Victoria's Resilient Coast – Adaptation Actions Compendium

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The Amendment Record below records the history and issue status of this document.

Version	Version Date	Distribution	Record
00	28 August 2022	DEECA	Draft
01	13 January 2023	BMT	DEECA revisions

Executive Summary

Context

Victoria has over 2,600 km of coastline, including extensive open coast sandy beaches, rocky coasts, bays, tidal estuaries, coastal lakes and floodplains. These diverse bio-cultural landscapes have been nurtured by Traditional Owners of Country for countless generations, and are dynamic environments shaped by natural coastal processes.

At times, coastal processes including erosion, inundation, and other physical/chemical processes adversely impact on current coastal values and uses. When this occurs, we refer to these processes as coastal hazards.

Coastal hazard exposure occurs periodically across the coast, and is projected to increase with changes in wave action, storm activity and sea level rise associated with climate change.

Compendium purpose and audience

DEECA's *Victoria's Resilient Coast – Adapting for 2100+* program provides a strategic approach to coastal hazard risk management and adaptation. This includes a framework, guidelines and support for Local Government, land managers and communities to:

- Enable place-based, best practice and long-term coastal hazard risk management and adaptation, and
- Build on the directions in the Marine and Coastal Policy 2020.

This **Adaptation actions compendium** has been prepared as part of the program as a resource available to land managers to assist with adaptation planning. It is intended to be a general guide to assist in identifying potential adaptation actions that can be further explored within place-based contexts. This compendium will be a live document that is updated periodically to reflect new real-world examples, changes in adaptation practice, and current policy and legislative contexts.

The intended audience for this document is coastal land managers and planners involved in adaptation planning using the *Victoria's Resilient Coast – Adapting for 2100+* guidelines and framework. This compendium provides additional information that supports the wider strategic planning and decision-making process outlined in the guidelines and framework.

Compendium development

Development of the Adaptation actions compendium involved a detailed review of similar compendiums across several jurisdictions, including those from the QCoast 2100 project in Queensland (GHD, 2012), various NSW Coastal Management Plan (CMP) Stage 3 (Options Assessment) documents, the Gold Coast Coastal Hazard Adaptation Strategy (CHAS) Options Compendium (BMT, 2022), and the Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards (Morris *et al.*, 2021).

The Victoria's Resilient Coast DEECA team and Collaborative Working Group were engaged throughout the development of the Compendium to identify and refine the adaptation actions.

The adaptation actions are presented in this compendium across three key functional types (Table 1):

1. **Land management, planning and design**
2. **Nature-based methods**
3. **Engineering.**

Adaptation actions are not mutually exclusive, and often a suite of measures is required to effectively manage coastal hazard risk over time, enabled through an adaptation pathways approach.

In considering adaptation actions, land managers in Victoria are guided by the directions in the Marine and Coastal Policy (2020), including an order of consideration for strategic actions of 1. Non-intervention, 2. Avoid, 3. Nature-based, 4. Accommodate, 5. Retreat, and 6. Protect, and using a pathways approach to defining short- and longer-term actions.

Victoria's Resilient Coast framework and guidelines – Adapting for 2100+ (DEECA 2022) provides guidance on coastal hazard definitions, exposure, risk and vulnerability assessments, and developing adaptation pathways. This compendium provides supporting detail on a range of actions that can be included in adaptation pathways. Additional actions not covered in this compendium including social, cultural and capacity building adaptation actions may also be included in pathways and informed by project specific studies. Detail in this compendium provides a guide only, and specialist technical expertise is required for planning and implementation.

Table 1. Actions summary table

Functional type	Category	Adaptation Action
Land management, planning and design	Land use	Land acquisition, swap, lease-back
		Controlled access
		Planning scheme zone change
		Planning overlays
		Rolling easements
		Removal / relocation of infrastructure
	Resilient design / development	Development setbacks
		Use of resilient materials and design in new and retrofitted infrastructure
	Cultural landscapes	Survey, document, salvage, other*
Nature-based (Nature-based methods use the creation of restoration of coastal habitats for hazard risk reduction[1])	Coastal vegetation and blue carbon ecosystems	Mangrove forests
		Seagrass meadows
		Salt marsh
		Kelp forests
	Beach and dune ecosystems	Beach and dune protection / vegetation / management
		Use of on-site natural materials to reduce erosion
		Wet sand fencing
		Supported littoral vegetation**
Engineering	Nourishment**	Localised beach scraping / dune nourishment / reconstruction
		Beach nourishment
		Sand by-pass system
	Reefs**	Shellfish reefs
	Dredging	Configuration dredging
	Seawalls	Vertical seawalls
		Eco-engineering of hard surfaces
		Rock revetments
		Geobag revetment / wall
		Rock bag revetment / wall
	Groynes	Groynes (rock, geobag, other)
	Breakwaters	Breakwaters
	Flood/tidal barriers	Levees / dykes
		Tidal / surge barriers
		Tidal valves on stormwater system
		Saline groundwater intrusion barrier
	Drainage	Upgrade of drainage network
		Water sensitive urban design
	Road network	Upgrade of road network

**As led by Traditional Owners – guidance should be sought directly from local groups.*
***May be considered a hybrid engineering and nature-based action, pending detail of the approach*

[1] Morris *et al* 2021

Coastal hazards

This compendium adopts the coastal hazard definitions from *Victoria's Resilient Coast – Adapting for 2100+* framework and guidelines (Table 2).

Table 2. Coastal hazard definitions

Category	Process/ hazard	Setting classes include
Erosion	**Short-term erosion** Event-based erosion of sediment (storm-bite) and recovery **Long-term erosion** (recession) Progressive retreat of shoreline position over time	Sandy shorelines Low-earth scarp Soft rock Hard rock
Accretion	Short- or long-term build-up of sediment in a localised area	All shoreline types
Inundation	**Storm tide inundation** Temporary event-based inundation	All low-lying coastal land
	Permanent inundation Regular or persistent inundation by the regular tidal cycle	All low-lying coastal land
Estuary dynamics	Changes in form and processes associated with estuarine and tidal areas	Estuary/ tidal areas
Off-shore sediment dynamics	Changes in form and processes associated with offshore bathymetry and sediment transport	Up to 3 nautical miles offshore
Saline intrusion	Movement of saltwater into freshwater aquifers/groundwater	All low-lying coastal land

An overview of which coastal hazard types each adaptation action is generally suitable for is provided for reference in Attachment A.

Approvals context

Each action detailed in this compendium includes likely approvals / relevant legislation based on relevant project examples – however each action should be considered within its site-based context to ensure all relevant legislation and approvals are accounted for.

The following, non-exhaustive list includes Acts that are often relevant when considering/gaining approval for the types of actions outlined in this compendium:

- *Australian Maritime Safety Authority Act 1990*
- *Catchment and Land Protection Act 1994*
- *Crown Land Reserves Act 1978*
- *Environment Effects Act 1978*
- *Environment Protection Act 2017*
- *Environmental Protection and Biodiversity Act 1999*
- *Flora and Fauna Guarantee Act 1988*
- *Heritage Act 2017*
- *Marine and Coastal Act 2018*
- *Marine Safety Act 2010*
- *Native Title Act 1993*
- *National Parks Act 1975*
- *Planning and Environment Act 1987*
- *Sea Dumping Act 1981*
- *Underwater Cultural Heritage Act 2018*
- *Wildlife Act 1975*.

Contents

1 Land management planning and design

1.1 Land use

1.1.1 Land acquisition, swap, lease-back

<table>
<tr><th>Action</th><th colspan="3">Land management, planning and design – Land use - Land acquisition, swap, lease-back</th></tr>
<tr><td>Description</td><td colspan="2">Land acquisitions involve the transfer of land from private ownership to public ownership.

Land acquisitions can be undertaken using a range of mechanisms, including land purchase/acquisition (negotiated purchase or compulsory acquisition), land swap or land lease-back.

Relevant statutory processes for land acquisition include powers under the Land Acquisition and Compensation Act 1986, Crown Land Reserves Act 1978 and Conservation Forests and Lands Act 1987.

Land acquisition can be through a negotiated purchase process, or compulsory acquisition. A 'Public Acquisition Overlay' is applied to the specified area, through the relevant planning processes.

Land swap involves exchanging a suitable alternative parcel of land outside the hazard zone for the at-risk land parcels. Land swaps require suitable land to be available for relocation of uses, which may which may also involve reviewing planning scheme zones and overlays.

Land lease-back operates in a similar manner to the acquisition approach, but support the government leasing the property out until such future time as risks become untenable. Lease-backs allow the continued use of the land and may encourage participation in acquisition programs. Lease-backs allow governments to recover some costs of acquisition programs.</td><td rowspan="4"></td></tr>
<tr><td rowspan="3">Functional type</td><td>✓</td><td>Land management planning and design</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td></td><td>Coastal engineering</td></tr>
<tr><td rowspan="8">Coastal hazard mitigation</td><td>✓</td><td>Short-term erosion</td><td rowspan="8">Notes on suitability:
Land acquisition, swap and lease-back can be implemented in any area subject to current or future coastal hazards. Due to cost considerations they are often less suited to intensively developed areas.

Finding suitably equivalent parcels of land can be complex from a coastal lifestyle perspective, and the alternative parcels may be perceived as less desirable than beach-front property.

The intent that the land use will be transitioning over time should be communicated well ahead of critical risk levels being reached.</td></tr>
<tr><td>✓</td><td>Long-term erosion</td></tr>
<tr><td>✓</td><td>Accretion</td></tr>
<tr><td>✓</td><td>Storm tide inundation</td></tr>
<tr><td>✓</td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td>✓</td><td>Saline intrusion</td></tr>
<tr><td rowspan="5">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="5">Notes on policy context:
Where no development has occurred on the subject land then acquisition may be considered an avoid action.

Where existing development or development rights are in place, acquisition may be considered "retreat".</td></tr>
<tr><td>✓</td><td>Avoid</td></tr>
<tr><td></td><td>Nature-based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td>✓</td><td>Retreat</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="4">Land management, planning and design – Land use - Land acquisition, swap, lease-back</th></tr>
<tr><td></td><td></td><td colspan="2">Protect</td><td></td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td colspan="2">Low</td><td rowspan="3">Considerations:
Acquisition, swap our lease-back enables a transition of land use in the hazard zone to one with a lower risk profile, and allows natural coastal processes to continue.</td></tr>
<tr><td></td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations:
Land acquisition, swap or lease-back require significant engagement, time and planning with landowners and the broader community.
Statutory planning / other legal processes may be required to implement these actions.
Depending on the existing land use, acquisitions can be expensive, and the overall public benefit needs to be clearly demonstrated to decision makers and the community.
Land use change may have a range of implications for local coastal values, and should be underpinned by evidence-based and place-based strategic planning.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="6">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>Several years</td><td>Land acquisition, swap and lease-back projects can take multiple years to plan, coordinate, and consult on. Preparation and design can run concurrently with other interim hazard risk mitigation actions.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>50+ years</td><td>Once the acquisition process is complete, the ‘effective lifetime’ of the action is ongoing, however may be subject to future changes in policy or planning scheme revisions.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Many</td><td>Acquired land in coastal hazard areas can provide a range of local benefits, including community open space and public access to coastal areas, ecosystem corridors and services, and enhancement of a diversity of cultural, environmental and economic values.</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">Legal advice should be sought on which statutory processes and approvals apply.</td></tr>
<tr><td colspan="2">Design considerations, constructability, and materials</td><td colspan="2">Important considerations for the design of land acquisition programs include:
• Understanding the coastal hazards of the subject area and the long-term emerging risk profile
• Availability of suitable land for land swaps
• Existing and future uses of the acquired land
• Requirements under the authorising legislation Community and stakeholder engagement required
• Political support at state and local levels.</td></tr>
<tr><td colspan="2">Cost considerations</td><td colspan="2">The cost of land acquisition can be high. Purchase prices are based on market rates via a formal and regulated valuation process.
Swaps and lease-backs can reduce the overall expenditure, however they introduce additional administrative requirements which is not typically core business for government.</td></tr>
<tr><td>References</td><td colspan="4">ABC 2007, Govt forces penguin reserve land buyback, viewed 25 January 2022, https://www.abc.net.au/news/2007-10-04/govt-forces-penguin-reserve-land-buyback/688692?site=news
ABC 2011, Flood-ravaged Grantham moves to higher ground, viewed 25 January 2022, https://www.abc.net.au/news/2011-06-07/flood-ravaged-grantham-moves-to-higher-ground/2750114
Victorian Ombudsman, 2019. Investigation into Wellington Shire Council's handling of Ninety Mile Beach subdivisions. August. https://assets.ombudsman.vic.gov.au/assets/Reports/Parliamentary-Reports/1-PDF-</td></tr>
</table>

Action	Land management, planning and design – Land use - Land acquisition, swap, lease-back
	Report-Files/Investigation-into-Wellington-Shire-Councils-handling-of-Ninety-Mile-Beach-subdivisions-Victorian-Ombudsman.PDF

Project example

Land management, planning and design – Land use - Land acquisition, swap, lease-back – Project example		
Project title	Ninety Mile Beach Subdivision Land Project (and predecessors)	 Subdivision layout, Golden Beach, circa 1950s Source: Panel Report into the Wellington Planning Scheme Amendment C71 (2012)
Action type	Land acquisition	
Location	Golden Beach, Flamingo Beach, Glomar Beach, on Ninety Mile Beach, Gippsland	
Land manager	Shire of Rosedale / Wellington Shire Council and Victorian Government	
Year of implementation	1978 – ongoing	
Project objectives	From the mid-1950s to the late 1960s, 23 subdivisions along 25 km of the coast in the vicinity of Ninety Mile Beach and the Gippsland Lakes were sold for residential development, prior to the implementation of planning controls. Limited services to the area were provided, and many of the nearly 12,000 land parcels were located on sand dunes, subject to coastal hazard risks, bushfire risks, or were inaccessible. While some un-serviced dwellings were constructed on flood prone land or in the primary dunes, it was recognised by the mid-1970s that services could not be provided, and further development of these land parcels was blocked while detailed studies were undertaken.	 Golden Beach area, March 2021 (Source: Google Earth)
Project process	Over time, restrictions on which parcels could be developed resulted in several planning approaches (including rezoning) being applied to manage overall development in the area.	
Measures implemented	Since the late 1970s, different schemes for either local or State government to acquire those parcels considered unsuitable for development have included: • compulsory acquisition • voluntary surrender of title for assistance payment • buy back scheme • voluntary transfer scheme • voluntary surrender of title in lieu of rates debt.	
How well project met objectives	94% of voluntary assistance payment offers made to landowners of properties between the settlements were accepted and ownership transferred to Council (Victorian Ombudsman, 2019. Investigation into Wellington Shire Council's handling of Ninety Mile Beach subdivisions. August). By 2019, nearly 2000 properties were transferred to Council ownership under that scheme. While the Council-led acquisition process has now been completed, the State government continues to progress compulsory acquisitions with the aim of transferring all of the approximately 1900 remaining privately owned "undevelopable" parcels to public ownership.	
Cost	Not available. Generally dependent on land valuations plus administrative, legal, and appeals costs.	
Further considerations	The overall solution for the area included a range of planning tools, including forcing the amalgamation of small parcels into larger blocks, limiting development actions and rezoning land use. Hazards other than just those for coastal management (e.g. bushfire, flooding and conservation value) also contributed to the planning actions taken. Further information on this example can be found at: marineandcoasts.vic.gov.au/coastal-programs/gippsland-projects/ninety-mile-beach-plan	

1.1.2 Controlled access

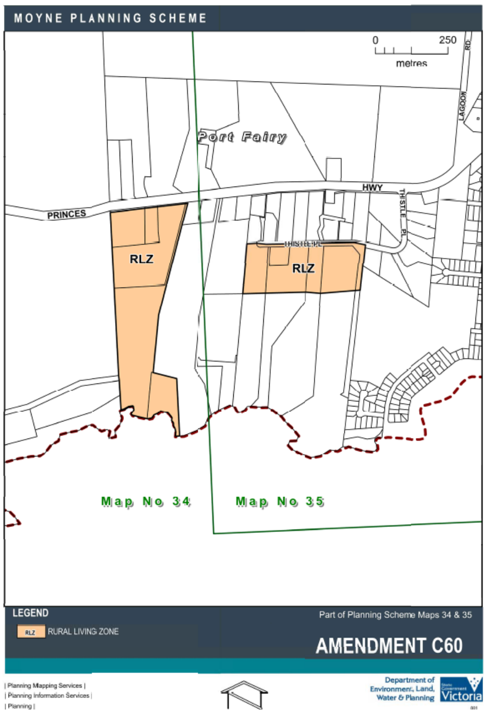
Action	Land management, planning and design – Land use – Controlled access		
Description	Controlled access involves restricting public access to coastal areas. Restrictions may be temporary or permanent to ensure public safety, and to protect coastal values and sensitive areas. Restrictions may typically apply to areas with unstable and/or eroding cliff faces, erosion scarps, coastal caves, flood-prone/flooded areas, sensitive dune systems and areas of environmental and cultural significance.		 *Controlled access at Anglesea*  *Demons Bluff – Anglesea (Source: Geelong Advertiser)*
Functional type	✓	Land management planning and design	
		Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Controlled access allows natural coastal processes to continue, while minimising risk to public safety, and protecting coastal values. Controlled access can be part of a strategic adaptation pathway that includes a range of actions, including nature based approaches such as dune protection, vegetation and management.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Controlled access can be applied to avoid the risk from coastal hazards, and also to support implementation of other actions including nature-based methods, retreat and protect actions.
	✓	Avoid	
	✓	Nature-based	
		Accommodate	
	✓	Retreat	
	✓	Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Controlled access interventions are intended to remove people from areas potentially impacted by natural coastal processes, without modifying the processes themselves.
		Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations:** Controlled access impacts the ability of people to access areas of the marine and coastal environment. Potential implications for social, cultural, environmental and economic values should be considered, and balanced with the need for restrictions. This may be particularly challenged when permanent restrictions are required.
	Cultural values		
	Environmental values		
	Social values		

Action	Land management, planning and design – Land use – Controlled access		
	Economic values		Economic implications may include impacts on tourism, visitation, and the local economy. Care is also required to ensure that redirected pedestrian and/or vehicle access around the exclusion area/s does not cause detrimental impacts elsewhere. Controlled access can assist to support the protection of local coastal values and natural rehabilitation of costal ecosystems.
Guidance for implement-tation	**Preparation / design period**	Days to months	For temporary closures where there is an imminent risk to public safety / coastal values, closures can occur within a matter of hours/days through existing management / emergency response processes. To implement longer-term permanent restrictions, several months (or more) may be required for consultation and strategic planning.
	Effective lifetime	Ongoing	Controlled access measures can be in place for as long as required providing the exclusion mechanism (i.e., fencing and signage) is maintained and replaced when necessary.
	Co-benefits	Many	Co-benefits may include protection of environmental and cultural areas of significance, and broader benefits of minimising human disturbance to sensitive coastal areas.
	Approvals and requirements	The range of approvals that may be required for controlled access and any supporting measures (fencing, bollards, platforms, signage, other) include: • Landowner's consent • *Marine and Coastal Act 2018* consent (DEECA) (if applicable) which is founded on alignment to the directions in the Marine and Coastal Policy (2020) for all works in the marine and coastal environment. • Marine Park Approvals (Parks Victoria) if restriction extends into Marine Park areas • Planning Permit (Local Government) in accordance with local government regulations	
	Design considerations, constructability, and materials	Controlled access requires careful design to address the risks, while balancing impacts on access and other values, and maximising likelihood of compliance. Signage relating to the purpose of exclusion will be essential to help with compliance. Where exclusion is extensive, small areas of limited access may be appropriate (depending on the risks) to balance the competing values, and avoid the public ignoring exclusion fences and warning signs. When implementing, public engagement should be undertaken to maximise public acceptance and compliance.	
	Cost considerations	Costs will vary depending on type, size and scale of public access infrastructure used such as fencing, bollards and signage, as well as engagement activities, especially if exclusion is to be long-term or permanent.	

Project example

Land management, planning and design – Land use – Controlled access – Project example		
Project title	Demon's Bluff Beach Closure	 *Anglesea cliffs (source: ABC News, Rachel Clayton)*
Action type	Controlled access	
Location	Anglesea, Victoria	
Land manager	DEECA and the Great Ocean Road Coast and Parks Authority ('The Authority')	
Year of implementation	2021	
Project objectives	The intention of the project was to restrict access to a portion of beach directly in front of a soft, eroding cliff face that is highly susceptible to landslip. Tension cracking of the cliff face was observed through monitoring programs, with large failures potentially occurring without warning, presenting a serious risk to safety for users of the beach in front of the cliff face.	
Project process	Initially, a temporary closure was put in place when large cracking was observed in the cliff face. Expert assessment of the cliffs, and a collaborative consultation process with local land manager sand agencies, led to the temporary closure being upgraded to a permanent closure given the ongoing nature of the landslip risk.	
Measures implemented	A two-kilometre section of coastline was closed to the public, with natural headland features at either end of the cliff extent being ideally situated as the closure points. The Authority also installed fencing along the clifftop and is delivering revegetation programs to help reduce the risk to the public in these areas.	
How well project met objectives	Initial closures have been successful in keeping people away from the area. Monitoring and evaluation of the risk and compliance with restrictions will continue to inform future approaches. On-going works related to the beach access exclusion include: • the continued relocation of the Surf Coast Walk inland away from the cliff edge as erosion encroaches landward • regular geotechnical investigation • ongoing monitoring including site visits, aerial imagery analysis and drone surveys.	
Cost	Not disclosed	
Further considerations	N/A	

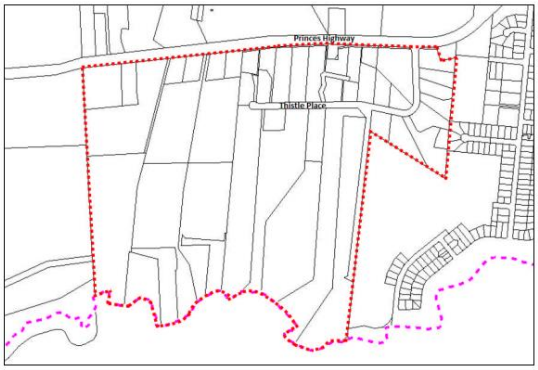
1.1.3 Planning scheme zone change

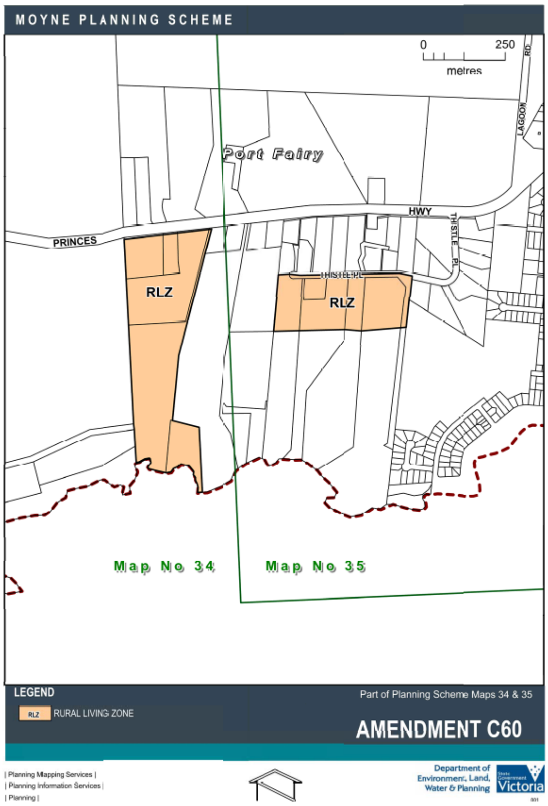
Action	Land management, planning and design– Land use - Planning scheme zone change		
Description	Planning scheme zones are defined to control the types of development or usage that are acceptable in that location. Zoning changes identified through a planning scheme amendment can assist to ensure: • additional people and property are not placed at unacceptable risk due to coastal hazards • development is not permitted to intensify in areas with high coastal hazard risk, at present day or in the future due to climate change and sea level rise • risk appropriate development and uses can continue to be established on land that is subject to coastal hazards • areas of future hazard exposure can be zoned appropriate to manage future risk. Zoning changes are informed by strategic planning processes and risk-based assessments and implemented through a formal planning scheme review or amendment processes. Available planning scheme zones are selected from a standardised list in the **Victoria Planning Provisions.** Zones may have specific objectives set through a statement in a schedule. These objectives may be general or may relate to a specific matter, such as building design.		 *Moyne Shire Amendment C60 – South of Thistle Place, land vulnerable to coastal inundation was rezoned from Low Density Residential Zone to Rural Living Zone (i.e. a decrease in the density of allowable development*).
Functional type	✓	Land management planning and design	
		Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Changes to planning scheme zones are often more applicable to locations where the full development potential has not been exploited. It is usually applied to areas with permanent or frequent hazard exposure (present day or future). Importantly, land use changes only affect outcomes for future development. Where land is already developed, land use change cannot mitigate hazards and risks relevant to that development. Existing use rights under clause 63 of the planning scheme cannot be extinguished through planning scheme amendments.
	✓	Long-term erosion	
	✓	Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Planning scheme zones that are changed to allow only risk-appropriate uses represent an avoid action. A zone change may also accompany a decision or signal an intention to remove development or infrastructure from a coastal hazard area, or not permit replacement at the end of its functional life, representing a retreat action.
	✓	Avoid	
		Nature based	
		Accommodate	
	✓	Retreat	
		Protect	
	✓	Low	**Considerations:**
		Moderate	

Action	Land management, planning and design– Land use - Planning scheme zone change		
Likely impact on natural coastal processes	High		Planning scheme zone changes in the context of reducing coastal hazard risk typically enable natural coastal processes to continue. Existing impediments to coastal processes may also be able to be removed because of a change in zone.
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Changing the planning scheme zone to support risk-appropriate uses can support a diversity of coastal values including: • avoiding inappropriate future development and ensuring public safety • reducing future economic impacts/costs of hazards • retention of natural landforms, habitats and associated ecosystems for as long as practicable, and enabling habitat migration • maintenance of public access to or along the coast.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	>12 months	Planning scheme zone changes are often undertaken to address a range of issues/opportunities, so may be combined with other amendments for efficiency. There are statutory requirements associated with the process and stakeholder consultation.
	Effective lifetime	Ongoing	Planning scheme zones remain in place until changed by a subsequent amendment.
	Co-benefits	Many	A change to planning scheme zones can also support the achievement of broader strategies and other planning issues relating to management of land and natural environments within the coastal zone.
	Approvals and requirements	A planning scheme amendment is required to implement a change to a planning scheme zone. A planning authority such as a local council may only prepare an amendment to the local provisions of its planning scheme once it receives authorisation from the Minister for Planning. A planning scheme amendment will need to meet the statutory requirements of the *Planning and Environment Act 1987*, Planning and Environment Regulations 2005 and associated Ministerial Directions and Victoria Planning Provisions to demonstrate consistency with the policies, objectives and strategies for coastal Victoria as outlined in the State Planning Policy Framework.	
	Design considerations, constructability, and materials	Consideration should be given to the extent of land to be rezoned, particularly on large land parcels where the coastal hazards impact only part of gazetted lots. Beyond the area of coastal hazard impact, other land uses may still be appropriate. In such circumstances, a subdivision may also be required to provide greater statutory clarity. Depending on the existing use of the land, and the proposed development restrictions imposed by the zoning amendment, there may be pressure from existing landowners for the rezoned land to be acquired for public purposes.	
	Cost considerations	As planning scheme amendments are considered to be ‘business as usual’ for most local governments, however there are generally notable costs through amendment fees, consultation requirements and resourcing.	
References	Victoria Planning Provisions. planning.vic.gov.au/__data/assets/pdf_file/0020/604064/UVPS-Using-Victorias-Planning-System-2022.pdf		

Project example

Land management, planning and design – Land use – Planning scheme zone change – Project example	
Project title	Amendment C60
Action type	Planning scheme zone change
Location	Port Fairy
Land manager	Moyne Shire Council
Year of implementation	2016
Project objectives	Implement recommendations of the Port Fairy West Structure Plan September 2014 and the Port Fairy Local Coastal Hazard Assessment 2013, by rezoning land, inserting a new local planning policy, applying new overlays and amending existing overlays. The Structure Plan provides a framework to guide land use and development within the designated area, which: • protects the low density and rural living character, and coastal landscape of the area • identifies a clear settlement boundary • avoids further intensification of tourism and commercial development • facilitates better road and footpath connections from east to west • avoids additional development in areas at risk of coastal inundation and erosion • resolves issues caused by land being within two zones.
Project process	Amendment C60 involved: • rezoning land areas in Port Fairy West from Farming Zone and Low Density Residential Zone to Rural Living Zone (Schedule 1) • including a new local planning policy and a settlement boundary for Port Fairy West at Clause 21.09-5 of the Planning Scheme • application of the Land Subject to Inundation Overlay - Schedule 3 to areas subject to inundation and Erosion Management Overlay - Schedule 1 to areas subject to coastal erosion • amending the existing Schedules 14 and 20 to the Design and Development Overlay.
Measures implemented	The changes to zoning entail the back zoning of land south of Thistle Place from Low Density Residential to Rural Living Zone to respond to the risk of coastal inundation by limiting the potential for additional allotments to be created and removing ongoing issues caused by land in two zones.

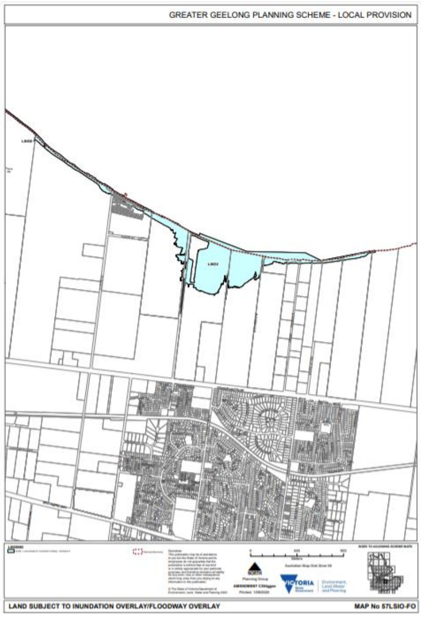




Moyne Shire Amendment C60 – South of Thistle Place, land vulnerable to coastal inundation was rezoned from Low Density Residential Zone to Rural Living Zone (RLZ) (i.e. a decrease in the density of allowable development

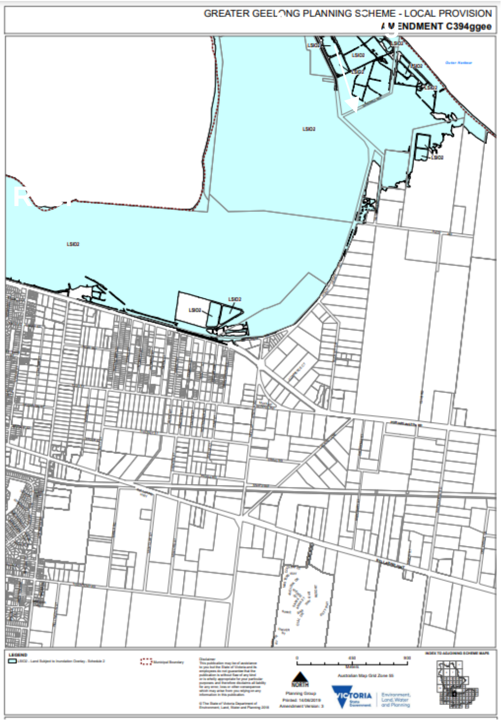
How well project met objectives	Amendment C60 to the Moyne Planning Scheme was approved by the Minister for Planning and came into operation on 27 October, 2016.
Cost	Not disclosed.
Further considerations	Amendment C60 involved multiple planning scheme changes, beyond zone changes, that worked together to achieve the overall outcomes of implementing the Port Fairy West Structure Plan September 2014.

1.1.4 Planning overlays

Action	Land management, planning and design – Land use - Planning overlays		
Description	A planning overlay applies to land in a planning scheme and can set out objectives, matters to consider and particular requirements that apply to that land; most often via development assessment. Identified land is mapped and the controls set out in schedules that specify the objectives of the overlay, the matters to be considered and the requirements that planning proposals must demonstrate. In the context of coastal hazards, this generally requires demonstration of how the proposed development considers the hazards and actively minimises the risk associated with those hazards. Relevant planning overlays through the Victoria Planning Provisions include the Land Subject to Inundation Overlay (LSIO) and the Erosion Management Overlay.		 *Greater Geelong Planning Scheme – Land Subject to Inundation Overlay (LSIO)*
Functional type	✓	Land management planning and design	
		Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Planning overlays used to manage development in areas affected by coastal hazards usually consider hazard extents to 2100, and are often conservative to ensure that affected land parcels are adequately captured and accommodate uncertainty. The mapped extents are supported by technical studies prepared by suitably qualified hazard specialists. Overlays are applicable when considering and assessing new development, and certain changes to existing development.
	✓	Long-term erosion	
	✓	Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Planning overlays are used to identify areas where further consideration is required. As such, overlays support the range of actions to mitigate coastal hazards, from avoid through to protect.
	✓	Avoid	
	✓	Nature-based	
	✓	Accommodate	
	✓	Retreat	
	✓	Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Planning overlays are a tool to identify the need for adaptation actions, and can support decision makers with avoiding risk and minimising impacts on natural coastal processes. In some cases, the overlay may prompt other responses (accommodate, protect) which may have more substantial impacts on coastal processes.
		Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations:** Overlays must be consistent with the purpose and vision for schemes expressed in Municipal Planning Strategies and planning policy at all tiers – state, regional and local. For coastal hazards, they will

Action	Land management, planning and design – Land use - Planning overlays		
	Cultural values Environmental values Social values Economic values		need to reflect hazard extents, and provisions will need to avoid contradictions with other overlays, such as heritage or environmental landscapes. The controls do not change what the land can be used for, e.g. residential, industrial, commercial (which is set by the planning zone), but instead can be used to address a single issue (e.g. inundation), or a set of related issues (e.g. coastal hazards). Multiple overlays can apply at any location, e.g. landscape, heritage, landslide etc. The schedules can be customised for particular locations and can also identify the type or scale of development that is exempt from consideration against the requirements of the overlay. The community may perceive an impact on property values or insurance premiums as a result of inclusion in the overlay, however inclusion of land in an overlay does not change the actual risk of the hazard occurring. Depending on the hazard and overlay requirements, the cost of implementing a development may increase to achieve compliance.
Guidance for implementation	**Preparation / design period**	>12 months	Planning overlays are often introduced with a range of other planning scheme changes to address a range of issues. There are statutory requirements associated with the process and stakeholder consultation.
	Effective lifetime	Ongoing	Planning overlays remain in place unless changed by a planning scheme amendment or enactment of a new scheme.
	Co-benefits	Some	Planning overlays are a useful tool for setting clear expectations about the outcomes that development in hazard areas needs to meet. Overlays can also be used to manage impacts for different hazards with similar impacts, e.g. an inundation overlay covering sea level rise, storm tide and flood.
	Approvals and requirements	A planning scheme amendment is required to implement a planning overlay. A planning authority such as a local council may only prepare an amendment to the local provisions of its planning scheme once it receives authorisation from the Minister for Planning. A planning scheme amendment will need to meet the statutory requirements of the *Planning and Environment Act 1987*, Planning and Environment Regulations 2005 and associated Ministerial Directions and Victoria Planning Provisions to demonstrate consistency with the policies, objectives and strategies for coastal Victoria as outlined in the State Planning Policy Framework.	
	Design considerations, constructability, and materials	Consideration should be given to the extent of land to be included in the overlay and will need to be supported by technical studies prepared by suitably qualified hazard specialists. Clear guidance on expectations for a range of development situations may be required, for example infill or redevelopment in intensively developed areas versus greenfield development. Overlays may be an "easier" planning tool to implement but not necessarily the most appropriate – consideration should also be given to back-zoning / re-zoning particularly in cases of inappropriate uses.	
	Cost considerations	Costs include those associated with a planning scheme amendment and/or associated processes to establish the overlay.	
References	Planning Victoria Glossary. www.planning.vic.gov.au/__data/assets/pdf_file/0020/604064/UVPS-Using-Victorias-Planning-System-2022.pdf		

Project example

Land management, planning and design – Land use – Planning overlay – Project example		
Project title	Greater Geelong Planning Scheme Amendment C394GGEE – Corio Bay and Bellarine Peninsula	 *A section of the Corio Bay foreshore that shows the LSIO extents*
Action type	Planning overlay	
Location	Corio Bay and Bellarine Peninsula	
Land manager	City of Greater Geelong Council	
Year of Implementation	2016	
Project objectives	An amendment to the Greater Geelong Planning Scheme was made to implement the Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment of December 2015. The amendment included policy changes to the Municipal Strategic Statement, introduced a new Land Subject to Inundation Overlay (LSIO) schedule and applies the LSIO to properties identified as being subject to future flood events and sea level rise. The objectives of the LSIO were to: • protect land vulnerable to coastal inundation from inappropriate development • plan for projected sea level rise to ensure that the community and assets are not exposed to an unacceptable level of risk associated with the coastal impacts of climate change • ensure that any new development is suitably designed to ensure that it is compatible with the identified flood hazard and local drainage characteristics.	
Project process Measures implemented	Amendment C394 involved: • amending Clause 21.05 Natural Environment to refer to the Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment and including a new objective and strategy at Clause 21.05-5 Climate Change relating to coastal impacts of climate change • introducing a new Schedule 2 to Clause 44.04 Land Subject to Inundation Overlay titled “Coastal Inundation and Hazard” (LSIO2) • applying the Land Subject to Inundation Overlay Schedule 2 (LSIO2) to land identified in the Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment as being inundated by the combined effects of the 1% Average Event Probability (AEP) flood event plus 0.8 metre sea level rise • amending the Schedule to Clause 72.03 to update the list of maps forming part of the scheme.	
How well project met objectives	The planning scheme amendment was placed on public exhibition and a total of 43 submissions were received including 39 objections. Council resolved to refer the submissions to an independent Panel as required under the Planning and Environment Act. The Panel held a hearing on 28 February 2020 and provided its report to Council in early April 2020, which endorsed the proposed amendments. Specifically, the Panel found the LSIO to be the most appropriate planning tool available to address the risk of sea level rise and storm-tide surge. The Planning Scheme Amendment was adopted by Council in 2020.	
Cost	Not disclosed.	
Further considerations	Requires significant administrative capacity and resourcing including for panel costs and technical expertise/peer review.	

