existing range of channel movement, or the changed sediment supply due to the groynes may result in a channel change outside of the bounds experienced previously.

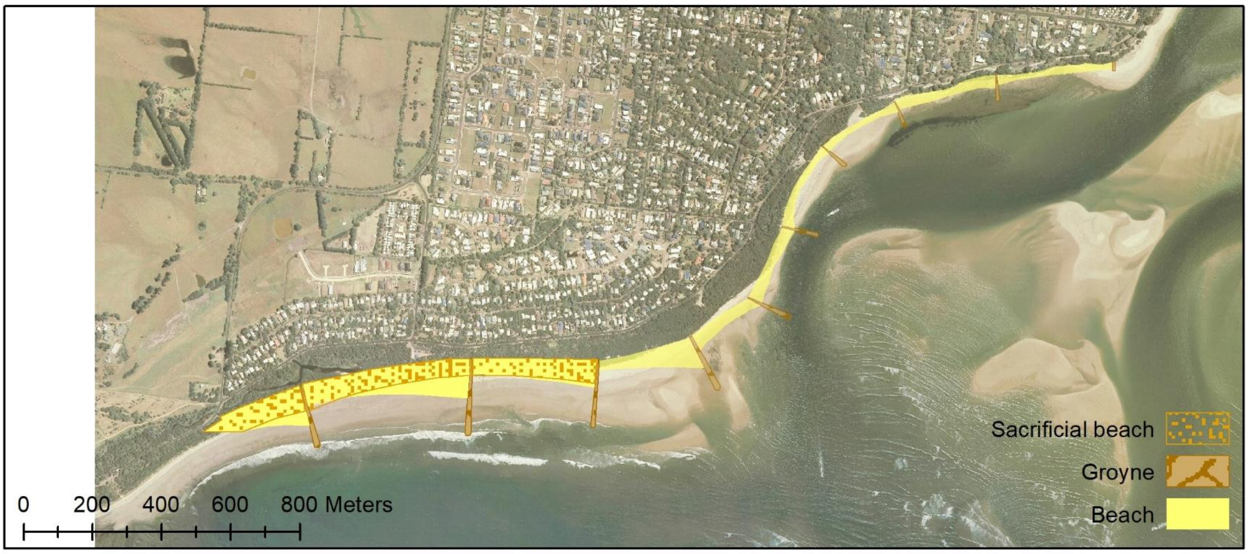


Figure 5-12 Surf Beach Groyne Field Extension

5.5 Long Groyne at Point Norman

A single long groyne/breakwater at Point Norman has also been modelled to **reduce the rate of coastal recession to the dunes** which currently provide a buffer between the road, services (water, power, communications etc), residential areas and the ocean wave and tidal forces. The Surf Beach and Wreck Creek dunes and beach area are also highly valued by the community for their recreation and aesthetic values.

A long groyne or breakwater has been proposed for Inverloch previously as early as 1890 where a survey chart by J. B. Mason presents a long crib wall with a proposed dredged channel to train the entrance channel across the bar into deeper waters. A similar proposal is presented in survey by T. H. Smith in 1910 with a stone groyne and crib wall extending seaward from Point Norman (Figure 5-13).

However, it is likely these proposals were presented to provide safer navigation across the bar to Inverloch rather than prevent recession of the coastline at Surf Beach. Training walls to enable permanent and safer navigation into tidal estuaries was common practice in the early 20th Century and the entrance to the Gippsland Lakes at Lakes Entrance provides a good example of the ability of engineers at the time to achieve this.

A long groyne at Point Norman assessed herein has the function of preventing recession of Surf Beach for the short-term planning horizon (i.e. through to 2040) whilst other actions on an adaptation pathway can be progressed.

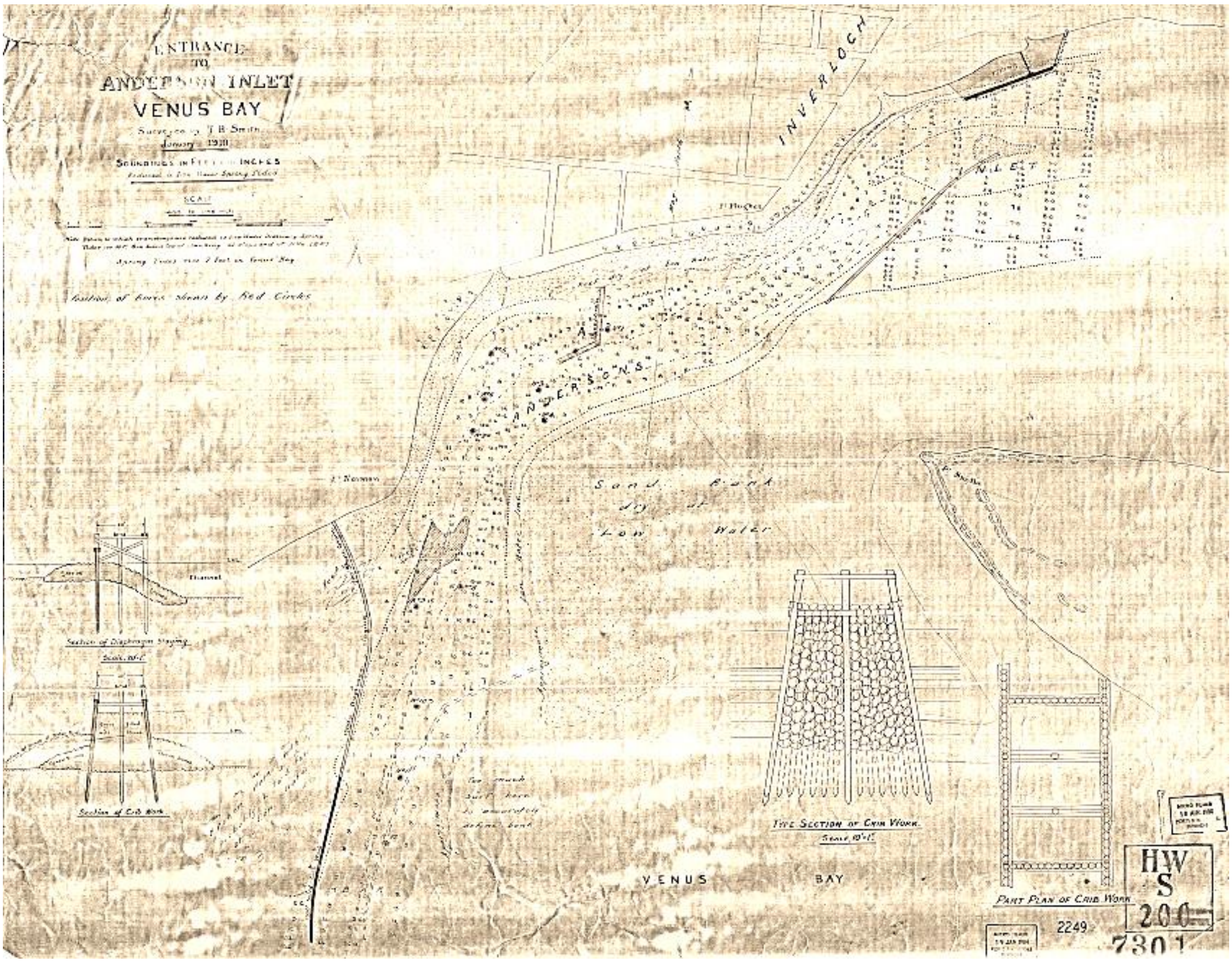


Figure 5-13 Previous long groyne designs (T.H. Smith, 1910)

5.5.1 Technical Effectiveness

Like the groyne field and beach nourishment option assessed in Section 5.4, to prevent erosion of the existing shoreline at Surf Beach a long groyne must retain a stable beach along the shoreline which provides a buffer to storm events and realigns the beach to minimise the loss of sediment from alongshore transport.

5.5.1.1 Sacrificial Beach Width

The beach width required to prevent erosion of the existing coastline from the 2% AEP storm has been determined using SBEACH, as detailed in Section 5.4.1.2.

The sacrificial beach width varies along the coastline and is generally between 50 and 80m in width at a 2m AHD crest level. The sacrificial beach is shown in orange in the long groyne layout in Figure 5-14.

