NbS Benchmark Assessment Report

Customer	Caitlin Ziviani and Scott Hardy
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1 Introduction

1.1 Coastal Hazard Management in Queensland

Queensland coastal councils are responsible for managing large areas of public coastal land and beaches, with the State Government, Traditional Owners, national and state marine park managers, port authorities and other operators managing specialist areas of the coast and tidal water. Local Government in partnership with the State government is also responsible for the planning and management of climate change related coastal hazard risks relating to storm tide, coastal erosion and rising sea levels.

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report released in August 2021 contains findings relevant to Queensland Councils as they continue to adapt to climate impacts. Key findings relevant to coastal hazard management, include[1]:

- relative sea level across Australia has risen at a rate higher than the global average and is projected to continue and contribute to increased coastal flooding and sandy shoreline retreat (high confidence)
- an increase in marine heatwaves and ocean acidity has been observed and is projected to continue (high confidence)
- projected mean rainfall changes are uncertain but an increase in heavy rainfall and river flooding is projected by mid-century (medium confidence)
- it is projected there will be a decrease in cyclone frequency but an increase in the proportion of severe cyclones (medium confidence).

Property, infrastructure and ecosystems along Queensland's coast will be increasingly exposed to coastal erosion, storm tide inundation and flooding as a result of a changing climate. Rising sea level will also increase the salinity of estuarine and coastal aquifer groundwater. Sea level rise and associated erosion and inundation due to storm surge can pose significant challenges to coastal councils as implementing coastal adaptation measures and policies requires consideration of various interests such as private and public infrastructure, economic development, public safety, scenic amenity, and environmental values.

Whilst coastal retreat may provide the greatest opportunity for adaptation of coastal ecosystems to changing conditions this may not be feasible in highly developed coastal zones. Artificial structures, including seawalls, breakwaters and groynes, are commonly used for coastal protection throughout Queensland. However, these structures can be non-adaptive and may require on-going maintenance and upgrading. This can incur significant economic cost and in some instances may be unsustainable over the long-term. It may also be difficult for Councils to justify public expenditure for coastal defence structures for the protection of private property. Such structures may also exacerbate erosion, reduce beach amenity and impact on coastal habitat values on public lands. These factors can make the value proposition of coastal defences difficult to resolve.

There is growing interest globally and locally in developing more sustainable and adaptive nature-based solutions to help build more climate-resilient coastal communities and ecosystems, which also have the potential to deliver a range of other social and environmental benefits beyond coastal protection.

[1] https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Australasia.pdf

Nature-based Solutions

Nature-based Solutions (NbS) are defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

Various terms are used globally in reference to NbS, such as 'ecosystem-based adaptation', 'nature-based features', 'building with nature', 'natural infrastructure solutions', 'ecosystem-based disaster risk reduction', 'green infrastructure', 'nature-based infrastructure', 'nature-based interventions', 'working with nature', 'building with nature', 'ecological engineering', 'ecoengineering' and 'reconciliation ecology'. NbS is the umbrella term adopted for this report.

NbS are being widely promoted internationally by the United Nations Framework Convention for Climate Change, World Bank, International Union for the Convention of Nature, United Nations Development Program, European Union's Biodiversity Strategy, The Nature Conservancy and Worldwide Fund for Nature. The US has also introduced the Living Shorelines Act of 2019 to support the establishment of "living shorelines," or nature-based protections against storms and pollution that improve biodiversity, recreation, and climate resilience. There is also considerable scientific and community guidance available on living shorelines such as the Guidance for Considering the Use of Living Shorelines (NOAA, 2015) and GIS based decision support tools such as the US Coastal Resilience Toolkit .

NbS to enhance coastal resilience primarily involves the restoration or rehabilitation of locally occurring coastal ecosystems to stabilise shorelines and increase protection against coastal storms, flooding, sea level rise and erosion, whilst also promoting other social and environmental ecosystem services. Coastal ecosystems, particularly beaches, dunes, saltmarsh, mangroves, seagrass, coral reefs, shellfish reefs and coastal wetlands, can play a critical role in reducing the impacts of coastal hazards through their role in wave attenuation, sediment capture and reduction of erosion, storm surge and debris movement.

Beaches are highly dynamic and replenishment may be required when natural sand movement processes are inhibited by foreshore development or following erosion events. Sand dunes play a vital role in protecting beaches, coastline and infrastructure from coastal storms, wind and waves and are a vital supply of sand to beaches. Restoring estuarine and marine habitats can influence the depth of the intertidal zone, promote sediment deposition, alter shoreline profiles and can contribute to coastal protection.

In contrast to traditional hard engineering approaches alone NbS can be adaptive to changing conditions, may rehabilitate after extreme events and could provide longer term defence to coastal hazards. NbS also have the capacity to provide a number of other core benefits including enhancing biodiversity, fisheries productivity, water filtration, carbon and nutrient storage, landscape and visual amenity and socio-economic values through employment, recreation, tourism, education and research.