1.1.5 Rolling easements

Action		Land management, planning and design – Land use – Rolling easement	
Description		[NOTE: there is currently no legal mechanism for implementing this action in Victoria.] Rolling easements involve the establishment of an easement on privately owned land within areas exposed to coastal hazards. The landward position of the easement is based on a set distance or presence of a feature (such as the permenant vegetation line) from a mobile shoreline (see development setback). As recession or permanent inundation occurs, the landward boundary of the easement also migrates landward in parallel with the new shoreline. Rolling easements are used to reduce the risk to people and built assets from coastal hazards over time. They can also support retention of public access along the coast. They support usage of the land for existing purposes for as long as possible, and prevent further development intensification of the area. Built assets are only removed, relocated or adapted once they are within the easement boundaries. This approach directly responds to actual hazard impacts but in a planned fashion. Rolling easements also support the preservation of a buffer in which coastal habitats can migrate landward under the influence of sea level rise, avoiding coastal squeeze and maintaining natural shoreline forms.	 *Coastline eroding back into private property at Queensferry, Western Port Bay. Fencing denotes where erosion is intersecting with private property.*
Functional type	✓	Land management planning and design	
		Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** As a rolling easement essentially creates a buffer to accommodate coastal processes, it is relevant to managing most coastal hazards. Rolling easements are most effective on privately held land in locations that are not intensively developed, and where there is a willingness for vulnerable land to continue to be managed privately. Any existing built assets in the easement area should either be removed or acknowledged as being sacrificial. While examples exist internationally, there is currently no legal mechanism for implementing the migrating nature of the easement boundaries in Australia. This is an evolving area for coastal management.
	✓	Long-term erosion	
	✓	Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Rolling easements enable coastal hazard risk to be avoided, through conditions applied to the easement. The presence of the easement may also support nature-based, accommodate and retreat actions, including supporting habitat migration, use of resilient design in the easement zone, and managed retreat as the easement moves.
	✓	Avoid	
	✓	Nature based	
	✓	Accommodate	
	✓	Retreat	
		Protect	

Action	Land management, planning and design – Land use – Rolling easement			
Likely impact on natural coastal processes	✓	Low	Considerations: Rolling easements support the creation of a buffer where coastal processes can continue naturally.	
		Moderate		
		High		
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** The application of a rolling easement can provide benefit for a diversity of site values, including habitat migration, access to the coast and associated social and economic benefits. However, there are site specific complexities to be considered. These include: • Challenges in applying rolling easements to freehold and private land where landowners may not voluntarily accept the arrangement • Costs may be high to implement • Implementation may not be supported where an investment-backed expectation exists to be able to develop coastal land • Land values may be impacted in areas subject to rolling easements, and also in adjacent areas. Rolling easements are useful to delay the need for high-cost decision making. As hazard impacts progress landward, the easement may eventually intersect with built assets. At that time a decision on whether to change the adaptation response by progressively relocating, removing, or protecting built assets will need to be made. Ultimately, properties subject to rolling easements may also need to be rezoned to clearly signal the intent that the land use will change in response to coastal hazard risks.	
	Cultural values			
	Environmental values			
	Social values			
	Economic values			
Guidance for implementation	**Preparation / design period**	> 12 months	The implementation of a rolling easement will require time for discussion and negotiation with landowners. Given that there is currently no legal mechanism for implementing the migrating nature of the easement boundaries in Australia, it is anticipated that setting a legal precedence for this measure may take several years to resolve.	
	Effective lifetime	Varies	The longevity of a rolling easement is highly site specific and will depend on the local hazards, the proximity of built assets as well as the size of the buffer created.	
	Co-benefits	Yes	Rolling easements create space for buffers for habitat or ecosystem strengthening, and enable the additional benefits of maintain public access to the coast.	
	Approvals and requirements	There is currently no legal mechanism for implementing this action in Victoria.		
	Design considerations, constructability and materials	Important considerations for success include: • A willingness to engage in sincere and genuine dialogue with directly affected landowners • A willingness to explore and develop a legal framework to support implementation • Understanding of coastal processes, local biodiversity and geotechnical conditions at the site • Understanding the existing and proposed usage of the easement area and its value to the landowners, local community and other key stakeholders • Ongoing management of the easement area, including habitat maintenance and safety for adjacent foreshore users		
	Cost considerations	As rolling easements do not change the existing management of privately owned land, expenditure additional to what is already incurred associated with rolling easements will be largely for:		

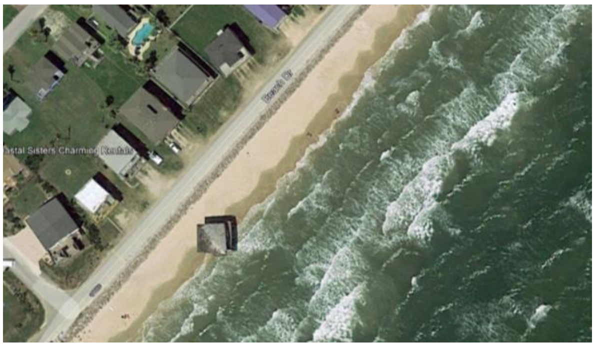
Action	Land management, planning and design – Land use – Rolling easement	
		• legal fees for implementation • planning costs for implementation • ongoing habitat strengthening and maintenance (if required). There will be monetary losses associated with the abandonment or removal of built assets within the easement. However, rolling easements avoid the costs (tangible and intangible) associated with protecting vulnerable land and built assets by supporting natural processes to continue for as long as possible.
References	Bell, J. (2014). Climate change and coastal development law in Australia. Federation Press. Bell-James, J., Fitzsimons, J. A., Gillies, C. L., Shumway, N., & Lovelock, C. E. (2021). Rolling covenants to protect coastal ecosystems in the face of sea-level rise. Conservation Science and Practice, e593. https://doi.org/10.1111/csp2.593 O'Donnell, T. (2014). Rolling easements: A flexible solution. Paper presented to the 23rd NSW coastal conference, 11–14 November 2014, Ulladulla, NSW, Australia Titus, J. G. (2011). Rolling easements (Report prepared for Climate Ready Estuaries Program). US Environment Protection Agency. Retrieved from https://www.epa.gov/sites/default/files/documents/rollingeasementsprimer.pdf Titus, J. G. (1998).Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches without Hurting Property Owners, 57 Maryland Law Review. 1281, 1308–1318 (1998).	

Project example

Land management, planning and design – Land use – Rolling easement – Project example	
Project title	Texas Open Beaches Act
Action type	Rolling easement
Location	Surfside, Texas, USA
Land manager	Texas State
Year of Implementation	1959
Project objectives	The Texas Open Beaches Act (TOBA) was passed so that the public had free and unrestricted right of ingress and egress to and from public beaches, defined as the area between the line of vegetation and the mean low tide line. The intention was to prevent the privatisation of beaches as the coastline receded into existing private property.
Project process	The TOBA prevents the construction of any barriers to prevent the unrestricted right of the public to use the beach and buildings that are located seaward of the vegetation line must be removed if they impede public access. The TOBA does not remove the land rights from the private ownership but creates an easement for access by the public.
Measures implemented	Because the TOBA affects property in the short-term erosion hazard zone, relocation of properties after storm events occurs, with little time to plan or execute relocation. The execution of the TOBA has been met with resistance from the landowners, that has frequently resulted in litigation that has been upheld by the courts. In the case of Surfside, Texas (see photos), erosion of the coastline due to Hurricanes pushed the vegetation line behind the houses. Permits for repairs of the houses were subsequently denied and the homes were removed from the erosion prone zone.
How well project met objectives	The TOBA was successful at maintaining an easement for the public use of beaches, however, there was considerable conflict each time it needed to be enforced, given the lack of buffer between and therefore time between the defined easement area and the development of private properties.
Cost	-
Further considerations	Within the TOBA no compensation is paid to landowners for the removal of structures that are within the easement and landowners are responsible for the cost of relocation or demolition. There is a duty to disclose this risk at the time of sale of the property that has been in place since 1986 and as such, landowners are suitably aware of the risk of ownership in potential erosion areas. Legal challenges to the lack of compensation have arisen, but in all cases have been upheld by the courts.

Surfside, Texas (2004). Homes behind the vegetation line. (Source: Google Earth)

Surfside, Texas (2006). Homes in front of vegetation line and ordered for removal. (Source: Google Earth)



Surfside, Texas (2008). Homes in front of vegetation line removed.

(Source: Google Earth)

1.1.6 Removal / relocation of infrastructure

<table>
<tr><th>Action</th><th colspan="3">Land management, planning and design - Land use – Removal / relocation of infrastructure</th></tr>
<tr><td rowspan="4">Description</td><td colspan="2">Removal / relocation of infrastructure refers to taking built assets out of the coastal hazard zone.
The removal of infrastructure can enable natural coastal processes to continue, including the landward migration of beaches, dunes and other important coastal and estuarine habitats, and prevent coastal squeeze.
Infrastructure removal / relocation may include:
• Removing or relocating important public or community assets to a new landward location
• Replacement of existing infrastructure with alternatives that are moveable (e.g. beach accesses, surf life saving towers)
• Realignment of utilities to a new landward alignment to reduce exposure of main pipelines, where branch piplelines may service infrastructure in higher risk areas.
Some infrastructure may remain in the hazard zone where it is accepted that it may be impacted and/or require relcoation at a future date, and where it is coastally dependant (e.g. signage, coastal footpaths, beach showers, beach access).</td><td rowspan="4">
Removal of Amenities Block, Marengo, Victoria, 2010 (top), 2017 (bottom) Image source: Google street view.</td></tr>
<tr><td>✓</td><td>Land management planning and design</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td></td><td>Coastal engineering</td></tr>
<tr><td rowspan="8">Coastal hazard mitigation</td><td>✓</td><td>Short-term erosion</td><td rowspan="8">Notes on suitability:
This may occur when an asset is impacted by a hazard event, or pre-planned to ensure the asset is not impacted in the future.
Removal / relocation of infrastructure is often used to mitigate risks associated with both short and long term erosion. It is also an effective mitigation for inundation, although there are often alternative ‘accommodate’ actions also available for inundation.
Relocation is particularly effective where suitable land is available so that the assets (e.g. Surf Life Saving Clubs, amenities blocks) can maintain their original function, and/or provide additional community benefits in their alternative location.</td></tr>
<tr><td>✓</td><td>Long-term erosion</td></tr>
<tr><td>✓</td><td>Accretion</td></tr>
<tr><td>✓</td><td>Storm tide inundation</td></tr>
<tr><td>✓</td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td>✓</td><td>Saline intrusion</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="6">Notes on policy context:
The removal or relocation of infrastructure is typically associated with retreat. Asset removal / relocation may be combined with additional actions in an adaption pathway including nature-based and accommodate.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td></td><td>Nature-based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td>✓</td><td>Retreat</td></tr>
<tr><td></td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td rowspan="3">Considerations:
The removal / relocation of infrastructure out of the coastal hazard zone supports the creation of a buffer where coastal processes can continue naturally.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="4">Land management, planning and design - Land use – Removal / relocation of infrastructure</th></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td colspan="2" rowspan="5">Applicability considerations
The removal / relocation of infrastructure can provide benefit for a diversity of site values, including habitat migration, access to the coast and associated social and economic benefits. However, there are site specific complexities to be considered. These include:
• If relocating, suitable alternative locations for the infrastructure are required, which may not be physically possible or which may involve modifications to connect to other infrastructure. Some services may have to remain in place until all development is relocated.
• Removal of infrastructure may result in changes to habitats and environmental biodiversity, both positively and negatively.
• Visitation experience is likely to be changed as a result of the modification of coastal infrastructure (positively or negatively)
• Substantial costs to mitigate impacts of replacement infrastructure may be incurred depending on the characteristics of the relocation site.
Careful planning may allow works to coincide with planned asset renewal, thereby maximising the use of existing assets and minimising accelerated maintenance or continued protection costs.
Assets such as sewerage and drainage are often by necessity located in low-lying areas, and it may not be possible to relocate these long-life assets to outside of inundation hazard areas.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="4">Guidance for implement-ation</td><td>Preparation / design period</td><td>> 6 months</td><td colspan="2">Removal / relocation of infrastructure may require more than 6 months for planning, particularly for master planning including community and stakeholder engagement, and resolving design and approvals for connections with other infrastructure. Coordination between multiple agencies is likely to be necessary and may increase planning timeframes.</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td colspan="2">The effective lifetime is dependent on the distance of relocation and the design life of the infrastructure.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td colspan="2">Relocation of assets allows the opportunity to renew existing infrastructure and preserve natural coastal landscapes. Enjoyment of coastal spaces may be enhanced by inclusion of access, pathways and other infrastructure that is either removable or planned to be removed / moved in future. Removal of infrastructure from coastal hazard areas allows space for natural biodiversity to re-establish which may improve natural coastal defences and enhance environmental value.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">Approvals may require Marine and Coastal Act 2018 consent which is founded on alignment to the directions in the Marine and Coastal Policy (2020) for all works in the marine and coastal environment. This includes the adaptation actions order of consideration and using a pathways approach.
The range of approvals that may be required to demolish or re-establish relocated infrastructure include:
• Land Owner's Consent
• Marine and Coastal Act 2018 consent (DEECA)
• Planning Permit (Local Government)
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Parks Victoria – works permit
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
</table>

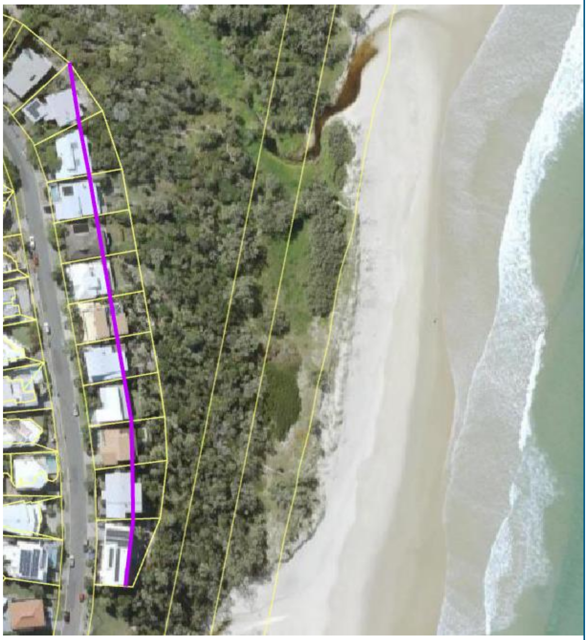
Action	Land management, planning and design - Land use – Removal / relocation of infrastructure	
	Design considerations, constructability, and materials	Important considerations for successful relocation plans include: • Understanding of community sentiment towards the style of relocation proposed, and a willingness to engage in dialogue with the community • Understanding of coastal processes, local biodiversity and geotechnical conditions at the site • Existing and proposed usage of the relocation areas and its value to the local community and other key stakeholders • Ongoing management of the retreat area, including public access, habitat and emergency response.
	Cost considerations	The relocation of public infrastructure may result in long-term costs savings if there is sufficient space to relocate or rebuild outside of hazard areas. Costs should be considered over the “whole of life” of the asset.

Project example

Land management, planning and design - Land use – Removal / relocation of infrastructure – Project example		
Project title	Marengo amenities removal	 Amenities block at Marengo on sand dune, 2016. (Source: geelongadvertiser.com.au)   Removal of Amenities Block, Marengo, Victoria, 2010 (top), 2017 (bottom) Image source: Google street view.
Action type	Removal / relocation of infrastructure	
Location	Marengo	
Land manager	Victorian Government	
Year of Implementation	2017	
Project objectives	The amenities block on the Great Ocean Road at Marengo (near the intersection with Ocean Park Drive) was at risk of collapse due to ongoing erosion along the Marengo beach front.	
Project process	It was removed in 2017. No suitable location on the landward side of road was available for relocation.	
Measures implemented	The removal of the amenities block increased the available area for the continuation of natural coastal processes. Following the removal of the amenities block, erosion continued at the site, with beach nourishment and protective works carried out to protect the road (see example under 'beach nourishment').	
How well project met objectives	By removing the amenities block, additional time to plan and implement other works was provided, allowing for better outcomes.	
Cost	Not disclosed.	
Further considerations	The beach and toilet block at this location had low utilisation and it was determined by land mangers that a replacement was not immediately required. There is an intention to construct a new block the southern end of the beach subject to a master planning process. Before the facility was removed there were notices published in local news sheets and articles in the local paper but no formal public consultation.	

1.2 Resilient design / development

1.2.1 Development setbacks

Action	Land Management planning and design – Resilient design / development - Development setbacks		
Description	A development setback is a prescribed distance landward of the coastline or property boundary within which certain types of development, e.g., permanent residences, are prohibited. They are typically only applied to privately owned land. The setback distance can be either a distance from the coast at one point in time, or a distance from a mobile feature such as the high tide mark, dune toe, or vegetation line, which may move landward over time due to coastal recession or sea level rise (see rolling easements). Setbacks are intended to provide sufficient room for the shoreline to fluctuate or migrate landward in response to natural coastal processes and sea level rise, without placing the development at risk for the entirety of the property's design life. This allows natural coastal processes to be maintained, minimising risk to assets and preserving that natural state of the beach. Development setbacks can also be used to maintain access to coastal protection structures for maintenance purposes.		 Development setback (purple line) at Sunrise Beach, Queensland.
Functional type	✓	Land management planning and design	
		Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Development setbacks are suited to locations where private properties are large enough to accommodate development/re-development landward of the intended setback. In locations where development is intensive and coastal protection structures such as seawalls have been implemented, a development setback can be used to ensure sufficient space on the private property for access to maintain the structure. This is most effectively implemented in conjunction with seawall approvals.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Setbacks can be included in adaptation pathways to avoid hazard impacts for a period of time, and may be combined with other measures long-term in transitioning towards land use change and retreat of infrastructure.
	✓	Avoid	
		Nature based	
		Accommodate	
		Retreat	
		Protect	

<table>
<tr><th>Action</th><th colspan="4">Land Management planning and design – Resilient design / development - Development setbacks</th></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td colspan="2">Low</td><td rowspan="3">Considerations:
Development setbacks enable natural coastal processes to continue for a period of time.</td></tr>
<tr><td></td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations
Setbacks restrict the development rights of property owners and may conflict with development aspirations in an area, and associated social and community expectations. There may be perceived concerns for property values where setbacks are applied, however there is little evidence to support this where sufficient room for development exists landward of the setback within the lots.
Setbacks can enable a natural buffer between development and the coastline, with benefits for preserving environmental, cultural and social values in this zone, including biodiversity and amenity.
Allowing sandy coastlines to migrate landward (recession) without building protective structures also maintains the profile of the natural beach, which is often valued as a community asset for recreation and may positively influence local property values.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="6">Guidance for implementation</td><td>Preparation / design period</td><td>Multiple Years</td><td colspan="2">Development setbacks may require multiple years for implementation, particularly to undertake genuine community and stakeholder engagement and allow for adoption within the planning scheme.</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td colspan="2">The effective lifetime for development setbacks is dependent on the setback purpose and distance. For use as a buffer, the setback should be designed such that development elsewhere on the land parcel can be used for their entire intended life (e.g. 50 years for residential housing). Once the setback no longer functions as a buffer, a transition to other approaches may be appropriate as part of a pathways approach, e.g. a rolling easement or land buy back.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td colspan="2">The restriction of development in coastal zones allows space for natural habitats to migrate landward in response to sea level rise and erosion, thus enhancing or protecting biodiversity.
This measure also preserves a natural beach profile which is often highly valued as a community asset for recreation.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">Establishing a variation to setback standards within the Building Regulations 2018 can be established through a Local Planning Scheme.</td></tr>
<tr><td>Design considerations, constructability, and materials</td><td colspan="3">Important considerations for successful development setback implementation include:
• Understanding of community sentiment towards development setbacks and a willingness to engage with the community and directly affected landowners
• Understanding of the coastal processes and coastal hazards of the subject area and how they are expected to evolve over time with sea level rise
• Ongoing monitoring and suitability assessment of the development setbacks over time
• Consistent assessment and conditioning of development applications within the setback
• Community and stakeholder engagement to build support of the program.</td></tr>
<tr><td>Cost considerations</td><td colspan="3">Development setbacks are a low-cost strategic planning tool, with costs involved in undertaking detailed coastal assessments to set the development setback distances appropriately and robustly, and planning costs associated with engagement and planning scheme amendments.
In areas where setbacks are used as buffers, there may be savings for property owners due to the avoided or delayed costs of structural protection works such as seawalls to protect threatened development.</td></tr>
</table>

Project example

<table>
<tr><th colspan="3">Land Management planning and design – Resilient design / development - Development setbacks – Project example</th></tr>
<tr><td>Project title</td><td>Sunrise Beach coastal building lines</td><td rowspan="8">
Figure 1-2: Development setback at Sunrise Beach, Queensland.</td></tr>
<tr><td>Action type</td><td>Development setback</td></tr>
<tr><td>Location</td><td>Sunrise Beach, Queensland</td></tr>
<tr><td>Land manager</td><td>Noosa Council as trustee for Queensland Government</td></tr>
<tr><td>Year of Implementation</td><td>1995</td></tr>
<tr><td>Project objectives</td><td>The building lines implemented at Sunrise Beach are intended to limit development within the coastal management district. The coastal building lines ensure that there is sufficient space for natural coastal processes to occur as well as natural migration/meandering of the coastal creek to the north of the site.</td></tr>
<tr><td>Project process</td><td rowspan="2">Coastal management districts and coastal building lines are declared under the relevant coastal and planning legislation by the Queensland Government, and reflected in local government planning schemes. Development proposals in this area are assessed by local government for compliance with the requirements of the building line.</td></tr>
<tr><td>Measures implemented</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">The coastal building lines at Sunrise Beach have been very successful, as they were established with sufficient room for current natural processes to occur, with built assets landward of present climate erosion extents. With support from residents and local community groups the overall dune health has improved over time.</td></tr>
<tr><td>Cost</td><td colspan="2">-</td></tr>
<tr><td>Further considerations</td><td colspan="2">The setbacks defined by the coastal building line were considered sufficient when they were established, however, may not be adequate under a changing climate. Given that development has occurred right up to the coastal building line, monitoring of the effectiveness of the coastal building line will be required into the future.</td></tr>
</table>

1.2.2 Use of resilient materials and design in new and retrofitted coastal infrastructure

Action	Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure		
Description	Use of resilient materials and design can reduce coastal hazard risk and enable the most appropriate infrastructure in coastal hazard areas. This can be achieved a number of ways, including: - raising floor levels to limit exposure to inundation - using building materials that are resilient to temporary inundation - floorplan designs that reduce the consequence of temporary inundation (e.g. flood tolerant materials/uses on ground floor, elevated wiring) - constructing modulated / easily removable structures / buildings that can be moved further inland when necessary. The coastal environment is very harsh on building materials due to corrosive salt spray, saltwater inundation and wind-blown sand. In additional to minimising coastal hazard risk, selecting durable materials or ensuring that they are treated (i.e. hot dipped galvanised steel), is effective way of extending the life of new buildings or upgrading existing buildings. Other examples of resilient building materials for the coastal environment include recycled plastic planks, fibre reinforce plastic mesh, aluminium panels, stainless steel and appropriately selected and treated timber. Resilient materials can significantly increase the lifetime of the structure and reduce maintinence costs.		 Raised floors at Seaford SLSC  Coastal boardwalk made with more durable, maintenance-free recycled plastic in Wynyard, Tasmania (Source: Envire).
Functional type	✓	Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** This approach is suitable for buildings or other assets located within current and future coastal hazard zones, to reduce costal hazard risk for a diversity of hazard types.
	✓	Long-term erosion	
	✓	Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Before considering the use of resilient materials and design, managers and asset owners should first consider if the
		Avoid	
		Nature based	

<table>
<tr><th>Action</th><th colspan="4">Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure</th></tr>
<tr><td rowspan="3"></td><td>✓</td><td colspan="2">Accommodate</td><td rowspan="3">infrastructure is coastally dependent, and if there are alternative ways to avoid coastal hazard exposure.
In progressing with the use of resilient materials and design as an accommodate approach, managers/asset owners must also consider the useful life of the asset and the corresponding timeline where the coastal hazard risks are tolerable.
Opportunities for longer term retreat should also be considered in adaptation pathways, and/or the need for protection works for critical assets.</td></tr>
<tr><td></td><td colspan="2">Retreat</td></tr>
<tr><td></td><td colspan="2">Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td colspan="2">Low</td><td rowspan="3">Considerations:
Infrastructure development within the marine and coastal environment may impact on natural coastal processes, however resilient design can assist to minimise the impact.</td></tr>
<tr><td>✓</td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.
Cultural values</td><td rowspan="5">Applicability considerations
In additional to reducing hazard risk, the use of resilient materials and design also provides opportunity to best align/blend infrastructure with local values, including preservation and promotion of environmental and cultural values.
Design can also be combined with nature-based adaptation responses (biomimicry).</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="4">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>> 12 months</td><td>The preparation time is 1-2 years depending on the complexity of the resilient design. It is estimated to take approximately six months to a year for coastal studies and six months to a year for architecture design and approvals.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>Varies</td><td>Guidance has been provided by the Institute of Public Works and Engineering Australasia (IPWEA) on the useful lives of various assets classes and the likelihood of how climate change may impact the asset to reduce, and in some cases, increase the useful life of an asset: IPWEA Practice Note 12.1: Climate Change Impacts on the Useful Life of Infrastructure. With good design structures could last 10 to 30 years in the active beach zone. Materials, particularly cladding may not last as long and need maintenance every few years at best.
Engineers Australia has provided Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering (2017), which may be used for site specific guidance for the planned coastal infrastructure on how climate change is likely to affect the design life of the asset in the concept design phase. The Guidelines also provide guidance on likely environmental impacts from each of the climate variables and effect on the structure at each phase of its development: investigation, design, construction, operation, maintenance and removal.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Yes</td><td>Many resilient materials are also low carbon, or use recycled waste, eg HDPE planks for jetties and decks. Using resilient materials which are also low carbon, enables innovative products to be trialled. Low carbon, and in some cases carbon neutral, materials are being developed to meet carbon emission reduction targets both in Victoria and internationally. Recycled materials may be used to facilitate a circular economy and reduce waste to landfill.</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">The land tenure will determine the planning approval requirements. Proposals for development on coastal Crown land all require consent under the Marine and Coastal</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="2">Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure</th></tr>
<tr><td></td><td></td><td> Act 2018 and where required, referral under the Planning and Environment Act 1987 to obtain a planning permit from the local council under the relevant municipal planning scheme.
It is anticipated that approvals may need to be sought for:

Landowner's Consent
Endorsement by the Crown land reserve voluntary committee of management with support and oversight from DEECA.
Marine and Coastal Act 2018 consent (DEECA) which is founded on alignment to the directions in the Marine and Coastal Policy (2020) for all works in the marine and coastal environment. This includes the adaptation actions order of consideration and using a pathways approach.
Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).
Planning Permit from the local council where the land is located within the corresponding Local Government Area. Note that Local Planning Policies, Zoning definitions, Overlays, Strategies and Design Responses may vary between different municipalities.

Planning permits will be required to comply with the Victoria Planning Provision (VPP) 13.01 Climate Change Impacts and in particular the following specific provisions:

13.01-1S Natural hazards and climate change; and
13.01-2S Coastal inundation and erosion. This includes the strategy to plan for sea level rise of not less than 0.8m by 2100.

The retirement of the asset at the end of its useful life may also be a Planning Permit Condition. </td></tr>
<tr><td></td><td>Design considerations, constructability and materials</td><td> Important considerations for success include:

A willingness to and incorporate innovative approaches that have not yet been streamlined into architectural design for standard asset templates.
A willingness to research and incorporate innovative materials that have limited applications and performance history to inform and compare design lives with more traditional materials. Examples include recycled plastic products and wood-like aluminium.
Understanding of coastal processes, geotechnical conditions and local biodiversity at the site and how climate change projections may impact these.

Make use of available guidelines:
The South East Council Climate Change Alliance (SECCA 2021), has published 'A guide for councils to assess the vulnerability of assets to climate change', which provides the Victorian context of the key issues for consideration when selecting a resilient infrastructure design and/or materials as an adaptation measure.
The Victorian Siting and Design Guidelines (2020) provides direction on adaptive infrastructure design within the coastal environment according to 15 fundamental elements which address cultural, social, environmental and economic values. It recommends standard materials for the coastal environment including hardwood timber and hot dip galvanised steel.
For more resilient material options, which also have a sustainability rating, refer to the IPWEA Practice 12.2: Climate Resilient Materials for Infrastructure Assets. </td></tr>
<tr><td></td><td>Cost considerations</td><td> To construct an asset with resilient infrastructure design and materials should consider:

Architectural design – require for an adaptive design specific to the site's coastal geomorphology and coastal hazards over the asset's design life.
Planning permit applications and approval fees.
Material supply – unusual/resilient materials make cost more to supply than standard equivalents
Construction - unusual/resilient materials make cost more to install than standard equivalents
Ongoing maintenance such as water proofing, painting and oiling of structure and cladding if required. (e.g. painting timber wish a lacquer or varnish. The need for this may be removed by using recycled plastic products or aluminium that looks like timber).
</td></tr>
</table>

Action	Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure	
		• Management of impacts on coastal processes and habitat protection where needed (e.g. if a building is protected by a seawall ongoing beach nourishment may be needed)
Reference	Engineers Australia, 2017, Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering. IPWEA Practice Note 12.1: Climate Change Impacts on the Useful Life of Infrastructure IPWEA Practice 12.2: Climate Resilient Materials for Infrastructure Assets Modular Bench - Replas Recycled Plastic Furniture Product Knotwood - Wood look Aluminium systems. No Maintenance & Australian Made.	

Project example

Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure – Project example		
Project title	Seaford SLSC clubhouse precinct	 Seaford SLSC clubhouse with patrol – December 2021 Moveable hardwood timber batten screens  Disability access ramp built above the dune system  Seaford SLSC with rock wall – December 2021 
Action type	Planning - Resilient design	
Location	Seaford, Victoria	
Land manager	Frankston City Council owned asset	
Year of Implementation	2005	
Project objectives	The Seaford SLSC clubhouse, café, public amenities and disability beach access ramp were designed to provide an asset which is resilient to climate change impacts of sea level rise combined with increasing severity of coastal storms, while also meeting community needs and having a limited impact on the coastal dune ecosystem.	
Project process	During the construction of the building, prefabrication processes were used to minimize on-site construction to avoid disturbance to the local natural ecology.	
Measures implemented	The building was designed to minimise adverse impacts on the dune ecosystem as a result of erosion. The portal frame structure was fabricated using plywood sheathing and supported on pile footings. The plywood structure is able to withstand the persistent forces of wind and earthquakes, and is low-carbon material. The building's floors are raised above ground level to avoid inundation from sea water. Vertical 'sun-visors' offer protection to the ocean-facing west elevation in summer which also reduce the risks associated with summer heatwaves when lifesavers are responsible for protecting beaches users from hazards. In response to heatwaves, the moveable timber batten screens can be adjusted. The internal spaces can be adapted to maximise thermal comfort and natural light by moving these screens according to season and time of day. The raised floor levels and beach access ramp have been constructed to reduce disturbance to the dune ecology. The cladding system at ground level was designed as stacked 'sand-shelves' for the retention of windblown sand. This structure also performs the adaptive role of an additional anchor for the propagation of endemic grasses and plants, similar to the function of an artificial reef in the sea.	
How well project met objectives	The building is now greater than 15 years old and the key maintenance requirement is the annual timber varnishing. This cost could be avoided by use of newer innovations with greater durability that look like timber such as recycled plastic and wood-like aluminium products now available. Five years ago, the rock wall was constructed to protect the asset from beach erosion.	
Cost	The total cost of the project in 2004 was estimated at $3,427,000 which includes the demolition of the former building, removal of any asbestos material and design of the new asset. There are ongoing operational and maintenance costs including the annual varnishing and the additional capital works cost of the sea wall construction five years ago.	
Further considerations	Sustainability should also be considered alongside resilient infrastructure design and materials. In the Seaford SLSC asset example, a number of sustainability measures were considered in the architectural design. To provide both ocean views to the west and a northerly orientation, the Seaford LSC was designed as a suite of	

Land management, planning and design - Resilient design / development - Use of resilient materials and design in new and retrofitted coastal infrastructure – Project example	
	buildings. Solar energy is captured by either transpired solar air heaters or concrete floor panels on all northerly aspects to supplement winter heating. Rainwater is collected from all horizontal surfaces of the building, courtyard and car park and stored in underground tanks.