5.5.1.2 Groyne Length

As with the shorter groynes, to prevent loss of material which builds up along a long groyne, the groyne would need to extend beyond the depth where the majority of alongshore sediment transport occurs. Again, as material builds up on the long groyne, the beach and nearshore contours would align as noted above and the -2m AHD contour, which is noted in Figure 5-7 as the point at which 90% of transport occurs inshore of, would migrate seaward.

The realigned contours shown in Figure 5-14 indicate the length of the long groyne required could be in the order of 500m, potentially beyond the current edge of the entrance delta bar. The distance to the 0m AHD contour (280m) and the -1m AHD contour (400m) are shown for reference.

5.5.1.3 Stable Beach Alignment

The stable beach alignment is the alignment which the beach and nearshore contours would adjust to following construction of a long groyne as material builds up on the wave facing side of the groyne. The groyne would need to be long enough to support the realignment of the coast to the equilibrium beach alignment.

Section 5.4.1.3 details LITPACK modelling which has been used to estimate the stable beach alignment and nearshore depth contours aligned with the dominant incoming wave. The stable beach alignment for each beach profile at the edge of the sacrificial beach is shown in the top image in Figure 5-14. The nearshore contours realigned to the incoming wave angle are presented in the middle image.

However, the alignment of the beach, when assessing both the net zero sediment transport stable beach, and the realignment of the nearshore contours to the incoming waves, is very difficult to determine. The beach would be more likely to take the form of the nearshore contours, however net sediment transport at the western end of the beach, adjacent to the Bunurong Road / Wreck Creek seawall may result in constant erosion of the sacrificial beach and beach management (relocation of sand from the east to the west) may be a regular requirement.

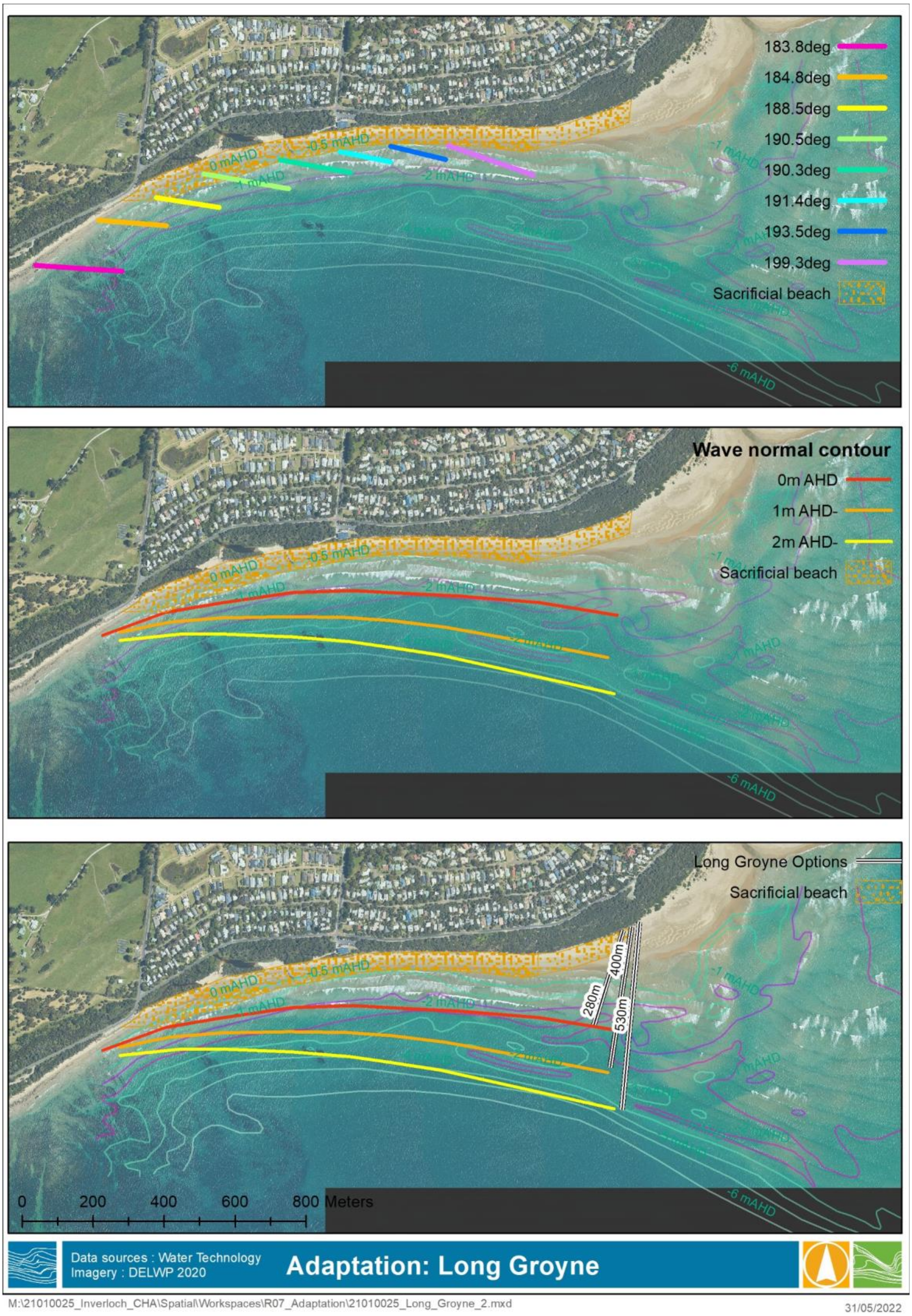


Figure 5-14 Long Groyne Concept

5.5.2 Coastal Response

The distance of the groyne from the coastline west of the Bunurong Road / Wreck Creek seawall, and the dominant net eastward sediment transport means there would be little impact from the groyne on the coastline west of the seawall. The constant rotation of the beach would require monitoring and potential beach management as noted above to ensure the beach alignment did not result in erosion of the sacrificial beach adjacent to the seawall.

To the east of the groyne the impacts would be significant, and like the groyne field, difficult to accurately predict given the complex interaction between wave driven sediment transport and the ebb and flood tide forces of the entrance channel.

The interruption to the supply of sediment along the beach to the coast north/northeast of the groyne (into Anderson Inlet) will result in erosion of the coast as waves from a more southerly direction push material north and sand is not able to infill. As this happens, a tidal channel may form along the groyne and eventually realign the entrance to attached to the channel. The groyne would need to be constructed with significant footings to anticipate this change in depth at the toe. Migration of the channel to the groyne may result in the channel resuming a previous path close to the coastline along Surf Parade towards Ayr Creek and the existing, poor condition, coastal protection would need repair and reinforcing, or an additional groyne field established along this coast as presented above in Figure 5-12.

5.5.3 Risks

Unlike a series of groynes which can be complimented by nourishment to form smaller pocket beaches to protect the shoreline, a single large groyne creating a realigned beach at Surf Beach would be very unlikely to provide stable protection to the existing coastline due to the natural beach alignment and the volume of sand required to build up along the groyne at Point Norman to provide protection to the dunes at Wreck Creek. Thus, the primary risk is that the single groyne is ineffective at protecting the shoreline.

Additionally, the following potential risks are noted:

- Construction works
  - Safety to workers and plant to construct a groyne extending 500m+ offshore
  - Availability of material and plant to construct long groyne – the size of individual armour rocks required for the groyne would be considerable and sourcing of the volume required to construct the groynes to sufficient depth would be difficult. The additional need to protect against future toe scour would complicate construction and increase costs.
- Beach nourishment
  - Beach nourishment should be carried out with the construction of a groyne to prevent erosion of the existing beach. Until the beach reaches an equilibrium alignment beach nourishment would be required to protect the existing coastline. This would need to be continued for some time.
  - A suitable source of sand is required for ongoing nourishment and beach management.
  - The sacrificial beach has been designed to offer protection in a large storm event, after which the beach will be lost or largely diminished. Renourishment would be required to maintain the erosion hazard reduction.
  - Loss of beach material without renourishment as required over time will result in a narrowing of the protective beach along the coastline.
- Inundation

  - If nourishment of the beach occurred in tandem with the groyne construction, the nourished beaches would initially prevent the drainage of Wreck Creek until the net sediment transport allowed the creek to reopen.
  - The low dunes at the western most beach (Bunurong Road / Wreck Ck) would belikely to be overtopped during a 2% AEP storm event. If this dune was overtopped dune material would be deposited into Wreck Creek and could cause the creek to have further reduced drainage capacity and result in inundation upstream.
- Amenity
  - Construction of a large groyne would have a significant impact on the visual aesthetics of the beach along Surf Beach and Point Norman.
  - The equilibrium alignment of the coastline would benotably different to the current alignment. If the beach extended out to the stable alignment, the beach width would be potentially very wide at Point Norman.