Coastal NbS in Australia

Despite international precedence and support for the development of NbS as a potentially cost-effective and sustainable approach to coastal protection they are not adopted in Australia at a comprehensive scale with the exception of sand nourishment and dune rehabilitation and small-scale trialling or research of NbS methods. Uncertainties around the use of NbS for coastal protection may be due to the lack of national, state and industry accredited evidence-based design guidelines and readily accessible data on the environmental and cost effectiveness of these natural systems in comparison to artificial protection structures.

The National Centre for Coasts and Climate (NCCC), supported through the Earth Systems and Climate Change Hub in the Australian Government's National Environmental Science Program, developed the first national guideline to introduce NbS approaches specific to Australian coastal ecosystems. The Australian guide to nature-based methods for reducing risk from coastal hazards summarises physical, ecological and engineering considerations for major coastal ecosystems, frameworks and policies for implementing NbS and benefit-cost analysis. The guideline complements the following national guidelines (Morris et.al. 2021):

- Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering (NCCOE, 2012)
- Coastal Engineering Guidelines for Working with the Australian Coast in an Ecologically Sustainable Way (NCCOE, 2012)
- Climate Change Adaptation Guidelines in Coastal Management and Planning (NCCOE, 2012) International.

The federal Department of Agriculture, Water and the Environment are also supporting nature-based solutions for climate, including funding research, on-ground projects, capacity building and global partnerships on the protection and restoration of coastal blue carbon ecosystems and wetlands.

Coastal NbS in Queensland

NbS to enhance dune and beach resilience have been implemented in Queensland for several decades. Since the mid-1900's "soft" methods, such as beach nourishment, artificial reefs and dune revegetation, have been applied for shore protection as it was recognised they could provide technical, environmental, social and financial advantages over "hard" shore protection methods, such as seawalls, groins and detached breakwaters (Piorewicz, 2002). A series of Coastal Dune Management technical papers were also prepared by the former Queensland Beach Protection Authority (active 1968 to 2003) which addressed NbS including guidelines for beach nourishment; dune repair, re-establishment and stabilisation; and dune management and revegetation. The Queensland Coastal Plan (DERM, 2011) also provided high level guidelines on maintaining, protecting and rehabilitating dune vegetation and coastal ecosystems to manage coastal land in Queensland.

The Queensland government, in partnership with the Local Government Association of Queensland (LGAQ), are funding local governments to develop Coastal Hazard Adaptation Strategies (CHAS) through the QCoast2100 program to help councils understand their coastal hazard risks up to 2100 and plan for safer, more resilient communities. The QCoast2100 2.0 Program consists of additional funding to be rolled out in the 2021/2022 financial year to support the implementation of some CHAS actions through on-ground works and activities. Projects that demonstrate innovative solutions and benefit other councils will be encouraged and may include a range of NbS projects.

Currently, the C-CAT have been working with James Cook University and Griffith University to assess state-wide NbS projects and review coastal ecosystems, their 'defence' capabilities and opportunities to provide co-benefits such as biodiversity, improved water quality and carbon sequestration. This report is part of that study.

1.2 Purpose and scope of this report

The Coastal Councils Adaptation Taskforce (C-CAT) commissioned this independent review of NbS being implemented by Queensland councils to address coastal hazards. The aim of the review was to collate current local knowledge and perspectives to gain a better understanding of the key issues that may need to be considered when evaluating NbS and to benchmark their effectiveness and efficiencies in mitigating risks associated with coastal hazards.

Survey data was collated from coastal councils and natural resource management organisations to understand current NbS practices and their feasibility in managing coastal hazards in Queensland. A secondary aim of this report is to gauge local interest and knowledge on NbS to help coastal managers evaluate their use for local coastal defence over, or in combination with, more traditional engineering approaches. Improved understanding, communication and application of this shared knowledge forms a critical part of coastal adaptation planning across the state.

1.3 Structure of the report

This report includes the following sections:

- Section 2 describes the activities that were undertaken to gather information from stakeholders and assess the survey responses
- Section 3 describes the results of the survey
- Section 4 provides examples of NbS for coastal hazard management used in Queensland, including case studies
- Section 5 includes a summary of key issues documented in the literature on NbS for coastal hazard management
- Section 6 summarises potential barriers and recommendations for coastal NbS in Queensland
- Section 7 is a summary of the project findings
- Annex A: contains the survey questions
- Annex B: identifies the survey recipients
- Annex C: presents the compiled survey results
- Annex D: provides NbS case studies
- Annex E: provides examples of NbS resources.

2 Stakeholder Survey and Data Assessment

The following process was applied to the stakeholder survey and data assessment:

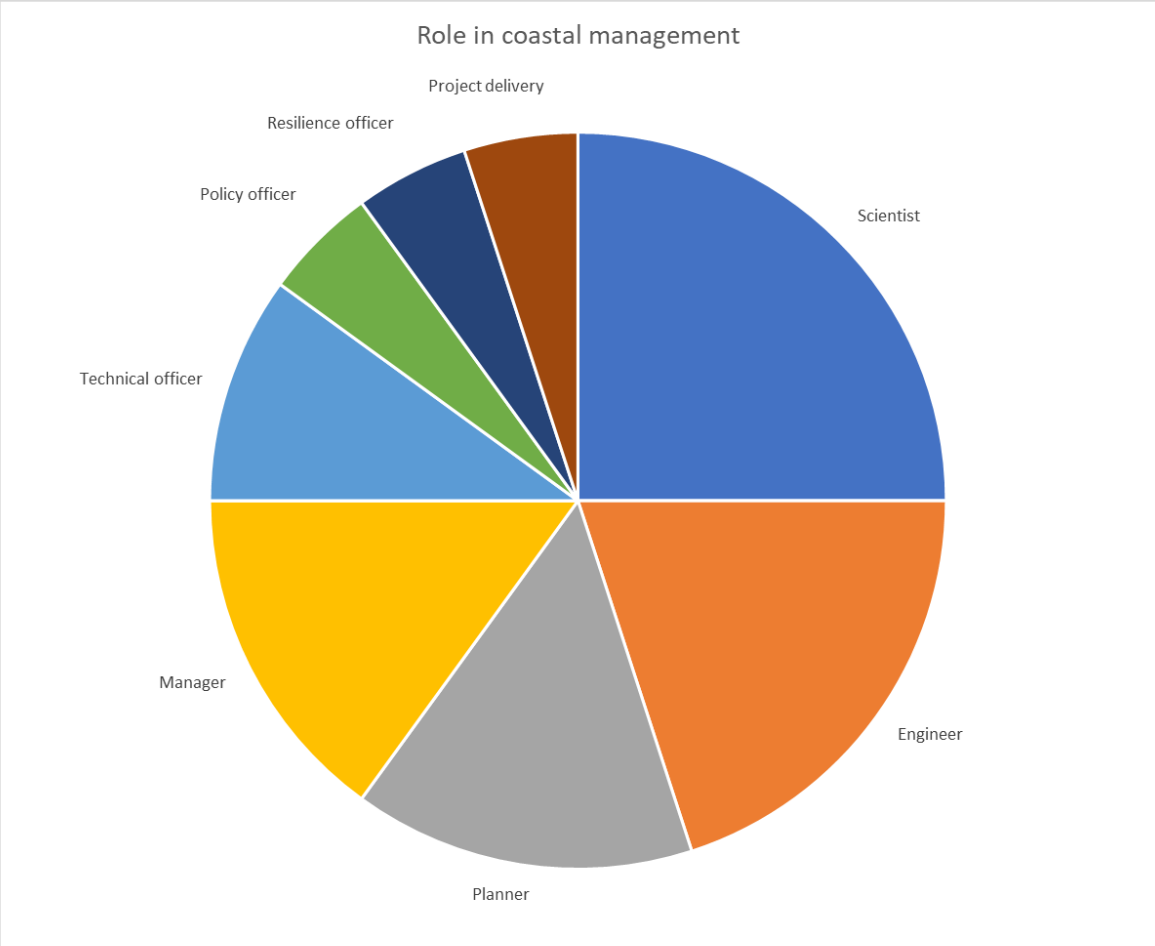
1. Relevant organisations and contacts were identified across coastal Queensland using the existing networks of C-CAT and BMT. This focussed on local government and natural resource management organisations.
2. Survey questions were designed to extract an understanding of the current awareness of NbS to mitigate against coastal hazard risks, local applications, opportunities, challenges and lessons learned (see Annex A:for the survey questions).
3. The survey was circulated to 37 organisations (refer Annex B:). Recipients were encouraged to share the survey with their networks and colleagues.
4. The survey was open for 6 weeks and 20 completed survey responses were received.
5. Collected survey data was assessed using statistical frequency analysis using MS Excel (refer Annex C: for compiled survey results).
6. Five NbS case studies were prepared using project information voluntarily supplied by survey participants.
7. A broad review of recent, open-source literature was also undertaken to:
    a. identify examples of NbS for coastal hazard management used in Queensland
    b. provide global insights on the effectiveness of NbS for coastal hazard management
    c. identify potential barriers and criteria to be considered when determining suitability of NbS at the site scale.