2. Nature-based methods

1.3 Coastal vegetation and blue carbon ecosystems

1.3.1 Mangrove forests

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Mangrove forests	
Description	*Mangrove forests* Mangrove forests are coastal wetlands comprised of trees and shrubs, growing between the low tide and high tide line in sheltered bays, lagoons and estuaries. Mangroves can reduce the risk of coastal inundation and erosion, as the plants intercept and dissipate incoming wave energy. This creates lower energy environments inside and landward of the mangrove forest, which assists sediment deposition, and protects the shoreline from coastal erosion and storm inundation. Mangroves also help to bind the seabed together with their roots, further stabilizing the shoreline. Mangrove forests occur along the Victorian coastline predominantly in Western Port Bay, Port Phillip Bay, Anderson Inlet, Corner Inlet and throughout the Gippsland Lakes. There are also small mangrove forest colonies in West Victorian estuaries predominantly at Portland, Port Fairy, Warnambool and Peterborough. Protecting existing extents of Mangrove forests is an important baseline adaptation action. *Habitat restoration / creation* Where mangrove forests have been removed, cleared, lost due to natural processes, or their ability to naturally establish is resticted, coastlines may be impacted more severly by erosion and inundation. As sea levels rise, mangrove forests will tend to retreat landward with the changing intertidal zone. If structures such as seawalls and earthen bunds are present, landward retreat will be impeded (coastal squeeze), minimising the future extent of mangrove forests. Restoration / creation of mangrove forests, and enabling natural inland migration, can reduce coastal hazard risk for local coastal values, uses and assets. This can be done through: - Planting propagules or seedlings - sometimes using a hybrid approach to lower wave energy and increase propagule/seedling survival. - Removing restrictions to natural establishment including fencing areas to reduce disturbance, removing restrictions to tidal flows such as seawalls and earthen bunds, improving awareness of of the role of Mangrove forests to support stewardship.	 *Melbourne Water Mangrove Restoration Project, Lang Lang – Western Port Bay – 2012.*  *Mature mangrove forest, Pioneer Bay, Westernport*  *Mangrove seedling eroding from mudflat after protective PVC pipe was removed at Lang Lang. Source (WPSP 2019)*

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Mangrove forests		
Functional type		Land management planning and design	
	✓	Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Plant-based habitat restoration such as mangrove planting is generally more successful/suitable in protected bay and estuary coastal environments with low wave energy (e.g., Western Port Bay, Corner Inlet). Generally, mangrove forest establishment is most likely to be successful where mangroves have previously grown but have been removed (naturally by storm events or through human activity), provided the cause of loss can be addressed prior to restoration. In these locations, likelihood of success is highest at the edges of existing forests. Mangrove restoration for coastal protection is best suited to relatively sheltered locations where coastal erosion rates are low, enabling restored mangroves to grow to maturity. This may take many years depending on the site/species; thus, this measure is less suitable where coastal values or assets are already at high risk from short-term (storm) erosion, although may be combined with other actions in adaptation pathways.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
	✓	Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Mangrove forest restoration is a nature-based method. *Some forms of mangrove forest restoration may use a hybrid approach with physical support/engineering elements to locally reduce wave energy and increase likelihood of restoration success. Enabling natural inland migration of mangrove forests (reducing coastal squeeze) may also be part of a managed retreat / land use transition.
		Avoid	
	✓	Nature based	
		Accommodate	
		Retreat	
		Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Mangrove forest restoration typically occurs where mangroves have previously grown, and/or the current conditions and natural processes are right to support plant establishment.
		Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Successful restoration of a mangrove forest represents a regime shift, often from bare mudflats and eroding low earth cliffs to a vegetated coastal wetland. Some general considerations include that: • Mangrove forest establishment may align well with Traditional Owner assertions for country and protection/restoration of values. • A mangrove forest is habitat for threatened migratory birds to roost and feed within while they over-winter on the Victorian Coast. • The mangrove forest will create habitat for juvenile fishes and other marine animals, increasing the biodiversity of the region and potentially increasing the quality of the local fishery. • The sediment build up behind the forest can increase the area of beach available for recreation and other coastal habitats, particularly saltmarsh. • The establishment of a mangrove forest will alter the look and feel of a coastline, potentially limiting access to the water from the beach. This may lead to implications for cultural, boating, and other values, and compromises may need to be considered.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Mangrove forests		
			• Mangrove forests are blue carbon ecosystems which sequester relatively high amounts of carbon dioxide from the atmosphere as they grow. Land managers may gain carbon credits from such projects. • Benefits can be realised relatively quickly. Removing impediments and reintroducing tidal cycling to a coastal wetland in the Mungalla wetlands, North Queensland resulted in less weeds, higher fish biodiversity and reappearance of natural vegetation in a relatively short timeframe (Abbott et al. 2020). • Mangrove restoration may have negative community perceptions around amenity and access issues, which may need to be managed.
Guidance for implementation	**Preparation / design period**	> 12 months	Restoration of a mangrove forest to maturity may take many years (>15 years), although benefits will begin to be realised earlier.
	Effective lifetime	50+ years	Mangrove forests can adapt to rising sea levels as they initially accrete vertically, raising the level of the mudflat as sea level rises. When this adaptation can no longer keep up with sea level rise, successive generations of mangrove seedlings colonize shorelines to higher and higher elevations, resulting in a slow landward migration of the forest as sea levels rise. Providing natural migration is not impeded, effective lifetime is ongoing.
	Co-benefits	Many	There are many co-benefits of a mangrove forest including increased biodiversity, water purification, carbon sequestration, increased bird life, and the economic benefits of ecosystem services.
	Approvals and requirements	The range of approvals that may be required for a mangrove forest restoration project include: • Marine Park Approvals • Parks Victoria Works Permit • *Marine and Coastal Act 2018* consent (DEECA) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of a mangrove forest restoration include: • Understanding of coastal processes and wave exposure at the site • Source mangrove propagules or seedlings in sufficient numbers • Access to the site for planting/material supply • Environmental conditions (water quality, nutrient levels, water temperature, tidal inundation etc.) • Mangrove type *Avicennia marina* is the only species that grows on the Victorian Coastlines. Mangrove forest restoration has been attempted in Western Port Bay at Lang Lang and Grantville (with and without concrete planters). At Lang Lang, these have met with limited success due to the high wind waves causing considerable mortality of seedlings. At Grantville, a relatively high number of planted propagules remain surviving. Further trials are required to determine the most effective method for raising mangroves to maturity in such locations. Greater success has been achieved at more protected locations such as Stony Creek Backwash, Melbourne. Common failure mechanisms for mangrove forest restoration projects are wave damage to seedlings, wave-induced erosion around young seedlings, and smothering of seedlings/seeds with mobile sediment.	
	Cost considerations	When costing a mangrove forest restoration project, the following items should be considered: • Site specific coastal process studies • Design and approval costs • Supply of mangrove propagules or seedlings	

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Mangrove forests	
		• Construction of any hybrid protection structures (e.g., low crested breakwaters, planter pots etc.) • Removal costs (levees/bunds, tidal gates) for restoring tidal flows where applicable • Planting and maintenance (monitoring and infill plating).
References	Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. (2021) The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia. Victorian State Government, 2020. Victorian Marine and Coastal Policy. ISBN 978-1-76077-888-0 Sinclair S, Boon, P. (2012). Changes in the area of coastal marsh in Victoria since the mid-19th century. Cunninghamia: a journal of plant ecology for eastern Australia, 12 (2): 153–176.	

Project example

Nature-based methods – Coastal vegetation and blue carbon ecosystems – Mangrove forests – Project example	
Project title	Lang Lang Mangrove forest restoration
Action type	Mangrove forest
Location	Lang Lang – Western Port Bay
Land manager	• Melbourne Water • Lang Lang Foreshore Reserve Committee of Management
Year of Implementation	2010 - 2013
Project objectives	• Stabilise the eroding Lang Lang coastline to improve the water quality in Western Port Bay. • Establish mangrove forests on the eroding Lang Lang coastline.
Project process	• Melbourne Water applied for funding to DSE in 2010 through the Victorian Investment Framework. Funding was granted to the project for 3 years. • Consultation with the Western Port Seagrass Partnership to determine the most appropriate method for mangrove planting. • Mangrove planting and associated monitoring at Lang Lang over the three-year period.
Measures implemented	• Mangrove propagules were collected from mature mangrove forests in Western Port Bay. • Some propagules were used to raise mangrove seedlings prior to transplantation into the natural environment. • A total of 25,000 mangrove propagules/seedlings were planted at Lang Lang using various methods (including some Supported Littoral Vegetation methods) in four separate planting sessions between 2011 and 2013. • Some seedlings/propagules were planted behind Pile Fields, mesh fencing and other structures as a form of protection against waves. • Survival of seedlings/propagules planted was monitored during the project and reported.
How well project met objectives	Plantings initially had relatively good survival, however in the long-term most plantings had very low long-term survival of mangroves. Presently only one small, planted area in a protected cove has mangroves remaining from this project. The coastline at Lang Lang is still eroding. The project provides key learnings to inform future trials and plantings.
Cost	This project estimates that four people can feasibly plant 1000 mangrove seedlings/propagules in one day. This is reported as a cost of $1,650 per 100m (using a 3m wide planting area).
Further considerations	Results of the most recent plantings in Western Port Bay by the NCCC should be considered when deciding on planting techniques. For example, recently, it was found that the milk containers have a plastic inner lining which does not degrade and constrains root growth.

Extensive Mangrove plantings at Lang Lang in 2012.

Mangrove seedlings planted in milk containers. Note the plastic liner of the carton constrains root and plant growth in the long-term.

1.3.2 Seagrass meadows

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Seagrass meadows</th></tr>
<tr><td>Description</td><td colspan="2">Seagrass meadows

Seagrass meadows are areas of marine flowering plants, typically found in shallow water habitats of sheltered bays, lagoons and estuaries, but can also be found on more exposed coasts.

They have complex root systems which stabilise the sandy or muddy sea bed, and can colonize large areas under favourable conditions. When this occurs, seagrass meadows cause drag on incoming waves, dissipating wave energy. This creates lower wave energy environments inside and landward of the seagrass meadow, leading to increased sediment deposition, and assisting to protect the shoreline from coastal erosion.

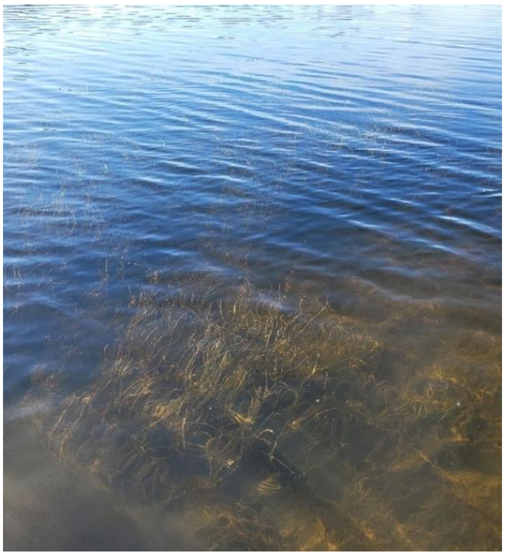
There are extensive seagrass meadows on parts of the Victorian coast including in Western Port Bay, Port Phillip Bay (especially Corio Bay), Corner Inlet and the Gippsland Lakes. Different types of seagrass can survive in more exposed locations with specific adaptations, however typically seagrasses thrive in calm, shallow waters.

Protecting existing extents of Seagrass meadows is an important baseline adaptation action.

Habitat restoration / creation

Where seagrass beds have have been cleared, lost due to natural processes, or their natural establishment is restricted, coastlines may be impacted more severely by erosion and inundation, and changes in off-shore sediment dyamics.

Restoration of seagrasses in appropriate environments can contribute to reduced coastal hazard risk for local marine and coastal values, uses and assets.

This can be done through:
- Addressing factors limiting seagrass establishement (e.g. reduce sedimentation from waterways, improve water quality, reduce disturbances)
- Planting fragments (which are often anchored into the sediment to minimise hydrodynamic disturbance), cores or seeds - sometimes using a hybrid approach to lower wave energy and increase fragment survival.</td><td>
Seagrass meadow on the Bass Coast</td></tr>
<tr><td rowspan="3">Functional type</td><td></td><td>Land management planning and design</td><td rowspan="3"></td></tr>
<tr><td>✓</td><td>Nature-based methods</td></tr>
<tr><td></td><td>Coastal engineering</td></tr>
<tr><td rowspan="8">Coastal hazard mitigation</td><td></td><td>Short-term erosion</td><td rowspan="8">Notes on suitability:

Seagrass meadows may be used to mitigate long-term shoreline recession, where sediment transport is driven by waves or currents. Restoration is most successful in areas that naturally have supported seagrass in the past. Establishment of seagrass in areas where it has not grown historically is generally unsuccessful.

Seagrass meadows once mature are effective in low-moderate wave energy environments, however, success in meadow planting/restoration occurs most often in low energy environments. Although</td></tr>
<tr><td>✓</td><td>Long-term erosion</td></tr>
<tr><td></td><td>Accretion</td></tr>
<tr><td></td><td>Storm tide inundation</td></tr>
<tr><td></td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td>✓</td><td>Offshore sediment dynamics</td></tr>
<tr><td></td><td>Saline intrusion</td></tr>
</table>

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Seagrass meadows		
			seagrass presence can be seasonal, persistent roots networks afford protection all year round from erosion of seabed sediment. Seagrass meadows may not survive in areas with low light, high wave energy, and where high nutrient levels in the water column cause eutrophication via growth of abundant macroalgae which smothers the seagrass. While seagrass beds may assist to stabilise areas of the seabed and reduce long-term shoreline recession, they are unlikely to mitigate broader erosion and inundation risks alone, and should be combined with other actions as appropriate in adaptation pathways.
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Seagrass meadow restoration is a nature-based method.
		Avoid	
	✓	Nature based	
		Accommodate	
		Retreat	
		Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Seagrass meadow restoration typically occurs where the current conditions and natural processes are right to support grass establishment.
		Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Successful restoration of a seagrass meadows represents a regime shift, often from a bare sandy or muddy seabed to a vegetated state. Some general considerations for this intervention include that: • Seagrass meadow establishment may support a diversity of environmental, cultural, social and economic (including ecosystem services) values. • The establishment of a seagrass meadow on a previously sandy seafloor will alter how swimmers and beach users experience the area. Swimmers may find an area colonized by seagrass less amenable, but it may attract alternative beach users interested in snorkelling. • Seagrasses tend to deteriorate during colder months in Victoria. This may cause large amounts of seagrass wrack to accumulate on beaches, potentially impacting amenity and recreational beach use. • Seagrass meadows are blue carbon ecosystems which sequester relatively high amounts of carbon dioxide from the atmosphere as they grow. Land managers may gain carbon credits from such projects.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	> 12 months	Restoration of a seagrass meadow to maturity has proven difficult in many Victorian regions (e.g., Western Port Bay) for various reasons. In order for the physical, nutrient, and hydrodynamic characteristics of a site to be well understood, preparation time may be greater than 1 year.
	Effective lifetime	50+ years	Seagrass meadows can adapt to rising sea levels through vertical accretion of sediment, and by migration when vertical accretion is not sufficient to keep up with sea level rise. Where rising sea levels cause larger waves more frequently, this may pose a risk to the ongoing success of seagrass

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Seagrass meadows		
			meadows. Providing natural migration is not impeded, effective lifetime is ongoing.
	Co-benefits	Many	There are many co-benefits of a seagrass meadow including increased biodiversity (vegetation, fish, bird life etc.), increased fishery quality (seagrass is a nursery for juvenile fishes) and increased carbon sequestration.
	Approvals and requirements	The range of approvals that may be required for a seagrass restoration project include: • Marine Park Approvals • *Marine and Coastal Act 2018* consent (DEECA) • Parks Victoria Works Permit • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of seagrass restoration include: • Understanding of coastal processes and exposure at the site • Most appropriate plant species for the restoration attempt (use species found in local seagrass meadows) • Access to the site for planting/material supply (SCUBA divers often required) • Environmental conditions (water quality, nutrient levels, water temperature etc.) • Understanding of conditions that led to natural seagrass loss at the site. Seagrass restoration has been attempted at various Victorian locations. Most recently, the Yarram Yarram Landcare network has successfully restored seagrass meadows in Corner Inlet during the summer of 2020, which were previously lost to overgrazing by urchins. With subsequent planting in future summers, the group plans to restore approximately 200 hectares of seagrass meadow. The most common failure mechanism for seagrass meadow restoration projects is low light availability from high turbidity and/or eutrophication.	
	Cost considerations	When costing a seagrass meadow restoration project, the following items should be considered: • Design and approval costs • Supply and collection of plant seeds or seedlings • Planting technique (e.g., using hessian sacks full of sand) and labour availability (paid/volunteer).	
References	Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. (2021) The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia. Victorian State Government, 2020. Victorian Marine and Coastal Policy. ISBN 978-1-76077-888-0 DEECA, 2020. Corner Inlet Broadleaf Seagrass Restoration Project. https://www.marineandcoastalcouncil.vic.gov.au/news-and-events/victorian-marine-and-coastal-awards/2020/corner-inlet-broadleaf-seagrass-restoration-project		

Project example

Nature-based methods – Coastal vegetation and blue carbon ecosystems – Seagrass meadow – Project example		
Project title	Corner Inlet Broadleaf seagrass restoration project	
Action type	Seagrass meadows	
Location	Corner Inlet	
Land manager	Gippsland Lakes Committee of Management Inc	
Year of Implementation	2020-2021	
Project objectives	• Increase the quality of habitat in Corner Inlet to increase the survival of juvenile fishes in these areas • Increase the quality and sustainability of the local commercial fishery by increasing fish stocks • Improve local water quality • Increase the buffering capacity of the area to catchment flood inflows • Increase the resilience of Corner Inlet to climate change.	
Project process	• Yarram Yarram Landcare network designed the planting approach using hessian sacks filled with sand and seedlings planted in the sacks • Commercial fishers teamed up with volunteers and the Landcare network to install these sacks in areas where seagrass had been lost • Yarram Yarram Landcare network has performed subsequent monitoring.	Broadleaf seagrass seedling in sand filled hessian snake.
Measures implemented	Hessian snakes (long, thin hessian bags) were filled with sand and seeded with broad leaf seagrass (*Posidonia* species). These were then placed on the seafloor during low tide by volunteers using commercial fishing boats. The snakes afford the seedlings greater protection from erosion by tidal streams and/or waves than if they were planted on the seabed.	 Volunteers seeding hessian snakes
How well project met objectives	• This project occurred during the summer of 2020-2021. Survival rates of planted seagrass in some areas have been relatively high. • It remains to be seen if the planting will result in a regime shift to a vegetated state which would have a significant effect on the juvenile fish production within the Corner Inlet fishery.	
Challenges	• COVID19 made preparation for the planting during summer difficult • Long-term success of the project cannot be determined yet.	
Cost	Cost depends largely on the area to be restored and the substrate (seabed) type. Typically, bare sand requires more intervention and will cost more.	

1.3.3 Saltmarsh

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Saltmarsh		
Description	*Saltmarsh* A saltmarsh is a coastal wetland comprised of small trees, shrubs, low bushes and grasses which grow in the high intertidal zone along sheltered bays, lagoons and esturies. The plants cause drag on incoming waves, dissipating wave energy and enhancing sediment sediment deposition, assisting to protect the shoreline from erosion and inundation. The saltmarsh root networks further assist with stabilizing the shoreline. Saltmarshes occur in low-lying coastal areas of Victoria including the Gippsland Lakes, Corner Inlet, Shallow Inlet, Anderson Inlet, Western Port Bay, Port Phillip Bay, the Bellarine Peninsula, Peterborough Coastal Reserve, Bellfast Coastal Reserve and in many other smaller inlets and river/creek mouths. *Habitat restoration / creation* Where saltmarshes have been removed, cleared, lost due to natural processes, or their natural establishment is restricted, coastlines may be impacted more severely by erosion and inundation. As sea levels rise, saltmarsh areas will tend to retreat landward with the changing intertidal zone. If structures such as seawalls and earthen bunds are present, landward retreat will be impeded (coastal squeeze), minimising the future extent of saltmarsh. Restoration / creation of saltmarsh in appropriate environments can contribute to reduced coastal hazard risk for local coastal values, uses and assets. This can be done through removing distrubances (e.g. fencing), restoring the hydrology of an area, direct saltmarsh planting and/or via hybrid approaches using rock sills, rock fillets, smart tide gates or similar**Invalid source specified.**.		 *Wide salt marsh at Hastings, Western Port Bay.*  *Fencing to exclude livestock from former coastal saltmarsh land allows saltmarsh to regenerate near the Bass River Mouth – Western Port Bay. Source: [Blue Carbon Lab]*
Functional type		Land management planning and design	
	✓	Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Saltmarshes may be used to mitigate short-term erosion and long-term shoreline recession by providing a buffer zone that dissipates wave energy and traps sediment. This buffer, and the roughness of the saltmarsh may also have a mitigating effect on wave run-up and hence storm tide inundation, as compared to a unvegetated coastline. Saltmarshes are effective on protected coastlines with low wave energy (e.g., Port Phillip Bay, Western Port Bay, Gippsland lakes, estuarine environments). Where wave energy is persistently high, plants may be eroded from the soil and erosion will likely continue. Saltmarsh plants are specifically adapted to survive in harsh environments with periodic inundation, saline soils and low-level wave attack, however, plant species chosen for a restoration attempt should reflect those found in nearby salt marshes to ensure the highest chances of restoration success.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	

<table>
<tr><th>Action</th><th colspan="4">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Saltmarsh</th></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td colspan="2">Non-intervention</td><td rowspan="6">Notes on policy context:
Saltmarsh restoration is a nature-based method.
Enabling natural inland migration of saltmarsh (reducing coastal squeeze) may also be part of a managed retreat / land use transition.</td></tr>
<tr><td></td><td colspan="2">Avoid</td></tr>
<tr><td>✓</td><td colspan="2">Nature based</td></tr>
<tr><td></td><td colspan="2">Accommodate</td></tr>
<tr><td></td><td colspan="2">Retreat</td></tr>
<tr><td></td><td colspan="2">Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td colspan="2">Low</td><td rowspan="3">Considerations:
Saltmarsh restoration may occur where coastal areas are periodically inundated by tides. Reinstating these ecosystems reinstates natural coastal processes to areas where they have been altered by habitat loss and/or hydrological change (e.g., flood gates causing loss of tidal inundation to coastal areas).</td></tr>
<tr><td></td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations
Successful restoration of a saltmarsh represents a regime shift, often from a bare mudflat to a vegetated coastal wetland. Some general considerations for this intervention include that:
• The establishment of a saltmarsh will alter the look and feel of a coastline, possibly limiting access to the water from the beach. This may lead to implications for cultural, boating, and other values.
• The saltmarsh plants may colonize up to, and above the hightide line on soils with high salt content. This could cause plants to colonize any beach present, lowering the amenity recreational beach use.
• The saltmarsh will increase the biodiversity of the area and will create habitat for migratory and other shorebirds (e.g., Orange Bellied Parrot).
• Birdwatchers target saltmarshes, leading to economic benefits for the surrounding communities.
• Saltmarshes provide nursery habitat for fish, supporting commercial and recreational fisheries.
• Saltmarshes are blue carbon ecosystems which sequester relatively high amounts of carbon dioxide from the atmosphere as they grow. Land managers may gain carbon credits from such projects.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="4">Guidance for implementation</td><td>Preparation / design period</td><td>> 12 months</td><td colspan="2">Restoration of a saltmarsh to maturity may take many years (>10 years), although benefits will begin to be realised earlier.</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td colspan="2">Saltmarshes can adapt to rising sea levels as they initially accrete vertically, raising the level of the higher intertidal zone as sea levels rise. When this adaptation can no longer keep up with sea level rise, successive generations of seedlings colonize areas further landward. This represents a progressive landward movement of the saltmarsh as sea levels rise. Providing natural migration is not impeded, effective lifetime is ongoing.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td colspan="2">There are many co-benefits of a saltmarsh including increased biodiversity, cleaner water, carbon sequestration, fisheries support and increased bird life and the economic benefits of ecosystem services.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">The range of approvals that may be required for a saltmarsh restoration project include:
• Marine Park Approvals
• Parks Victoria Works Permit
• Marine and Coastal Act 2018 consent (DEECA)
• Planning Permit (Local Government)</td></tr>
</table>

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Saltmarsh	
		• Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).
	Design considerations, constructability, and materials	Important considerations for successful design of a saltmarsh restoration include: • Understanding of coastal processes and exposure at the site • Most appropriate plant species for the restoration attempt (mirroring nearby salt marshes) • Access to the site for planting/material supply • Environmental conditions (water quality, nutrient levels, water temperature etc.) Natural recovery of previously grazed saltmarshes has been successfully achieved through fence installation. The Blue Carbon Lab has recently undertaken fencing on public and private land near the Bass River in Western Port Bay to protect and restore saltmarsh habitat after it had been grazed. Failure mechanisms for saltmarsh restoration projects include wave induced erosion of young seedlings, smothering of seedlings/seeds with sediment, inappropriate location for saltmarsh.
	Cost considerations	When costing a saltmarsh restoration project, the following items should be considered: • Design and approval costs • Supply of plant seeds or seedlings • Construction of any hybrid protection/ hydrological restoration structures (e.g., low crested breakwaters, smart tide gates, etc.)
References	Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. (2021) The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia. Victorian State Government, 2020. Victorian Marine and Coastal Policy. ISBN 978-1-76077-888-0	

Project example

<table>
<tr><th colspan="3">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Saltmarsh – Project example</th></tr>
<tr><td>Project title</td><td>Victorian Coastal Wetland Restoration Project – Blue Carbon Lab</td><td rowspan="6">
Partial fencing of coastal saltmarsh adjacent to the Bass River Mouth Nature Conservation Reserve showing degraded, grazed areas on one side of the fence. Source: Blue Carbon lab.</td></tr>
<tr><td>Action type</td><td>Saltmarsh</td></tr>
<tr><td>Location</td><td>Private Property next to Reef Island and Bass River Mouth Nature Conservation Reserve – Western Port Bay</td></tr>
<tr><td>Land manager</td><td>Private landowners</td></tr>
<tr><td>Year of implementation</td><td>2020</td></tr>
<tr><td>Project objectives</td><td>Rehabilitate degraded saltmarsh in areas where cattle have grazed and trampled the vegetation and soil.
Monitor the effects of the fencing over a 24-month period to investigate any increases in carbon storage in the soils.</td></tr>
<tr><td>Project process</td><td>The Victorian Coastal Wetland Restoration Project undertaken by the Blue Carbon Lab focuses on 8 separate sites across the Victorian Coast where wetlands have been degraded. The Bass River Mouth NCR project is a small part of a broader project.

Consultation with local landowners was undertaken to create a shared understanding of the coastal protection benefits, carbon sequestration benefits, and the potential benefits of blue carbon credits relating to coastal saltmarsh restoration. A fencing trial was agreed on, and commenced.</td><td rowspan="2">
Purple fencing enclosing 5ha of degraded saltmarsh on private property. Source: Blue Carbon Lab.</td></tr>
<tr><td>Design details</td><td>500m of wire fencing was installed around 5ha of degraded saltmarsh.
Fencing was installed during summer months when the land was dry to minimise compaction of soil by the tractor
Active weed control within the fenced area to encourage native vegetation growth.
Monitoring of soil carbon content, soil microbe communities, vegetation coverage, and bird biodiversity is currently occurring.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">The project is still ongoing, however preliminary pictorial results show that fencing to exclude cattle can considerably improve coastal wetland condition.</td></tr>
<tr><td>Challenges</td><td colspan="2">Supporting private landowners to consider the potential long-term benefits for their business and property from coastal saltmarsh restoration required sufficient time for consultation, materials and discussions.</td></tr>
<tr><td>Cost</td><td colspan="2">This project is relatively low cost with the 500m of fencing representing the main costs. All other planting, weed control and monitoring was conducted by volunteers.</td></tr>
</table>

1.3.4 Kelp forests

Action	Nature-based methods – Coastal vegetation and blue carbon ecosystems – Kelp forests

Description

Kelp forests

Kelp are large brown seaweeds which grow on rocky reefs below the low tide line.

Kelp attaches to rocks via a 'holdfast' with some species growing to >40 metres long. When kelp colonises a large area, it becomes a kelp forest with a dense canopy.

Kelp forests can live in depths up to approximately 30 metres, however they typically thrive in shallow subtidal regions of moderate wave energy.

Kelp forests increase drag on incoming waves, disipating some wave energy before it reaches the shore. This creates lower wave energy environments inside and landward of the forest, leading to increased sediment deposition, and assisting to protect the shoreline from coastal erosion.

Kelp species with stiff, erect stalks supporting the canopy attenuate more wave energy than kelp with a prostrate canopy.

Extensive kelp forests are widespread along much of the Victorian rocky coastline. Recent studies, however, have shown the loss of up to 90% of kelp forests in the north of Port Philip Bay due to over-grazing from sea urchins which proliferated in the millenial drought.

Protecting existing extents of kelp forests is an important baseline adaptation action.

Habitat restoration / creation

Where kelp forests have been cleared, lost due to natural processes, or their natural establishment is restricted, coastlines may be impacted more severely by erosion and inundation, and changes in off-shore sediment dyamics.

Restoration of kelp forests in appropriate environments can contribute to reduced coastal haard risk for local marine and coastal values, uses and assets.

This can be done through:

- Specific actions to limit or stop disturbance, in order to produce/protect a self-sustaining kelp population. This could be in the form of removing grazing animals, improving water quality, limiting particular uses.
- Hybrid approaches where an artifical reef is introduced to provide substrata for kelp to attach.

Shallow Kelp Forest on Victorian rocky shoreline

Functional type		
		Land management planning and design
	✓	Nature-based methods
		Coastal engineering

Coastal hazard mitigation		
	✓	Short-term erosion
	✓	Long-term erosion
		Accretion
	✓	Storm tide inundation
		Permanent inundation
		Estuary dynamics
		Offshore sediment dynamics
		Saline intrusion

Notes on suitability:

Once mature, kelp forests can reduce wave energy in moderate wave energy environments where incoming waves are typically of low period (i.e., 2 – 6 seconds).

Kelp forests may not survive in areas with low light availability, high water temperature (approximately >20°C) and where high nutrient levels in the water column cause eutrophication via growth of abundant algae which smothers the kelp.

Restoration is most successful in areas that naturally have supported kelp in the past.

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Kelp forests</th></tr>
<tr><td></td><td></td><td></td><td>Kelp forests are likely to have a greater effect on wave propagation to shore in shallow water and where stipitate kelp taxa take up a large portion of the water column.
While kelp forests may assist to reduce wave energy and associated erosion, they are unlikely to mitigate broader erosion and inundation risks alone, and should be combined with other actions as appropriate in adaptation pathways.</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="6">Notes on policy context:
Kelp forest restoration is a nature-based method.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td>✓</td><td>Nature based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td></td><td>Retreat</td></tr>
<tr><td></td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td rowspan="3">Considerations:
Kelp forest restoration typically occurs where the current conditions and natural processes are right to support kelp establishment.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations
Successful restoration of a kelp forest represents a regime shift, often from a bare rock barren area or a bed of turfing algae to a forested state. Some general considerations for this intervention include that:
• Kelp forest establishment may support a diversity of environmental, cultural, social and economic (including ecosystem services) values.
• The establishment of a kelp forest on a previously barren rock seafloor will create habitat for other marine life and may attract beach users interested in snorkelling or SCUBA diving.
• In the case that a self-sustaining population of kelp grows, wrack from the forest accumulating on nearby sandy shores may lower the amenity for recreational beach use.
• Kelp forests are blue carbon ecosystems which sequester carbon dioxide from the atmosphere as they grow.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="4">Guidance for implementation</td><td>Preparation / design period</td><td>> 12 months</td><td>In order for the physical, nutrient, and hydrodynamic characteristics of a site to be well understood, preparation time may be greater than 1 year.</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td>Kelp forests can adapt to rising sea levels through growing vertically, and by migration to shallower waters when vertical growth is not sufficient to keep up with sea level rise. Where rising sea levels cause larger waves more frequently, this may pose a risk to the ongoing presence of a kelp forest.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td>There are many co-benefits of a kelp forest including increased biodiversity (vegetation, fish, invertebrates etc.), increased fishery quality (kelp forests act as nurseries for juvenile fishes) and increased carbon sequestration.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="2">The range of approvals that may be required for a kelp forest project include:
• Marine Park Approvals
• Marine and Coastal Act 2018 consent (DEECA)</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="2">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Kelp forests</th></tr>
<tr><td></td><td></td><td>Parks Victoria Works Permit
Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td></td><td>Design Considerations, constructability, and materials</td><td>Important considerations for successful design of a kelp forest project include:
Understanding of coastal processes and exposure at the site
Environmental conditions (water quality, nutrient levels, water temperature etc.)
Most appropriate plant species for the restoration attempt (use species found in local kelp forests)
Kelp establishment technique (e.g., allow natural establishment, seeding, transplantation etc.)
Access to the site for establishment works/material supply (SCUBA divers often required)
Understanding of conditions that led to natural kelp loss at a site (if applicable)
Restoration of kelp forest to a self-sustaining population has been met with mixed results throughout Australia due predominantly to water quality issues or unresolved overpopulation of grazing animals.

A kelp forest restoration attempt is currently being conducted by the Blue Carbon Lab in collaboration with Deakin University, The University of Melbourne and Parks Victoria in the northern areas of Port Phillip Bay where overgrazing by sea urchins has led to up to a 90% decline in kelp coverage. This project focusses on the removal of overabundant urchins and the creation of a sea-urchin management plan for the site.</td></tr>
<tr><td></td><td>Cost considerations</td><td>When costing a kelp forest project, the following items should be considered:
Design and approval costs
Supply, collection and propagation of reproductive tissue/juvenile/adult plants (depending on establishment methodology)
Attachment technique (e.g., using SCUBA divers to attach plants to the reef)
Costs associated with monitoring the condition of the restoration.</td></tr>
<tr><td>References</td><td colspan="2">Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. (2021) The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia. Victorian State Government, 2020. Victorian Marine and Coastal Policy. ISBN 978-1-76077-888-0

https://www.bluecarbonlab.org/kelp-forest-restoration/

Layton Cayne, Coleman Melinda A., Marzinelli Ezequiel M., Steinberg Peter D., Swearer Stephen E., Vergés Adriana, Wernberg Thomas, Johnson Craig R. 2020. Kelp Forest Restoration in Australia. Frontiers in Marine Science. https://www.frontiersin.org/article/10.3389/fmars.2020.00074</td></tr>
</table>

Project example

<table>
<tr><th colspan="3">Nature-based methods – Coastal vegetation and blue carbon ecosystems – Kelp forests - Project example</th></tr>
<tr><td>Project title</td><td>Operation Crayweed</td><td rowspan="8">
Kelp forest restoration by Operation Crayweed

Juvenile Crayweed colonising reef near a restoration site.</td></tr>
<tr><td>Action type</td><td>Kelp Forest</td></tr>
<tr><td>Location</td><td>Sydney Metropolitan Region</td></tr>
<tr><td>Land manager</td><td>Various</td></tr>
<tr><td>Year of Implementation</td><td>2011 - Present</td></tr>
<tr><td>Project objectives</td><td>• Reforest 70km of coastline with cray weed (a kelp species) from Palm beach to Cronulla. Kelp was lost in this area due to pollution of the Sydney beaches during the 1980s</td></tr>
<tr><td>Project process</td><td>• A study was published in 2008 describing the decline of cray weed kelp forests in the Sydney region
• Attempts to transplant cray weed to some of these areas in 2011 were successful
• Operation Crayweed, an NGO was started and still runs today seeking to reforest the 70km of coastline with cray weed kelp</td></tr>
<tr><td>Design details</td><td>• Adult cray weed plants were taken from areas of Sydney where they still remain and shifted to areas to be reforested.
• The adult plants were attached to sections of biodegradable mesh with cable ties.
• The mesh sections are then attached to rocky reefs around Sydney.
• In time, the adult plants multiply, and juvenile plants begin to colonise the area.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">This project has been successful in producing self-sustaining populations of cray weed in areas where they once existed but were lost to pollution. Operation cray weed has not yet reforested the entire Sydney coastline, but they are growing in capacity.</td></tr>
<tr><td>Challenges</td><td colspan="2">As an NGO, Operation cray weed has limited funding and resource availability.</td></tr>
<tr><td>Cost</td><td colspan="2">Unknown</td></tr>
<tr><td>References</td><td colspan="2">http://www.operationcrayweed.com/</td></tr>
</table>

1.4 Beach and dune ecosystems

1.4.1 Beach and dune protection / vegetation / management

<table>
<tr><th>Action</th><th colspan="2">Nature-based methods – Beach and dune ecosystems – Beach and dune protection / vegetation / management</th></tr>
<tr><td>Description</td><td>
Beach and dune management is a holistic approach to protecting, enhancing, and maintaining healthy beach and dune systems and habitats, by enabling natural processes.