In addition to risk to the Surf Beach coastline, and as noted in the coastline response, there are very significant “neighbouring beach” risks from the groyne construction:

- Erosion of the coastline north of the groyne would occur as replacement sediment would be blocked by the groyne.
- Erosion of the beach profile adjacent to the groyne may result in the main channel drawing closer to the groyne as scour increases.
- Undercutting of the groyne by the migrating channel could cause the structure to fail and collapse.
- The resulting change in sediment supply within the entrance and migration of the entrance channel could lead to scour of the dunes north of Point Norman and recession of the coastline towards Surf Parade and Veronica Street. Review of early aerial photography indicates the dune here was once much narrower (30m) and the channel closer to the residential area.
- The beach alignments are based on the long term wave climate. An extended deviation from the long term climate has been observed in more recent times contributing to the rapid recession of the Surf Beach coastline. A similar deviation from the long term wave climate could change the beach angle or offshore location at which sediment transport occurs, resulting in a different response or equilibrium beach.

Balancing the above risks, the length and size of the groyne, together with significant realignment of the existing coastline to the stable beach alignment, indications are that a single long groyne at Point Norman would be an unsuitable adaptation option to prevent short term erosion of the Surf Beach coastline.

5.6 Nearshore breakwater

A series of short nearshore breakwaters, combined with beach nourishment along the Inverloch Surf Beach from the Wreck Creek seawall east beyond the Inverloch SLSC has been modelled to reduce the rate of coastal recession to the dunes which currently provide a buffer between the road, services (water, power, communications etc), residential areas and the ocean wave and tidal forces. The Surf Beach and Wreck Creek dunes and beach area are also highly valued by the community for their recreation and aesthetic values.

Nearshore breakwaters work to protect the coastline by reducing the amount of wave energy reaching the shoreline. The reduction of wave energy in the nearshore zone also reduces the alongshore sediment transport potential and sediment moving along the coastline in the lee of the breakwater may be deposited along the shoreline. A salient or tombolo may form, as depicted in Figure 5-15., the formation dependant on the offshore distance and length of a breakwater.

Figure 5-15 also shows that as material is trapped in the low energy zone in the lee of the breakwater, erosion of the adjacent shoreline may occur in response. A series of nearshore breakwaters is often used to continue the shoreline protection. The distance, individual length and spacing between offshore breakwaters then determine the response to the coastline in terms of formation of salient or tombolos.

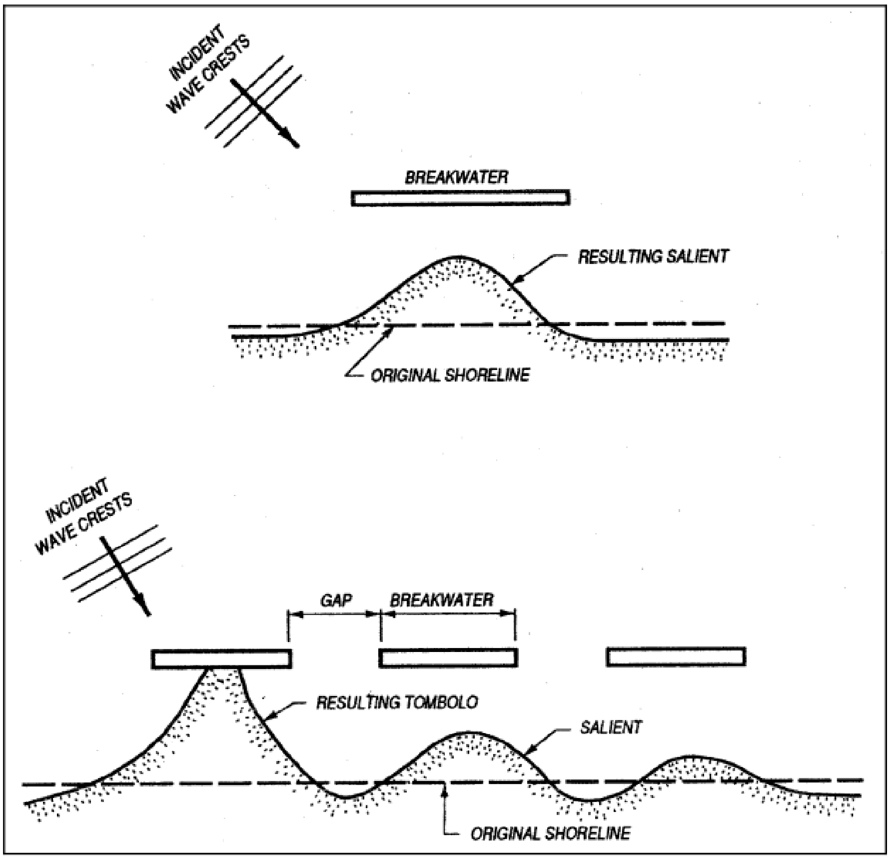


Figure 5-15 Generation of a salient or tombolo by a nearshore breakwater/breakwaters (CEM, 2003)

5.6.1 Technical Effectiveness

Formula exist to design the offshore distance, length and spacing of a series of nearshore breakwaters, based on empirical formula for sediment transport and field data of constructed examples. The USACE Coastal Engineering Manual (CEM, 2003) sets out a method to design an offshore breakwater field which has been followed to establish the potential for coastal protection at Inverloch Surf Beach. Key to the design is the desired beach response, either a salient or tombolo. The CEM (2003) notes the following with respect to design:

- Salients are generally considered the more desirable response as they allow some continuation of the alongshore sediment transport along the coast
- Tombolos can act like a groyne blocking alongshore transport and cause downdrift erosion

Salients are more likely to develop when breakwaters are:

- Further from shore, tombolos when breakwaters are closer to shore.
- Low crested such that wave energy can overtop.
- Spaced with large gaps to allow wave action and currents to disperse landward of the structure

As the objective of the coastal protection is to prevent erosion of the dune until 2040, beach nourishment, along with salient-forming nearshore breakwaters have been assessed for technical effectiveness in an attempt to minimise the impact of interfering with the existing alongshore processes described previously.

The detailed coastal processes investigation and numerical modelling developed as part of the CHA has been used to undertake this assessment.

The parameters required to determine the offshore distance, length and spacing of breakwater are presented in Figure 5-16. The following factors are considered:

- The volume of material required for beach nourishment
- The distance of the breakwater from the nourished shoreline, Y
- The length of the breakwater, L_S
- The gap between breakwaters, L_g (if multiple breakwaters are required)
- Bed depth at breakwater, d_s