3 NbS Survey

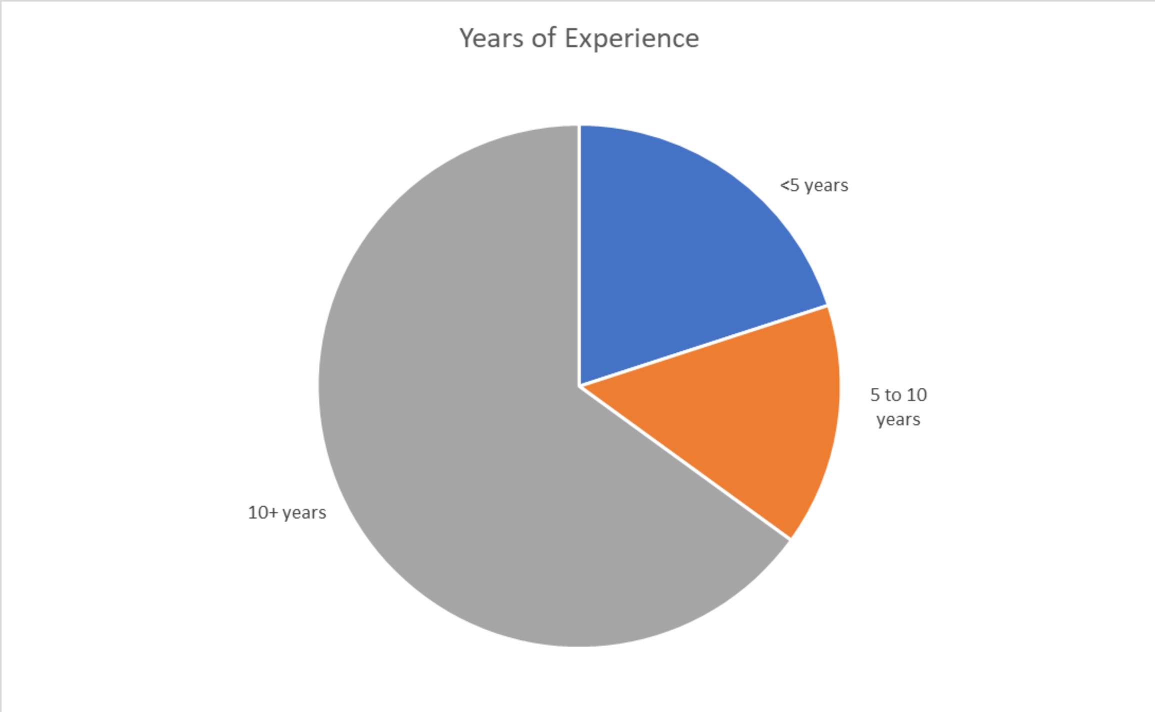
3.1 Survey results

This section provides the survey results as provided by respondents. Section 3.2 provides insights from the survey which are discussed in the context of the literature review in section 6.

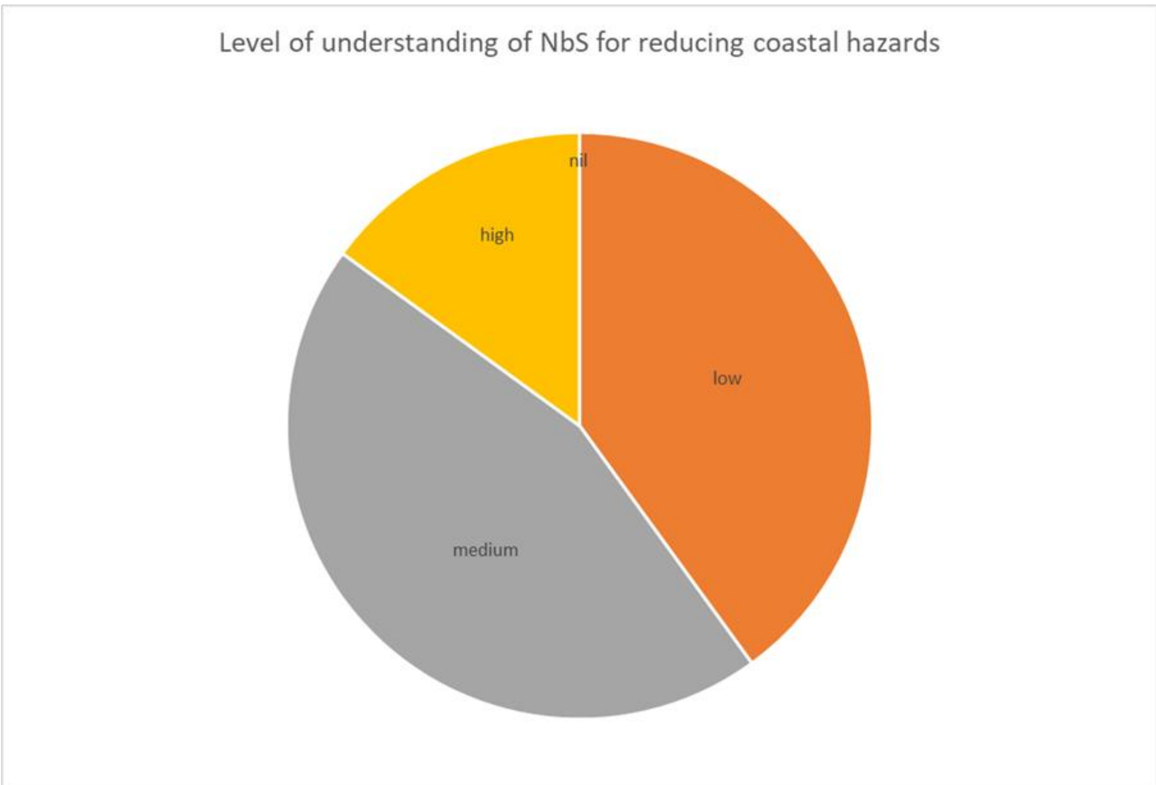
1. Survey respondents had the following role in coastal hazard management:



2. Survey respondents had the following level of experience:



3. Survey respondents considered their level of understanding of NbS for reducing coastal hazards as:



4. Organisations had used the following engineering solutions to address coastal hazards in the last 10 years:

Engineering Solution Used	not used	1-3 projects	>3 projects
sand replenishment	40%	15%	45%
groynes/training walls	55%	30%	15%
shoreline armouring with rock	35%	40%	25%
shoreline armouring with other materials	55%	20%	25%

5. Coastal ecosystems were ranked in the following order of importance for NbS in the local region:

- dune
- beach
- mangrove
- saltmarsh
- reef.