Sandy beach and dune systems are dynamic, and will periodically erode and accrete with changing wave activity and sediment supply.

Beach and dune systems provide a natural buffer to coastal hazards, protecting areas further inland from erosion and inundation.

Beach and dune management may include the following.

Minimise disturbance

A core action for beach and dune management is to reduce disturbance to the system, to enable natural accretion / recovery of sand volumes, and vegetation colonisation. This includes through fencing, designated tracks, and signage.

Support vegetation establishment and succession

Well vegetated dunes encourage natural dune building processes, whereby the vegetation slows the wind velocity and traps sand blown inland from the beach, increasing dune height and width. Vegetation also binds the sand together with its roots, further stabilizing the dune.

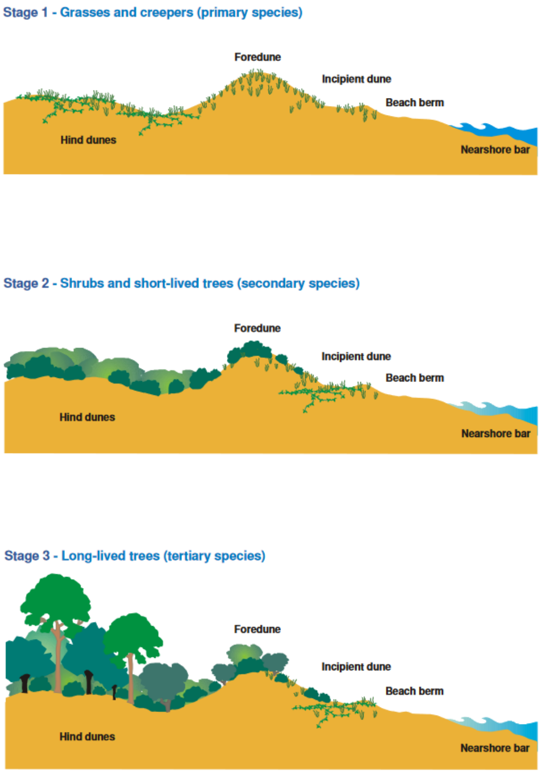
Periodically storm waves will erode the seaward edge of a dune, but the eroded sand is gradually returned to the beach following the storm. With a healthy dune habitat this sand is colonised by dune vegetation and the rebuilding process begins.

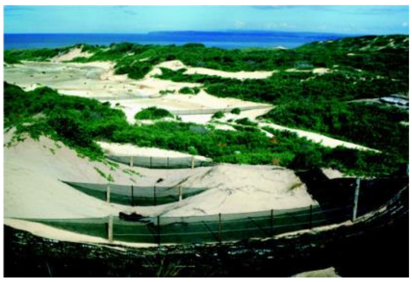
In addition to minimising disturbance, supporting vegetation establishment and succession may include planting, weed control, and supplementary materials to encourage plant survival and dune growth such as jute matting, plant protectors, and sand-trap fencing.

Sand-trap fencing catches wind-blown sands in a designated enclosed area. As these fences are buried under accumulated sand, more fences can be built atop these to continue to build the dune.

These actions are often implemented via a dune management plan, which may also specific actions to control grazing animals and weeds.
</td><td>

Bellarine & Great Ocean Rd DuneCare project

Example dune revegetation works


Idealised vegetation succession on coastal dunes

</td></tr>
</table>

Action	Nature-based methods – Beach and dune ecosystems – Beach and dune protection / vegetation / management		
			Dune Forming Fences, Kurnell
Functional type	✓	Land management planning and design	
	✓	Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** This action is suitable for locations where sandy beaches and dunes exist, or have existed in the past, and there is sufficient room to for the beach and dune system to grow / migrate, and sufficient sediment supply. Beach and dune management may often be combined with other actions including beach nourishment and engineering works.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Beach and dune management is a nature-based method, and a baseline action for coastal management. Beach and dune management actions, with monitoring, may be a first line of intervention in adaptation pathways, with trigger points set to indicate when additional actions associated with retreat or protect may be required.
		Avoid	
	✓	Nature based	
		Accommodate	
		Retreat	
		Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Beach and dune management acts to support / enable natural coastal processes.
		Moderate	
		High	

Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.	**Applicability considerations** Beach and dune management can support the protection / enhancement of existing coastal values. Works are usually non-intrusive, designed to minimise disturbance to sensitive environmental and cultural values. Vegetation and weed management approaches need to consider biodiversity and cultural settings. Restricting access to the beach and dunes may have social implications, which can be balanced through planning and enhancing community awareness. The long-term social benefits include improved beach and dune amenity, and environmental values, which will have flow-on economic benefits for the region.
	Cultural values	
	Environmental values	
	Social values	
	Economic values	

Guidance for implementation	**Preparation / design period**	6-12 months	This preparation timeframe may vary depending on the scale of beach dune management required, and is typically designed to be part of a long-term program of management.
	Effective lifetime	Ongoing	Approximately 2-5 years for establishment (fencing, signage, established vegetation), and effective lifetime is ongoing with regular monitoring and maintenance over time, and room for the beach and dune system to migrate with sea level rise.
	Co-benefits	Many	Co-benefits include complementary ecological and amenity benefits, the increase of habitat for local/native flora and fauna, a reduction in temperature of the beach (vegetated dunes are cooler than non-

Action	Nature-based methods – Beach and dune ecosystems – Beach and dune protection / vegetation / management		
			vegetated) and providing an opportunity to promote community stewardship.
	Approvals and requirements	Beach and dune management works often require less approvals than other approaches to coastal protection as there is limited or no construction involved. The full range of range of approvals that could be required, depending on the scale, for beach and dune management projects include: • *Marine and Coastal Act 2018* consent (DEECA) • Land Owner's Consent • Parks Victoria – Works Permit • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful implementation of dune management include: • Traditional Owner and community values around the site, vegetation, recreational use and beach access. • In-depth understanding of coastal processes. • Understanding the climate, soils and native vegetation at the site. • Source of suitable dune seedlings for planting. Fast-growing ‘primary’ and ‘secondary’ species such as grasses and groundcovers are most suitable in regeneration works. • Labour force to carry out the works – often volunteers or community groups are available to assist with planting. • Use of endemic plant species. The scale at which a beach and dune management plan can be implemented varies greatly. This can be from a localised section of a particular beach experiencing targeted erosion, to larger, region-wide plans to fortify dunes on a broad scale.	
	Cost considerations	When costing a dune management plan, the following items should be considered: • Seedling costs, supply and delivery • Labour for planting and fencing (can be volunteers) • Additional infrastructure costs (depending on the extent of the plan) • Ongoing monitoring, maintenance or further revegetation costs.	
References	NSW Coastal Dune Management Manual https://www.environment.nsw.gov.au/resources/coasts/coastal-dune-mngt-manual.pdf Roger Carolin and Peter Clarke (1991), ‘Beach Plants of South Eastern Australian’, Sanity and Associates, Potts Point NSW.		

Project example

Nature-based methods – Beach and dune ecosystems – Beach and dune protection / vegetation / management – Project example	
Project title	Bellarine and Great Ocean Road Dunecare Project
Action type	Beach and dune management
Location	Great Ocean Road, Bellarine Peninsula to Marengo, Victoria
Land manager	Corangamite CMA / Barwon Coast Committee / Great Ocean Road Coasts and Parks Authority
Year of implementation	2020
Project objectives	• Conserve coastal sand dune native flora and fauna habitat at risk of erosion.
Project process	• Establish reference committee of experts to guide implementation • Develop plan for investment and funding • Develop and implement Dunecare secondary schools program in the area • Provide opportunities for involvement of Wadawurrong Traditional Owners • Conduct social research to ensure conservation messaging is targeted and effective • Develop Initiative Communication and Outcomes Promotion Plan that describes specific public communication actions to promote the initiative.
Measures implemented	• A Dunecare on-ground works program to protect and remediate fragile coastal dune systems that support native flora and fauna • A Dunecare Stewardship program targeting Year 9 and 10 students in Geelong, the Bellarine Peninsula and Surf Coast.
How well project met objectives	Project ongoing
Cost	$1.5 million
Further considerations	This project covers a vast section of coastline from St Leonards to Marengo, approximately 120km of coastline, equating to approximately $12,500/km, noting that some sections of coastline require no intervention.

Bellarine & Great Ocean Road DuneCare project site

HIGH SCHOOL STUDENTS LEADING CHARGE TO PROTECT COASTAL DUNES - Corangamite Catchment Management Authority (ccma.vic.gov.au)

1.4.2 Use of on-site natural materials to reduce erosion

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Beach and dune ecosystems – Use of on-site natural materials to reduce erosion</th></tr>
<tr><td>Description</td><td colspan="2">Natural materials found on-site can be used to provide additional resistance to erosion.
This includes material readily available on the beach including seaweed wrack, brushwood, and gravel.
Material can be used to armour the base of dunes and dissipate wave energy, and some material such as brushwood can also be formed into short groynes to encourage sand retention.
Typically, a bobcat is used to push material from the hightide line to the dune toe or designated locations.
This action can be implemented rapidly, and is usually employed as an emergency measure until a more long-term solution can be implemented.
Effectiveness is limited, but this approach can provide some short- term protection while additional planning is underway, and can be part of ongoing maintenance actions to support existing works.</td><td rowspan="4">
Seaweed dune-toe armouring using kelp/seaweed wrack at Eastern View</td></tr>
<tr><td rowspan="3">Functional type</td><td></td><td>Land management planning and design</td></tr>
<tr><td>✓</td><td>Nature-based methods</td></tr>
<tr><td></td><td>Coastal engineering</td></tr>
<tr><td rowspan="8">Coastal hazard mitigation</td><td>✓</td><td>Short-term erosion</td><td rowspan="8">Notes on suitability:
This measure is opportunistic and may be used only where sufficient material is freely available on the beach.
Using on-site natural materials will likely only provide very short-term protection to an area and should only be used as an emergency measure while other more effective measures are planned and executed, or as supporting maintenance works.
This measure is not suitable where there is no beach vehicle access.</td></tr>
<tr><td></td><td>Long-term erosion</td></tr>
<tr><td></td><td>Accretion</td></tr>
<tr><td></td><td>Storm tide inundation</td></tr>
<tr><td></td><td>Permanent inundation</td></tr>
<tr><td></td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td></td><td>Saline intrusion</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="6">Notes on policy context:
Use of on-site natural materials is a nature-based method.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td>✓</td><td>Nature based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td></td><td>Retreat</td></tr>
<tr><td></td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td rowspan="3">Considerations:
Use of on-site natural materials is intended to work with / support natural coastal processes.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
</table>

Action	Nature-based methods – Beach and dune ecosystems – Use of on-site natural materials to reduce erosion		
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Works should be undertaken in the context of environmental and cultural values for the site. Use of on-site materials does not involve disturbance to the dune or backshore, limiting potential impacts. Care should be taken that placement does not disturb any shorebirds (e.g., hooded plovers) which feed around the high-tide line. Placement of large quantities of seaweed wrack above the high tide line can generate an odour issue, which may have social implications for beach use in the short-term.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	< 1 month	This measure is opportunistic and can be used only when there is available material on the beach and pre-approvals are in place. If appropriate material is identified, this action can be implemented in days to weeks depending on contractor availability.
	Effective lifetime	< 1 month	This measure is typically only effective for a very short time (days-weeks).
	Co-benefits	Few	Immediate action through use of local on-site materials demonstrates that work is underway.
	Approvals and requirements	The range of approvals that may be required for the use of natural onsite material include: • *Marine and Coastal Act 2018* consent • Parks Victoria – Works Permit • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for the implementation of this measure are: • Availability of suitable material on the beach (e.g., seaweed/kelp rack) • The habitat value of any on-beach material (e.g., shorebird feeding habitat) • Beach access for bobcat/excavator to shift material to base of dunes.	
	Cost considerations	When costing the use of on-site natural materials for erosion protection, the following items should be considered: • Excavator/bobcat hire (typically one day is sufficient for works – up to $500/day) • Approvals applications where necessary (this cost can vary depending on sensitivity of the area, i.e., shorebird habitat, marine park etc.)	
References	-		

Project example

<table>
<tr><th colspan="3">Nature-based methods – Beach and dune ecosystems – Use of on-site natural materials to reduce erosion – Project example</th></tr>
<tr><td>Project title</td><td>Eastern View Seaweed Dune Toe Armouring</td><td rowspan="8">
Seaweed at the base of eroding carpark for initial erosion protection at Eastern View.</td></tr>
<tr><td>Action type</td><td>Use of on-site natural material</td></tr>
<tr><td>Location</td><td>Devil's Elbow – Eastern View</td></tr>
<tr><td>Land manager</td><td>Great Ocean Road Authority</td></tr>
<tr><td>Year of implementation</td><td>2021</td></tr>
<tr><td>Project objectives</td><td>To limit erosion of the Devil's Elbow beach carpark while a more effective measure for shoreline protection could be designed and implemented.</td></tr>
<tr><td>Project process</td><td>Erosion of the area during recent decades has impacted on multiple carparks and beach accesses at Eastern View.
During the preparation of a coastal adaptation plan for the area, The GOR Authority identified the presence of a large amount of seaweed wrack (large kelp fronds) on the beach in the Devil's Elbow corner which could be used to protect the eroding carpark edge.</td></tr>
<tr><td>Measures implemented</td><td>In consultation with DEECA, GOR Authority used a bobcat to build a berm of wrack, sand and cobbles against the erosion escarpment.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">Within 1 month, all seaweed was washed away and the carpark was again exposed to wave erosion. This was expected and during this time plans had been progressed for longer term erosion mitigation actions.</td></tr>
<tr><td>Cost</td><td colspan="2">Minimal costs (GOR Authority used a bobcat which they own)</td></tr>
<tr><td>Further considerations</td><td colspan="2">-</td></tr>
</table>

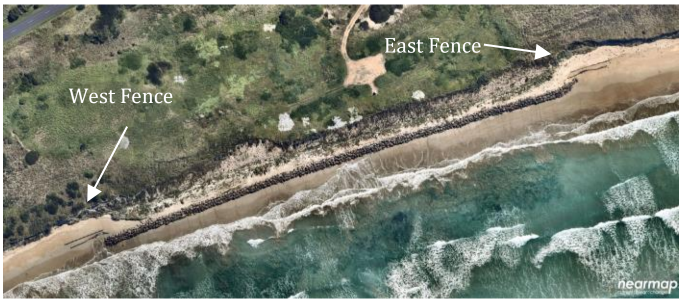
1.4.3 Wet sand fencing

Action	Nature-based methods – Beach and dune ecosystems – Wet sand fencing		
Description	Wet sand fencing (or sand fencing), uses a wood slat fence on the beach to limit wave run-up erosion on exposed dune faces and to encourage sand accretion on the beach behind the fence. Given the mobile nature of sandy shores, sand fencing is usually designed to have large and deep fence posts spaced at regular intervals with wooden slats spread between them. The slats are usually held together using corrosion-resistant wire or similar material. The fence is placed around the normal hightide line. During elevated water level conditions (created by storm surge and/or large waves), wave run-up reaches and passes through the permeable fence structure. The fence slows (but does not stop) the runup and thereby dissipating energy and decreasing erosion potential of the dune face behind the fence. During calmer conditions the fence can also encourage beach recovery / sand build up. Sand fencing may only be effective for a period, and is often combined with additional adaptation actions longer-term.		 *Wet sand fencing at the base of a high section of dune erosion at Dog Beach Point Lonsdale. This fence forms a dual-purpose keeping people off the unstable dune.*
Functional type		Land management planning and design	
	✓	Nature-based methods	
		Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Sand fencing is used to help limit short-term storm erosion of the beach and dunes, and to encourage sand build up. As such, this action is most suited to locations and scenarios where short-term erosion is the key coastal hazard. Where long-term recession due to net sediment loss is occurring, additional actions will be required. Sand fencing is most effective in low wave energy environments of bays and estuaries, where it is less vulnerable to damage and may also trap and hold seagrass wrack which further reduces wave erosion. Sand fencing is easily damaged when large waves impact the fence. This may occur if the fence is situated on high energy coastlines (e.g., fences damaged at Port Fairy). On open coasts, sand fencing may have a very short design life (perhaps less than 5 years). In these cases, sand fencing can provide an initial action that is readily implementable, with additional / alternative action required longer-term.
		Long-term erosion	
		Accretion	
		Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Wet sand fencing is a nature-based action.
		Avoid	
	✓	Nature based	
		Accommodate	
		Retreat	
		Protect	

<table>
<tr><th>Action</th><th colspan="4">Nature-based methods – Beach and dune ecosystems – Wet sand fencing</th></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td colspan="2" rowspan="3">Considerations:
Wet sand fencing is intended to work with (and have minimal impact on) natural coastal processes.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td colspan="2" rowspan="5">Applicability considerations:
Well maintained sand fences may serve a dual purpose by restricting access to the dunes, discouraging beach users from climbing on unstable slopes, and protecting sensitive vegetation.
Damaged or derelict fences can become a significant amenity hazard to beach users. As such, sand fencing may not be suitable on beaches with high usage and significant recreational amenity.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="5">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>3 – 6 months</td><td>Sand fencing is relatively easy to design and implement and does not require long periods of time to design and prepare.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>1 – 5 years</td><td>Sand fencing is not typically effective for long periods of time due to storm waves damaging the fencing.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Some</td><td>Can be used to help control pedestrian access to dangerous dune areas and protect vegetation (e.g., Point Lonsdale Dog Beach).</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">The range of approvals that may be required for wet sand fencing include:
• Landowner’s consent
• Marine and Coastal Act 2018 consent (DEECA)
• Cultural Heritage Approval (where cultural heritage material is, or may be present at the site)
• Marine Park Approvals (Parks Victoria)
• Planning Permit (Local Government)
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td colspan="2">Design considerations, constructability, and materials</td><td colspan="2">Important considerations for successful design include:
• Understanding of coastal processes and key coastal hazards present at the site
• Access to and along the beach for material supply and construction, and understanding of how this access may impact on beach amenity
• Location of the fence on the beach (i.e., how close to the shore should the fence be placed)
• Whether sand fencing can be used in combination with other adaptation measures at a location
• Depth of penetration of posts and slats into the beach material to provide lasting stability.
Sand fencing has been used in various locations across Victoria with many of these fences damaged during storm events. Typical failure mechanisms for sand fencing include:
• Large waves during storm events impacting the fencing, breaking the wood slats and wire joinery
• Large storm waves carrying debris (e.g., large pieces of seaweed, driftwood etc.) impacting the fence
• Erosion of the beach undermining fence posts, possibly exacerbated by local scour and turbulence around post structures
• Rapid degeneration of timber material due to marine borer activity.</td></tr>
</table>

Action	Nature-based methods – Beach and dune ecosystems – Wet sand fencing	
	Cost considerations	When costing a sand fencing project, the following items should be considered: • Suitable wood supply (fence posts and slats) • Construction of slat fencing • Approvals and consent applications • Construction methodology and site access.
References	-	

Project example

<table>
<tr><th colspan="3">Nature-based methods – Beach and dune ecosystems – Wet sand fencing – Project example</th></tr>
<tr><td>Project title</td><td>Port Fairy Revetment and Sand Fencing</td><td rowspan="8">
Rock structure end in the left of image and Sand fencing east of the revetment. Note the front fence has been damaged.


Large end scour bite behind sand fencing in the east, less pronounced end scour bite in the west. Image: Nearmap September 2021.

Google maps image from 2022 showing West fence gone completely.</td></tr>
<tr><td>Action type</td><td>Wet sand fencing – Rock revetment hybrid</td></tr>
<tr><td>Location</td><td>Port Fairy</td></tr>
<tr><td>Land manager</td><td>DEECA</td></tr>
<tr><td>Year of Implementation</td><td>2015</td></tr>
<tr><td>Project objectives</td><td>• To limit end scour at both ends of the Port Fairy Rock Revetment.</td></tr>
<tr><td>Project process</td><td>• In 2015 long-term erosion of Port Fairy's East Beach began to impact old landfill and nightsoil sites within the dune system.
• A rock ‘wave energy dissipation structure’ (WEDS - between a revetment and an intertidal breakwater) was implemented to stop erosion of this hazardous material onto the beach and into the ocean.
• After construction of the WEDS, end scour soon began to impact the dunes at both revetment ends.</td></tr>
<tr><td>Measures implemented</td><td>• Two rows of sand fencing were implemented at each end of the revetment, one row further seaward and one landward.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">The sand fencing to the west of the revetment may have helped to reduced end scour, however, the fencing to the east has seemingly had little impact. It is unclear whether the fencing has caused the less severe end scour to the west of the revetment, or whether this has occurred due to natural coastal processes. The west fence has now been removed.</td></tr>
<tr><td>Cost</td><td colspan="2">Undisclosed.</td></tr>
<tr><td>Further considerations</td><td colspan="2">This is a high energy beach and the fences lasted about 6 years before being significantly damaged.</td></tr>
</table>

1.4.4 Supported littoral vegetation

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Beach and dune ecosystems – Supported littoral vegetation</th></tr>
<tr><td>Description</td><td colspan="2">Supported littoral vegetation involves encouraging the establishment and persistence of littoral vegetation along shorelines, with supportive minor works.

Natural littoral vegetation is introduced/re-introduced or expanded along a section of coastline to mitigate erosion. The vegetation is supported through the inclusion of low-profile hard structures that are designed to offer partial protection to the vegetation only, thus facilitating revegetation success.

The structures are not aimed at providing direct shoreline armouring. These structures can take a variety of forms including concrete breakwater pods, shellfish reef berms and low-profile rock rubble mounds.

Supported littoral vegetation methods mimic natural shoreline structure and behaviour by integrating layers of protection through combinations of hard materials and natural vegetation. Each layer progressively reduces dissipates wave energy, mitigating erosion and inundation hazards.

Supported littoral vegetation approaches encompass a range of solutions using different materials, plants, and surfaces. The most ideal supported littoral vegetation configuration at a specific site will depend on individual local shoreline environments, the hydrodynamic characteristics and available room for development.

Supported littoral vegetation works may also form part of broader programs of mangrove forest, saltmarsh, and seagrass establishment for other ecosystem objectives (beyond erosion mitigation).

Some examples of works include:
• Mangroves planted behind low rock fillets (e.g., NSW North Coast)
• Saltmarsh colonising intertidal areas behind a low rock berm (e.g., Raymond Island, Gippsland Lakes)
• Planting of coastal reeds (e.g., Phragmites plants) behind a low rock or shellfish reef sill
• A multi-layer combined approach with an offshore low crested breakwater, mangrove forest planting and saltmarsh vegetation planted inshore.</td><td rowspan="4">
Coastal reeds/grasses behind multi-layered low breakwaters. source: Delaware Living Shorelines Committee

Coastal saltmarsh and grasses growing behind low crested rock sill. Raymond Island, Gippsland Lakes.

Mangroves planted behind a low rock fillet on an estuary bank in northern NSW. Source: Rebecca Morris (Morris et al., 2021).</td></tr>
<tr><td rowspan="3">Functional type</td><td></td><td>Land management planning and design</td></tr>
<tr><td>✓</td><td>Nature-based methods</td></tr>
<tr><td>*</td><td>Coastal engineering</td></tr>
<tr><td></td><td>✓</td><td>Short-term erosion</td><td>Notes on suitability:</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Beach and dune ecosystems – Supported littoral vegetation</th></tr>
<tr><td rowspan="7">Coastal hazard mitigation</td><td>✓</td><td>Long-term erosion</td><td rowspan="7">The design approach (vegetation and supportive works) is dependent on the local site conditions, such as the vegetation communities, shoreline slope, water levels, wave energy, and available room.
Typically, supported littoral vegetation methods are best suited to environments with low wave energy such as protected embayments and/or estuaries.
Once vegetation is established, supported littoral vegetation can effectively mitigate short and longer-term erosion, and storm-tide inundation. The low-profile hard structures that provide the support for the vegetation may or may not be required once the vegetation is established and reaches maturity.
These actions typically require a large footprint to implement and are therefore most successful where there is existing space for vegetation rehabilitation.</td></tr>
<tr><td></td><td>Accretion</td></tr>
<tr><td>✓</td><td>Storm tide inundation</td></tr>
<tr><td></td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td></td><td>Saline intrusion</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="6">Notes on policy context:
Supported littoral vegetation is a hybrid nature-based and protect action.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td>✓</td><td>Nature based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td></td><td>Retreat</td></tr>
<tr><td>*</td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td rowspan="3">Considerations:
Supported littoral vegetation is intended to work with natural coastal processes. Minor structural works included to support vegetation establishment may have a low – moderate impact on existing physical processes.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations:
Works should be undertaken in the context of environmental and cultural values for the site.
Shoreline vegetation establishment limit human access and some recreational activities, which may have implications for some community values.
Vegetation establishment and reduced coastal hazard impacts will provide environmental and ecosystem service benefits, including for marine and terrestrial ecosystems and activities.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
</table>

<table>
<tr><td rowspan="2">Guidance for implementation</td><td>Preparation / design period</td><td>>12 months</td><td>Supported littoral vegetation approaches are multidisciplinary solutions to coastal protection that require extensive planning and trialling to be successful. Typical solutions will develop a small trial section to test the concept before extending further, which allows evaluation of the coastal protection benefit and the success of the plant species.
As the ultimate solution is dependent on fully established vegetation, the full timeframe for development is governed by the maturity of the vegetation planted. Mangroves for example take 15-20 years to develop into mature trees.</td></tr>
<tr><td>Effective lifetime</td><td>Various</td><td>Supported littoral vegetation approaches have a variable effective timeline that is largely dependent on the ability of plant species to thrive within the available area. Successful solutions should have long life spans (>50 years) providing that they can accommodate rising sea levels. This may require removal of any backshore structures which may block the landward migration of vegetation as sea levels rise. If revegetation fails to thrive, the lifetime of this solution would be very short.</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="3">Nature-based methods – Beach and dune ecosystems – Supported littoral vegetation</th></tr>
<tr><td></td><td>Co-benefits</td><td>Many</td><td>Supported littoral vegetation solutions are attractive for coastal protection as they have a range of co-benefits that include:
• Habitat creation and biodiversity improvements
• Water purification
• Shoreline accretion
• Carbon sequestration
• Improved amenity.</td></tr>
<tr><td></td><td>Approvals and requirements</td><td colspan="2">The range of approvals that may be required for supported littoral vegetation include:
• Landowner's consent
• Marine and Coastal Act 2018 consent
• Marine Park Approvals (Parks Victoria)
• Parks Victoria – Works Permit
• Planning Permit (Local Government)
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td></td><td>Design considerations, constructability, and materials</td><td colspan="2">Considerations for design include:
• Assessment of the site conditions to ensure the suitability of the desired solution configuration. This will vary considerably from site to site, but as a basis, the presence of existing marine plants (mangroves, saltmarsh) is indicative that revegetation can be successful when integrated within a supported littoral vegetation solution.
• Coastal processes, geotechnical and sea level rise investigations.
• Propagation of suitable endemic plants may need to occur off site before the project. A suitable location/supplier will need to be sourced well in advance of the project.
• Construction methodology - Supported littoral vegetation solutions are often constructed in sensitive environments which limits machinery access and may need to be constructed within narrow 'windows' of time where site conditions are amenable to construction (e.g., low wind/wave/tide conditions)
• Development of suitable criteria for success and continual monitoring and evaluation of the project.</td></tr>
<tr><td></td><td>Cost considerations</td><td colspan="2">• Design and program management.
• Capital costs associated with initial construction works, including sourcing of materials.
• On-going maintenance costs associated with periodic post-storm repairs, sediment removal etc., to ensure design objectives of the works continue to be satisfied.
• Periodic monitoring and evaluation of the works including maturity of vegetation and signs of continuing erosion.</td></tr>
<tr><td>References</td><td colspan="3">Bilkovic DM. (ed) 2017. Living Shorelines: The Science and Management of Nature-Based Coastal Protection. CRC Press, 519p
Morris RL, Konlechner TM, Ghisalberti M, Swearer SE. 2018. From grey to green: efficacy of eco-engineering solutions for nature-based coastal defence. Global Change Biology 24, 1827-1842.
Strain EMA, Morris RL, Bishop MJ, Tanner E, Steinberg P, Swearer SE et al. 2019. Building blue infrastructure: assessing the key environmental issues and priority areas for ecological engineering initiatives in Australia's metropolitan embayments. Journal of Environmental Management 230, 488-496.
Morris RL, Strain EMA, Konlechner TM, Fest BJ, Kennedy DM, Arndt SK, Swearer SE. 2019. Developing a nature-based coastal defence strategy for Australia. Australian Journal of Civil Engineering 17 (2), 167-176.
Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. 2021. The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia</td></tr>
</table>

Project example

Nature-based methods – Beach and dune ecosystems – Supported littoral vegetation – Project example		
Project title	Grantville – Lang Lang Mangrove Forest Restoration	 Grantville Planter Pods  *Avicennia marina* propagule attached to bamboo stake.
Action type	Supported littoral vegetation - Mangrove	
Location	Grantville, Lang Lang North – Western Port Bay	
Land manager	• Grantville & District Foreshore Reserve Committee of Management • Lang Lang Foreshore Reserve Committee of Management	
Year of implementation	2020	
Project objectives	• Reduce coastal erosion shoreward of restoration attempt through long-term facilitation of mangrove forest restoration. • Increase biodiversity of the site by creating habitat for migratory birds, juvenile fish etc. • Successfully use specially designed innovative concrete planter pots to lower the local hydrodynamic environment and increase survival of planted propagules and seedlings.	
Project process	• Planter pot design was conducted by Reef Design Lab in collaboration with the Western Port Seagrass Partnership and researchers from the National Centre for Coasts and Climate (NCCC) at the University of Melbourne. • Deployment of planter pots was undertaken by the NCCC and Reef Design Lab. • Planting of propagules was undertaken by the NCCC with volunteers from the local and university community.	
Measures implemented	• 12 separate arrays of specially designed concrete planter pods were installed (1300 pods in total) on jute matting between Grantville and Lang Lang covering approximately 600m of coastline. • *Over 2500 Avicennia marina* propagules were attached to bamboo stakes using rubber bands then planted inside and behind each planter pot, and in control plots away from planter pots during January 2020. One year old seedlings were planted in January 2021. • Subsequent survival of planted mangrove propagules was assessed monthly to determine the effectiveness of each treatment.	
How well project met objectives	Mangrove survival showed significant variation among sites, with those planted at Grantville being most successful. Low seedling survival at Lang Lang was due to smothering of seeds or erosion of seedlings. Planting 1 year old seedlings overcame problems of smothering by algal wrack.	
Cost	Approximately $445,000, including costs for pod design and a dedicated research program to analyse the efficacy of the approach.	
Further considerations	Lang Lang planting had lower survival of mangroves than Grantville likely due to higher wave energy, and unlikely historical presence of mangroves. Mangroves are currently (2022) still surviving at Grantville, and it is yet to be seen whether sufficient survival has been achieved to create a regime shift to a vegetated mudflat.	

3. Engineering

3.1 Nourishment

3.1.1 Localised beach scraping / dune nourishment

Action	Engineering – Nourishment – Localised beach scraping / dune nourishment		
Description	Localised beach scraping / dune nourishment involves the movement of sand from the lower part of the beach to the upper beach or dune. This assists to accelerate beach and dune recovery from short-term erosion (storm bite). This mimics the natural beach recovery process but is much faster. By increasing the sand volume on the upper beach and dunes, an additional erosion buffer is created. However, the reduction in sand level lower down the beach means the dunes may be more vulnerable to wave attack. Sand scraping may also assist with addressing accretion hazards by removing sand build-up in undesirable areas (e.g. boat ramps) and relocating to the upper beach / dunes. Beach scraping is typically undertaken by earth moving plant such as bull dozers and excavators. Beach scraping differs from beach nourishment (see beach nourishment) in that no new sand is introduced into the site / coastal compartment.		 *Beach Scraping following a storm at Cowes East (source: BMT)*
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Beach scraping tends to have a relatively short-term effect as subsequent storms can rapidly reshape the beach profile, moving sand back to the lower beach. As no new sand is introduced to the beach, this technique will not offset long term net sediment loss and recession. Beach scraping is suited to locations with wide inter-tidal zones from which sand can be sourced, and the resultant holes are filled by natural processes of along shore transport. Beach scraping may be used concurrently or consecutively with beach nourishment and other adaptation actions to assist with mitigating erosion in the longer-term.
		Long-term erosion	
	✓	Accretion	
		Storm tide inundation	
		Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Depending on the design and site context, beach scraping may be considered a nature-based or hybrid protect action.
		Avoid	
	*	Nature-based methods	
		Accommodate	
		Retreat	

<table>
<tr><th>Action</th><th colspan="4">Engineering – Nourishment – Localised beach scraping / dune nourishment</th></tr>
<tr><td></td><td>✓</td><td>Protect</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td colspan="2" rowspan="3">Considerations:
Beach scraping typically removes sand from the lower beach to the upper beach which will modify the wave run up and energy dissipation across the profile – allowing larger waves to reach the shore and increasing wave run-up. The impact of this activity is likely to be minimal providing the scraping of the shoreface remains shallow.
Poorly executed beach scraping can set the beach in to an overly steep and unstable profile (a dis-equilibrium profile). However, natural processes (wind and waves) tend to correct this in a short time.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td colspan="2" rowspan="5">Applicability considerations
Beach scraping:
• should be applied within the context of local coastal values
• can have positive impacts on beach amenity, as it increases the availability of usable beach at high tide
• requires regular operation of earth moving equipment on the beach - environmental considerations include habitat disturbance, interference with breeding or nesting sites and smothering of fragile dune vegetation
• can provide economic benefits associated with improved beach and dune ecosystems and amenity
• will require a program of regular scraping and/or combination with other adaptation actions longer term.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="6">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>3 - 6 months</td><td>Preparation for beach scraping is minimal, provided the volumes of sand involved are low. Where large beach scraping campaigns are planned, additional planning and permits may be required.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>Short</td><td>The effective timeline for beach scraping is highly variable and dependant on nearshore coastal processes, volume of nourishment and any other stabilisation efforts. Generally, beach scraping can be effective from a few weeks to a year.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Some</td><td>As well as increasing the buffer against storm erosion, beach scraping provides improved amenity through widening of the beach and increased area for dune habitat.</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">The range of approvals that may be required for beach scraping include:
• Marine and Coastal Act 2018 consent (DEECA)
• Parks Victoria – Works Permit
• Marine Park Approvals
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td colspan="2">Design considerations, constructability, and materials</td><td colspan="2">Important considerations for the success of Beach Scraping campaigns include:
• A good understanding of the coastal processes in the target site, including an understanding of the net erosion/accretion volume over time.
• A suitable plan for continuous monitoring of the Beach Scraping and triggers to undertake further campaigns if needed.
• A good understanding of any local environmental constraints at the site, in particular the presence of vulnerable species such as the endangered shore birds hooded plovers.
• Safe access to the beach for earth moving equipment
• Managing public access and safety around the works</td></tr>
<tr><td colspan="2">Cost considerations</td><td colspan="2">Costs for beach scraping are typically low (less than $10,000), with price impacted by availability of machinery, volume of sand to be moved, distance for sand relocation and length of tidal window for relocation.</td></tr>
</table>

Action	Engineering – Nourishment – Localised beach scraping / dune nourishment
References	Carley, J.T., Shand, T.D., Coghlan, I.R., Blacka, M.J., Cox, R.J., Littman, A., Fitzgibbon, B., McLean, G. and Watson, P., 2010, November. Beach scraping as a coastal management option. In Proceedings of the 19th NSW Coastal Conference (Vol. 890).