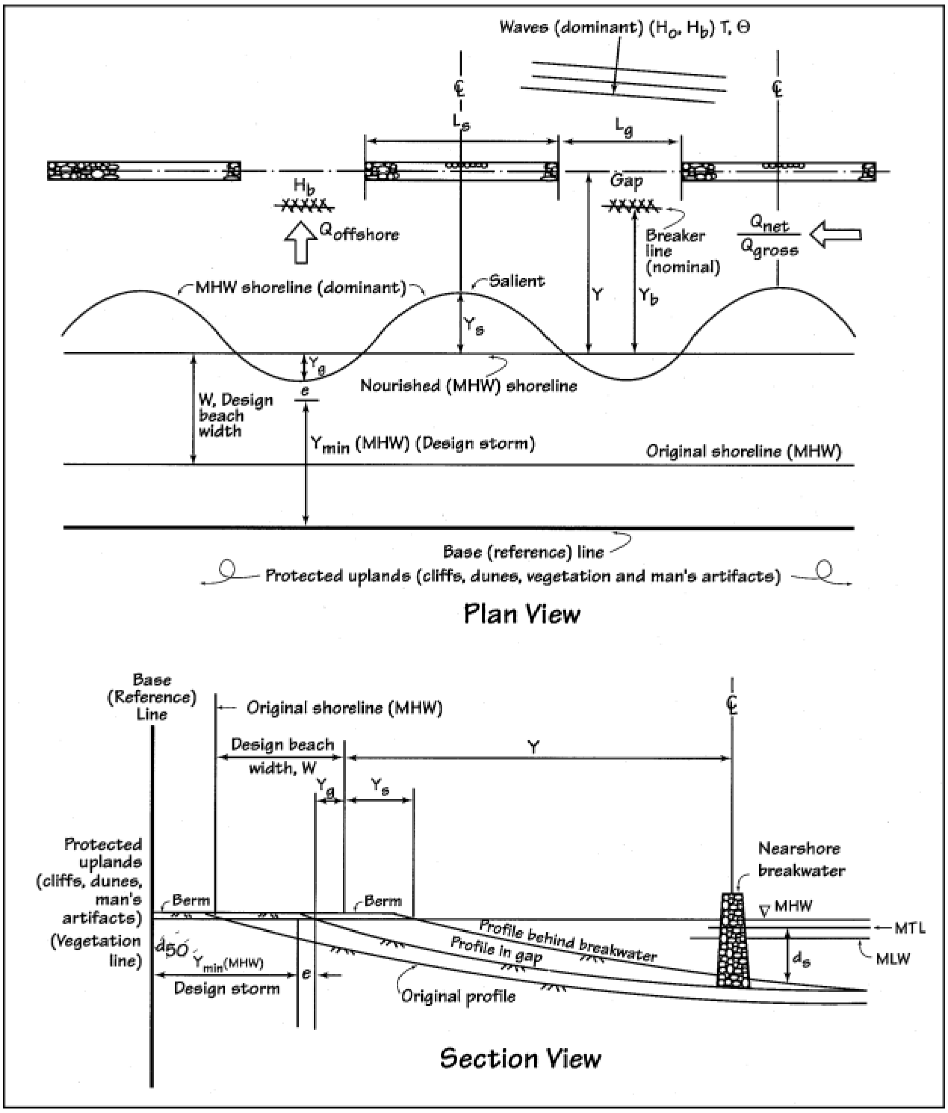


Figure 5-16 Considerations for determining nearshore breakwater parameters

5.6.1.1 Sacrificial Beach Width

The volume of beach required to survive a 2% AEP storm has been determined in Section 5.5.1.1. The beach required is wide (40 – 80m) with a crest of +2.0m AHD.

In the lee of the nearshore breakwater, the sacrificial beach width required would be less as the incoming wave is reduced by the breakwater.

5.6.1.2 Offshore distance

The location of the nearshore breakwater is determined by the incoming wave climate, and the desire to avoid formation of a tombolo. To minimise formation of a tombolo, the breakwater would belocated seaward of the wave breaking zone. The limit of wave breaking is generally considered the depth associated with the depth of closure and the limit of sediment transport. As shown in Figure 5-7, this is between the -2m AHD and -3m AHD contours, a distance (based on the 2021 survey) of 150 to 240m from the existing shoreline, increasing from west to east. The exposed sacrificial beach width reduces this distance to 80 – 180m from west to east.

5.6.1.3 Breakwater Length and Spacing

The breakwater length can be derived from relationships between offshore distance, length and development of a salient or tombolo, summarised in Figure 5-17.

To form a salient at Surf Beach, the distance offshore to structure (Y) to structure depth (d_s) ratio is in the order of 40 – 60, shown in Table 5-4. This indicates the ratio of breakwater length and spacing can be within around 0.8 to 3.5, however to be more confident a tombolo will not form, the ratio of L_s/L_g along the pink line has been used for the conceptual development, resulting in a. L_s/L_g ratio of 1.6 – 3.0. The gap between structures should be reduced to maintain effectiveness as the distance offshore increases (i.e. as the beach becomes flatter), and this is shown in Table 5-4 such that the gap offshore of the SLSC and Wave Street is less than at Wreck Creek due to the shallower bed towards the entrance.

Table 5-4 Nearshore Breakwater Length and Spacing

	Bunurong Road / Wreck Ck (m)	Wreck Creek drain (m)	SLSC (m)	Wave St (m)
Distance to -2m AHD	145	170	180	208
Distance to -3m AHD	184	206	240	240
Sacrificial Beach width	65	70	55	65
Maximum L_s ($L_s/Y < 1$) at -2m AHD	80	100	125	143
Maximum L_s ($L_s/Y < 1$) at -3m AHD	119	136	185	175
Y/d_s at -2m AHD	40	50	62	72
Y/d_s at -3m AHD	40	45	62	58
Optimal L_s/L_g (Figure 5-17)	1.6	2	3	3
L_g at -2m AHD	50	50	42	40
L_g at -3m AHD	74	76	62	64
Salient width at -2m AHD	26	32	40	46
Salient width at -3m AHD	38	44	59	56

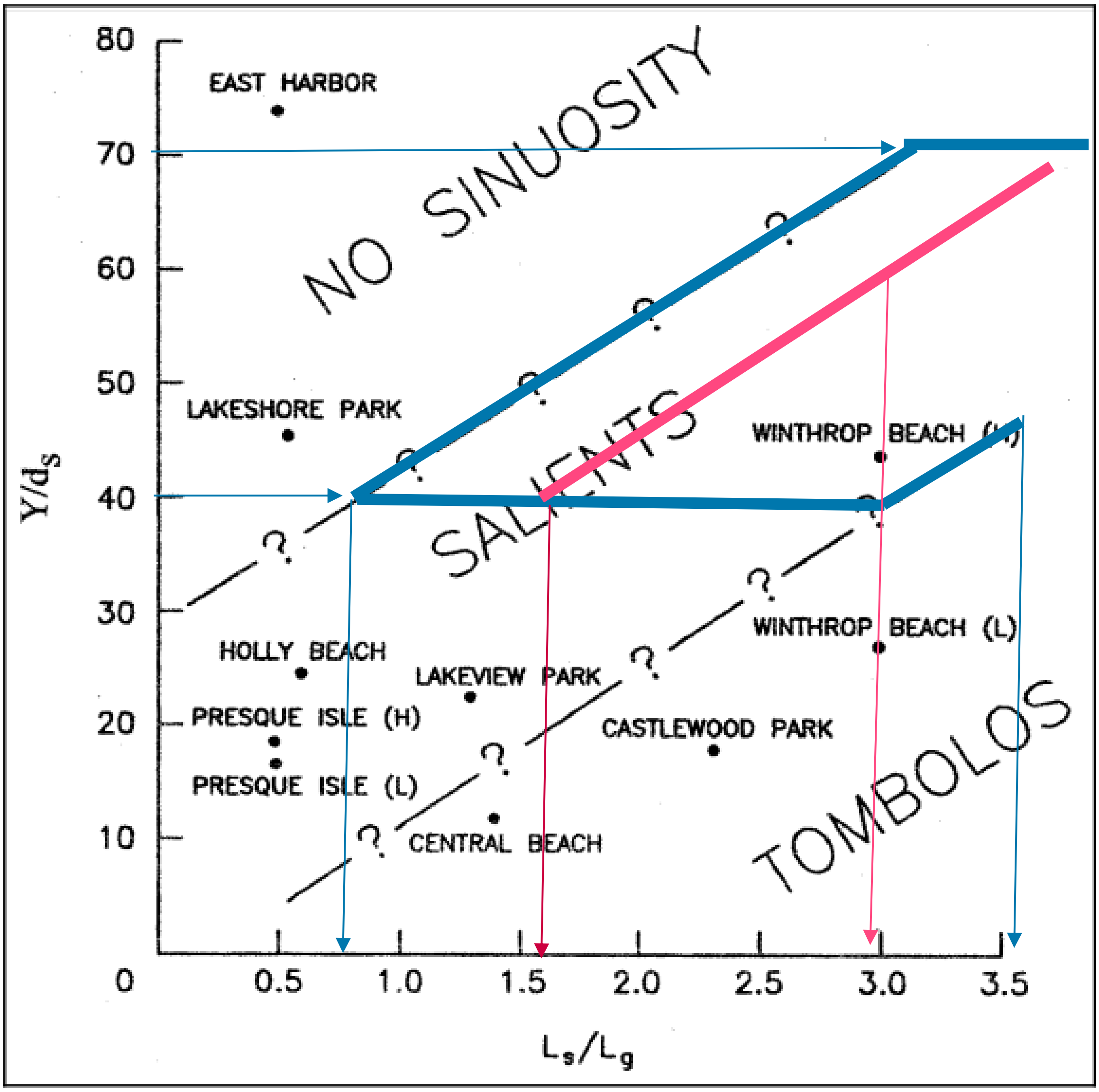


Figure V-3-22. Dimensionless plot of nearshore breakwater projects For Y/d_s versus L_s/L_g (from Pope and Dean 1986)

Figure 5-17 Conceptual Design of Nearshore Breakwater (CEM, 2003)

5.6.1.4 Salient Width

Empirical relationships based on constructed examples are available to assist with concept designs of the width of the salient, Y_s, as presented in Figure 5-16. Silvester (1997) provides a compilation of data from a number of other studies of nearshore breakwaters and can be used to estimate the salient width for the structure length and offshore distance as per Table 5-4.