Restoration of coastal wetlands, riverbanks and rocky reefs were also identified as important for NbS in the local region by some respondents.

6. NbS to address coastal hazards were ranked in the following order of use, or planned use:

- minimal intervention (planning / ecosystem protection zones / behavioural and community-based marketing)
- extensive or intensive management (revegetation and management)
- highly intensive ecosystem management or creation including hybrid systems.

7. Potential challenges for coastal ecosystem NbS were ranked in the following order of importance (1 being the most important and 7 being the least important):

Potential challenges	beach restoration	dune restoration	saltmarsh restoration	mangrove restoration	reef restoration
technical reliability	2	4	3	4	5
lack of internal/external support	3	3	2	2	3
approvability	6	7	4	3	2
cost	1	1	1	1	1
timeframes	5	5	6	6	4
public perception	4	2	5	5	7
potential liability	7	6	7	7	6

Other responses received by respondents included:

- Beach restoration: decisions driven by public perception and/or ignorance; sourcing suitable type and increasing volume of sand; potential impact on wildlife, invertebrates and turtle nesting; development and hard assets; gaining approvals in fish habitat areas and marine protection zones.
- Dune restoration: persistent hard assets, modification and encroachment limiting feasibility in developed areas and limiting landward migration of beach-dune systems with sea level rise; ongoing encroachment; unlawful clearing to provide views; decisions driven by public perception or ignorance; fish habitat areas and marine protection zones
- saltmarsh restoration: responsibility (ownership /right to manage)
- mangrove restoration: suitable sites, responsibility (ownership /right to manage).

8. Monitoring and evaluation:

- 75% of respondents indicated NbS project outcomes were being monitored
- 15% of respondents indicated NbS project outcomes were not being monitored
- 10% of respondents indicated there were no applicable NbS projects.

9. The percentage of respondents who rated NbS effectiveness in terms of expected outcomes were as follows:

NbS Technique	Effectiveness in terms of expected outcomes					
	very good	**good**	**average**	**poor**	**very poor**	**not rated**
beach restoration	15%	20%	15%	15%		35%
dune restoration	5%	40%	25%	5%		25%
saltmarsh restoration		5%	10%	5%		80%
mangrove restoration		10%	10%	10%		70%
reef restoration	5%	5%	5%	10%		75%
NbS Effectiveness:	**5%**	**16%**	**13%**	**9%**		**57%**

Other responses received by respondents included: Hybrid methods including pile field method with revegetation was considered 'very good' for estuary restoration; and green seawalls were considered to be 'good' in terms of effectiveness and expected outcomes.

10. The percentage of respondents who rated NbS efficiency in terms of project timing and cost relative to more traditional engineering solutions were as follows:

NbS Technique	NbS efficiency relative to traditional engineering solutions					
	very good	**good**	**average**	**poor**	**very poor**	**not rated**
beach restoration	10%	15%	10%	20%		45%
dune restoration	25%	20%	5%	5%		45%
saltmarsh restoration	5%	5%	5%	5%		80%
mangrove restoration	5%	5%	10%	10%		70%
reef restoration	10%			10%		80%
NbS Efficiency:	**11%**	**9%**	**6%**	**10%**		**64%**

Other responses received by respondents included: Hybrid methods including pile field method with revegetation for estuary restoration was considered to have 'very good' efficiency and green seawalls were considered to be 'average' in terms of efficiency relative to more traditional engineering solutions.

11. NbS is delivered by the following organisations:

Responsible for NbS Delivery	NbS Technique				
	beach restoration	dune restoration	saltmarsh restoration	mangrove restoration	reef restoration
local government	16	16	5	7	
natural resource manager (NRM)	4	9	3	4	
local communities and traditional owners*	5	10	2	3	1
state government	1	2	1	4	
private	2	2	0	1	

***Traditional owners were considered to be part of the 'local community' for the survey purposes, however one survey respondent had separated these groups.**

Riverbank restoration was also provided as another NbS technique delivered by local government and NRMs.

3.2 Insights from the survey

The majority of survey respondents were coastal practitioners with more than 10 years' experience. Almost half of the surveyed respondents (35-55%) had not used engineering solutions to address coastal hazard risks in the last 10 years but remaining organisations had implemented (in order of use) shoreline armouring with rock, sand replenishment, groynes/training walls and shoreline armouring with other materials.

The majority of survey respondents considered themselves to have a moderate understanding of NbS for reducing coastal hazards. All respondents had some understanding of NbS for coastal hazards but 40% considered their level of understanding to be low.

Survey respondents considered the most important ecosystems for NbS to address local coastal hazards to be (in order of importance): dunes, beaches, mangroves, saltmarsh and reefs. Restoration of coastal wetlands, riverbanks and rocky reefs were also identified as important for managing coastal hazards.

NbS requiring minimal interventions, such as strategic planning and education, followed by extensive or intensive management (such as revegetation) were considered the most usable NbS techniques to address coastal hazard risks. Highly intensive ecosystem restoration and management, such as reef creation, was considered the least usable NbS management measure.