Project example

Engineering – Nourishment – Localised beach scraping / dune nourishment – Project example	
Project title	Cowes East Beach Scraping
Action type	Beach scraping
Location	Cowes East Beach, Phillip Island, VIC
Land manager	Bass Coast Shire Council
Year of Implementation	Initially 1976, then 1986. Two to three times a year from 2018.
Project objectives	Repair dune erosion behind timber seawall and preserve high tide access and erosion buffer.
Project process	Sand excavated from the intertidal area of Cowes Bank at low tide and placed in front and behind timber wall.
Measures implemented	Repeated as required after erosion events.
How well project met objectives	Council considered the placed sand to be 'sacrificial' and repeated the scraping as necessary. This way an effective dune buffer and maintained, with erosion limited to a zone of approximately 5m behind the wall. In 2021 the Council concluded that the rate of erosion (and frequency of scraping required) was increasing, and the beach scraping was no longer an effective way to manage risk from storm erosion and recession. The Council has commenced planning for permanent protection works (groynes and revetment) for the longer-term.
Cost	Each beach scraping campaign cost in the order of $10,000, to repair up to 330m of beach.
Further considerations	-

Beach scraping following a storm at Cowes East (source: Bass Coast Shire)

Beach scraping following a storm at Cowes East (source: Bass Coast Shire)

3.1.2 Beach nourishment

Action	Engineering – Nourishment – Beach nourishment		
Description	Beach nourishment involves providing additional sand to a beach system. This can assist with maintaining or increasing beach and dune volume and width, to mitigate erosion and other hazards. The design of beach nourishment programs involve consideration of sand source, transport, and placement. Sand may be sourced from accreting areas outside of the local sediment compartment, quarries, and offshore sources (dredged). Transport may be via trucks, pumped from offshore as a slurry, 'rainbowed' from a dredge to the nearshore, and moved around the beach via excavator. Placement options include: - directly on the upper beach/dune - creating a wide berm on the beach - in the nearshore zone where wave action will slowly work sand onshore. The key point with beach nourishment is that additional sand is being added to a coastal compartment, creating a net gain of sand in the system.		 *Beach nourishment via truck at Apollo Bay, Victoria (source: https://www.marineandcoasts.vic.gov.au)*  *Beach nourishment via dredging and 'rainbowing' (source: City of Gold Coast Council)*
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Beach nourishment is suited to settings where nourishment will be supported by local coastal processes (e.g. suitable cross-shore and long-shore sediment transport conditions) to enhance beach and dune recovery and growth. Beach nourishment increases the beach and dune volume to provide a buffer against short term erosion, and adds sand to the system to offset long-term recession. The enhancement of beach and dune volumes can also mitigate storm tide inundation (behind dunes) and influence estuary dynamics. An ongoing program of nourishment is typically required to maintain beach and dune volumes for a period (months to years). Nourishment is often combined with additional strategic actions (accommodate, retreat, protect actions) for longer term adaptation.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
	✓	Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Pending details of the design, beach nourishment may be considered a hybrid nature based action (if a primary purpose is creating / restoring habitat), or otherwise is considered to be a protect action.
		Avoid	
	*	Nature based	
		Accommodate	
		Retreat	

Action	**Engineering – Nourishment – Beach nourishment**		
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Beach nourishment increases the volume of sand in the tertiary coastal compartment. This will have some impact on existing coastal processes, however in general the movement of nourished sand will ultimately mimics natural processes. Coastal process at the site where the additional sand is sourced may also be modified, with possible changes to wave propagation over dredged areas.
	✓	Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Beach nourishment is a highly flexible action, used either alone or in conjunction with other approaches such as groynes or seawalls. Beach nourishment: - should be applied within the context of local coastal values - should consider ecological implications of sand addition/placement - requires consideration of the environmental impacts on the site where the additional sand is sourced - can have positive impacts on beach amenity, as it increases the availability of usable beach at high tide - requires operation of earth moving equipment on the beach - environmental considerations include habitat disturbance, interference with breeding or nesting sites and smothering of fragile dune vegetation - can provide economic benefits associated with improved beach and dune ecosystems and amenity.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	3-6 months	Preparation for beach nourishment usually takes 3-6 months to complete, with preparation timelines increasing with complexity and volume.
	Effective lifetime	1-5 Years	The effective timeline for beach nourishment is highly variable and dependant on coastal processes, volume of nourishment and any other stabilisation efforts.
	Co-benefits	Some	As well as protection, beach nourishment provides improved amenity through widening of the beach and improved stability for dune re-establishment.
	Approvals and requirements	The range of approvals that may be required for beach nourishment include: • *Marine and Coastal Act 2018* consent (DEECA) • Marine Park Approvals • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for the success of beach nourishment campaigns include: • A good understanding of the coastal processes in the target site, including an understanding of the net erosion volume over time. • Suitable nearby source of sand for nourishment. It is important that nourishment sand is of an equal or greater grain size to the native sand at the site to be nourished, otherwise it will be lost very quickly. Matching colour and shape may also be important. • Potential sources or nourishment sand need to be sampled and tested to ensure they are uncontaminated and free of organic material, odour causing compounds and excessive fines (silts and clays) which cause turbidity.	

Action	Engineering – Nourishment – Beach nourishment	
		• Access to the site for placement and spreading of nourishment sand, and interaction with beach users.
	Cost considerations	Costs for beach nourishment campaigns can be highly variable but are typically made up of a combination of fixed mobilisation costs (which can be high for marine plant such as dredgers) and variable sand relocation costs (proportional to volume). It is often more cost effective to do less frequent, higher volume campaigns than the inverse, but this may restricted by sand availability, coastal processes, or permit restrictions.
References	-	

Project example

Engineering – Nourishment – Beach nourishment – Project example		
Project title	Marengo to Apollo Bay renourishment	 *Beach nourishment via truck at Apollo Bay, Victoria (source: https://www.marineandcoasts.vic.gov.au)*
Action type	Beach nourishment	
Location	Marengo and Apollo Bay	
Land manager	DEECA, Great Ocean Road Coasts and Parks Authority	
Year of implementation	2020	
Project objectives	Provide an immediate buffer from winter storms to mitigate the erosion threat to the Great Ocean Road located on the dune crest, whilst promoting natural beach building processes.	
Project process	This section of beach has required nourishment every year or two for the last decade.	
Measures implemented	In the 2020 campaign 16,000 cubic metres of sand was moved from Barham River spit to south to the centre of Mounts Bay, Marengo to provide an additional three metres of sand dune along approximately 500 metres of beach.	
How well project met objectives	The project achieved the objective of providing a sufficient buffer for a winter season. Additional nourishment campaigns, with extensive dune stabilisation works (matting, planting) have continued to be implemented to mitigate ongoing erosion.	
Cost	The cost of the 2020 renourishment campaign was $120,000.	
Further considerations	-	

3.1.3 Sand by-pass system

Action	Engineering - Nourishment – Sand by-pass system
Description	Features along the coast often interrupt long-shore sediment transport processes (e.g. river, headland, groyne, harbour). This can result in a deficit of sand supply to down-drift shorelines. Sand by-pass systems are used to transport sand around these features, and restore sediment supply to shorelines in deficit. This assists to reduce accretion on the up-drift side, and mitigate erosion and other hazards on the down-drift side. Frequently by-pass systems are used to pump sand that is trapped against an updrift river training wall, or harbour breakwater, and discharge the sand downdrift of the river/harbour, bypassing the entrance and preventing siltation of the channel. Infrastructure may be established for the short or long term to facilitate the by-pass arrangements. This includes fixed slurry pumps and pump stations for ongoing by-pass systems, or the use of dredges and pipes/outlets for more intermittent by-pass programs. Sand back-passing is also a similar approach, using similar infrastructure, which transports sand in the opposite direction to the alongshore transport. Sand by-passing has been used in Portland, Lakes Entrance and Patterson Lakes in Victoria, with larger operations also on the Gold Coast. Sand back-passing is less common, but has been used in Noosa and the Gold Coast.

A dredge connecting to pipes at Patterson lakes. (source: ssm.com.au)

Sand bypassing station. Lakes Entrance.
(source: ssm.com.au)

Functional type		Land management planning and design
		Nature-based methods
	✓	Coastal engineering

Coastal hazard mitigation	✓	Short-term erosion
	✓	Long-term erosion
	✓	Accretion
	✓	Storm tide inundation
		Permanent inundation
	✓	Estuary dynamics
	✓	Offshore sediment dynamics
		Saline intrusion

Notes on suitability:

Sand by-passing facilities can assist to mitigate accretion and erosion on different parts of the coast, and associated mitigation of other hazards.

Sand bypassing facilities can be utilised in a variety of wave conditions, with fixed infrastructure more suited to higher wave energy environments where it is difficult for normal dredge operations to take place.

Sand by-passing is most effective where sand can be adequately captured at the intake zone. This is most commonly against a groyne or headland structure.

Marine and Coastal Policy order of consideration		Non-intervention
		Avoid
	*	Nature based
		Accommodate
		Retreat
	✓	Protect

Notes on policy context:

Sand by-pass systems are a protect action, and typically require substantial engineering works.

However pending the magnitude of the project, similar to beach nourishment, some sand by-pass projects may be considered a hybrid nature-based and engineering action.

<table>
<tr><th>Action</th><th colspan="3">Engineering - Nourishment – Sand by-pass system</th></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td>Low</td><td rowspan="3">Considerations:
Sand bypassing facilities are often used to restore the natural flow of sand along modified sections of coast. The by-passing process with alter existing coastal processes, however is likely to restore a more natural regime. Sand back-passing will have similar implications to beach nourishment, and depend on the magnitude of sand involved. In both cases, the sand is redistributed via natural coastal processes.</td></tr>
<tr><td>✓</td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations
As a major intervention, some general considerations include that:
• The establishment of a sand bypassing facility will involve substantial disturbance of the beach face and dune area, with implications for cultural, environmental, and other values.
• Once established, sand bypassing facilities are typically less intrusive (visually, noise, pollution) than dredge operations and can therefore be used in more sensitive (environmentally, tourism) locations.
• The operation of the sand bypassing facility can create local depressions in the beach face which need to be managed.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
</table>

<table>
<tr><td rowspan="5">Guidance for implementation</td><td>Preparation / design period</td><td>Several years</td><td>Design and approvals for a sand by-pass facility can take several years to implement. Previous examples have utilised temporary facilities as proof-of-concept before implementing fixed facilities. Construction speed will depend on site access, length of bypass/back pass pipeline, wave conditions and power availability.</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td>Sand by-pass facilities are actively operated and maintained and the effective lifetime is only limited by the maintenance program. Typical wear and tear on mechanical components is expected to require periodic replacement.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td>Captured sand can be placed in desirable locations to create near shore or onshore nourishment that can benefit the beach system. By-passing reduces/prevents the occurrence of river mouth shoaling which makes navigation of channels safer, more reliable and possible for larger vessels.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="2">The range of approvals that may be required for a sand by-pass project include:
• Land Owner’s consent
• Marine and Coastal Act 2018 consent (DEECA)
• Marine Park Approvals (Parks Victoria)
• Planning Permit (Local Government)
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td>Design considerations, constructability, and materials</td><td colspan="2">Important considerations for successful design of a sand by-pass project include:
• Understanding of coastal processes and geotechnical conditions at the site.
• Suitable location, access and power for construction of facility.
• Suitable location for sand outlet.
• Distance of bypassing/back passing pipeline (pipelines over 1.5km may need additional booster pumps).
• Availability of funds and personnel for maintenance and operation of the facility.
• Fixed sand bypassing facilities are often electric powered which reduces local emissions compared with diesel dredge operations.
Sand by-pass facilities have been established at many sites in Victoria, Australia and internationally. Larger sites (Tweed River, Gold Coast Seaway) require permanent</td></tr>
</table>

Action	Engineering - Nourishment – Sand by-pass system	
		operation, while smaller sites (Lakes entrance (Nankervis (2005), Portland (Cowper and Nakervis (1997), Noosa) can be operated on an as-needs basis.
	Cost considerations	When costing a sand by-pass project, the following items should be considered: • A good understanding of coastal processes and how a sand by-pass facility will modify them. • Volume of sand to be removed. • Distance of sand to be moved. • Operational regime (permanent, seasonal, as-needed) including staffing considerations. • Need for permanent/semi-permanent facility and structures. • Energy source (diesel/electric) • Environmental, social and cultural heritage impacts. Typically, sand by-pass facilities have large capital cost, but are cheaper to run on a volume of sand transport basis than comparable dredge operations. Depreciation, maintenance and replacement of parts will need to be considered when planning for a sand by-pass facility.
References	Nankervis, L. (2005). Beach Nourishment with the Submarine Sandshifter. Coasts and Ports 2005 : Coastal Living - Living Coast; Australasian Conference; Proceedings, 1, 1, 2005, 341-344. https://search.informit.org/doi/10.3316/informit.498878579680212 Cowper, N. T., & Nankervis, L. (1997). Innovative Sand Shifter Technology for Maintaining Clear Ocean Entrances Year Round: Sands Bypassing at Port of Portland, Victoria, Australia. In: Pacific Coasts and Ports '97: Proceedings of the 13th Australasian Coastal and Ocean Engineering Conference and the 6th Australasian Port and Harbour Conference; Volume 2. Christchurch, N.Z.: Centre for Advanced Engineering, University of Canterbury, 1997: [843]-[847]. https://search.informit.org/doi/10.3316/informit.032129910253292 A series of animated videos on bypassing/back passing technologies can be found at the following website: https://www.swashpd.com.au/sand-management-in-action/	

Project Example

<table>
<tr><th colspan="3">Engineering - Nourishment – Sand by-pass system – Project example</th></tr>
<tr><td>Project title</td><td>Lakes Entrance By-pass System</td><td rowspan="9">
Lakes Entrance sand bypassing station (source: ssm.com.au)

Lakes entrance sand outfall. (source: ssm.com.au)</td></tr>
<tr><td>Action type</td><td>Sand by-pass system</td></tr>
<tr><td>Location</td><td>Lakes Entrance</td></tr>
<tr><td>Land manager</td><td>Gippsland Ports</td></tr>
<tr><td>Year of implementation</td><td>2000-2009</td></tr>
<tr><td>Project objectives</td><td rowspan="4">Siltation of the entrance channel was a navigational hazard that needed to be continuously managed. The objective of the sand by-pass facility was to reduce siltation within the channel to improve access and relocate the sand further away. This allowed better navigation of the channel with fewer dredge deployments needed.
A sand by-pass station was installed by Slurry Systems Marine in conjunction with Gippsland Ports to collect sand from within and outside the entrance and pump it back to the beach on the downdrift beach.
Sand collected by conventional dredging is pumped to the transfer station before being boosted through a discharge pipeline and back to the beach.
Initial trials of a diesel-powered system were conducted between 2000 and 2002 as a proof of concept, and subsequently upgraded to an electric system for further trials between 2007 and 2009.
While the trials were successful, further funding is required to establish the sand by-passing ongoing.</td></tr>
<tr><td>Project process</td></tr>
<tr><td>Measures implemented</td></tr>
<tr><td>How well project met objectives</td></tr>
<tr><td>Cost</td><td colspan="2">-</td></tr>
<tr><td>Further considerations</td><td colspan="2">-</td></tr>
</table>

3.2 Shellfish reefs

Action	Engineering – Reefs – Shellfish reefs		
Description	Shellfish reefs are natural or artificial structures populated by bivalve molluscs (commonly mussels and/or oysters). The reefs are commonly situated nearshore or offshore and can act to dissipate waves before they reach the shore (Morris et. al, 2021). In this way they act as low-crested breakwaters dissipating incoming wave energy through friction and depth-induced wave breaking. Reduced wave energy in the lee of the reef reduces storm erosion and along-shore sediment transport, trapping sediment and protecting the area from erosion. The build-up of sand and the shoreline may also provide some protection from inundation. These reefs historically occurred naturally throughout much of Port Phillip Bay, Western Port Bay, Corner Inlet, and the Gippsland Lakes (Ford, Hammer 2016). Construction of shellfish reefs in nearshore environments is possible by placing artificial substrates (of rock, shell, concrete, steel or other eco-engineering modules) offshore in a variety of configurations (long linear structures or scattered modules), and either seeding with shellfish or allowing natural recruitment.		  Ramblers Reef, Portarlington
Functional type		Land management planning and design	
	✓	Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Shellfish reefs are used to mitigate short-term storm erosion and long-term shoreline recession, including undercutting of cliffs and bluffs where sediment transport and erosion are driven by waves. Shellfish reefs are most effective on relatively protected coastlines in an embayment with moderate wave energy (e.g., Port Phillip Bay, Western Port Bay, Gippsland lakes etc.), or in the lower energy environment of estuaries. Areas of high sediment transport volume will readily build sand spits landward of the reef. Shellfish may not survive at sites of low water quality, high nutrient levels or in the presence of other environmental stressors.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
		Permanent inundation	
		Estuary dynamics	
	✓	Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Construction of artificial shellfish reefs is a protect action involving substantial engineering works. Given a key objective is also habitat creation / restoration, shellfish reefs can also be considered as a hybrid nature based action.
		Avoid	
	*	Nature based	
		Accommodate	
		Retreat	
	✓	Protect	

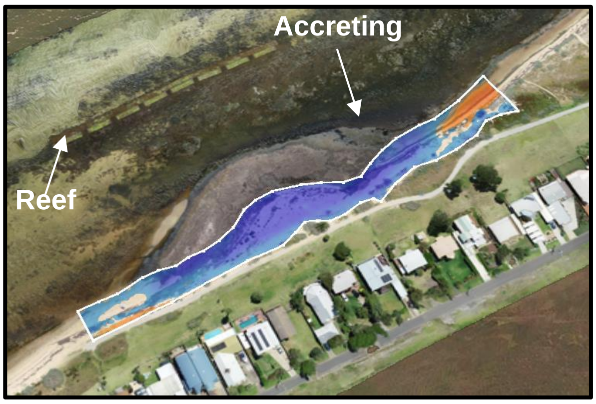
Action	**Engineering – Reefs – Shellfish reefs**		
Likely impact on natural coastal processes		Low	**Considerations:** Shellfish reefs aim to accrete sediment between the reef and the shoreline. Build-up of sediment in this area may disrupt sediment movement to other parts of the coastline, which may lead to increased erosion elsewhere.
	✓	Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** As a major structural intervention, some general considerations include that: • The establishment of a shellfish reef may involve substantial disturbance to the shoreline and offshore marine areas, with implications for cultural, environmental, and other values. • The sediment build-up behind the reef can increase the area of beach available for recreation and coastal habitat. • The shellfish reef may be a navigational hazard for boaters and appropriate signage must be implemented. • The reef may also be a hazard for swimmers at the beach and appropriate measures should be undertaken to minimise public access to the structure and ensure a safe environment. • A shellfish reef can increase marine biodiversity, support recreational fisheries, provide water filtration, and may become a dive tourist attraction.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		

Guidance for implementation			
	Preparation / design period	> 12 months	A shellfish reef typically requires 6 to 18 months for design and approvals. After this, construction speed will depend on construction methodology (from land or barge), site access, plant used, weather, rock supply and Larval oyster/mussel supply if seeding with shellfish.
	Effective lifetime	50+ years	Shellfish reefs can adapt to rising sea levels as successive generations of shellfish attach to the outside surface of the reef. This increases the reef crest level as sea levels rise.
	Co-benefits	Many	There are many co-benefits of a shellfish reef including increased biodiversity, cleaner water (shellfish filter feed) and increased tourism. There is also opportunity for community stewardship of the reef.
	Approvals and requirements	The range of approvals that may be required for a shellfish reef include approvals from: • Marine Park Approvals • Parks Victoria works permit • *Marine and Coastal Act 2018* consent (DEECA) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of a shellfish reef include: • Understanding of coastal processes and geotechnical conditions at the site • Source and price of reef base material (rock, shell, concrete etc.) • Access to the site for material supply • Environmental conditions (water quality, nutrient levels, water temperature etc.) • Reef geometry/design (linear or modules) • Shellfish type (oysters, mussels etc.) and source of spat (juvenile shellfish larvae) these must not be invasive species. One example of an artificial shellfish reef has been built in Victoria for coastal protection (Ramblers Reef), which has been successful, and other reefs are in development. However, this is an emerging technology and additional effort, and time is required for design, modelling and trials for this type of project. Failure mechanisms for shellfish reefs are likely instability of base material, failure of shellfish recruitment (due to poor water quality, incorrect shellfish species used for	

Action	Engineering – Reefs – Shellfish reefs	
		location) or failure to have the desired impact on coastal processes due to changing local conditions.
	Cost considerations	When costing a shellfish reef project, the following items should be considered: • Design and approval costs • Reef base material supply, delivery, and placement • Shellfish spat (if seeding the reef) • Cost of managing impacts on coastal processes/environment/beach amenity. Ramblers Reef is a 130m long linear reef and cost the City of Greater Geelong approximately $450,000 excluding design, approval and rock supply costs.
References	Morris RL, Bishop MJ, Boon P, Browne NK, Carley JT, Fest BJ, Fraser MW, Ghisalberti M, Kendrick GA, Konlechner TM, Lovelock CE, Lowe RJ, Rogers AA, Simpson V, Strain EMA, Van Rooijen AA, Waters E, Swearer SE. (2021) The Australian Guide to Nature-Based Methods for Reducing Risk from Coastal Hazards. Earth Systems and Climate Change Hub Report No. 26. NESP Earth Systems and Climate Change Hub, Australia. Victorian State Government, 2020. Victorian Marine and Coastal Policy. ISBN 978-1-76077-888-0 Ford, J.R., Hamer, P. 2016. The forgotten shellfish reefs of coastal Victoria: documenting the loss of a marine ecosystem over 200 years since European settlement. CSIRO Publishing. https://www.publish.csiro.au/rs/pdf/rs16008.	

Project example

Engineering – Reefs - Shellfish reefs – Project example	
Project title	Ramblers Road Reef – Point Richards
Action type	Shellfish reef
Location	Portarlington, Victoria
Land manager	City of Greater Geelong
Year of implementation	May 2018
Project objectives	• Reduce inundation / flooding during storm tide events • Prevent further coastal erosion and loss of foreshore land • Stabilize the beach • Reduce wave energy, run-up, and over-topping • Accumulate sand on the beach • Be cost effective • Minimal impact on natural coastal processes • Deliver co-benefits in terms of habitat creation and restoration.
Project process	Reef design was undertaken by Ralph Roob, an engineer at City of Greater Geelong. CMA permit application was prepared in-house at City of Greater Geelong. Construction occurred in May 2018 with shellfish seeding occurring immediately post construction.
Measures implemented	A 130m long linear hybrid shellfish reef with rock and shell base. Base was constructed via filling steel 'baskets' with waste basalt rock from nearby farm properties and shells. The surface of these were then seeded with live mussels from nearby aquaculture leases. Subsequent natural recruitment of shellfish, algae and other marine species has increased the biodiversity of the reef. It is hoped that further recruitment will increase coverage of shellfish on the reef.
How well project met objectives	Ramblers Reef has been successful since construction with sand accreting shoreward of the reef creating a wide beach, protecting foreshore areas, values and assets.
Cost	Reef construction costs were $450,000 excluding design and permit application costs (which were both conducted in-house at City of Greater Geelong), and rock supply costs (which were minimal in this case due to the use of waste rock from local farms). Indicative cost estimates for design and permit application are approximately 10-15% of capital costs, depending on desired design and location. The cost of rock supply and placement for a shellfish reef varies considerably depending on the accessibility of the desired reef location. The total cost may include fees for rock supply (from quarry), rock delivery (to barge), barge hire, rock placement from barge.
Further considerations	Trial dune planting has been undertaken onshore to trap windblown sand and raise low dunes for further protection.



Ramblers Reef

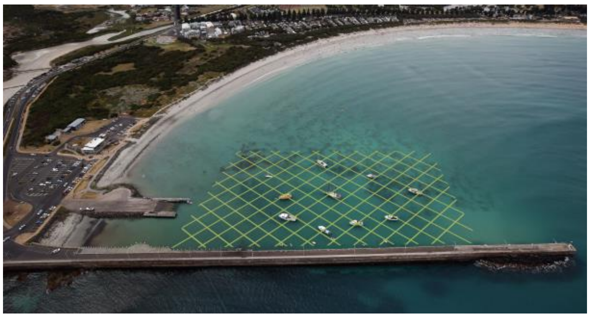

Steel baskets filled with shell

3.3 Configuration dredging

Action		Engineering – Dredging – Configuration dredging	
Description		Dredging involves the removal of sand from localised areas of the seafloor (offshore, river mouths, harbours, updraft of structures etc.), and placement of sand elsewhere (also see beach nourishment). Configuration dredging involves removal and placement of dredged sand to modify the seabed level to reduce the intensity of nearshore waves and wave refraction patterns. This can assist to mitigate shoreline erosion. Configuration dredging can be designed to be combined with other dredging outcomes, such as enhanced navigability, or specifically for wave modification purposes. The change to wave behaviour at the shoreline depends on the size, shape and extent of dredging relative to the wave characteristics (wavelength and incident direction) and water depth.	 *Port of Warrnambool,* Lady Bay, VIC, Australia.
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Configuration dredging changes the direction of waves approaching the shore, which can be used to reduce wave energy reaching a particular area, and therefore reduce sediment transport and erosion. This approach is most suitable where there is a localised shoreline erosion and regular dredging for navigation occurs. Dredged material from configuration dredging may be used to nourish adjacent beaches further mitigating shoreline erosion. Configuration dredging has the greatest effect on long period swell waves, with local wind waves being less influenced by seabed depths in front of the shoreline.
	✓	Long-term erosion	
	✓	Accretion	
		Storm tide inundation	
		Permanent inundation	
		Estuary dynamics	
	✓	Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Configuration dredging is a protect action, involving substantial engineering works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Configuration dredging involves disturbance of the seabed and wave environment, although usually to a relatively localised area. Configuration dredging may also lead to a corresponding increase in wave energy and erosion impacting another area along the shore.
	✓	Moderate	
		High	

Action	Engineering – Dredging – Configuration dredging		
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations:** The appropriateness of configuration dredging will depend on site specific marine and coastal values. Configuration dredging may cause loss of marine vegetation and benthic infauna within the direct impact area. Recovery of the affected area would be expected but may be modified if conditions are different (i.e., deeper water). There are different methods for dredging (e.g., suction dredger, barge-mounted excavator, frequency and volumes) to reduce impacts for local environmental, cultural and social values.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	6-12 months	Planning and design of configuration dredging may take some time depending on the degree of background investigations required and approvals necessary. Typically, the process would involve an initial concept plan, supported by logistical assessments covering geotechnical and metocean conditions of the area. Engagement with project partners and decision-makers should commence at this early stage to ensure key issues are addressed through the works. Detailed design would be refined based on conditions and dredging approach. Once approved, the dredging works could be completed within a 1 – 3 month timeframe, depending on the extent and difficulty of dredging required.
	Effective lifetime	> 1 years	The effective lifetime varies depending on the rate of infill, which is a function of the local coastal processes. The lifetime of the works can be extended if ongoing maintenance dredging was included in a forward works program.
	Co-benefits	Some	Improved navigability would be the key co-benefit from configuration dredging. To fully realise the co-benefit, there may need to be extensions to the configuration dredging scope to allow navigable access to the area.
	Approvals and requirements	The range of approvals that may be required for a configuration dredging include: • *Marine and Coastal Act 2018* consent (DEECA) • Marine Park Approvals (Parks Victoria) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	• Preliminary geotechnical and metocean study of the area. • Designing the size, depth, and orientation of the dredging configuration to maximise benefits for wave diffraction. • The quality and volume of the dredged sand and the proposed disposal of the dredge materials, which could include nourishment of an adjacent eroding shoreline. • Need for maintenance dredging given potential sediment transport. Monitoring of in-fill rates will be important to gauge effectiveness of the configuration dredging and to plan maintenance dredging intervals.	
	Cost considerations	Configuration dredging can be very costly, especially for relatively small volumes, where mobilisation costs can be high relative to the overall works costs. However where dredging is already underway (e.g. for navigation), the cost for additional dredging / placement for erosion mitigation will be relatively low.	
References	Nielsen A and Williams B (2018) Configuration dredging for beach stabilisation. Proc NSW Coastal Conference. Available online at https://www.coastalconference.com/2018/papers2018/Ben%20Williams.pdf		

Project example

<table>
<tr><th colspan="3">Engineering – Dredging – Configuration dredging – Project example</th></tr>
<tr><td>Project title</td><td>Safer boat launching and retrieval at Lady Bay</td><td rowspan="8">
Dredged Configuration area (highlighted in yellow), Port of Warrnambool, Lady Bay, VIC, Australia.</td></tr>
<tr><td>Action type</td><td>Configuration dredging</td></tr>
<tr><td>Location</td><td>Port of Warrnambool, Lady Bay, VIC, Australia.</td></tr>
<tr><td>Land manager</td><td>Warrnambool City Council</td></tr>
<tr><td>Year of Implementation</td><td>Major dredging was undertaken in 2010 with follow up dredging</td></tr>
<tr><td>Project objectives</td><td>To diffuse wave energy at the boat ramp</td></tr>
<tr><td>Project process</td><td rowspan="2">• Upgrade boating facilities including the boat ramp. Widened boat ramp made with porous structure to diffuse wave energy.
• Wave height to be managed by regular dredging of key sections of the Port area.</td></tr>
<tr><td>Measures implemented</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">Dredging was effective at reducing the waves heights experienced on the public boat ramp up to 50%. Safety of launching boats was improved by 90% for a period of several months after the works.
Sand accumulation within the dredged area did occur quickly and the benefits diminished. Wave conditions at the boat ramp retuned to pre-dredge conditions within about 1 year, requiring a program of regular dredging.</td></tr>
<tr><td>Cost</td><td colspan="2">$1.5 million plus $250,000 annual maintenance</td></tr>
<tr><td>Further considerations</td><td colspan="2">Possible options for disposal of dredge materials including beach nourishment along a wide stretch of Lady Bay.</td></tr>
</table>

3.4 Seawalls

3.4.1 Vertical seawalls

Measure	Engineering – Seawalls -Vertical Seawalls		
Description	Vertical seawalls are structures desiged to protect the land behind from wave action and erosion. These types of seawall may be fully vertical, near vertical, incorporate slopes, steps or wave refelectors. They are solid and imperveous as compared to more porus rock revetments. Vertical seawalls may be constructed using either cemented masonry blocks, precast concrete modules, timber planks or sheet piles. The structure may vary with site conditions and material availability. In some instances, rock may be placed at the toe of the wall to minimise the risk of scour undermining the structure. Seawalls reflect wave energy, which can cause scour and the loss of the beach in front (seaward) of the structure.		 Steel sheet pile seawall at San Remo Victoria  Vertical seawall Barwon Heads Victoria
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Vertical seawalls are used to mitigate short and long-term erosion, including undercutting of cliffs and bluffs. Vertical seawalls are most effective on semi-protected coastlines with moderate wave energy (e.g., exposed shorelines of Port Philip Bay), or in the lower-energy environment of bays and estuaries (e.g. Gippsland Lakes). In situations where erosion is driven by tidal currents or flow from creek/river mouths, seawalls can be effective but other actions may be more suitable. Vertical seawalls may also provide some protection from inundation pending details of the design.
	✓	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Vertical seawalls are a protection action, requiring major engineering works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Vertical seawalls are a hard, fixed structure at the shoreline. Local beach levels in front of seawalls are often lower than they were before construction due to reflected wave energy initiating scour. This can cause the loss of the beach in front of the seawall. At the ends of the seawall, "end effects" can increase erosion for up to 100m along the coast, although the effect is most pronounced immediately adjacent to the wall.
		Moderate	
	✓	High	

Measure	Engineering – Seawalls -Vertical Seawalls		
			Seawalls also 'lock up' sand behind the wall, such that it is not available for the natural recovery of the beach or supply of sand to adjacent areas.
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations:** • Vertical seawalls are a major structural intervention that may have implications for a range of local coastal values. • Reflected wave energy often causes progressive loss of sand/upper beach, or erosion elsewhere along the coast. • The seawall creates a physical barrier between the beach and backshore area that changes natural look of beach, blocks access and halts natural landward retreat/migration of habitat. • Vertical seawalls can provide protection for critical landward values, assets and infrastructure, and support access / amenity. • There is a need to consider trade-offs related to asset protection vs loss of the beach and impacts on other values. • Social amenity of seawalls can be improved by incorporating access stairs and seating within the wall • The establishment of seawalls requires ongoing maintenance and renewal / upgrades over time.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	6-12 months	A vertical seawall typically requires 6 to 18 months for design and approvals. After this, construction speed can be 5 to 10 linear metres per day, depending on access, plant used, weather and material supply.
	Effective lifetime	Up to 50 years	Typical design life of 50 years can be achieved, with longer design life possible, but requiring appropriate design detailing and maintenance. Some materials, such as steel sheet piles, cannot achieve this design life.
	Co-benefits	Few	Vertical seawalls can provide benefit compared to other shore hardening structures because of its reduced footprint, which can provide additional beach width (initially) or as an option in confined spaces. Vertical seawalls can also be constructed or retrofitted with texture panels the provide intertidal habitat (see eco-engineering of hard surfaces).
	Approvals and requirements	The range of approvals that may be required for a vertical seawall include: • Land Owner's consent • *Marine and Coastal Act 2018* consent (DEECA) • Marine Park Approvals (Parks Victoria) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of a vertical seawall include: • Coastal processes and geotechnical conditions at the site • Historic beach level fluctuations, wave exposure and sediment transport to determine natural range of beach height • Understanding of the potential impact of the wall on the surrounding coastline • Provision of pedestrian and/or vehicular access to the beach over the structure • Access to the site for material supply and construction plant • Wall geometry: crest and toe levels. The most common failure modes for seawalls are damage to the wall structure (e.g., loss of cement between masonry blocks), overtopping during storms, or toe scour.	
	Cost considerations	When costing a vertical seawall project, the following items should be considered: • Design and approval costs, including geotechnical investigations	

Measure	Engineering – Seawalls -Vertical Seawalls	
		• Wall construction material supply and delivery (e.g., masonry blocks, timber, sheet piles, concrete modules) • Wall construction • Cost of managing impacts on coastal processes/environment/beach amenity. Cost of a vertical seawall depends on the height, length and design of the structure. A 55 m sheet pile seawall at San Remo on the Bass Coast, constructed in 2016 cost approximately $440,000 ($8,000 per m).
References	-	

Project example

Engineering - Seawalls - Vertical seawall – Project example		
Project title	Sorrento Front Beach Coastal Protection	 *Sorrento stepped seawall*
Action type	Vertical seawall (stepped)	
Location	Sorrento, Victoria	
Land manager	Mornington Peninsula Shire Council, DEECA	
Year of Implementation	2016 - 2017	
Project objectives	Replace and upgrade the previous timber seawall and to provide greater coastal amenity for beach users in the form of seating and viewing locations.	
Project process	The occurrence of hazardous sinkholes behind the old timber seawall drove the need to replace the wall. After considerable community consultation, the stepped design was selected to increase the amenity of the area. Project design and construction required several studies including: - an Aboriginal and historical cultural heritage assessments of the old wall, - design wave, water level and sediment transport assessment - onsite assessment of potentially culturally significant material when the wall was removed. Landscaping of the park area immediately behind the wall was also undertaken including park benches.	
Measures implemented	Approximately 90 m of stepped seawall was constructed along the Sorrento foreshore adjacent to the ferry terminal between 2016 and 2017 to increase safety of users of the area, to halt further erosion and protect assets including a foreshore walking trail, and parkland. The works were part of a larger project to increase accessibility to the Queenscliff – Sorrento Ferry terminal which included a reclamation and new revetment adjacent to the seawall. The design included a seawall 90 m long, constructed in 1 stage. Crest elevation 4 m AHD. Toe elevation -1 m AHD from concrete precast blocks.	
How well project met objectives	The seawall was completed in 2016 and has reportedly been effective at stabilising the shoreline. The wall has also been effective at providing a popular seating and viewing location for beach users.	
Cost	Seawall construction costs were under $1M.	
Further considerations	-	

3.4.2 Eco-engineering of hard structures

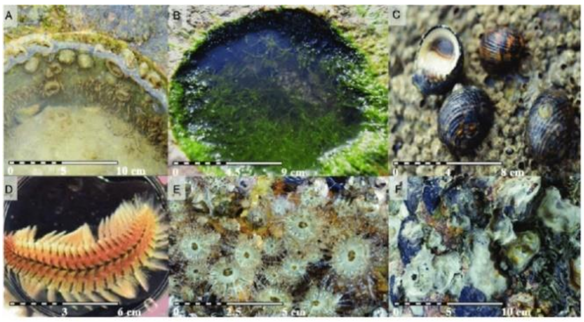
<table>
<tr><th>Action</th><th colspan="3">Engineering – Seawalls – Eco-engineering of hard structures</th></tr>
<tr><td>Description</td><td colspan="2">Eco-engineering of hard structures involves adding complexity to the seaward face of a hard coastal protection structure such as a seawall, to encourage colonisation and growth of marine and intertidal organisms.