Salient widths are generally in the length of 25 – 45m, increasing from west to east as the length of the structure increases with the flattening of the beach profile. There is a greater risk that a tombolo could form further to the west as the ebb tide channel delta shifts across the entrance.

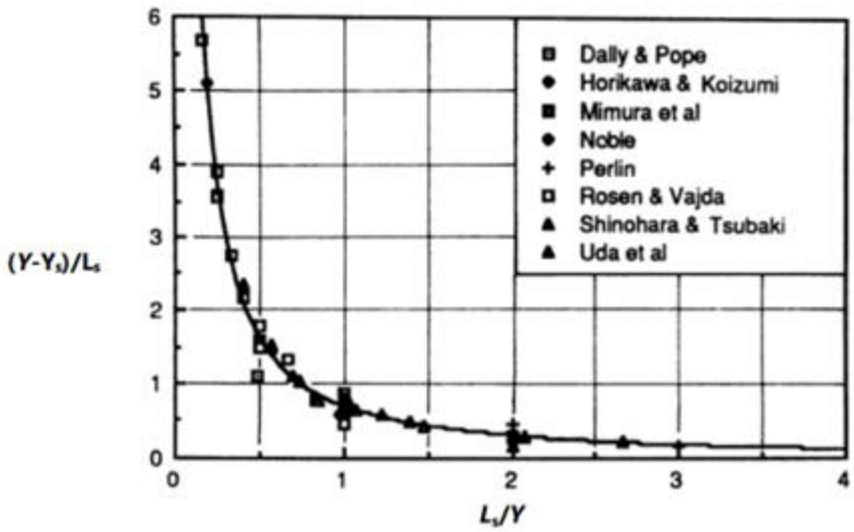


Figure 5-18 Salient Growth (Silvester & Hsu, 1997)

5.6.1.5 Breakwater Height

The conceptual design assumes a breakwater high enough to block incoming waves (i.e., not a submerged structure) and as such the crest of each breakwater would need to be above the regular wave level plus wave height.

As with the short groynes (Section 5.4.1.4), in addition to the capacity to block wave energy the following aspects are assessed in the design of the breakwater crest height:

- Safety
- Constructability
- Visual impact

Nearshore breakwaters are typically submerged or emergent, and whilst a submerged nearshore breakwater will provide a better visual outcome, it will be less effective at reducing beach erosion along the section of the coast required and will provide a hazard to users of nearshore waters.

The average annual peak water level, based on the 40 year numerical hindcast is in the order of 1.8m AHD offshore compared with the 2% AEP storm tide level for present day conditions of 2.15m AHD, indicating the minimum level for an emergent breakwater would need to be at least 1.8 to 2.0m AHD to ensure the breakwater was not regularly overtopped.

However, these levels represent the still water levels, and consideration should also be given to the incident wave climate. Offshore, the exceedance level of the annual 90th percentile wave height is around 2.75m (Water Technology, 2022). This could be expected to reduce to approximately half this in the nearshore waters of Surf Beach, to around 1.2 – 1.5m Hs based on the localised wave transformation model. This would add an additional 0.6 – 0.75m of height to the water level at a nearshore breakwater. The crest level should thus be in the order of 2.0 to 2.5m AHD to provide adequate protection to the shoreline.

At this level, the breakwaters would be a significant visual disturbance during low tide where 2 to 2.5m of the breakwater would be exposed above the water level. A scale conceptual cross section is provided in Figure 5-19 for reference.

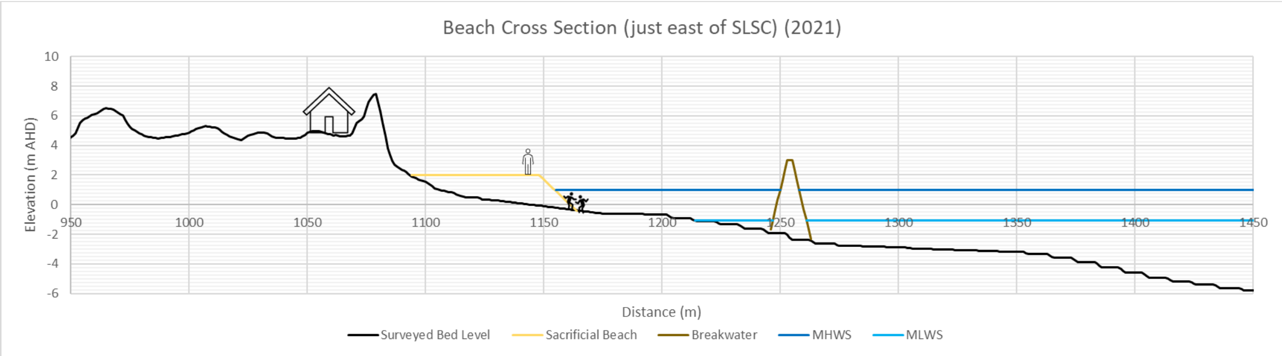


Figure 5-19 Conceptual cross section of nearshore breakwater

Waves during the design 2% AEP storm would be expected to overtop the breakwater at this height with a water level of 2.15m AHD plus significant wave height in the order of 3m resulting in a nearshore water level of over 3.5m AHD for a short period.

5.6.1.6 Conceptual design

A conceptual design of nearshore breakwaters and salient is presented in Figure 5-20. The shape of the salient is highly conceptual however the growth from the sacrificial beach is based on data presented in Table 5-4. Additional forces such as overtopping, return currents, variations in the wave climates etc all contribute to the planform of the beach.

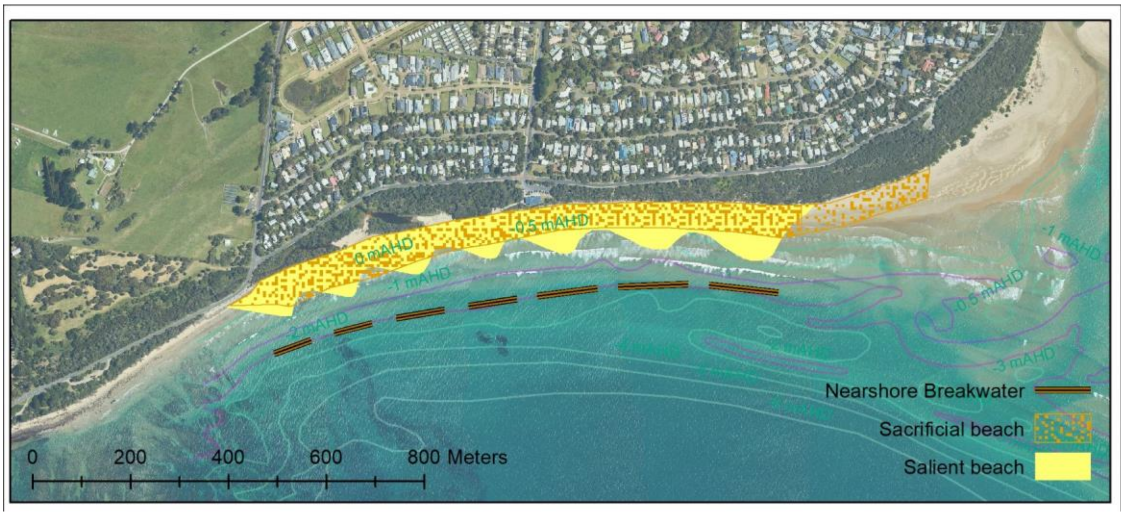


Figure 5-20 Nearshore Breakwater Design

5.6.2 Coastal Response

The construction of a field of offshore breakwaters as presented in Figure 5-20 would work to significantly reduce alongshore transport at Surf Beach. Given the high rate of sediment transport potential to the east, additional material may accumulate at the western end of the breakwaters offshore off the Bunurong Road / Wreck Creek seawall, however this will be limited by the available sediment moving along the shoreline.