Cost was considered the most important challenge for NbS regardless of the coastal ecosystem type. Lack of internal and external support also rated highly as a potential barrier to NbS implementation, particularly for works involving estuarine wetlands. The reliability of beach and saltmarsh restoration, public perception around dune restoration, and approvability of mangrove and reef restoration were also identified as potential challenges.

Other potential barriers identified included:

- political pressure in decision making
- difficulties in sourcing materials, particularly sand
- potential impacts of NbS on existing biodiversity values in the coastal zone
- difficulties associated with working within protected reserves, such as fish habitat areas and marine protection zones
- limited feasibility for NbS given increasing coastal development and sea level rise
- community impacts on restoration projects, such as illegal clearing
- tenure and responsibility issues within marine and estuarine ecosystems.

The majority (75%) of NbS projects were being actively monitored and evaluated however only 43% of respondents reported on the effectiveness of NbS in terms of expected outcomes. The majority of project outcomes were considered to be 'good' to 'average' and no projects rated very poorly in terms of outcomes. Approximately 64% of respondents did not rate NbS project efficiency in terms of time and cost relative to more traditional engineering solutions, with fairly equal ranking for very good to poor efficiencies across reported NbS.

As expected, the majority of NbS projects are delivered by local government with other participants commonly including NRMs, local communities and Traditional Owners. State government and private organisations were not heavily involved in the delivery of local NbS projects.

3.3 Summary

In summary, the key issues emerging from the survey are:

- majority of coastal practitioners are highly experienced but understanding of NbS for coastal hazards among decision makers and the broader community may be low
- the greatest opportunities for NbS amongst respondents were considered to be
  - dune and beach NbS
  - strategic planning and education interventions
- cost is considered to be the most important challenge for NbS regardless of ecosystem type
- other barriers to NbS include:
  - perceived lack of support (from bureaucracy, politicians and/or the community)
  - political pressure in decision making
  - uncertainty and perception around NbS reliability, particularly beach, dune and saltmarsh restoration
  - complexities in marine restoration around approvals, tenure and permissibility
  - availability of materials, particularly sand for nourishment or dune management purposes
  - potential impacts of NbS on existing biodiversity values
  - limited feasibility for NbS given increasing coastal development and sea level rise
  - uncertainties around effectiveness of NbS and efficiencies relative to traditional engineering solutions
- delivering local NbS requires multiple stakeholders, particularly local government, NRMs, local communities and Traditional Owners.

4 Coastal NbS Projects in Queensland

The Queensland coast is highly varied in terms of population, land use, ecosystems and vulnerability to coastal hazards which are broadly grouped into the following:

- Gulf of Carpentaria coastline is sparsely populated with extensive estuarine low-lying areas vulnerable to increased frequency of extreme sea levels and storm tide inundation
- Torres Strait islands are low lying and island communities are extremely vulnerable to increased frequency of extreme sea levels and loss of land through permanent inundation
- Northern Queensland coast is characterised by low wave energy, however it can be severely eroded during cyclones and its low coastal dunes are very vulnerable to overtopping by storm tide inundation. Development density is varied, ranging from intensive urban development to small or isolated coastal communities
- Central Queensland has tide-dominated coasts with wide gently sloping intertidal flats. Dunes range from low to well-developed throughout the region, leading to localised vulnerability to erosion and storm tide inundation. Similar to northern Queensland, development density is varied, ranging from intensive urban development to small or isolated coastal communities
- Southern Queensland coast is characterised by sandy beaches with well-developed and in places high dune systems exposed to high-energy wave conditions. Increased coastal erosion poses significant threats to this highly developed coast with intensively used beaches.
- There are a range of potential NbS for managing coastal hazards in Queensland depending on local environmental context and hazard exposure (refer Figure 4.1). The following section provides examples of nature-based interventions being implemented in Queensland and highlights the breadth of coastal ecosystems that may play an important role in helping to manage local coastal hazards. A range of coastal NbS projects implemented in Queensland have been sourced from the online literature and Annex D: provides case studies derived from information provided by survey participants.

4.1 Strategic Planning Approaches

Local governments are responsible for developing and implementing coastal management plans operating within the State government’s regulatory and policy frameworks. Coastal hazard adaptation strategies (CHAS) are developed by councils to assess the local risk from coastal hazards under present and projected climate change conditions, propose adaptation measures to mitigate impacts and initiate implementation programs. The recent development of CHAS by local councils indicates that coastal adaptation for much of Queensland is still in the planning phase with potential for NbS projects to follow through the QCoast2100 2.0 Program.

The Redland City Council Draft CHAS is one of several that indicates a strong community preference for nature-based options as the primary/initial pathway for coastal hazard adaptation with over 70% of respondents from a local online survey having a preference for NbS. The CHAS outlines a range of preferred actions for coastal hazard adaptation. Actions to protect, maintain and enhance dunes and mangroves are considered critical for enhancing local coastal resilience. Whilst it was acknowledged there was not a strong economic case at present-day for investing in the majority of options, the economic case for investment strengthens by 2070 and 2100. It was recognised there is benefit in commencing NbS trials early to monitor effectiveness and update adaption approaches accordingly. Actions across capacity building, land use planning, and trials of nature-based options are the core focus for most localities within the local government area (LGA). A summary of priority strategic NbS actions to be completed within 5–10 years include:

- knowledge sharing, training and education on the role of coastal ecosystems in mitigating coastal hazards and NbS focusing on mangroves, dunes and living shorelines
- undertaking pilot NbS projects, including research opportunities, focusing on dunes, mangroves and living shorelines
- developing monitoring protocols to measure effectiveness of NbS actions.