This increases the habitat value of the seawall and may also help to reduce wave impact loads, reduce wave runup and provide a degree of protection to the wall itself from wave damage.

Typically, engineered coastal protection structures (such as concrete and masonary walls) have a relatively smooth seaward face with minimal textural features providing micro-habitats for colonising organisms. Rock revetments provide a more complex interface with the sea or waterway, however some quarried rocks can also have quite smooth surfaces. Eco-engineering of these structures involves modifying the seaward face to provide microhabitats for marine species including crevices, hollows, ridges and protrusions, swim-throughs and tidal pools. These design features encourage and support colonisation by a range of organisms, recreating an intertidal reef type habitat.

Micro-habitats can be designed into new seawalls by using naturally rough and porous material or customised mouldings and finishes on concrete. Habitat panels such as those used in the Living Seawall project in Sydney can be retrofitted to existing seawalls. These habitat panels come in a wide range of designs, with varying features and crevice sizes to suit different species. Multiple designs can be used in combination to increase biodiversity. Habitat panels can be installed bare or with key species such as oysters or seaweeds already attached to their surface to accelerate community development. Digital fabrication techniques such as 3D printing can be utilised to provide fine intricacies and a high degree of flexibility in the texture of the panels.

Drill-core rockpools can be drilled into rock revetment blocks to create more protected micro-habitats for intertidal organisms. These artificial rockpools have been shown to significantly enhance species richness and community structure on granite revetments in Malaysia compared to local emergent intertidal reef (Su Yin & Jean 2020). This technique is yet to be tried in Victoria.</td><td rowspan="4">
Living seawall at Sawmillers Reserve, Sydney NSW, 2 years after installation (Photo by Maria Vozzo).


Organisms found in drill-cored artificial rock pools situated on granite rock revetments in Malaysia (Su Yin & Jean 2020).


Textured concrete breakwater modules intended to provide habitat for intertidal flora and fauna. Netherlands. <u>Source</u> (ecoshape.org)</td></tr>
<tr><td rowspan="3">Functional type</td><td></td><td>Land management planning and design</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td>✓</td><td>Coastal engineering</td></tr>
<tr><td rowspan="2">Coastal hazard mitigation</td><td>✓</td><td>Short-term erosion</td><td rowspan="2">Notes on suitability:</td></tr>
<tr><td>✓</td><td>Long-term erosion</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="4">Engineering – Seawalls – Eco-engineering of hard structures</th></tr>
<tr><td rowspan="6"></td><td></td><td>Accretion</td><td colspan="2" rowspan="6">Eco-engineering of hard structures can occur wherever suitable structures are situated, and subject to local site conditions. Eco-engineering can be retrofitted to existing structures or planned into new structures.
The Living Seawall approach, as practiced extensively in Sydney, is very well suited to retrofitting on existing vertical seawalls or incorporation into upgrade works to increase habitat value and structure resilience.
Rockpool drill-coring and introduction of textured habitat blocks is most suitable for rock revetment structures.</td></tr>
<tr><td>✓</td><td>Storm tide inundation</td></tr>
<tr><td></td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td></td><td>Saline intrusion</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td colspan="2" rowspan="6">Notes on policy context:
Eco-engineering is added to existing or new coastal protection structures, and as such is considered to be part of a ‘protect’ action, with co-benefits for habitat creation.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td></td><td>Retreat</td></tr>
<tr><td>✓</td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td>Low</td><td colspan="2" rowspan="3">Considerations:
While seawalls and hard structures can have a high impact on coastal processes, the addition of eco-engineering elements does not increase this impact, and may even reduce impacts, as the increased roughness will tend to reduce wave runup and reflection.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td></td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td colspan="2" rowspan="5">Applicability considerations
Eco-engineering of hard structures is typically applied in highly modified coastal environments, and can assist with restoring / enhancing some coastal values.
Many existing eco-engineered coastal structures in Australia are situated in highly prominent public urban spaces in cities where seawalls have been in place for a long time (e.g., Living Seawall Project in Sydney).
The installation of eco-engineering elements to hard structures should be informed by ecological assessments of potential ecosystem changes, including benefits as well as risks (e.g. invasive species).</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="4">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>6 - 12 months</td><td>Eco-engineering of coastal protection structures may be incorporated into the initial design phase for new structures. Retrofitting Eco-engineering elements to existing structures may require around 6 months for design and approval. Additional time may be required for ecological assessments to inform the design of eco-engineering elements.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>20+ years</td><td>Many eco-engineered elements in hard coastal structures either use concrete or rock as a substrate. As such, these elements typically have long effective lifetimes, with maintenance.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Many</td><td>In addition to the small benefits to the performance of the coastal protection structure, eco-engineering elements have many co-benefits including:
• Increasing intertidal habitat and biodiversity of the area and waterbody, as these type of reef habitats form a basis for larger food chains. This also has benefit for recreational and commercial fisheries.
• Encrusting shellfish and other filter-feeders clean the waterways by feeding on pollutants and particles in the water, activating a natural filtration system with positive impact on water quality that extends benefits to recreational fishers and beachgoers.
• Opportunities for community stewardship.</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">The range of approvals that may be required include:
• Land Owner’s Consent</td></tr>
</table>

Action	Engineering – Seawalls – Eco-engineering of hard structures	
		• *Marine and Coastal Act 2018* consent (DEECA) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) (if encrusting algae is already present) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).
	Design considerations, constructability, and materials	Important considerations for successful eco-engineering of hard surfaces include: • Understanding of the site ecology, biodiversity, water quality and coastal processes (wave exposure, water level variation, sediment movement) is necessary for the design of habitat panels • Material selection for the panels/textures surface. This can include specialty concrete that can incorporate various recycled/low carbon additives. • Access to the site for installation and fixing system.
	Cost considerations	Cost of eco-engineering will vary greatly depending on the desired methodology. For example, drill-coring rockpools may be relatively cheap, however, 3D printed Living Seawall panels may cost approximately $400-$500 each installed. In general, the following items should be considered when costing an eco-engineering project: • Baseline survey of environmental and ecological conditions and biodiversity necessary for eco-engineering design of habitat panels • Design/material selection/manufacturing of required elements • Installation of the eco-engineering (e.g., contractor for drill coring, civil construction firm for habitat block installation, any diving required for installation.
References	Chee, Su Yin & Yee, Jean. (2020). Drill-Cored Artificial Rock Pools Can Promote Biodiversity and Enhance Community Structure on Coastal Rock Revetments at Reclaimed Coastlines of Penang, Malaysia. Tropical Conservation Science. 13. 10.1177/1940082920951912. 'Environmentally Friendly Seawalls', NSW Office of Environment and Heritage (2012) Reef Design Lab, Alex Goad	

Project example

Engineering – Seawalls – Eco-engineering of hard structures – Project example		
Project title	Sawmiller Reserve - Living Seawall Project	 Living seawall at Sawmillers Reserve, NSW, shortly after installation (Photo by Alex Goad)
Action type	Eco-engineering of hard structures	
Location	Sawmiller Reserve, Sydney, NSW.	
Land manager	North Sydney Council	
Year of Implementation	2017 – 2018	
Project objectives	Construction of a living seawall by adding habitat units to the flat surface of an existing vertical seawall to increase biodiversity and improve water quality.	
Project process	• Baseline survey of environmental and ecological conditions and biodiversity of the marine species conducted by the Sydney Institute of Marine Sciences (SIMS). • Design of 10 different habitat panels each providing shelters for target species tailored to the environmental and ecological conditions of the exposure site. • Construction of habitat panels using an eco-friendly concrete, a material that Sydney rock oyster responds to very positively. • Laboratory and in-site tests of habitat panels to ensure they perform in environmental conditions of the exposure site. • Manufacturing habitat panels in 5 different designs using 3D printing technology to reduce the cost and increase the speed of the manufacturing process as well as increase the habitat complexity. • Panel installation in 2018.	
Measures implemented	Installation of 108 habitat panels of five different designs developed by the Reef Design Lab, each targeting a specific species or group of species. Panels were manufactured using eco-friendly concrete. Each panel had an individual weight between 23-30 kg, diameters of ~0.55m, and thickness of ~0.1m. Installation by the Sydney Institute of Marine Sciences (SIMS).	
How well project met objectives	Over 2 years after installation of the living seawall, up to 115 different species have already colonised the panels including oysters. Panel designs were found to support three times as many species as a flat seawall and are supporting 36% more life than unmodified seawalls which have hosted decades of marine growth.	
Cost	Living Seawall panels cost approximately $400-$500 each including transport, installation and fixings.	

3.4.3 Rock revetments

<table>
<tr><th>Action</th><th colspan="3">Engineering – Seawalls – Rock revetments</th></tr>
<tr><td rowspan="4">Description</td><td colspan="2" rowspan="1">Rock revetments are engineered walls made of loose, interlocking rock.
Revetments assist to protect the land behind from wave attack and erosion.
Rock revetments usually have multiple layers of rock armour, each of different sizes. Sand filter layers or geotextile fabric are placed behind and beneath the rocks to stop finer sand/fill washing out through the structure.
The structure of a revetment may vary with site conditions and material availability, and the outer-most armour units may be manufactured from concrete if suitable rock is not available.
Like all seawalls, revetments reflect wave energy which can cuase scour and the loss of the beach in front (seaward) of the structure.
However revetments differ from vertical seawalls in that they provide a rougher surface with interstices between the rocks, that can assist with absorbing and dissipating some wave energy.</td><td rowspan="4">
Rock Revetment along Great Ocean Road, Skenes Creek</td></tr>
<tr><td></td><td>Land management planning and design</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td>✓</td><td>Coastal engineering</td></tr>
<tr><td rowspan="8">Coastal hazard mitigation</td><td>✓</td><td>Short-term erosion</td><td rowspan="8">Notes on suitability:
Rock revetments are used to prevent short and long-term erosion, including undercutting of cliffs and bluffs.
If designed appropriately, rock revetments can be effective in a diversity of coastal settings. They have effectively been implemented in estuarine environments as well as on the open coast.
Pending detail of the design, revetments can offer some limited protection from storm tide inundation.
Rock revetments are expensive and are thus best suited to protection of critical assets.</td></tr>
<tr><td>✓</td><td>Long-term erosion</td></tr>
<tr><td></td><td>Accretion</td></tr>
<tr><td>✓</td><td>Storm tide inundation</td></tr>
<tr><td></td><td>Permanent inundation</td></tr>
<tr><td>✓</td><td>Estuary dynamics</td></tr>
<tr><td></td><td>Offshore sediment dynamics</td></tr>
<tr><td></td><td>Saline intrusion</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td>Non-intervention</td><td rowspan="6">Notes on policy context:
Rock revetments are a protect action, requiring major engineering works.</td></tr>
<tr><td></td><td>Avoid</td></tr>
<tr><td></td><td>Nature based</td></tr>
<tr><td></td><td>Accommodate</td></tr>
<tr><td></td><td>Retreat</td></tr>
<tr><td>✓</td><td>Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td>Low</td><td rowspan="3">Considerations:
Rock revetments are a hard, fixed structure at the shoreline. Local beach levels in front of a revetment are often lower than they were before construction due to reflected wave energy initiating beach scour. This can cause the loss of hightide beach in front of a revetment.
At the ends of the revetment, so-called ‘end scour’ can increase erosion for up to a 100 m past the revetment, although the effect reduces as the distance from the revetment increases.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td>✓</td><td>High</td></tr>
</table>

Action	**Engineering – Seawalls – Rock revetments**		
			Rock revetments also 'lock up' sand in the protected area, such that it is not available for the natural recovery of the beach or sand supply to adjacent areas.
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site. Cultural values Environmental values Social values Economic values		**Applicability considerations** • Rock revetments are a major structural intervention that may have implications for a range of local coastal values. • Reflected wave energy often causes progressive loss of sand/upper beach, or erosion elsewhere along the coast. • The revetment creates a physical barrier between the beach and backshore area that changes natural look of beach, blocks access and halts natural landward retreat/migration of habitat. • A rock revetment is a hard barrier between the backshore and the beach making beach access more difficult. • There is a need to consider trade-offs related to asset protection vs loss of the beach and impacts on other values. • A rock revetment may pose a danger to beach users with large voids between rocks and potential sharp edges. When beach sand erodes during storm periods, the top of the rock revetment may be considerably higher than the beach level, and safety will need to be managed. • The establishment of revetments requires ongoing maintenance and renewal / upgrades over time.
Guidance for implementation	**Preparation / design period**	6 - 12 months	A rock revetment typically requires 6 to 12 months for design and approvals. After this, construction speed will depend on construction methodology, site access, plant used, weather and rock availability.
	Effective lifetime	50+ years	Rock revetments with good design and rock sizing have lifespans exceeding 50 years. Revetments may also be modified in future by placement of additional rock as sea levels rise to increase the crest height and effective lifespan.
	Co-benefits	Few	Rock revetments can provide roosting habitat for some shorebirds.
	Approvals and requirements	The range of approvals that may be required for a rock revetment include: • Land Owner's consent • *Marine and Coastal Act 2018* consent (DEECA) • Parks Victoria Works Permit • Marine Park Approvals • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of a rock revetment include: • Understanding of coastal processes and geotechnical conditions at the site • Access to and along the beach for material supply and construction, and how these impact on beach amenity • Impacts on coastal processes in surrounding area • Rock supply (supply locations far from revetment site may incur high cost associated with cartage) • Revetment crest and toe design elevations • Rock sizing (depending on the design wave). Revetments are a common and proven technique to mitigate erosion along parts of the Victorian coast. There are contractors in Victoria who specialise in the construction of rock	

Action	Engineering – Seawalls – Rock revetments	
		revetments and many coastal engineers with design experience. The process of design and construction of a rock revetment may thus be streamlined. Typical failure mechanisms for rock revetments include: • Undersized armour rocks being dislodged by waves, destabilising rocks above and causing the armour layer to collapse • Sand/soil being washed out from behind the revetment due to wave overtopping or migration of fine particles from between the armour • Undermining of the revetment toe causing destabilisation of rocks above and armour layer collapse.
	Cost considerations	When costing a rock revetment project, the following items should be considered: • Rock supply • Design and approval costs • Size of revetment (often scales with exposure of coast) • Construction methodology and access • Costs of managing impacts on coastal processes (e.g., any sand nourishment required at revetment toe to maintain beach, maintenance of downdrift erosion).
References	-	

Project example

<table>
<tr><th colspan="3">Engineering – Seawalls – Rock revetment – Project example</th></tr>
<tr><td>Project title</td><td>Skenes Creek Revetment</td><td rowspan="8">
Skenes creek rock revetment adjacent to the Great Ocean Road.

Another rock revetment near Skenes Creek adjacent to the Great Ocean Road</td></tr>
<tr><td>Action type</td><td>Rock revetment</td></tr>
<tr><td>Location</td><td>Skenes Creek</td></tr>
<tr><td>Land manager</td><td>GOR Authority, Regional Roads Victoria (RRV)</td></tr>
<tr><td>Year of Implementation</td><td>2018</td></tr>
<tr><td>Project objectives</td><td>• Protect the Great Ocean Road from undermining due to erosion and recession</td></tr>
<tr><td>Project process</td><td>• The Department of Transport (DOT) through Regional Roads Victoria (RRV) is undertaking a major program of upgrades along the Great Ocean Road involving stabilization of rock cliffs, upgrade of bridges, upgrade of drainage infrastructure, and protection from coastal erosion and recession.
• Over 20 high-risk areas for coastal erosion threatening the road were identified and a set of four standard revetment designs were developed that could be applied to each area (with some customisation)
• Around ten revetments have been constructed as of 2022 with several more planned.</td></tr>
<tr><td>Measures implemented</td><td>• Construction of a multi layered rock revetment with armour layer rocks and underlayer rocks.
• Rocks are basalt from local quarries.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">This project has so far met objectives with many high-risk areas of the Great Ocean Road protected from being undermined due to erosion.</td></tr>
<tr><td>Cost</td><td colspan="2">The revetment pictured at Skenes creek coast approximately $7,500 per m of revetment.</td></tr>
<tr><td>Further considerations</td><td colspan="2">-</td></tr>
</table>

3.4.4 Geobag revetment / wall

Action	Engineering – Seawalls – Geobag revetment / wall		
Description	Geobag (or sandbag) revetments / walls are engineered structures consisting of stacked sand-filled geotextile containers / bags. These are commonly situated at the back of the beach against an erosion escarpment where they act to protect the land behind from erosion and recession. Geobag containers are filled with local beach sand, which limits the need for imported material. The modular nature of the geobags allows for structures to be built flexibly and conform to natural landscapes. They are often employed as emergency or temporary measures as they are relatively quick to install and remove. Empty geobags can be stockpiled and pre-approval sought for their use in emergency situations. Like all seawalls, geo-bag walls can reflect wave energy which can cause scour and the loss of the beach in front (seaward) of the structure. However the wall design, bag spacing and vegetation cover can assist to absorb and dissipate energy. In areas with high sediment transport and beach fluctuation these structures can be periodically buried and vegetated. Geobag revetments have been successfully used at many sites within Victoria, across Australia and Internationally. The geotextile fabric does typically include plastic material, and bags may breakdown over time, which needs to be managed to minimise environmental impacts.		 Inverloch geotextile sand container wall. (source: engage.vic.gov.au)  Aspendale geotextile sand container wall. (source: geofabrics.com.au)
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Geobag revetments are used to prevent short-term and long-term erosion. Geobag revetments are effective on sheltered coastlines with moderate wave energy (e.g., Port Phillip Bay, Western Port Bay, Gippsland lakes etc.), or in the lower-energy environment of estuaries. They are generally not suitable in high wave energy environments for extended periods of time. Geobag revetments are most often used on high-use beaches where the stepped profile and relatively soft surface may be safer for public access.
	✓	Long-term erosion	
		Accretion	
		Storm tide inundation	
		Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Geobag walls are a protect action, requiring engineering design and works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	

<table>
<tr><th>Action</th><th colspan="4">Engineering – Seawalls – Geobag revetment / wall</th></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td>Low</td><td colspan="2" rowspan="3">Considerations:
Like all forms of seawalls, geobag walls create a harder structure at the shoreline that can increase local and adjacent erosion.
Local beach levels in front of a geobag wall are often lower than they were before construction due to reflected wave energy initiating beach scour.
At the ends of the revetment, so-called ‘end scour’ can increase erosion for up to a 100 m past the wall, although the effect reduces as the distance from the wall increases.
Geobag walls also ‘lock up’ sand in the protected area, such that it is not available for the natural recovery of the beach or sand supply to adjacent areas.</td></tr>
<tr><td></td><td>Moderate</td></tr>
<tr><td>✓</td><td>High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td colspan="2" rowspan="5">Applicability considerations
Geobag walls are a major structural intervention that may have implications for a range of local coastal values.
Reflected wave energy often causes progressive loss of sand/upper beach, or erosion elsewhere along the coast.
The geobag wall provides generally level, stepped platforms that can be used for seating/access when the beach is eroded.
Stabilisation of the dune face may make propagation and growth of dune vegetation more likely. With management, the wind-blown sand can be encouraged to bury the bags and improve aesthetics / dune habitat over time.
Loss of geobags or geobag fibres may introduce plastic contaminant into the local environment.
Geobag walls can be more readily removed after a period of time (compared to other seawalls), to enable retreat or other protect actions.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="5">Guidance for implementation</td><td colspan="2">Preparation / design period</td><td>6-12 months</td><td>A geobag wall typically requires 6 months or more for design and approvals. In emergency situations, or if plans and approvals are already in place, it may be much faster, a matter of days. After this, construction speed is quite rapid as long as there is sufficient sand available to fill the bags.</td></tr>
<tr><td colspan="2">Effective lifetime</td><td>20+ years</td><td>Geobag walls that are exposed to wave conditions and UV degradation have shown life spans exceeding 20 years. Greater life is expected where the wall is intermittently buried or in environments with lower wave and/or UV. However the bags are made of fabric and can be susceptible to damage from vandalism / wear and tear.</td></tr>
<tr><td colspan="2">Co-benefits</td><td>Some</td><td>Where walls stabilise the dune they can contribute to an increase in vegetation and habitat. They also provide some recreational benefits by providing areas for sitting or lying.</td></tr>
<tr><td colspan="2">Approvals and requirements</td><td colspan="2">The range of approvals that may be required for geobag walls include:
Land Owner’s consent
Marine and Coastal Act 2018 consent (DEECA)
Marine Park Approvals (Parks Victoria)
Planning Permit (Local Government)
Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td colspan="2">Design considerations,</td><td colspan="2">Important considerations for successful design of a geobag revetment wall include:
Understanding of coastal processes and geotechnical conditions at the site</td></tr>
</table>

<table>
<tr><th>Action</th><th colspan="2">Engineering – Seawalls – Geobag revetment / wall</th></tr>
<tr><td></td><td>constructability, and materials</td><td>Impacts on coastal processes in surrounding area
Availability of suitable sand for filling containers
Access to the site for material supply and construction
Container material type. More durable fabrics are required where there is a high level of exposure (waves, UV and people)
Wall geometry, container sizing and end detailing.
The use of engineered geobags for construction of revetment walls has been available for more than 20 years, with development in the understanding of the stability, fabric types, construction, repairs and suitably all advancing during this time. Research on stability (Couglan et al. 2009) and exposure (Hornsey et. al. 2011; Wishaw et al. 2011) should be considered when undertaking planning and design for these structures.

Failure mechanisms for geobag structures can be caused by instability, vandalism or degradation. Instability of geobag structures typically occurs when the container sizes are not suitable for the wave climate or haven't been appropriately filled and/or closed, leading to containers being pulled from the structure, with subsequent slumping of the remainder of the wall. Vandalism can occur where containers are cut deliberately, or otherwise accidently damaged, but can be reduced by specifying vandal-resistant fabrics.</td></tr>
<tr><td></td><td>Cost considerations</td><td>When costing a geobag wall project, the following items should be considered:
Design and approval costs
Size of structure and containers, need to double stack containers
Cost of managing impacts on coastal processes/environment/beach amenity.</td></tr>
<tr><td>References</td><td colspan="2">Coghlan, I., Carley, J., Cox, R., Blacka, M., Mariani, A., Restall, S., Hornsey, W. and Sheldrick, S. (2009). Two-dimensional Physical Modelling of Sand Filled Geocontainers for Coastal Protection. Coasts and Ports Conference.

Hornsey, W.P., Carley, J.T. , Coghlan, I.R. , Cox, R.J. Geotextile sand container shoreline protection systems: Design and application, Geotextiles and Geomembranes, Volume 29, Issue 4, 2011, Pages 425-439, ISSN 0266-1144, https://doi.org/10.1016/j.geotexmem.2011.01.009.

Wishaw, D.M., Gibbs, D., Hornsey, W.P. 2011. Durability of Geosynthetic Sand Containers Subjected to Extreme Weather Conditions. Coasts and Ports 2011 : Diverse and Developing: Proceedings of the 20th Australasian Coastal and Ocean Engineering Conference and the 13th Australasian Port and Harbour Conference.</td></tr>
</table>

Project example

<table>
<tr><th colspan="3">Engineering – Seawalls – Geobag revetment / wall – Project example</th></tr>
<tr><td>Project title</td><td>Inverloch geotextile container wall</td><td rowspan="8">
Inverloch beach before installation of the geobags
(source: marineandcoasts.vic.gov.au)

Inverloch geobag wall
(source: engage.vic.gov.au)</td></tr>
<tr><td>Action type</td><td>Geobag revetment / wall</td></tr>
<tr><td>Location</td><td>Inverloch, Victoria</td></tr>
<tr><td>Land manager</td><td>Bass Coast Shire</td></tr>
<tr><td>Year of implementation</td><td>2020</td></tr>
<tr><td>Project objectives</td><td rowspan="3">A 70-metre long wall was constructed using 270 sand-filled geotextile sand containers to help protect the surf life saving club from the impacts of wave erosion.
The geotextile container wall was built to compliment existing coastal erosion interventions, with wet sand catch fences installed on the foreshore as well.
The geotextile sand container wall is expected to have a usable design life of over 20 years, however, it was initially designed as temporary structure with a life of 10 years while longer-term adaptation planning is undertaken.</td></tr>
<tr><td>Project process</td></tr>
<tr><td>Measures implemented</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">The geotextile container wall is currently performing as expected, although some minor repairs to individual containers is expected and some erosion at either end of the wall has occurred.</td></tr>
<tr><td>Cost</td><td colspan="2">Costs included $450,000 for the construction of the geotextile wall, with additional funds being required for establishing a construction bund around the site.</td></tr>
<tr><td>Further considerations</td><td colspan="2">-</td></tr>
</table>

3.4.5 Rock bag revetment / wall

<table>
<tr><th>Action</th><th colspan="3">Engineering - Seawalls – Rock bag revetment / wall</th></tr>
<tr><td>Description</td><td colspan="2">Rock bag revetment walls are engineered structures consisting of stacked mesh bags filled with rock rubble.

These are commonly situated at the back of the beach against an active erosion escarpment where they act to protect the land behind from erosion and recession.

Rock bags are typically filled with rock rubble approximately 150-200mm in diameter. Rocks may be sourced relatively easily from quarries that supply similarly sized rocks for road construction. When stacked, rock bags slump into a round flat shape that is very stable under wave attack. Multiple layers are often employed where large waves impact the bottom of an eroding escarpment (e.g., Wamberal NSW).

Rock bags differ from the older-style rock gabion baskets (metal cage like boxes filled with rock) in that the bags are flexible and can be stacked and positioned like individual armour units.

Rock bags are created by filling a casing with rock that is lined with the mesh. The mesh is then lifted out of the casing by crane/excavator containing the rocks within. Rock bags can be created with unit mass of 2t up to 8t.

Rock bags are most often used as an interim measure where erosion poses imminent risk to coastal values, before a more long-term solution can be planned and implemented. They can be implemented as a temporary solution as they are relatively quick to install and have a metal O-ring for easy removal with a crane/excavator. Rock bags can easily be emptied, stockpiled, and re-used for multiple projects when required.

If used as a permanent solution, Rock bags have an approximate lifetime of 20-30 years depending on exposure to sunlight, water, and people etc.

Potential breakdown of the bags needs to be managed, as they may release microplastics, and the individual rocks released from the bags may be mobilised under high energy environments.

The first Rock bag project in Victoria at Inverloch has recently been completed with one further project under construction at Eastern View. Rock bags have been used extensively throughout NSW and Queensland as emergency response to coastal erosion threatening houses and other shoreline assets during recent years.

Like all seawalls, geo-bag walls can reflect wave energy which can cause scour and the loss of the beach in front (seaward) of the structure. However the wall design, bag spacing and flexibility, and vegetation cover can assist to absorb and dissipate energy.</td><td rowspan="4">
Inverloch Rock Bag wall protecting public reserve on the shore of Anderson Inlet. source: engage.vic.gov.au.


Wamberal (NSW) Rock Bag wall protecting houses at imminent risk of being undermined. (source: coastcommunitynews.com.au).</td></tr>
<tr><td rowspan="3">Functional type</td><td></td><td>Land management planning and design</td></tr>
<tr><td></td><td>Nature-based methods</td></tr>
<tr><td>✓</td><td>Coastal engineering</td></tr>
</table>

Action	Engineering - Seawalls – Rock bag revetment / wall		
Coastal hazard mitigation	✓	Short-term erosion	**Notes on suitability:** Rock bag revetments are predominantly used to prevent short-term storm erosion but can also be used to mitigate long-term erosion. As a short-term measure, rock bag revetments can be effective on most coastlines in Victoria from highly exposed to more protected locations. In high wave environments, large storms may damage or shift the bags. In these environments, larger rock bags (e.g., 8 tonnes) would be recommended. The aesthetics of rock bag revetments may be less appropriate for high use areas in the long-term. Rock bags are highly permeable and do not form an effective barrier against inundation.
	✓	Long-term erosion	
		Accretion	
		Storm tide inundation	
		Permanent inundation	
	✓	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Geobag walls are a protect action, requiring engineering design and works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Like all forms of seawalls, rock bags create a harder structure at the shoreline that can increase local and adjacent erosion. Local beach levels in front of a rock bag revetments are often lower than they were before construction due to reflected wave energy initiating beach scour. At the ends of the revetment, so-called 'end scour' can increase erosion for up to a 100 m past the wall, although the effect reduces as the distance from the wall increases. Rock bag revetments also 'lock up' sand in the protected area, such that it is not available for the natural recovery of the beach or sand supply to adjacent areas.
		Moderate	
	✓	High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** • Rock bag revetments are a major structural intervention that may have implications for a range of local coastal values. • Reflected wave energy often causes progressive loss of sand/upper beach, or erosion elsewhere along the coast. • Stabilisation of the dune face may make propagation and growth of dune vegetation more likely. • Breakdown of bag materials may introduce plastic contaminant into the local environment. • The rock bag revetment may be perceived as looking unnatural in what is often a natural landscape. • Rock bags can be readily removed / relocated after a period of time (compared to other seawalls), to enable retreat or other protect actions.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	6-12 months	A rock bag revetment typically requires 6 months or more for design and approvals. In emergency situations, or if plans and approvals are already in place, it may be much faster, a matter of days. After this, construction is quite rapid as long as there is sufficient rock rubble available to fill the bags.

Action	Engineering - Seawalls – Rock bag revetment / wall		
	Effective lifetime	20+ years	Rock bags that are exposed to wave conditions and UV degradation have shown life spans exceeding 30 years. Greater life is expected where the bags are intermittently buried or in environments with lower wave and/or UV exposure. However, the bags are typically made of recycled plastic mesh and can be susceptible to damage from vandalism / wear and tear.
	Co-benefits	Some	Where walls stabilise a shoreline dune they contribute to increases in vegetation and habitat.
	Approvals and requirements	The range of approvals that may be required for use of rock bags include: • Land Owner’s consent • *Marine and Coastal Act 2018* consent (DEECA) • Marine Park Approvals (Parks Victoria) • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials	Important considerations for successful design of a rock bag revetment include: • Understanding of coastal processes and geotechnical conditions at the site • Impacts on coastal processes in surrounding area • Availability of suitable rock (and distance of available source from site) for filling bags • Access to the site for material supply and construction • Wall geometry, rock bag size and end detailing. Rock bags have been used for construction of revetment walls for more than 20 years globally, however, the technique is relatively new in Australia. There have been recent developments in the understanding of bag stability under wave and current loading performed by Water Research Laboratory, but results of this research are not currently (2022) available. Evolving research on stability and exposure should be considered when undertaking planning and design for these structures. Failure mechanisms for rock bag structures include instability under large waves, vandalism or degradation. Instability of rock bag structures typically occurs when the container sizes are not suitable for the wave climate or when bags have not been appropriately filled and/or closed, leading to containers being pulled from the structure, with subsequent slumping of the remainder of the wall. Vandalism can occur where containers are cut deliberately, or otherwise can be accidentally damaged.	
	Cost considerations	When costing a rock bag revetment project, the following items should be considered: • Design and approval costs • Size of structure and containers, need to stack containers in multiple levels • Cost of managing impacts on coastal processes/environment/beach amenity.	
References	Rock bag information: https://www.bluemont.com.au/erosion/kyowa-rock-filter-bags/		

Project example

Engineering – Seawalls – Rock bag revetment / wall – Project example	
Project title	Inverloch Rock Bag Wall
Action type	Rock bag revetment
Location	Inverloch, Victoria
Land manager	Bass Coast Shire
Year of implementation	2022
Project objectives	• Stop further erosion along the shore of the Pymble Avenue picnic and barbecue precinct. • Protect the barbecue, shelter, and park benches from being undermined due to erosion. • Successful first use of rock bags on the Victorian coast. • Utilise a removable option awaiting the results of the Cape-to-Cape Resilience Project which will inform preferred long-term coastal management practices for Inverloch.
Project process	• Rock bag wall design by qualified consultant • Required permits granted including MACA Consent (DEECA) and Planning Permit (Council) • Wall construction by civil contractor (MAW Civil Marine Pty Ltd)
Measures implemented	A 70 m long wall was constructed using approximately 75 4t Kyowa Rock Bags. The bags were filled onsite using an excavator, then places in three stacked layers adjacent to the eroding bluff. The area behind the wall was then landscaped and grassed for increased amenity.
How well project met objectives	The rock bag revetment is currently performing as expected as it has only recently been put in place. Terminal scour has not yet begun to impact areas either side of the wall.
Cost	The Bass Coast Shire Council Marine Structure Renewal Priority Program fully funded this project by providing $148,000 for the Kyowa Rock Bags, construction of the revetment wall, and landscaping the area landward of the wall.
Further considerations	This project has only just been implemented at the time of writing. It is unclear how the structure will perform against the project objectives into the future.