To the east of the groyne field, beyond a shadow zone of the last breakwater coastal erosion would be expected, much like the terminal scour at the end of the groyne field discussed above. Sediment trapped in the lee of the most eastern breakwater would not replace material lost to longshore or cross shore erosion further east and either a continuation of the breakwaters or other coastal protection may be required to prevent realignment of the coast.

As with the long groyne and groyne field options, it is difficult to accurately predict the response of the sand around Point Norman into the entrance given the complex interaction between wave driven sediment transport and the ebb and flood tide forces of the entrance channel.

5.6.2.1 Alternative Arrangement

The balance between salient and tombolo formation is sensitive and difficult to predict. Of the four identified nearshore breakwaters constructed in Australia for beach protection (Jam Jerrup, Victoria, Kwinana, WA, and Semaphore Beach and Glenelg Beach, SA), the 3 interstate examples have formed a tombolo whilst the salient at Jam Jerrup is transient (Figure 5-21).

Larger sub-surface breakwaters constructed on the Gold Coast for coastal protection and surfing amenity have been designed to provide protection to a very finite section of coastline, complimented by protection of the buried A-Line seawall.

Examples of nearshore breakwaters in high wave energy locations are relatively limited globally. Internationally, nearshore breakwaters are more common in lower wave energy environments such as the Great Lakes in the United States of America and along the Mediterranean coastline. Additionally, nearshore breakwaters are more commonly found in environments with a small tidal range. Three examples of nearshore groynes around the world illustrating the different uses and range of coastal responses are shown in Figure 5-22.

Jam Jerrup, Victoria

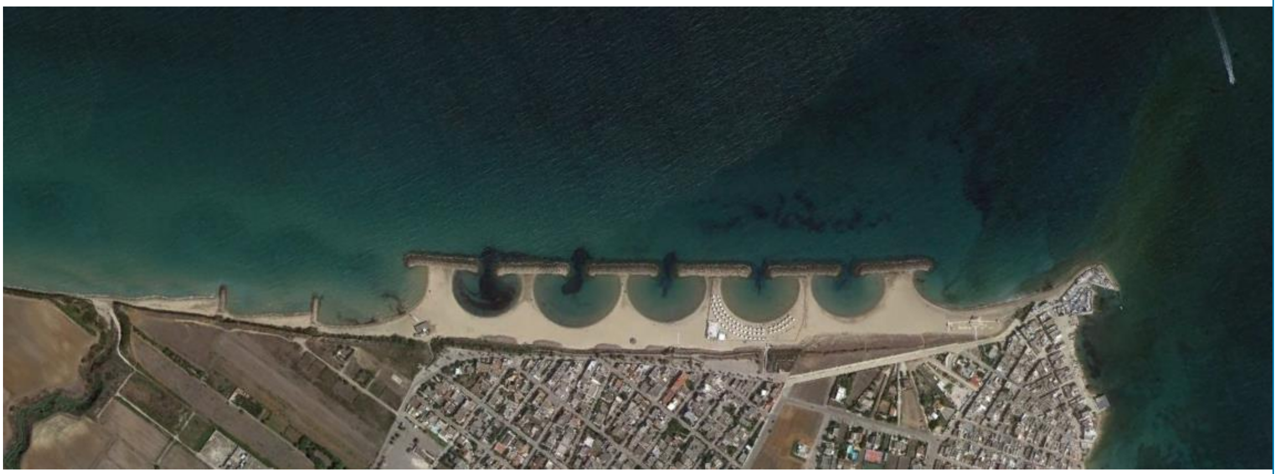
Semaphore, South Australia

Glenelg, South Australia

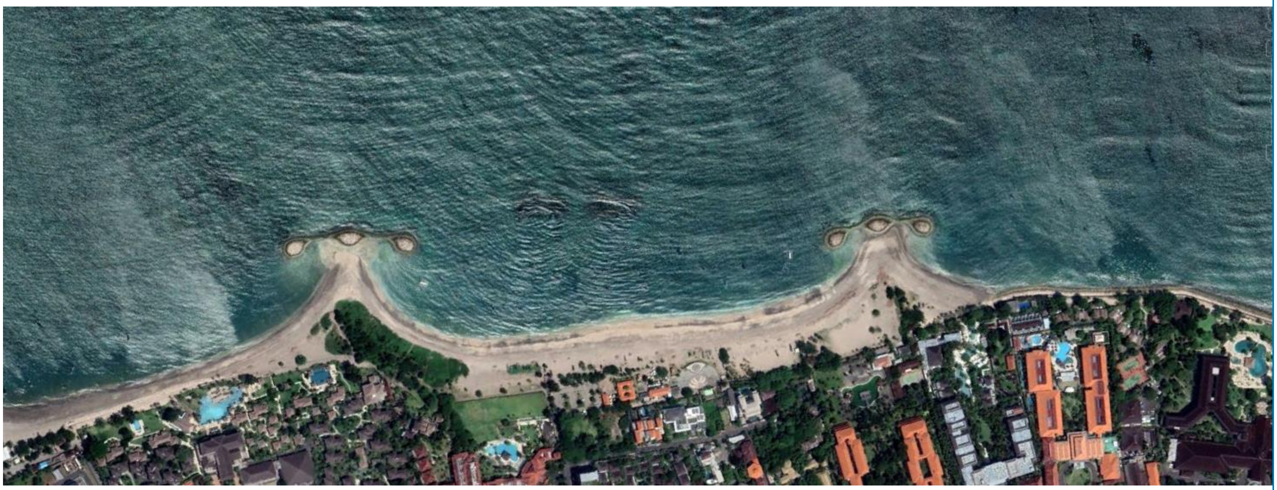
Kwinana, Western Australia

Figure 5-21 Australian nearshore breakwaters (Google Earth)

Presque Isle, USA



Torre San Gennaro, Italy



Kuta Beach, Indonesia

Figure 5-22 International examples of nearshore breakwaters (Google Earth)

5.6.3 Risks

There are a range of risks associated with the construction of nearshore breakwaters, the most significant being the formation of an unwanted tombolo which blocks sediment transport along the coast, changing the nature of the beach and significantly impacting the downdrift beach through lack of sediment supply, and the safety risk of structures within the nearshore zone.

Additional risks associated with nearshore groynes at Surf Beach are as follows:

- Construction works
  - Safety to workers and plant to construct a series of nearshore breakwaters within the surf zone
  - Availability of material and plant to construct breakwaters. The placement of nearshore breakwaters at the seaward side of the breaker zone means they would be exposed to the largest of waves and may experience extremely large waves breaking onto the structure. This would require very large rock or other constructed armour units which may be expensive and difficult to source, transport and place.
- Beach nourishment
  - The sacrificial beach has been developed to offer protection in a large storm event. Storm erosion would be reduced by the nearshore breakwaters and the volume of sacrificial beach could be reduced. However, the sections of the coast exposed through gaps in the breakwater would be exposed to the storm wave and would also likely suffer from some erosion of the sacrificial beach as the salient system forms. The sacrificial beach would require monitoring to ensure sufficient volume of sand is available to maintain the dune protection.
  - Nourishment may be required at the eastern end of the breakwater system to replace material trapped in the salient system.
  - A suitable source of sand is required for ongoing nourishment and beach management.
- Inundation
  - The sacrificial nourished beach would prevent the drainage of Wreck Creek.
- Amenity
  - Construction of nearshore breakwaters would have a significant impact on the visual aesthetics of the beach along Surf Beach and Point Norman.
  - The reduction of wave energy for much of the coastline may not be desirable for beach users or for surfing.
  - Growth of large salients may not be desirable for beach users.
  - Significant seaweed is known to accumulate on Surf Beach. This is likely to become trapped in the lee of the breakwaters and may cause odour and water quality issues.