1. **Minimal intervention**: land-use planning / designation of zones to protect and enhance coastal ecosystems (such as planning scheme provisions; installation of permanent barrier fencing, bollards, environment protection zones)

2. **Extensive or intensive management**: active restoration to enhance and/or expand coastal habitat:
    - dune planting (may include installation of temporary 'soft' structures such as barrier-fencing, brush matting)
    - saltmarsh planting (may include installation of temporary 'soft' structures such as barrier fencing, coir logs)
    - mangrove planting (may include installation of temporary 'soft' structures such as barrier fencing, coir logs)
    - coral restoration (e.g. coral gardening and transplantation, macroalgae removal)
    - indirect ecosystem enhancement (e.g. catchment-derived water quality improvements to improve growth of coastal corals)

3. **Highly intensive ecosystem management or creation including engineering approaches (hybrid solutions):**
    - beach nourishment
    - sand renourishment and dune planting
    - sand reprofiling and dune planting
    - removal of tidal barriers (such as seawalls; tidal gates) to promote saltmarsh and/or mangrove recruitment and planting
    - landform reprofiling to promote saltmarsh or mangrove recruitment and/or planting
    - installation of permanent engineering structures (such as permeable structures such as rock fillets or pile fields) to stabilise eroding banks or enhance intertidal habitat to promote mangrove recruitment and mangrove planting
    - installation of artificial reefs and seawalls (e.g. rock/concrete/geotextile/3D-printed) for substrate stabilisation and reef restoration

Figure 4.1 Examples of NbS for managing coastal hazards in Queensland

4.2 Ecosystem Restoration Approaches

The nature of coastal protection works is highly variable across the state and there is significant documentation available on traditional protective measures including development planning controls, sand nourishment, sea walls, groynes and artificial reefs. Evidence for NbS using other coastal ecosystem restoration measures is less well documented.

The following summary demonstrates the range of coastal ecosystem restoration approaches used in the state. Overall, there is limited monitoring and reporting data available on the environmental effectiveness and cost efficiencies of NbS approaches for coastal resilience and a lack of comprehensive cost data for projects. Most projects only provide a short-term snapshot of technique and performance.

Beaches

Beach nourishment, from small to large scale, is widespread along the Queensland coast. Sunshine Coast Council has recently undertaken the Maroochy Groyne Field Renewal Project to replace the existing rock groyne with geotextile bags[2]. Nourishment is also widely recognised as an essential element of the management of Gold Coast beaches[3]. Commencing in the early 1970's, the region is now dependent on ongoing beach nourishment to maintain all-tide beach width which is often combined with structures, such as groynes. Many complementary techniques have also been implemented on the Gold Coast to maximize nourishment efficiency, such as artificial reefs.

Nearshore artificial reefs can be designed to enhance beach resilience against storm erosion whilst providing recreational benefits and creating marine habitat. The Palm Beach Artificial Reef was delivered as part of the Gold Coast City's Ocean Beaches Strategy 2013-2023 to (after Elliott-Perkins, 2020):

- reduce vulnerability of the beach and beachfront development to storm damage
- protect and enhance beach amenity
- provide a sustainable, cost effective and integrated solution
- avoid or mitigate adverse environmental social impacts of erosion.

Eighteen management options were assessed for cost, coastal protection benefits, and impacts on coastal processes, ecology, surfing, and beach amenity. The City adopted a 'design with nature approach' involving sand nourishment and construction of an artificial reef using 60,000 tonnes of rock boulders approximately 270 metres offshore.

Post-construction monitoring and engineering certification was finalised in 2019 and regular monitoring is undertaken to assess structural integrity; ongoing benefits including coastal protection, recreational amenity, user safety, whole of-life costs and ecology; and beach width and volume (Elliott-Perkins, 2020). It is reported the $18.2 million project has delivered and retained approximately 550,000 cubic metres of additional sand to the city's coastline since completion[4]. Monitoring also indicates positive returns in terms of coastal protection, surfing outcomes, with an increase in marine flora and fauna (Elliott-Perkins, 2020). Monitoring data will be used to inform the design of any future artificial reefs.

Whitsunday Regional Council assessed a range of options to manage the coastal erosion risk associated with the dynamic nature of Sandhills Creek Estuary. Though it was acknowledged the preferred option may need to be repeated over time, particularly following extreme events, channel

[2] See: https://www.sunshinecoast.qld.gov.au/Council/Planning-and-Projects/Infrastructure-Projects/Maroochy-Groyne-Field-Community-Consultation
[3] See https://www.goldcoast.qld.gov.au/Council-region/About-our-city/Environment-sustainability/Protecting-our-environment/Coastal-management/Beach-nourishment
[4] https://www.goldcoast.qld.gov.au/Council-region/City-news/Palm-Beach-shoreline-bolstered-by-artificial-reef-23-September-2021

relocation was the adopted approach as it replicated natural coastal processes of the area (see Annex D: case study 1).