Pymble Ave reserve shoreline erosion before Rock Bags were implemented.

Toe layer of Rock Bags laid out during construction process (source: engage.basscoast.vic.gov.au).

Rock Bag revetment installed at Pymble Ave reserve, Inverloch (source: engage.basscoast.vic.gov.au).

3.5 Groynes

Action	Engineering – Groynes
Description	Groynes are engineered structures that extend perpendicular to the beach, into, and in some cases beyond, the surf zone. Groynes are used to trap sand that moves along the shore (longshore transport) building up sand and increasing beach width on the updrift side of each groyne. The beach down-drift of a groyne is typically starved of sediment and can experience erosion. Groynes may be singular or built as 'groyne fields' with multiple groynes at regular spacing. This way the down drift erosion is mitigated by the accretion effect of the next groyne and a long section of coast can be protected. The length of a groyne in relation to the width of the surf zone determines how much sediment is captured and the magnitude of the impact on the shoreline. Short groynes (such as Apollo Bay example on right) trap a small proportion of the longshore transport, resulting in a modest level of sand accretion up-drift, and correspondingly minor level of erosion down-drift. Longer groynes which protrude right across the surf zone (also called 'artificial headlands') can intercept all longshore transport resulting in large changes to the shoreline alignment (see Hampton example to right). Groynes have been widely used for coastal management in Victoria, constructed from materials including timber, sand-filled geotextile containers, rock, or concrete. Groynes can also be used to stabilise the entrance to river and creeks, in which case they are often termed 'training walls'. These can also reduce sedimentation in the river entrance and make channel maintenance easier.

Short groynes as used at Apollo Bay trap only a small proportion of the sediment moving alongshore

Long groynes at Hampton intercept all longshore transport, creating an isolated compartment with a wide stable beach.

Functional type		Land management planning and design
		Nature-based methods
	✓	Coastal engineering
Coastal hazard mitigation	✓	Short-term erosion
	✓	Long-term erosion
		Accretion
		Storm tide inundation
		Permanent inundation
	✓	Estuary dynamics
		Offshore sediment dynamics
		Saline intrusion

Notes on suitability:

Groynes are suited to locations where the predominate sediment transport is along-shore due to waves breaking at an angle to the beach. Groynes can be used to build a wider beach and stabilise shoreline position, thereby protecting against both short-term erosion and long-term erosion.

In locations with significant longshore transport, groynes can be passive structures, that accumulate sand on the updrift side until a new equilibrium shoreline is reached. Where there is little net longshore transport sand nourishment is needed to fill compartments between groynes and create a wider beach.

Action	Engineering – Groynes		
			Groynes are often combined with nourishment and/or revetments where long-term protection is required.
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Groynes are a protection action, requiring major engineering works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Groynes work by intercepting the natural along-shore movement of sand and influence local changes in coastal processes. The impact to coastal processes can be reduced somewhat by 'pre-filling' the updrift side of the groyne with sand so such that by-passing occurs.
		Moderate	
	✓	High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations** Groynes are a major structural intervention that may have implications for a range of local coastal values. In interrupting long-shore sediment transport, they can adversely impact adjacent areas of the coast. As they run across the beach at right angles to the shore they also: • Change the visual character of an area • Present a barrier to pedestrian access along a beach • Can be dangerous to pedestrians/recreational users who walk out on crest as they are frequently overtopped by waves, although can also provide some recreational amenity • Modify the patten of sand bars and rips in the surfzone, potentially impacting surf breaks (positive or adverse impacts). • Support retention of sand in high use areas. The establishment of revetments requires ongoing maintenance and renewal / upgrades over time.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		

Guidance for implementation			
	Preparation / design period	6-12 months	May be longer if in depth studies are needed to understand the coastal processes.
	Effective lifetime	50+ years	The effective lifetime for groynes depends on the materials used for construction and the wave climate. Geotextile sand containers have a life of 15-20 years, timber 20-30 years whereas rock and concrete structures are expected to last at least 50+ years.
	Co-benefits	Some	Wider beach areas may provide room for additional coastal habitat and the rock structures may provide additional complexity to the marine habitat.
	Approvals and requirements	The range of approvals that may be required for a groynes include: • Land Owner's consent • *Marine and Coastal Act 2018* consent (DEECA) • Parks Victoria Works Permit • Marine Park Approvals • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	

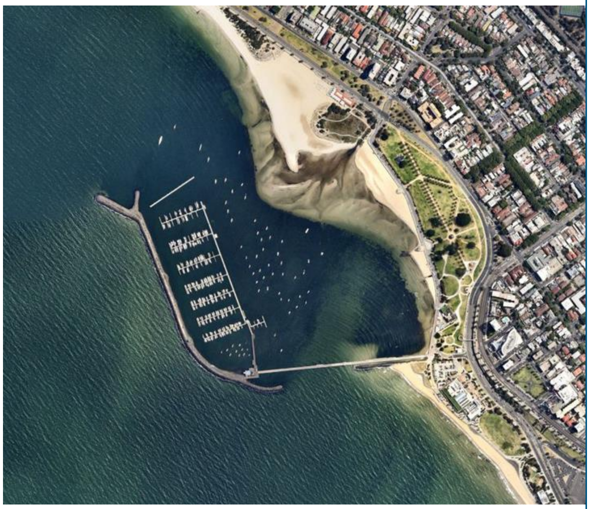
Action	Engineering – Groynes	
	Design considerations, constructability, and materials	Important considerations for the success of groynes include: • A good understanding of the coastal processes in the target site, including wave and net longshore sediment transport rates and direction. • Length and spacing - How much of the longshore transport should the groyne intersect? This is a key factor in the determining the level of impact on surrounding areas. • Understanding of the social, cultural and environmental values on the areas that may be impacted adversely. • Material selection: timber, geo bags, rock, concrete, sheet pile. Selected for design life and constructability with available plant and access constraints.
	Cost considerations	When planning a groyne project, cost is driven by: • Length and spacing of the groynes • Material selection • Access for construction plant • Need for sand nourishment to fill groyne compartments or improve access • Managing impacts on surrounding areas.
References	State Government of Victoria (2021), *Apollo Bay Coastal Erosion Management,* viewed 7 Feb. 22, https://www.marineandcoasts.vic.gov.au/coastal-programs/apollo-bay-and-marengo	

Project example

Engineering – Groynes – Project example		
Project title	Apollo Bay Long Term Foreshore Protection	 *Groynes at Apollo Bay*
Action type	Groynes and revetment (rock)	
Location	Apollo Bay	
Land manager	DEECA, Great Ocean Road Coasts and Parks Authority	
Year of implementation	2021	
Project objectives	The objectives were to: • Protect assets from coastal erosion and shoreline recession – Including the foreshore dune area and vegetation, heritage cypress trees, walking path, beach access, services, and the Great Ocean Road. • Maintain or enhance beach amenity – Wider beach, wider dune area, access along beach, access to beach. • Reduce coastal inundation risks – Particularly due to wave runup and overtopping backshore dune. • Mitigate negative impacts of seawall and revetments – Such as terminal (erosion) scour and beach lowering.	
Project process	Beach nourishment alone was no longer feasible to mitigate the erosion trend and in 2018 an emergency rock revetement was constructed to protect a section of the Great Ocean Road. Design studies in 2020 determined that groynes by themselves would not be sufficient to protect the uses and values of the shoreline due to the severe storm erosion that occurred at this beach. Rock revetments were recommended to protect assets while groynes were proposed to offset the negative impacts of the revetement – i.e., hold a beach seaward of the revetments.	
Measures implemented	In total over 1.3km of rock revetment and three 70m long rock groynes at 400m spacing were constructed.	
How well project met objectives	The revetment has halted the shoreline retreat and thus far groynes appear to be increasing the beach width, but further monitoring is required to assess the long term effectiveness of the groynes.	
Cost	$7 Million – for three 70m rock groynes, over 1 km of rock revetment and beach nourishment. Groynes were approx. $500k each.	
Further considerations	-	

3.6 Breakwaters

Action	Engineering – Breakwaters
Description	Breakwaters are engineering structures built in the water off-shore. They act to intercept waves and reduce wave energy reaching the shoreline. This assists with promoting sediment build-up and reducing erosion in the sheltered area. Breakwaters are often built with the primary objective of sheltering boat harbours (see St Kilda Breakwater image). Harbour breakwaters are typically higher than the largest waves and block all wave energy. Commonly these breakwaters are built using rock armour. Breakwaters can also be built for the purpose of shoreline protection, and these come in many forms including: • ‘Emergent’ breakwaters protrude above the wave level block all waves • ‘Low-crested’ breakwaters allow high waves to break over the crest but still block a significant proportion of the wave energy • ‘Submerged’ breakwaters are usually below the water level and block a smaller proportion of the wave energy. Artificial reefs are a type of submerged breakwater, designed to replicate natural features of a reef and induce wave breaking. Artificial reefs can be built of rock, concrete or synthetic materials, but also have potential to be designed as nature-based solutions, utilising the natural structure-forming propensity of organisms like coral or shellfish (see shellfish reef action). Floating wave attenuators and fixed vertical wave screens are also types of breakwater used in less exposed locations. Breakwaters can be either ‘attached’ to the shore, or ‘detached’ as in the St Kilda and Jam Jerrup examples (detached breakwaters are also called ‘offshore breakwaters’).



Wave action reduced by the St Kilda Harbour Breakwater

Ramblers Reef, a hybrid shellfish reef at Point Richards on the Bellarine Peninsula

Functional type		Land management planning and design
		Nature-based methods
	✓	Coastal engineering
Coastal hazard mitigation	✓	Short-term erosion
	✓	Long-term erosion
	*	Accretion
	✓	Storm tide inundation
		Permanent inundation
	✓	Estuary dynamics
	*	Offshore sediment dynamics
		Saline intrusion

Notes on suitability:

Breakwaters work by reducing wave energy reaching the shore and therefore they are very effective at preventing short-term erosion. Where longshore transport occurs, waves will move sediment into the lee of the breakwater but there is little wave energy to move it out again so it tends to accumulate – in this way breakwaters can reverse a long-term erosion trend. The build-up of sediment may also build dunes which reduce storm tide inundation locally.

Note that the build-up sediment behind the breakwater may come at the expense of surrounding beaches which can be starved of sediment.

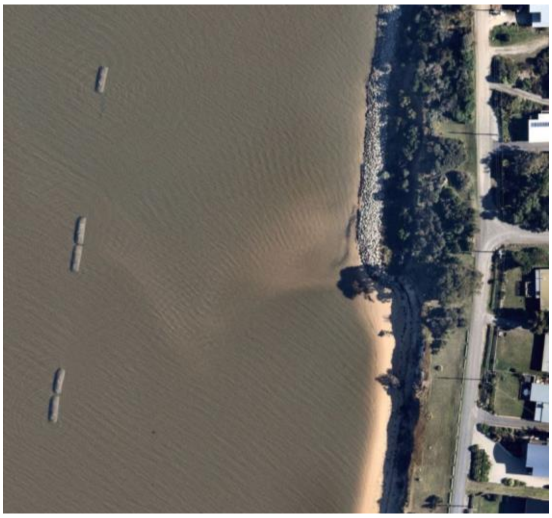
<table>
<tr><th>Action</th><th colspan="4">Engineering – Breakwaters</th></tr>
<tr><td></td><td></td><td colspan="2"></td><td>Breakwaters can be designed for a wide range of conditions from coastal lakes and estuaries up to fully exposed open coasts.</td></tr>
<tr><td rowspan="6">Marine and Coastal Policy order of consideration</td><td></td><td colspan="2">Non-intervention</td><td rowspan="6">Notes on policy context:
Breakwater are a protection action, requiring major engineering works.
Some breakwaters may also be defined as hybrid natured-based approaches, such as man-made reefs designed as a substrate for natural organisms (coral, shellfish), or minor near shore structures providing protection for vegetation establishment (see supported littoral vegetation).</td></tr>
<tr><td></td><td colspan="2">Avoid</td></tr>
<tr><td>*</td><td colspan="2">Nature based</td></tr>
<tr><td></td><td colspan="2">Accommodate</td></tr>
<tr><td></td><td colspan="2">Retreat</td></tr>
<tr><td>✓</td><td colspan="2">Protect</td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td colspan="2">Low</td><td rowspan="3">Considerations:
The degree of impact on coastal processes depends on the proportion of wave energy intercepted by the breakwater and may vary from minor to very substantial.
Where breakwaters block all or most of the wave energy they will tend to trap the majority of sand moving along the shore, leading to increased erosion and recession on adjacent beaches.
Attached breakwaters act as groynes with accretion on the up-drift side and corresponding erosion on the down drift side.</td></tr>
<tr><td></td><td colspan="2">Moderate</td></tr>
<tr><td>✓</td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations
Breakwaters are a major structural intervention that may have implications for a range of local coastal values.
In interrupting long-shore sediment transport, they can adversely impact adjacent areas of the coast.
A well-designed breakwater has a range of benefits associated with the shoreline stabilisation of sediment build-up in its lee.
Socially, breakwaters can provide a range of benefits including improved access; safer swimming, boating, and surfing; and improved beach conditions. However, breakwaters can also have negative aesthetic impacts.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="5">Guidance for implementation</td><td>Preparation / design period</td><td>> 12 months</td><td colspan="2">Breakwaters require extensive engineering design, environmental investigations and approvals prior to construction, and a realistic timeframe for implementation is >12 months, depending on the scale of the structure</td></tr>
<tr><td>Effective lifetime</td><td>50+ years</td><td colspan="2">Once constructed, design life is 50+ years, with limited provision for maintenance as required, depending on the materials used.</td></tr>
<tr><td>Co-benefits</td><td>Many</td><td colspan="2">Co-benefits may include habitat provision, improvements to recreational fishing, surfing, boating and swimming conditions at the site.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">The range of approvals that may be required for a breakwater include:
Land Owner’s consent
Marine and Coastal Act 2018 consent (DEECA)
Parks Victoria Works Permit
Marine Park Approvals
Planning Permit (Local Government)
Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td>Design considerations,</td><td colspan="3">Important considerations for successful design of breakwaters include:
Understanding of specific coastal processes (in particular wave climate and along-shore transport) and geotechnical conditions at the site.</td></tr>
</table>

Action	Engineering – Breakwaters	
	constructability, and materials	• Determining how much of the incoming wave energy should be intercepted. If wave are reduced too much there can be large impacts on surrounding areas, it too little then the breakwater will not achieve the objective of coastal hazard mitigation. • Understanding and managing the impact on coastal processes in adjacent areas. • Breakwater type and material suitable for the wave climate. For wave height over approximately 2m rubble mounds armoured with rock or concrete are used. For smaller wave climates there are many possibilities. • Access to the site for material supply and construction plant. Including considerations for construction in the water/surf zone. The most common failure modes for breakwaters relates to wave damage in storms.
	Cost considerations	The costs of breakwaters vary widely, but generally is proportional to the level of wave exposure. When costing a breakwater project, the following items should be considered: • Design and approval costs, including model testing if required • Rock supply and delivery (if rock armour breakwater, if not consider other material supply and delivery) • Rock placement/construction • Cost of managing impacts on coastal processes/environment/beach amenity in surrounding areas.
References	-	

Project Example

Engineering – Breakwaters – Project example	
Project title	Jam Jerrup Offshore Breakwaters
Action type	Offshore breakwater trial constructed from geotextile sand containers
Location	Jam Jerrup, Western Port Bay, Victoria
Land manager	DEECA
Year of Implementation	2012 - 2021
Project objectives	• Reduce wave energy and cause build up of sand on beach. • Reduce erosion of the cliffs • Protect landward assets
Project process	The offshore breakwater trial commenced in 2012 to address rapid erosion and retreat of sandy cliffs at Jam Jerrup.
Measures implemented	Three offshore breakwaters were installed on the tidal mud flats positioned 100m offshore of Jam Jerrup beach. Each consisting of two 10m long, 2m high geotextile sand containers, with approximately 30m gaps in between, Mangrove planting also occurred inshore of the breakwaters.
How well project met objectives	The trial was not deemed successful, and the breakwaters were removed in 2021. The breakwaters did not drive sufficient accretion of the shoreline and cliff retreat continued. This is attributed to a number of factors: • The spacing between the breakwaters was too large, the structures blocked only a small portion of the incoming wave energy. This was not helped by the failure and deflation of one of the geo tubes. • There was insufficient sand transport into the area to form a wider beach • The toe of the cliffs was progressively armoured with a revetment. Cliff erosion in a major source of sand to the beach so this reduced sand supply even further, and • Mangrove planting failed due to a combination of wave impact, burial by mobile sand bars and removal by local residents.
Cost	-
Further considerations	For a more successful example project – see ‘Ramblers Reef’ in the ‘Shellfish Reef’ measure.

Jam Jerrup Offshore Breakwater at low tide (2013)



Jam Jerrup Offshore Breakwaters at high tide (Nearmap, 2020)

Jam Jerrup Offshore Breakwaters at low tide (Nearmap, 2021)

3.6 Flood / tidal barriers

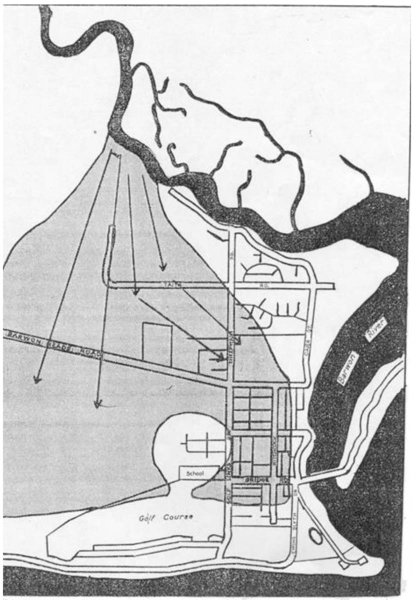
3.6.1 Levees/dykes

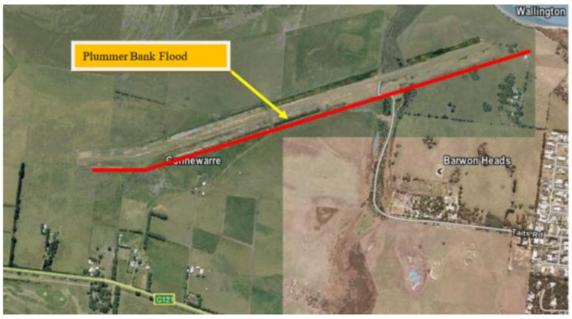
Action	Engineering – Flood/tidal barriers – Levees/dykes		
Description	Levees and dykes are physical barriers that prevent inundation of low lying land (e.g. adjacent to coasts, estuaries, rivers). **Levees** protect land that is normally dry but that may be periodically flooded (e.g. storm tide inundation or riverine flood events). **Dykes** protect land that would naturally be underwater most of the time. As such, dykes are larger structures than levees, typically built to protect or reclaim land that would otherwise be impacted by permanent inundation (e.g. regular tidal inundation and sea level rise). The general principle of levees and dykes is to exclude water from one side and typical construction methods are very similar hence terms are sometimes used interchangeably. They are built parallel to a shoreline or waterway and defend against inundation by providing an impermeable barrier with a crest elevation higher than storm tide or flood water levels. Typically, structures are constructed out of natural materials (soil, clay) or can be built from synthetic materials (e.g., concrete). The scale that levees/dykes are constructed on can vary greatly depending on water levels to be excluded and scale of landward area/assets to protect. When made from natural earthen materials, levees/dykes can be vegetated to provide better visual amenity and stability of structure. Larger levees/dykes can have wide crests, providing potential for resilient infrastructure to be built along the crestline – for example coastal footpaths or roads.		 *Low earthen levee. Coobowie, South Australia*  *Dyke at Petten, Netherlands*
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation	*	Short-term erosion	**Notes on suitability:** This action is applicable to locations where temporary or permanent inundation is the primary hazard. Inundation is prevented by raising the level of the impermeable barrier above that of the design water level. Where erosion is also a factor, dykes or levees need to be armoured or combined with other measures such as seawalls, breakwaters or groynes (as at Patten, Netherlands in the photo above). Levees/dykes can be designed at various scales for protection of different sizes of land area. Most levees are built to protect high-value critical infrastructure and services, and developed commercial or residential areas. Failures of a levee tend to be rapid and can result in high level of damage to building and risk to life. As such, levels need to be closely monitored and the overtopping risk reassessed regularly.
	*	Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
	*	Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	

Action	Engineering – Flood/tidal barriers – Levees/dykes			
Marine and Coastal Policy order of consideration		Non-intervention		**Notes on policy context:** Levees and dykes are a protection action, requiring major engineering works.
		Avoid		
		Nature based		
		Accommodate		
		Retreat		
	✓	Protect		
Likely impact on natural coastal processes		Low		**Considerations:** Levees and dykes alter natural overland flow and associated geomorphic processes, influencing sediment transport, erosion and deposition locally and more broadly. Smaller levee/dyke systems may have a more localised influence.
		Moderate		
	✓	High		
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.			**Applicability considerations**: Levees/dykes are a major structural intervention that may have implications for a range of local coastal values. In interrupting overland flow processes, they can adversely impact adjacent areas of the coast, including coastal wetlands by reducing/changing the inundation regime upon which these ecosystems depend. Levees can be effective for mitigating inundation risk to enable current land management to continue for a period of time (agriculture, assets, other). However risk of levee/dyke failure needs ongoing management, and long-term alternative actions are likely to be required.
	Cultural values			
	Environmental values			
	Social values			
	Economic values			
Guidance for implementation	**Preparation / design period**		>12mths months	May be longer if in-depth studies are required to understand inundation levels, or shorter if the inundation climate is well understood.
	Effective lifetime		20 - 50yrs	The effective lifetime of any coastal levee/dyke will be limited by to the upward trajectory of sea level rise, increase in storm intensity and increase in flood volumes due to climate change, all of which increase extreme coastal and estuary water levels. A longer design life requires a higher crest level, which increases costs and impacts.
	Co-benefits		Few	Dependant on place based design.
	Approvals and requirements		The range of approvals that may be required for a levee or dyke include: • Land Owner's consent • *Marine and Coastal Act 2018* consent (DEECA) • Parks Victoria Works Permit • Marine Park Approvals • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).	
	Design considerations, constructability, and materials		Important considerations for the success of levees/dykes include: • Understanding of the water level climate and how it will change with climate change. • Understanding the acceptable risk of failure and consequences. Levees and dykes typically fail through overtopping or geotechnical failure when saturated. • Selection of suitable materials is critical to the efficacy and longevity of this adaptation action. Materials need to have low permeability and sufficiently high internal friction, even when saturated.	

Action	Engineering – Flood/tidal barriers – Levees/dykes	
	Cost considerations	When constructing a levee or dyke, costs are driven by: • Flood / storm tide study for design elevations • Engineering design • Material selection and purchase • Earthworks, access for construction plant • Revegetation works (if applicable) • Monitoring and maintenance.
References	-	

Project example

<table>
<tr><th colspan="3">Engineering – Flood / tidal barrier – Levee / dykes – Project example</th></tr>
<tr><td>Project title</td><td>Plummer Bank</td><td rowspan="8">

Flooding of Barwon Heads in 1954 prior to levee construction


Project site


Site Photo of the Plummer Bank Levee showing borrow pit on upstream (river) side</td></tr>
<tr><td>Action type</td><td>Levee</td></tr>
<tr><td>Location</td><td>Barwon Heads, Greater Geelong, Victoria</td></tr>
<tr><td>Land manager</td><td>Geelong City Council</td></tr>
<tr><td>Year of Implementation</td><td>Originally constructed sometime after 1954
1700m Upgraded and raised and to current level in 1997/1998</td></tr>
<tr><td>Project objectives</td><td>To prevent inundation of the town of Barwon Heads from riverine and coastal flooding (see map to the right).</td></tr>
<tr><td>Project process</td><td>The levee held in the 1995 flood event (flood waters reached 2.33m AHD at the levee) but there were problems observed with seepage and stability, some of which may be related to rabbit burrows.
Subsequent investigation of the levee structure determined it was mainly comprised of sandy material and therefore had relatively high permeability and was difficult to compact, making it susceptible to slumping failure.</td></tr>
<tr><td>Measures implemented</td><td>The upgrade added 34,000m3 of earth to the embankment, increasing the base width, raised the crest by 1m to 4.25mAHD and providing a 3m wide gravel maintenance track along the crest.
This should provide a standard of protection estimated at the 0.1% AEP (i.e., 1:1000yr) event, however this will reduce over time due to sea level rise.
While most of the material added was sandy fill from the site, a 300mm clay layer and 300m of topsoil were added to the upstream face to exclude water from the structural centre.
The clay layer does not extend below the levee and there is a possibility of excessive seepage through the soil under the levee causing structural issues.
There is a drain under the levee that allows stormwater to drain from the south to the river on the north, with a one-way flap valve and a manually closed sluice gate.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">Since reconstruction, the levee has performed well.</td></tr>
<tr><td>Cost</td><td colspan="2">Unknown</td></tr>
<tr><td>Further considerations</td><td colspan="2">Monitoring and maintenance are managed by the council, and triggers are in place to begin these when flood warnings are issued. Flood gates must be closed prior to the arrival of the flood and the stability of levee monitored during the flood.</td></tr>
</table>

3.6.2 Tidal / surge barriers

Action	Engineering – Flood/tidal barriers – Tidal/surge barriers		
Description	Flood/tidal barriers are engineered structures built across a waterways. They act to protect upstream areas from inundation due to tidal surges or backwater flooding. The barrier acts as a dam to prevent the elevated water levels extending into areas that would be impacted, thereby avoiding significant damage and associated cost. Flood/tidal barriers are significant engineering structures. Designs can vary considerably depending on the size of the waterway and the scale (and frequency) of surge/flood prevention. As the barrier is only needed to stop inundation occasionally, most barriers are designed to allow regular passage through the waterway during normal times. For most, temporary walls or gates are moved into place when needed (such as in the Thames Barrier). Flood/tidal barriers can be designed to optimise water level and water quality management, and facilitate navigation (sometimes through a lock arrangement).		 *Thames Barrier preventing tidal surge from impacting Central London (NATIONAL POLICE AIR SERVICE/ GOV.UK)*  *Lake Orr Tidal Weir – Varsity Lakes QLD*
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation		Short-term erosion	**Notes on suitability:** Tidal/surge barriers principally address temporary inundation hazards. Typical installations may be in canals, estuaries or rivers that have a hydraulic connection to the coastline. These canals, estuaries or rivers are often bordered by development that would be susceptible to damage if inundated. Barriers are activated (closed) when a water level surge is forecasted. Future sea level rise as a result of global climate change will result in more frequent and higher tidal surges. Future conditions and future operational needs should be paramount when considering the suitability of a flood/tidal barrier.
		Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	*	Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Tidal/surge barriers are a protection action, requiring major engineering works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Influencing the volume of water moving into and out of a coastal waterway and coastal floodplain under storm surge conditions may alter sediment dynamics within the waterway
		Moderate	

Action	Engineering – Flood/tidal barriers – Tidal/surge barriers			
	✓	High		and alter the interactions of these sediments with the broader landscape and coastal compartment. Truncating the natural storm surge into coastal waterways will also limit the associated environmental processes that are dependent on this occasional inundation. Habitats such as saltmarsh and perched saline ponds are reliant on occasional saline recharge. These habitats are most at risk from flood/tidal barriers.
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site. Cultural values Environmental values Social values Economic values			**Applicability considerations:** Tidal/surge barriers are a major structural intervention that may have implications for a range of local coastal values. Impacts on environmental values can be extensive, as the significant hydraulic control can have associated impacts on water quality, sediment quality and habitat for aquatic flora and fauna . Navigation of commercial and recreational vessels can be negatively impacted by barriers. For some barriers, when they are closed, there is no navigable access across the barrier. Economic values can be enhanced through the avoidance of damage that would otherwise occur due to inundation. However, the construction and maintenance costs of flood/tidal barriers can be very high.
Guidance for implementation	**Preparation / design period**	>12months		Tidal/surge barriers can be installed in smaller waterways more quickly, but typically require a study to determine flood levels, currents and water quality impacts. Following this, detailed engineering design is required accompanied by environmental assessments.
	Effective lifetime	Up to 50 years		Tidal/surge barriers should be designed and constructed to a standard which allows maximum lifetime possible, and as such can have an effective lifetime of up to 50 years.
	Co-benefits	Few		There are minimal benefits beyond the exclusion of flood waters.
	Approvals and requirements	The range of approvals that may be required for a tidal/surge barrier include: • Land Owner's consent • *Marine and Coastal Act 2018* consent (DEECA) • Parks Victoria Works Permit • Marine Park Approvals • Planning Permit (Local Government) • Permit to clear protected flora under the *Flora and Fauna Guarantee Act 1988* (DEECA) • Approvals under the *Environment Protection and Biodiversity Conservation Act 1999* where applicable (Commonwealth DAWE).		
	Design considerations, constructability, and materials	Important considerations for successful design of tidal/surge barriers include: • Very high capital and maintenance costs • Founding material / geotechnical conditions have a major impact on feasibility • Impermeable barrier material and tight seal on barrier • Crest level above design water level • Construction in a waterway – area likely to require dewatering for construction • Often requires ancillary structures and works (including levees or other barriers in adjacent or connecting waterways) to maintain effectiveness .		
	Cost considerations	All costs for this adaptation action depend directly on the scale of the barrier to be constructed. Considerations should include: • Location of barrier – wider point in the waterway will require longer barrier which will be more expensive • Material costs • Labour/construction costs • Ongoing maintenance costs over design life		

Action	Engineering – Flood/tidal barriers – Tidal/surge barriers
	• Power costs and automation of opening/closing barrier mechanism.
References	https://www.profdivers.com/patterson-lakes-tidal-gate-seen-from-boat/ https://www.melbournewater.com.au/about/customer-service/our-customers/patterson-lakes/tidal-gates https://www.transport.wa.gov.au/mediaFiles/marine/MAC_P_Bunbury_stormsurge_barrier_brochure.pdf

Project example

Engineering – Flood/tidal barriers – Levees/dykes – Project example		
Project title	Patterson Lakes Tidal Gates	 *Patterson Lakes (Vic) Tidal barrier - Closed*  *Patterson Lakes Tidal barrier – Open*
Action type	Tidal barrier	
Location	Patterson Lakes	
Land manager	City of Kingston	
Year of implementation	c. 1970s	
Project objectives	To maintain suitable water levels in the canals of the housing estate, which are joined to the Patterson River, to protect the 1400 residents of the area.	
Project process	Three tidal gates were installed between the Patterson Lakes canal estate and the Patterson River. These are closed when the tide level reaches 0.60-0.65m AHD.	
Measures implemented	In 2018 the gates were automated to allow the gates to be closed remotely as soon as an alert is received about potential flood conditions. There is also "Next Gate Activity Prediction" on the Melbourne Water website.	
How well project met objectives	Works well to exclude flood waters and protect properties along the canals from flooding.	
Cost	-	
Further considerations	This canal estate is adjacent the Patterson River. As such, in the past flood water from Patterson River would have entered the Patterson Lakes estate. The design of the tidal gates is to prevent floodwaters and high tides from flowing into the canal estate. Melbourne Water report that a number of factors can raise water levels in the Patterson River and make gate closures more likely, including: • rainfall – increases the amount of water entering Dandenong Creek and Patterson River • strong westerly winds – push tides from the bay into Patterson River • high tides – high astronomical tides when combined with rainfall and westerly winds, but generally not on their own. When the gates are closed, navigable access into and out of the canals is not possible.	