In addition to risk to the Surf Beach coastline, and as noted in the coastline response, there are significant “neighbouring beach” risks from the breakwater construction, similar to those posed by the groyne field and long groyne:

- Erosion of the coastline east of the nearshore breakwaters may occur as the rate of incoming sediment is reduced by the breakwater system.
- Erosion of the beach profile adjacent to the breakwater system may result in the main channel drawing closer to the Surf Beach, cutting through Point Norman, as observed in the late 1970s.
- Undercutting of a breakwater by the migrating channel could cause the structure to fail and collapse.

- The resulting change in sediment supply within the entrance and migration of the entrance channel could lead to scour of the dunes north of Point Norman and recession of the coastline towards Surf Parade and Veronica Street. Review of early aerial photography indicates the dune here was once much narrower (30m) and the channel closer to the residential area.
- The conceptual design is based on existing depth contours and distances offshore. These have changed by 1m+ over the past decade and similar magnitude of change could impact the effectiveness of the nearshore breakwater and salient system.

6 SUMMARY & RECOMMENDATIONS

6.1 Summary

Coastal hazards along the Inverloch coastline pose the highest level of risk to the Bunurong Road and the Surf Beach dunes between Flat Rock and Point Norman.

Coastal erosion is the key process which drives risk, with inundation of the area landward Surf Beach influenced heavily by the availability of the dunes and beach to minimise storm surges overtopping the dunes and inundating the low lying land.

Erosion along this coastline is driven by net eastward sediment transport and storm erosion. The rapid rate of coastal erosion is likely to be influenced by the entrance configuration and loss of the ebb tide delta at Point Norman. The ebb tide delta may return and assist in stabilising the shoreline, however both short- and longer-term risks posed by coastal hazards remain regardless of the ebb tide delta.

The coastal environment between Flat Rocks and Point Norman is close to 100% natural with only the (relatively) short seawalls at Bunurong Road and at the SLSC interfering with the existing coastal processes. The existing coastal processes which generate hazard to assets and infrastructure valued by the community are driven by oceanographic and physical processes. It is noted that any engineered adaptation actions implemented along the coastline between Flat Rocks and Point Norman would be designed to interfere with these natural processes to protect assets and infrastructure located in the natural hazard zone.

A Multi Criteria Analysis of engineering adaptation actions to reduce coastal erosion hazard was undertaken to shortlist actions for detailed feasibility analysis. Engineered adaptation actions were assessed initially for a preliminary 20 year design life, to enable short or longer term incorporation into adaptation pathways planning.

The engineering feasibility, and the advantages and disadvantages of each adaptation action are summarised in Table 6-1.

Table 6-1 Summary of modelled engineering adaptation actions

Action	Technical ability	Advantage	Disadvantage
Bunurong Road – Flat Rocks to Wreck Creek			
Beach nourishment	75,000 to 100,000m^3 would be required to provide "sacrificial" beach to prevent erosion of 2% AEP storm event Ongoing re-nourishment of up to this volume could be required annually		
	Technically feasible, however significant volumes of renourishment on an ongoing basis to preserve the sacrificial beach for the 2% AEP storm make this action undesirable	Can be applied for an initial period of time while further planning undertaken without permanently impacting coastline	Constant nourishment likely required Community perception may see ongoing nourishment as a "failure" of the action Ongoing commitment to funding Significant change to beach amenity Unknown consequences to entrance through supply of additional sediment
Seawall	A total length of 1,020m is required to protect the entire length of the beach		

Action	Technical ability	Advantage	Disadvantage
	Technically feasible	Known construction method, can be designed to required planning horizon and event. Can be designed to allow drainage from catchment (with tidal gates or other mechanisms)	Probable loss of sandy beach due to lowering of bed to Flat Rocks platform Terminal scour impact on Surf Beach and Wreck Creek Permanent impact on coastline, once established a seawall of 1km will be difficult to remove
Surf Beach – Wreck Creek to Point Norman			
Groyne Field and Beach Nourishment	A conceptual configuration indicates 3 groynes of 180 – 210m along Surf Beach, with additional groynes likely into Anderson Inlet over time. Initial beach nourishment of 100,000 – 200,000m^3 could be required to allow for realignment to provide an ongoing sacrificial beach.		
	Feasible with beach nourishment. May need topping up of beach nourishment areas following storm event.	The arrangement of groynes can be designed to provide wide beaches at key locations for additional beach amenity.	High cost. Uncertainty as to final beach alignment and protection provided. Large change to current beach appearance and potential amenity. Would be difficult to remove after short planning horizon. May need to be designed for extended planning horizon. May impact sediment supply and wave patterns into entrance with unknown consequences.
Long Groyne at Point Norman	A groyne of from 300m to beyond 500m would be required to anchor enough sediment to realign the beach and protect the coastline at Wreck Creek. Beach nourishment volumes required to achieve this protection are unknown and the initial storm demand of approximately 100,000m^3 would be required to be managed or increased as the beach realigned.		

Action	Technical ability	Advantage	Disadvantage
	Unlikely to provide required level of protection along the vulnerable dune area without significant change in the rest of Surf Beach	A single structure rather than multiple structures	Very high cost likely due to complicated construction and size of armour units required. Uncertainty as to final beach alignment and protection provided. Large beach at Point Norman would be required (through nourishment) to provide the level of protection required at Wreck Creek. Significant change in the beach appearance and amenity. Would be difficult to remove after short planning horizon. May need to be designed for extended planning horizon. Potential for impact on the entrance channel is high with unknown consequences.
Nearshore Breakwaters	A conceptual configuration of eight nearshore breakwaters could be adopted. The breakwaters range between 80m and 145m and are 4 to 4.5m in height (crest at 2.0 – 2.5m AHD). The breakwaters would be placed at the -2m AHD contour, 150 to 200m from the present day shore, 80 to 120m from the proposed initial nourishment shore and 50 to 75m from the potential salient shoreline.		
	Feasible with beach nourishment.	Volume of sacrificial beach nourishment is likely to be less due to reduced wave climate.	Construction cost and complexity likely to be high. Uncertainty in level of protection and resulting change to beach amenity. Significant change to beach appearance and amenity. The nearshore breakwaters actively act to reduce wave energy and thus surfing amenity may be removed. Seaweed is commonly trapped behind nearshore breakwaters and can cause a water quality and odour issue. Would be difficult to remove after short planning horizon. May need to be designed to accommodate an extended planning horizon.

6.2 Recommendation

The coastal hazard drivers along the Inverloch coastline are complex and have recently resulted in a decade of rapid change in the shoreline position from Flat Rocks to Ayr Creek. The five engineered coastal protection actions assessed and modelled in this report all have various advantages and disadvantages and would require significant capital works and ongoing maintenance costs. None of the options come with no risks, and many of the impacts, particularly on the entrance dynamics, cannot be predicted or modelled due to the variability of the future wind and wave climate.

6.2.1 Flat Rocks to Bunurong Road Seawall

Whilst the rate of beach retreat and sand loss along the open ocean coastline appears to have reduced in the past 12 months, the existing shoreline position is less than 20m seaward of Bunurong Road at the western end near Flat Rocks and notably less than this adjacent to the existing rock seawall at the Bunurong Road / Wreck Creek bridge.

Continued armouring of the dune westward from the existing seawall will be required to prevent the terminal scour at the end of the seawall from undercutting the road and services at this end of the coastline. A progressive approach could be undertaken with trigger points (i.e. limit of acceptable terminal scour) for action to continue to extend this seawall whilst options for realignment or adaptive design (including relocation of services) are undertaken. A similar trigger point of dune buffer could be taken from the narrowest point at the western end of the road with the seawall progressively constructed eastward.

Monitoring, nourishment and other engineering works will be required to manage the terminal scour and probable breakthrough of the dune to Wreck Creek at the eastern side of the existing seawall.

The recommended coastal hazard mitigation action requires a decision to be made on the long term future position of Bunurong Road. For these two futures, the following actions are recommended:

- Pathway 1: Bunurong Road to remain in current position
  - Design a seawall suitable for future (2100+) conditions.
  - Include allowance for drainage of the landside catchment through the wall and tidal gates to prevent seawater backflow as sea levels rise.
  - Consider the height of the existing road and raise the road above future inundation levels to ensure access during and following extreme storm events.
- Pathway 2: Bunurong Road relocation
  - Design a seawall suitable for short term protection of the road (and services) for the full length.
  - Identify erosion trigger levels such that construction works should be undertaken at the required location along the wall. Ideally the wall would be extended from existing ends rather than constructing piecemeal along the coast.
  - Assess the feasibility of stockpiling rock or geotextile bags in preparation for rapid response to erosion.