3.6.3 Tidal valves/gates on stormwater system

Action	Engineering – Flood/tidal barriers – Tidal valves/gates		
Description	Tidal valves are backflow prevention devices that are installed within the drainage network, typically at the end of the network. The act to prevent elevated tailwater levels from flowing back up into the drainage network and causing inundation of low-lying lands surrounding the drainage inlets. Tidal valves are also referred to as tidal gates or stormwater backflow devices and are commonly used for flood mitigation purposes. Tidal valves/gates typically are available in two types: rubber duck bill flaps (either internal or external of the pipe) and hinged flaps. The operating principle of both these styles is the same – higher water pressure on the landward/upstream side allows for one-way flow into the waterway, while if there if higher water pressure on the downstream side, the device remains in a closed position. Careful consideration needs to be given to circumstances involving drainage outlets onto sand or gravel beaches. Sediment accumulation at the outlet may impede the device from functioning efficiently.		 *Duck bill outlet tidal valve (Tideflex)*
Functional type		Land management planning and design	 *Dysfunctional tidal value due to sediment accumulation. Source: MeasurIT.com*
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation		Short-term erosion	**Notes on suitability:** Tidal valves/gates are most suited to areas where elevated water levels within a waterway can exceed storm water drain inlets. This could be associated with tides, storm surge, riverine flooding or a combination of these. Tidal valves/gates may reduce the flow capacity of the drainage system due to hydraulic constriction. Impacts of this may include poorer drainage within the stormwater network upstream of the device. Care is required in positioning the device in the stormwater network to minimise impacts on drainage upstream.
		Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	*	Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Tidal valves may be considered an accommodate action and/or part of a broader program of protect actions.
		Avoid	
		Nature based	
	✓	Accommodate	
		Retreat	
	✓	Protect	
Likely impact on natural coastal processes		Low	**Considerations:** Tidal valves/gates have some localised impact on coastal floodplain inundation extents, and are usually part of a broader engineering drainage network managing overland flow and coastal inundation.
	✓	Moderate	
		High	

<table>
<tr><th>Action</th><th colspan="3">Engineering – Flood/tidal barriers – Tidal valves/gates</th></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="2">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations:
Tidal valves/gate structures, and as part of a drainage network, may have implications for a range of local coastal values.
With tidal valves/gates in place, the drainage system may not always fully drain, due to the hydraulic constriction of the gates. This may lead to issues with stagnant water in the network.
Benefits are associated with flood mitigation for coastal values, assets and uses. Tidal valves/gate structures are also used for limiting tidal ingress into freshwater/brackish coastal wetlands, and associated ecosystem benefits.</td></tr>
<tr><td colspan="2">Cultural values</td></tr>
<tr><td colspan="2">Environmental values</td></tr>
<tr><td colspan="2">Social values</td></tr>
<tr><td colspan="2">Economic values</td></tr>
<tr><td rowspan="6">Guidance for implementation</td><td>Preparation / design period</td><td>3-6 months</td><td>Tidal valves/gates can generally be readily installed on existing stormwater infrastructure although require an understanding of the stormwater network capacity, hydraulics, and coastal processes at the outlet.</td></tr>
<tr><td>Effective lifetime</td><td>Up to 20 years</td><td>Tidal valves/gates would need to be replaced at the end of their functional life, which is relatively short given the harsh environment they are exposed to.</td></tr>
<tr><td>Co-benefits</td><td>Few</td><td>There are few benefits beyond the prevention of backflow into the stormwater / drainage system.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="2">Installation of tidal valves/gates would usually be a component of broader drainage network upgrades, which would be undertaken by the relevant authority responsible for drainage. This would typically be Local Government Authority.
The applicable planning controls for each project area would outline the specific permit requirements for the proposed works, to be undertaken by a public authority. In many cases (not all), these works would likely be exempt from requiring a planning permit. Environmental overlays, particularly in relation to vegetation protection may require planning permits be issued.
Maintenance works carried out by a municipality or public authority to prevent or alleviate flood damage are always exempt (excluding where vegetation removal is necessary).</td></tr>
<tr><td>Design considerations, constructability, and materials</td><td colspan="2">For installation of tidal valves/gates, important considerations for successful implementation are:
• Understanding of the hydraulic capacity of the existing stormwater system
• Understanding of the anticipated rainfall patterns throughout the expected life of the storm water system
• Understanding of the coastal processes at the outlet and whether sediment may accumulate and block the outlet
• Evaluation of different tidal gate technologies and their suitability to the installation site. This may change from outlet to outlet depending on the specific hydrology, hydraulic performance, and capacity/need for maintenance of the storm water system at each area.</td></tr>
<tr><td>Cost considerations</td><td colspan="2">Installing tidal valves/gates is usually a relatively low-cost endeavour, however, if an entire stormwater network needs tidal valves/gates, costs can become significant. Cost implications for installing tidal valves/gates include:
• The preferred system/technology
• Maintenance considerations, including:
  ○ Clearing sediment from the outlet location
  ○ Cleaning inside the stormwater system due to build-up of debris.
  ○ Maintenance of the tidal valves/gates
• Construction, and installation costs.</td></tr>
<tr><td>References</td><td colspan="3">https://www.redvalve.com/tideflex
https://www.awmawatercontrol.com.au/products/flap-gate/
NSW Department of Industry and Investment (2009) ‘Water Control Structures: Design Suitability for Natural Resource Management on Coastal Floodplains’. Department of Industry and Investment (Aquatic Habitat Rehabilitation), Port Stephens. On-line at https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/634424/Water-Control-Structure-Review.pdf</td></tr>
</table>

Project example

<table>
<tr><th colspan="3">Engineering – Flood/tidal barriers – Tidal valves/gates – Project example</th></tr>
<tr><td>Project title</td><td>Backflow valves in New Farm and Milton</td><td rowspan="8">
Tideflex duck bill valve</td></tr>
<tr><td>Action type</td><td>Tidal valves/gates</td></tr>
<tr><td>Location</td><td>New Farm and Milton, Brisbane</td></tr>
<tr><td>Land manager</td><td>Brisbane City Council</td></tr>
<tr><td>Year of Implementation</td><td>2012</td></tr>
<tr><td>Project objectives</td><td>A large number of private properties were inundated by floodwaters in 2011 as a result of backflow inundation through the stormwater network. This project implemented the recommendations of an expert backflow study covering all of Brisbane.</td></tr>
<tr><td>Project process</td><td>Chambers were constructed within the stormwater network to locate the tidal valves/gates, which protected them from debris and siltation occurring within the river.</td></tr>
<tr><td>Measures implemented</td><td>Rubber duck bill and metal flap gates were installed at two locations in the suburbs of New Farm and Milton, which were worst hit by backflow inundation during the 2011 floods.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">Flooding in the Brisbane River occurred again in 2022. Backflow inundation of New Farm and Milton was considerably less than during 2011 due to lower river flood levels and the presence of tidal valves/gates preventing backflow through the stormwater system.</td></tr>
<tr><td>Cost</td><td colspan="2">$300,000 for two locations.</td></tr>
<tr><td>Further considerations</td><td colspan="2">Tidal valves/gates are effective at reducing inundation emanating from the downstream watercourse, however, they do not prevent inundation from local catchment runoff, or inundation if foreshores are completely overtopped.</td></tr>
</table>

3.6.4 Saline groundwater intrusion barrier

Action	Engineering – Flood/tidal barriers – Saline groundwater intrusion barrier

Description

Saline groundwater intrusion barriers are physical barriers constructed below the ground.

They act to restrict the movement of saltwater into freshwater areas/groundwater, which may be associated with sea level rise and elevated ocean water levels (combined tide, storm and wave effects).

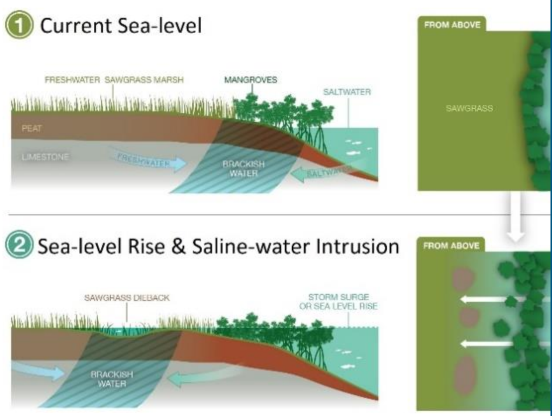
Physical barriers can be constructed from concrete, grout, bentonite, slurry walls, and sheet piles (Hussain et al., 2019). Physical barriers are very disruptive and expensive to construct, but once in place, have relatively low operational costs over their design life.

Hydraulic barriers can also be used to control the groundwater flow through a series of injection and/or extraction wells. While the capital costs of these wells may be modest (compared to the cost of physical barriers), the operational costs are very high as it requires continuous operation of pumps and potentially a permanent source of freshwater to inject into the groundwater aquifer. Treated effluent may be a suitable source for groundwater injection.

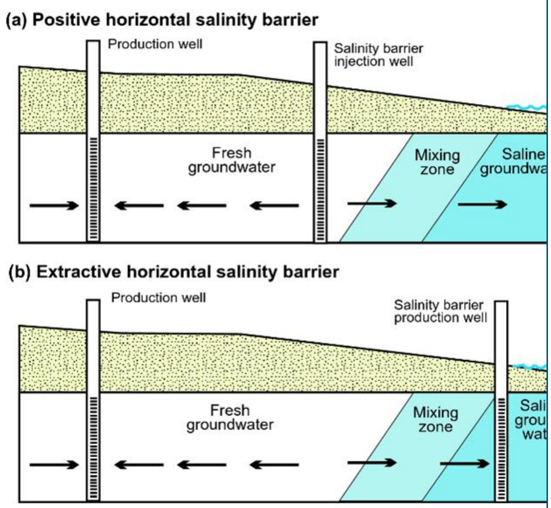
Hydraulic barriers can be created in two ways:

- A positive horizontal salinity barrier through Managed Aquifer Recharge (MAR) on the freshwater side of the saline-water interface to 'push' the saline water interface seaward
- An extractive horizontal barrier through an MAR on the seawater side to 'pull' the saline water interface back towards the coast

In circumstances where saline intrusion is influenced by extraction from freshwater aquifers, the intrusion can also be managed through restrictions on extraction.



Coastal saline groundwater intrusion (horizontal) into the fresh groundwater due to sea level rise



Conceptual diagram of (a) positive horizontal salinity barriers and (b) extractive horizontal salinity barriers

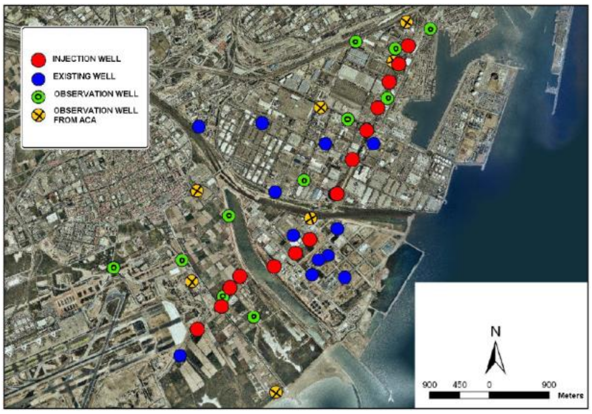
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation		Short-term erosion	**Notes on suitability:** Groundwater flow can be very complex, with movement in three dimensions. Creating physical or hydraulic barriers to groundwater flow may have implications and consequences that are not foreshadowed without extensive investigation, modelling and assessment. In order to protect a particular area or location, barriers may be needed around many sides, rather than just the coastal side, to prevent saline intrusion from flanking areas. Extensive monitoring is essential in managing saline groundwater intrusion. An operational system should have the ability to ramp up or ramp down pumping in response to real-time monitoring results.
		Long-term erosion	
		Accretion	
		Storm tide inundation	
		Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
	✓	Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Saline groundwater intrusion barriers are a protect action, requiring major engineering works.
		Avoid	
		Nature based	
		Accommodate	
		Retreat	

<table>
<tr><th>Action</th><th colspan="4">Engineering – Flood/tidal barriers – Saline groundwater intrusion barrier</th></tr>
<tr><td></td><td>✓</td><td colspan="2">Protect</td><td></td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td></td><td colspan="2">Low</td><td rowspan="3">Considerations:
Saline intrusion groundwater barriers can be designed to have generally low impacts on broader coastal processes, however do intervene in the natural inland expansion of saline water with sea level rise.</td></tr>
<tr><td>✓</td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations:
Like any major infrastructure, construction of saline groundwater intrusion barriers can impact on environmental, social, economic and cultural values.
Operationally, the majority of changes and impacts are subsurface. While some of this may manifest as a change to habitats and ecosystems within the impacted area, such changes are typically intended and form the basis for objectives for the works.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="5">Guidance for implementation</td><td>Preparation / design period</td><td>> 12 months</td><td colspan="2">Saline intrusion groundwater barriers require extensive environmental study of the coastal area, hydrological and geological investigation of the aquifer, as well as the risk assessment and potential effects prior to design and construction of the project. Therefore, it typically takes >12 months depending on the scale of the project and location of interest.</td></tr>
<tr><td>Effective lifetime</td><td>50 years</td><td colspan="2">Physical barriers should have a design life of at least 50 years. Hydraulic barriers require a high operational load, and therefore repair and preplacement of critical infrastructure such as pumps would be required on a much more frequent basis (every 10 years say).</td></tr>
<tr><td>Co-benefits</td><td>Some</td><td colspan="2">There may be potential to recharge groundwater using treated effluent, which would avoid discharge to sensitive receiving surface waters. Extracted saline or brackish water could be used for industrial purposes (with or without treatment, desalination etc).</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">The range of approvals that may be required for a saline intrusion groundwater barrier include, but not limited to:
• Land Owner’s consent
• Marine and Coastal Act 2018 consent (DEECA)
• Marine Park Approvals (Parks Victoria)
• Planning Permit (Local Government) for buildings and works and vegetation removal
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).
• Approvals under the Water Act 1989
• Approvals under the Environmental Protection Act 2017
• For large projects with potential impacts on surrounding areas and Environmental Effects Statement (EES) under Environment Effects Act 1978 may be required.</td></tr>
<tr><td>Design considerations, constructability, and materials</td><td colspan="3">• Size and extent of area across which saline groundwater intrusion needs to be managed, and whether it is urban land, environmental land, critical infrastructure etc. This will impact on the constructability of the barrier solution and appropriate materials.
• Operational parameters that will be accepted by responsible stakeholders. Hydraulic barriers will require a very high on-going operational management demand for example.
• Need and location of ancillary infrastructure, such as source or disposal of water.
• Need and location of groundwater monitoring wells and equipment for real-time monitoring and adaptive decision-making.</td></tr>
</table>

Action	Engineering – Flood/tidal barriers – Saline groundwater intrusion barrier	
	Cost considerations	Physical barriers have a high cost depending on their depth, length, construction materials and methods. Hydraulic barriers have a lower capital cost than physical barriers, but high operational expenses, as pumps need to be running permanently. Cost efficiencies can be introduced where the system is being used for multiple benefits, such as treated wastewater discharge.
References	Mohammed S. Hussain, Hany F. Abd-Elhamid, Akbar A. Javadi and Mohsen M. Sherif (2019) Management of Seawater Intrusion in Coastal Aquifers: A Review. *Water* **11**, 2467. MDPI, Basel, Switzerland	

Project example

Engineering – Flood/tidal barriers - Saline groundwater Intrusion barrier – Project example	
Project title	Seawater intrusion barrier in the deltaic Llobregate aquifer
Action type	Saline intrusion groundwater barrier
Location	Barcelona, Spain.
Land manager	Spanish Ministry of Environment and Rural and Marine Affairs
Year of Implementation	2007 - 2009
Project objectives	To prevent the advance of seawater intrusion in the main Llobregat delta aquifer.
Project process	Project was processed in two phases: an injection flow of 2,400 m^3/day in 4 wells (phase 1), and total injection flow of 15,000 m^3/day to 11 wells (phase 2). These phases included: • Hydrogeological study of the area • Construction of 14 injection wells • Reclaimed water treatment and control prior to injection • Installation of 17 specific monitoring piezometers with remote-control data system for water temperature, head, and water electrical conductivity • Installation of 13 wells and 7 piezometers specifically for the aquifer monitoring network, covering more than 30km2 to follow the impact of the barrier.
Measures implemented	Construction of a positive hydraulic barrier by injecting reclaimed water in 14 wells, raising the freshwater groundwater level near the coast to prevent seawater penetration inland.



Positive hydraulic barrier including 14 injection wells, 17 piezometers equipped with temperature and electrical conductivity remote sensors, 7 previously existing piezometers, 12 industrial wells, and the water treatment plant, Llobregat delta aquifer, Barcelona, Spain.

Dual extraction and injection well, Llobregat positive hydraulic barrier, Barcelona, Spain.

How well project met objectives	Hydrological analyses show highly positive results and is effectively reducing the saltwater intrusion process. Substantial improvement of the groundwater quality has been observed in wells surrounding the injection points and no clogging has appeared. The project outcome is considered extremely positive.
Cost	Total investment for the construction of the hydraulic barrier amounts to €23M. Total cost of operations is €0.28/m^3 of injected water.
Further considerations	-

3.7 Drainage

Action	Engineering – Drainage

Description

Drainage networks are designed to capture and remove rainfall and associated runoff, as efficiently as possible, to minimise impacts on urban environments.

Careful modifications to drainage networks can enable better accommodation of future changes in climatic conditions, including more frequent and higher intensity rainfall, and rising sea levels for areas where drainage discharges into coastal and estuarine waters.

Upgrades to the drainage network can include a range of modifications across all drainage infrastructure, such as:

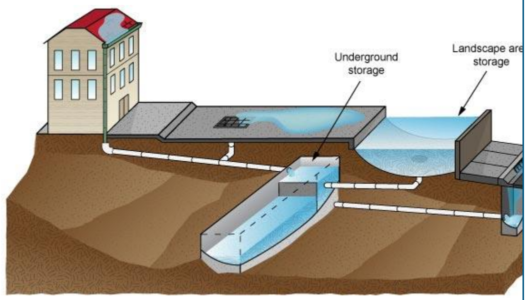
- Increasing pipe drainage capacity
- Controlling backflow at outfalls
- Regulators, flow controls and flow diversion/redirection devices
- Pumps and pump stations
- Increasing infiltration through greenspace
- Reconnection of natural wetlands / flood storage areas
- Diversion of stormwater into green infrastructure (rain barrels, rain gardens/bioretention units, vegetative swales, cisterns, infiltration trenches, permeable pavements, tree covers and green rooftops, street planters)
- Reducing volumes needing conveyance through stormwater capture and reuse / retention using ponds/lakes, underground storage or rainwater tanks
- Increasing retention capacity through use of dry retention structures (garden and ponds), underground storage, or private storage devices (household tanks)
- Response of nearby wetlands to storm surge events.

Elements of the above can be described as **Water Sensitive Urban Design (WSUD).** WSUD takes a whole of system approach that aims to:

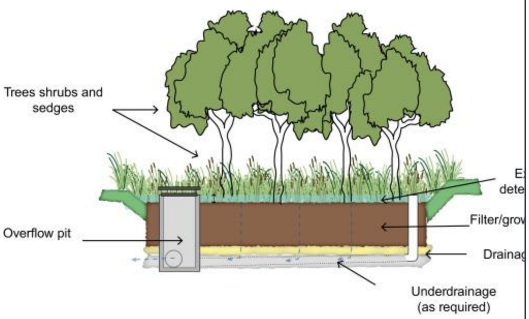
- Avoid modifying flow regimes within natural waterways as a result of development
- Avoid increasing nutrients and other pollutants in natural waterways, especially waterways of environmental significance
- Enhance natural elements throughout urban development to provide environmental and social benefits, including reducing the potential impacts of urban heat island effects.

Pumped stormwater discharge

Duckbill one-way vale on stormwater outlet



Network scale storm water storage (Source: RMIT)



Water sensitive urban design

Functional type		
		Land management planning and design
		Nature-based methods
	✓	Coastal engineering

Coastal hazard mitigation		
		Short-term erosion
		Long-term erosion
		Accretion
	✓	Storm tide inundation
	✓	Permanent inundation

Notes on suitability:

Storm surge and elevated tailwater conditions reduce the hydraulic effectiveness of urban drainage networks. Upgrades to the drainage networks can help to overcome some of the constraints imposed by tailwater (downstream water level) conditions, which

Action	Engineering – Drainage		
		Estuary dynamics	will increase in the future as a result of climate change, including sea level rise. Upgrades to the drainage network can be undertaken on existing drainage networks, provided that: • The water can still flow downhill to the river/ocean, even under future sea level rise (i.e. a positive hydraulic gradient is maintained), or where the hydraulic gradient no longer exists, storage and pump solutions can be used. • There is suitable space for upgrade works.
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Drainage network upgrades are an accommodate action, with Water Sensitive Urban Design typically applied as best practice for drainage/stormwater management and climate change adaptation in urban areas more broadly.
		Avoid	
		Nature based	
	✓	Accommodate	
		Retreat	
		Protect	
Likely impact on natural coastal processes	✓	Low	**Considerations:** Drainage network upgrades aim to manage stormwater flows and restore more natural runoff/retention rates and volumes, while also providing adequate flood risk mitigation.
		Moderate	
		High	
Applicability considerations for site values	Potential impacts on the range of coastal values require site specific assessments. A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.		**Applicability considerations:** • Drainage network upgrades can require substantial engineering works with a range of implications for coastal values • There may be environmental implications of stagnant water if outflows are reduced, or storage solutions are implemented • There may be environmental implications of pump solutions, both to inflow and outflow points but also with respect to power requirements • Proper implementation of drainage network upgrades should aim to maintain or reduce levels of nuisance inundation, which may have social and economic benefits • Capital and ongoing costs associated with the upgrades need to compare with economic benefits from maintaining or improving functionality. Benefits may include improved amenity and reduced requirement for elevating buildings and other infrastructure over time.
	Cultural values		
	Environmental values		
	Social values		
	Economic values		
Guidance for implementation	**Preparation / design period**	> 12 months	Drainage network modification typically requires longer than 12 months to prepare and design and is usually undertaken using multiple mechanisms. Existing infrastructure upgrades should be carried out at the end of life to reduce the cost of the upgrades. As a result of the large range of options available when upgrading the drainage network, suitable hydrology and hydraulic assessments of the network need to be conducted and a cost benefit assessment of available options undertaken.
	Effective lifetime	50+ years	Upgrading of the drainage network will have an effective lifetime beyond 50 years, with elements being replaced with more suitable ones incrementally as they reach the end of their life.
	Co-benefits	Some	Drainage network upgrades have some co-benefits, particularly with respect to water sensitive urban design. Small capacity storage devices, usually installed at a dwelling level, can intercept and store water for later use within the building, reducing water network demand and drainage demands. Further,

Action	Engineering – Drainage		
			increased green space for natural storage can be designed with co-benefits such as bio-retention devices, amenity, habitat and reduction of urban heat.
	Approvals and requirements	The applicable planning controls for each project area would outline the specific permit requirements for drainage network upgrades to be undertaken by a public authority.	
	Design considerations, constructability, and materials	As part of preparing a drainage network upgrade, the following should be considered: • Understanding of the exposure site including drainage, flooding history, topography, geotechnical, and ground conditions such as floor level, soil permeability, and excavation possibility • Understanding of hydrological and hydraulic patterns of the exposure site, design events and potential damage assessment • Risk mitigation assessment due to the designed adaptation measures • Economic assessment and cost analysis of the designed adaptation measures • Access to the site for material supply, transportation, and construction • On-site considerations during construction, such as safety fences, stabilisation of bed and banks of temporary channels, and removal and transport of excavated materials • Understanding of surface obstructions such as buildings, electricity supplier poles, native vegetation, trees, existing culverts and bridges, etc. • Understanding of underground obstructions such as electricity and communication cables, oil and gas pipelines, water and sewer mains, etc. • Understanding of provisions of future developments such as downstream extension of the pipeline and surface roads and pavements • Environmental considerations • Social constructability and culture and heritage assets such as landscapes and buildings.	
	Cost considerations	When developing a plan for upgrade of the drainage network, the following cost considerations need to be evaluated: • Background studies for hydrology, hydraulics, and geotechnical investigations • Cost of installing and upgrading pipes including excavation, materials, traffic control (when under roads) and reinstatement of surface layer • For replacement/upgrade of pipes, can the upgrade be delayed until the planned end of life for the existing infrastructure?, • Cost of supply, install, operation and maintenance of pump systems if applicable • Cost-sharing arrangements for storage devices on private property (if any) • Cost of converting hardstand or existing drainage pits to greenspace or retention space • Cost of maintenance of new urban green space.	
References	https://www.melbournewater.com.au/sites/default/files/South-Eastern-councils-WSUD-guidelines.pdf http://urbanwater.melbourne.vic.gov.au/wp-content/uploads/2014/12/WSUD_part1.pdf Sharma AK, Gardner T, Begbie D (ed.) 2019 Approaches to Water Sensitive Urban Design: Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions. Elsevier Burge, K., Browne, D., Breen, P., & Wingad, J. (2012). Water sensitive Urban design in a changing climate: Estimating the performance of WSUD treatment measures under various climate change scenarios. In *WSUD 2012 - 7th International Conference on Water Sensitive Urban Design: Building the Water Sensitive Community, Final Program and Abstract Book* (WSUD 2012 - 7th International Conference on Water Sensitive Urban Design: Building the Water Sensitive Community, Final Program and Abstract Book).		

Project example

Engineering – Drainage – Project example		
Project title	Barwon Heads Ozone Road Drainage Upgrade Project	
Action type	Upgrade drainage network	

<table>
<tr><th colspan="3">Engineering – Drainage – Project example</th></tr>
<tr><td>Location</td><td>Barwon Heads, Bellarine Peninsula</td><td rowspan="6">
Construction of the outfall opposite the junction of Flinders parade and Ozone Street, Barwon Heads in 2017</td></tr>
<tr><td>Land manager</td><td>City of Greater Geelong</td></tr>
<tr><td>Year of Implementation</td><td>2017</td></tr>
<tr><td>Project objectives</td><td>• Upgrade of existing stormwater network to effectively drain stormwater when there are high tail water levels in the Barwon River Estuary.
• Prevent inundation of low-lying areas from back flow through the drainage network at times of high coastal water levels in the Barwon River Estuary.</td></tr>
<tr><td>Project process</td><td>• City of Greater Geelong created a Flood Management Plan for Barwon Heads. This included hydrological and hydraulic modelling and mapping and a mitigation option assessment.
• Construction of the preferred option commenced in 2017.</td></tr>
<tr><td>Measures implemented</td><td>Upgrades were designed to eliminate flooding of private residences during 5- and 20-year ARI water level events and to reduce flooding during events of greater intensity. Specific measures included:
• Construction of 6 pump stations, largest on Clifford Pde,
• Installation of internal tideflex one-wave valve fitted to 1600mm diameter Clifford Pde outfall, and
• Pipe upgrades along Hitchcock Ave.</td></tr>
<tr><td>How well project met objectives</td><td colspan="2">These upgrades have been effective so far, successfully preventing inundation to private residences during a January 2022 storm surge event.</td></tr>
<tr><td>Cost</td><td colspan="2">The works had a capital cost of approximately $2,100,000.</td></tr>
<tr><td>Further considerations</td><td colspan="2">The tideflex value has an additional safety benefit of preventing access to the pipe system from the outfall on the beach.</td></tr>
</table>

3.8 Road network

Action	Engineering – Road network		
Description	Road network upgrades aim to reduce the frequency, duration and/or extent of inundation. Such measures may include: • Increased pavement heights • Improved drainage (see *Drainage*) • Realignment of existing roads • Reconfiguration of the road network to reduce risk to critical transport paths • Automated flood alert, road closures or other warnings. Road network upgrades for climate change adaptation should also accommodate future changes in temperature, inundation frequency and duration, and saline water exposure. These may impact on the design conditions and/or life expectancy. Climate change, including sea level rise, will result in more frequent and deeper inundation of low-lying roads close to coasts and estuaries, causing a reduction in serviceability and safety. Issues arise when these roads are important thoroughfares for egress from flooded properties and for access by emergency services. Critical times include periods of highest astronomical tide (or King tide), combined with storm conditions that cause storm surge and coincidental catchment flooding.			 *Road inundation (Source: Vicroads)*  *King tide inundation at Carrington (Source: Newcastle Herald)*
Functional type		Land management planning and design	
		Nature-based methods	
	✓	Coastal engineering	
Coastal hazard mitigation		Short-term erosion	**Notes on suitability:** Road network upgrades are applicable in all locations, and particularly in locations where the road network is the 'weak-link' to areas that are otherwise serviceable during inundation events. Road network upgrades should be prioritised where the existing infrastructure presents a threat to public safety or isolation. Road network upgrades also target infrastructure that requires periodic maintenance. For example, raising the elevation of a road by 20cm once per 20 years may be incorporated into regular road works programs, and in doing so, will address the impacts of gradual sea level rise. The timing of road network upgrades needs to align with drainage network upgrades and other accommodate actions for buildings and infrastructure (e.g. fill level and floor level increases) to ensure that surrounding areas and infrastructure do not end up lower than the road levels (exacerbating flood risk).
		Long-term erosion	
		Accretion	
	✓	Storm tide inundation	
	✓	Permanent inundation	
		Estuary dynamics	
		Offshore sediment dynamics	
		Saline intrusion	
Marine and Coastal Policy order of consideration		Non-intervention	**Notes on policy context:** Road network upgrades is considered an accommodate action. Relocation of roads may also align with managed retreat.
		Avoid	
		Nature based	
	✓	Accommodate	

<table>
<tr><th>Action</th><th colspan="4">Engineering – Road network</th></tr>
<tr><td></td><td>✓</td><td colspan="2">Retreat</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Protect</td><td></td></tr>
<tr><td rowspan="3">Likely impact on natural coastal processes</td><td>✓</td><td colspan="2">Low</td><td rowspan="3">Considerations:
Impacts on coastal processes will depend on road location and the nature of the upgrades, however can typically be designed to minimise impacts.</td></tr>
<tr><td></td><td colspan="2">Moderate</td></tr>
<tr><td></td><td colspan="2">High</td></tr>
<tr><td rowspan="5">Applicability considerations for site values</td><td colspan="3">Potential impacts on the range of coastal values require site specific assessments.
A partnership with Traditional Owners should inform the appreciation of cultural values and Traditional Owner rights and assertions for the site.</td><td rowspan="5">Applicability considerations:
• Road network upgrades can require substantial engineering works with a range of implications for coastal values
• Road network upgrades can limit the need for other interventions (or for a period of time), and provide broader benefits of maintaining serviceable and safe roads and access.
• There will be economic benefits of maintaining serviceable and safe roads. This may include increased visitation, trading potential and reduced wear on pavements and vehicles from saline exposure.</td></tr>
<tr><td colspan="3">Cultural values</td></tr>
<tr><td colspan="3">Environmental values</td></tr>
<tr><td colspan="3">Social values</td></tr>
<tr><td colspan="3">Economic values</td></tr>
<tr><td rowspan="6">Guidance for implementation</td><td>Preparation / design period</td><td>Several Years</td><td colspan="2">Road network upgrades are long term projects that involve a multi-disciplinary approach, consultation and careful planning and prioritisation before detailed design can commence.</td></tr>
<tr><td>Effective lifetime</td><td>Various</td><td colspan="2">Road network upgrades can be designed to suit a range of effective timeframes. Upgrades may consider a pathways approach where initial modifications may be made, before further modifications or retreat actions are required.</td></tr>
<tr><td>Co-benefits</td><td>Some</td><td colspan="2">Road network upgrades offer some co-benefits including reconfiguration of transport infrastructure to suit existing/desired uses. Realignment of roads may increase the safety of roads, while improvements to shared road/pathways may improve usability and safety for non-vehicle users.</td></tr>
<tr><td>Approvals and requirements</td><td colspan="3">The range of approvals that may be required for a road network upgrade include:
• Land Owner's consent
• Planning Permit (Local Government) for buildings and works and vegetation removal
• Permit to clear protected flora under the Flora and Fauna Guarantee Act 1988 (DEECA)
• Approvals under the Environment Protection and Biodiversity Conservation Act 1999 where applicable (Commonwealth DAWE).</td></tr>
<tr><td>Design considerations, constructability, and materials</td><td colspan="3">Considerations for design of a road network upgrades should include:
• Investigation of the impacts of sea level rise on the road network. This may include assessment of changes in frequency of frequent/nuisance inundation, storm tide inundation and flood-related inundation.
• Assessment of the current and future needs of the transport infrastructure, including a vulnerability (from isolation) and safety assessment.
• Planning for the most appropriate response to any hazards using the hierarchy outlined in the Victorian Marine and Coastal Policy 2020.
• Environmental, cultural, and geotechnical investigations of any proposed works.
• Planning of works to maximise the useful life of existing infrastructure and upgrading at the expected end of life of the asset where appropriate.
• The impact on the road infrastructure from saline intrusion, frequent inundation of the subgrade material and how this may be managed in future upgrades.
• Suitable monitoring and maintenance programs for the network performance.</td></tr>
<tr><td>Cost considerations</td><td colspan="3">Cost considerations for road network upgrades may include:
• Undertaking suitable background assessments including inundation (from storm tide, catchment flooding and sea level rise), geotechnical, transport network and disaster planning</td></tr>
</table>

Action	Engineering – Road network	
		• Obtaining relevant permits • Suitable consultation programs • Costs associated with early improvement of road infrastructure and unrealised useable life of existing infrastructure • Costs of new materials and construction • Acquiring land where needed to realign/move the existing infrastructure.
References	-	

Project example

Engineering – Road network – Project example	
Project title	Miami Beach Road Raising
Action type	Road network upgrade
Location	Miami Beach, Florida, USA
Land manager	City of Miami
Year of implementation	2014 onwards
Project objectives	Reduce vulnerability of roadways and adjacent properties to increased levels of inundation due to sea level rise and increased storm impacts.
Project process Measures implemented	Selected roads throughout Miami Beach are being raised by 600mm, combined with installation of as many as 80 stormwater pump stations throughout the city.
How well project met objectives	While the road raising has been successful at improving road access during periods of high tide, the road raising project has resulted in adjacent properties being lower than road level, meaning that they have been more susceptible to rainfall inundation and flooding. Stormwater pumps installed as part of the works have sometimes been inoperable during storm events.
Cost	The project continues but costs of road upgrade work and associated pumping stations are in the hundreds of millions of dollars.
Further considerations	Legal cases are mounting regarding exacerbation of flooding in adjacent properties. This has also manifest through denial of insurance cover for some property holders given lands are now lower than surrounding areas.

Miami Beach road raising (source: wusf news)

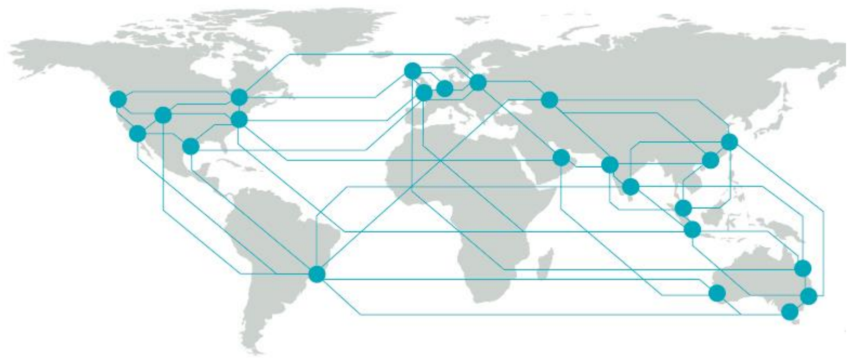
Pumping station at Miami Beach (source: npr.org)

Attachment A – Summary table of actions and types of coastal hazards they can mitigate

Functional type	Category	Adaptation Action	Coastal hazard type							
			Short-term erosion	Long-term erosion	Accretion	Storm tide inundation	Permanent inundation	Estuary dynamics	Offshore sediment dynamics	Saline intrusion
Land management, planning and design	Land use	Land acquisition, swap, lease-back	✓	✓	✓	✓	✓	✓		✓
		Controlled access	✓	✓		✓	✓	✓		
		Planning scheme zone change	✓	✓	✓	✓	✓	✓		✓
		Planning overlays	✓	✓	✓	✓	✓	✓		✓
		Rolling easements	✓	✓	✓	✓	✓	✓		✓
		Removal / relocation of infrastructure	✓	✓	✓	✓	✓	✓		✓
	Resilient design / development	Development setbacks	✓	✓		✓	✓	✓		✓
		Use of resilient materials and design in new and retrofitted infrastructure	✓	✓	✓	✓	✓	✓		✓
	Cultural landscapes	Survey, document, salvage, other*								
Nature-based (Nature-based methods use the creation of restoration of coastal habitats for hazard risk reduction[2])	Coastal vegetation and blue carbon ecosystems	Mangrove forests	✓	✓		✓		✓	✓	
		Seagrass meadows		✓				✓	✓	
		Salt marsh	✓	✓		✓		✓		
		Kelp forests	✓	✓		✓				
	Beach and dune ecosystems	Beach and dune protection / vegetation / management	✓	✓		✓		✓		
		Use of on-site natural materials to	✓							
		Wet sand fencing	✓					✓		
		Supported littoral vegetation**	✓		✓		✓			

[2] Morris *et al* 2021

Functional type	Category	Adaptation Action	Coastal hazard type							
			Short-term erosion	Long-term erosion	Accretion	Storm tide inundation	Permanent inundation	Estuary dynamics	Offshore sediment dynamics	Saline intrusion
Engineering	Nourishment**	Localised beach scraping / dune	✓		✓					
		Beach nourishment	✓	✓		✓		✓	✓	
		Sand by-pass system	✓	✓	✓	✓		✓	✓	
	Reefs**	Shellfish reefs	✓	✓		✓			✓	
	Dredging	Configuration dredging	✓	✓	✓				✓	
	Seawalls	Vertical seawalls	✓	✓		✓	✓	✓		
		Eco-engineering of hard surfaces	✓	✓		✓		✓		
		Rock revetments	✓	✓		✓		✓		
		Geobag revetment / wall	✓	✓						
		Rock bag revetment / wall	✓	✓				✓		
	Groynes	Groynes (rock, geobag, other)	✓	✓	***			✓		
	Breakwaters	Breakwaters	✓	✓		✓		✓	***	
	Flood/tidal barriers	Levees / dykes	***	***				***		
		Tidal / surge barriers				✓	***			
		Tidal valves on stormwater system				✓	***			
		Saline groundwater intrusion barrier								✓
	Drainage	Upgrade of drainage network				✓	✓			
		Water sensitive urban design				✓	✓			
	Road network	Upgrade of road network				✓	✓			



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