6.2.2 Bunurong Road Seawall to Point Norman

The adaptation actions required to reduce the risk at Surf Beach are to be presented to the community for further feedback in Stage 2 of the RaSP – development of the Cape to Cape Resilience Plan. Significant change in the beach amenity and aesthetics would result from all the adaptation actions assessed and community acceptance of any capital works should be sought to ensure works are in line with community expectations.

Any works taken to reduce the sediment loss from Surf Beach should also consider the potential for works to stimulate change in the entrance. A clear plan should be developed and communicated to respond to any impacts on the entrance caused by engineered structures to ensure the community clearly understands the risks and potential follow on works which may be driven by coastal adaptation action on Surf Beach.

As with Bunurong Road, recommendation of coastal erosion hazard mitigation action requires a decision to be made on the future of the roads, services and residential area of Surf Beach. For alternative pathway futures, the following actions are recommended:

- Pathway 1: Maintain existing dune position and maintain a level of beach amenity for a long term horizon (i.e. 2100+)
  - Construct a series of groynes to create smaller beach pockets
  - Undertake initial beach nourishment to either generate the "sacrificial beach" suitable to prevent erosion of the dune during design storm events, or consider constructing a buried seawall as a line of last defence against dune erosion
  - Conduct beach renourishment as required or regular sand management (back passing) to maintain either the sacrificial dune at the height and width required to prevent storm erosion of the existing dune, or a beach of suitable amenity for the community.
  - Design drainage pathways from Wreck Creek through the groyne field and nourished beaches to allow catchment drainage. Consider methods to prevent backflow of seawater as sea levels rise.
- Pathway 2: Plan for retreat
  - Identify trigger levels at which time beach nourishment is to be undertaken to restore the dune to an agreed form whilst retreat is planned and enacted
  - Assess the feasibility of annual beach nourishment and management (e.g. the "Sand Island"), to reduce the urgency of trigger levels and piecemeal nourishment to maintain the dune
  - Engage contractors, and gain permits for ongoing and rapid response works so delays do not occur when sand is required

6.2.3 Monitoring

Monitoring of the beach levels, bathymetric survey and aerial image collection and analysis should be continued along the open coast and into the Anderson Inlet entrance to add to the understanding of the coastal processes in the Study Area. As noted, the recent conditions have led to a slight recovery in beach levels and future works can use this information to inform detailed design considerations.

A key piece of work required for design of any constructed actions is the collection of additional wave data inshore. Inshore wave monitoring can be used to verify and refine inshore wave modelling and sediment transport assessments and optimise design solutions. Capture of wave height, period and wave direction is important for design of beach nourishment volumes and coastal protection structures.

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APPENDIX A
VICTORIA'S RESILIENT COAST FRAMEWORK

Victoria's Resilient Coast – Adapting for 2100+ framework	Purpose	Key questions	Cape to Cape Resilience Project key deliverables	Completion timeline	Document citation	Additional products
STAGE 1 **Scoping and preparation**	Provide a foundation for adaptation planning aligned to best practice guidance.	• Do we need action? • Who is involved? • Where's the study area? • What is our study scope?	Project plan	Mar-21	DELWP 2021, Inverloch Regional and Strategic Partnership Project Plan, Victoria, March 2021.	Website establishment and content. DELWP & Alluvium. May 2021. Project Update 1 - Introducing the Cape to Cape Resilience Project. DELWP & Alluvium. May 2021 Fact Sheet 1 - Project scene setting, introducing the RaSP. DELWP & Alluvium. May 2021. Project Update 2 - Data gathering, gap analysis, engagement commencement. DELWP & Alluvium. July 2021. Fact Sheet 2 - Coastal adaptation and hazards technical terminology. DELWP & Alluvium. July 2021.
			Engagement plan	Mar - July 2021	Alluvium 2021, Cape to Cape Resilience Project Engagement Plan, Victoria, March 2021.	
STAGE 2 **Values, vision and objectives**	Ensure adaptation planning is underpinned by regional and place-based values.	• What do we value? • As a region and as a State? • What do we want the future to look like?	Community values study	Oct-21	Alluvium 2021, Cape to Cape Resilience Project Community Values Study - Engagement Report - Values and Experiences, Victoria, October 2021.	Engage Victoria online survey & on-site drop in sessions - Community values and perspectives
			Cultural values assessment	Dec-21	Bunurong Land Council Aboriginal Corporation 2021, BLCAC Cultural Values Assessment: Cape to Cape Project, Victoria, December 2021.	
STAGE 3 **Coastal hazard exposure**	Assess coastal hazard exposure, including scenarios that enable best practice approaches to assessing current and emerging risk.	• What processes are occurring and how might these change?	Inverloch region coastal hazard assessment	June 21 - Mar 22	Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 1 - Project Summary Report, Victoria, June 2022.	Fact Sheet 3 - Understanding coastal landscape context, processes and hazards. DELWP & Alluvium. Oct 2021. Fact Sheet 4 - Understanding coastal hazard modelling. DELWP & Alluvium. Oct 2021. Project Update 3 - Technical work (LiDAR, models, Assessment work), engagement update. DELWP & Alluvium. Nov 2021.
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Victoria's Resilient Coast – Adapting for 2100+ framework	Purpose	Key questions	Cape to Cape Resilience Project key deliverables	Completion timeline	Document citation	Additional products
STAGE 4 Vulnerability and risk	Explore place-based coastal hazard vulnerability and risk, to enable strategic consideration of adaptation needs/priorities.	• How might these processes impact what we value?	Coastal hazard asset exposure assessment	April - May 22	Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 6 - Coastal Hazard Asset Exposure Assessment, Victoria, June 2022.	Project Update 4 - Technical work update (hazard mapping, values, economics), engagement update. DELWP & Alluvium. April 2022.
			Coastal hazard risk and vulnerability assessment		Alluvium 2022, Cape to Cape Resilience Project - Asset and Values Risk and Vulnerability Assessment, May 2022.	
			Economic base case		Natural Capital Economics & Alluvium, 2022, Cape to Cape Resilience Project – Economics Assessment, June 2022.	
STAGE 5 Adaptation actions and pathways	identify, assess, consult on and decide which adaptation options and actions are the most appropriate for managing the current and future coastal hazard risks in the study area. This includes a diversity of integrated actions across land management, planning and design, nature based and engineering themes.	• How can we manage and adapt to these impacts?	Adaptation options and preferences	May - June 22	Alluvium 2022, Cape to Cape Resilience Project Adaptation Options - Engagement Report - Adaptation Engagement Outcomes, Victoria, October 2021.	TBC
			Adaptation framework summary paper		Alluvium 2022, Cape to Cape Resilience Project – Adaptation Framework Summary Paper, Victoria, June 2022.	
			Adaptation feasibility modelling		Water Technology 2022, Inverloch Region Coastal Hazard Assessment - Report 7 - Adaptation Assessment, Victoria June 2022	
			Economic assessment & cost benefit analysis		Natural Capital Economics & Alluvium, 2022, Cape to Cape Resilience Project – Economics Assessment, June 2022.	
STAGE 6 Plan and implement	Confirm the plan of action for coastal hazard risk management and adaptation, and commence implementation. This includes priority actions in the adaptation pathways, shared roles and responsibilities, triggers for review and resources/requirements.	• Which options are feasible and suitable, both now and in the future? • How can we plan our response strategically?	Cape to Cape Resilience Plan		Inverloch RaSP Stage 2- TBC 2023	
			Cape to Cape Implementation plan/s		Inverloch RaSP Stage 2-& Partner Agencies TBC 2023 onwards	
STAGE 7 Ongoing monitoring and review	Ensure coastal hazard risk management and adaptation is accompanied by ongoing monitoring and evaluation process that enables effective implementation, learnings and improvement.	• How can our response be adaptive to changing conditions? • How are we tracking in implementing our plan?	Cape to Cape Resilience Plan including implementation, monitoring and evaluation		Inverloch RaSP TBC 2023 onwards	

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