Dunes

NbS to enhance dune resilience have been implemented in Queensland for several decades and a series of Coastal Dune Management technical guidelines were also available from the former Queensland Beach Protection Authority. Coastal dune planning and rehabilitation continue to be widespread along the Queensland coast from small-scale local projects involving community volunteers to strategic approaches addressing entire council coastlines.

Based on the findings of their local CHAS and community and stakeholder consultation, Burdekin Shire Council have adopted a 10-year strategy to improve dune resilience to coastal hazards. The strategy focuses on the principles of nature-based actions, education and working with the community to protect and enhance coastal dunes (see Annex D: case study 2).

The Mackay Coasts and Communities Program was also developed to provide a strategic and coordinated approach to manage the region's coastal zone. Twenty-one local beach management plans have been developed under the scheme to date and focus on improving and maintaining coastal vegetation (see Annex D: case study 3).

Survey respondents considered dunes and beaches to be the most important ecosystems for NbS to address local coastal hazards. Some project details on dune and beach restoration projects were also provided in the survey, highlighting the importance of these sandy ecosystems in coastal hazard management in Queensland. Key details provided can be summarised as follows:

- Capricorn: more than 100ha of passive dune restoration is being undertaken to protect public property from coastal hazards. With a two-year timeframe at a cost of >$100,000, the project required: consultation with local government, NRM and Traditional Owners; and local, state and federal approvals. The project received state and federal funding. Major challenges to the project area conflicting dune uses and damage by recreational vehicles.
- Mackay[5]: less than 10ha of dune restoration involving geobag seawall construction and sand nourishment is being undertaken to protect private property from coastal hazards following cyclone damage. With a two-year timeframe at a cost of >$500,000, the project required: consultation with local, state and federal government; and state approvals. The project received state and federal funding.
- Sunshine Coast: less than 10ha of beach and dune restoration involving geobag seawall and sand nourishment is being undertaken to protect public property from coastal hazards. Works are likely to be ongoing at a cost of >$500,000. The project required: consultation with local, state and federal government, the local community and research organisations; and state and federal approvals. The project was funded by local government. The major project challenge was sand availability.
- Cassowary Coast: 10-50ha of beach and dune restoration is being undertaken to protect private and public property from coastal hazards. With a two-year timeframe at a cost of >$100,000, the project required: consultation with local and state government and state approvals. The project is funded by local, state and federal government. The major project challenge is perception that sand nourishment is ineffective.

[5] https://www.mackay.qld.gov.au/__data/assets/pdf_file/0012/226011/CB1007_Summary_and_highlights_31MAY2018.pdf

Mangroves

Examples of mangrove restoration in Queensland typically occur to stabilise eroding riverbanks in upper estuaries and to improve water quality, particularly within the Great Barrier Reef catchment. There are fewer documented mangrove restoration projects along the coastal fringe for the purposes of coastal hazard management. Despite this lack of readily available data, mangrove restoration projects and research can provide valuable insights for best-practice techniques, particularly for site stabilisation and sedimentation which can be key limiting factors for mangrove recovery in erosion prone sites.

The Logan River Parklands Bank Stabilisation project was undertaken by Logan City Council in partnership with various stakeholders and the community (see Annex D: case study 4). Undertaken over 2 years with an approximate project cost of $250,000, log pile fields were installed to stabilise 250m of heavily eroding banks and to promote mangrove recruitment. Root balls were also incorporated into the design to improve fish habitat. Initial inspections by council show sedimentation and some mangrove recruitment. Based on monitoring outcomes the project may be upscaled to other locations along the river.

The City of Gold Coast used a similar technique using a combination of hardwood logs with root balls, hardwood marine piles and riparian revegetation to successfully stabilise 450m of foreshore along the Coomera River upper estuary[6]. A five-year monitoring and evaluation program is being undertaken and results in the 3rd year show the logs are promoting sedimentation with a 750% increase of mangrove seedlings.

The Gidarjil Caring for Country Program TropWATER Mangrove Research Hub Partnership[7] is undertaking a range of mangrove rehabilitation projects on the Burnett and Kolan Rivers. Project objectives include capacity building for Gidarjil Indigenous Rangers for monitoring, managing and rehabilitating estuarine wetland sea country within southern GBR. The projects also use innovative methodologies and research including oyster reef regeneration.

The TS Onslow shoreline project at Golden Beach, involved novel techniques to restore a highly modified shoreline for mangrove restoration. Although relatively small in scale, the project has shown signs of resilience to very high tides and severe storms in an urbanised environment (see Annex D: case study 5).

Seagrass

Whilst seagrasses have the potential to provide protection against flooding and erosion through wave attenuation, sediment capture and soil stabilisation, there are few documented cases where restoration of these ecosystems has been undertaken to specifically address coastal hazards. There is also limited local information on the capacity for seagrass to provide coastal protection under extreme conditions. Seagrasses in Queensland have shown high capacity to recover naturally following large disturbance events (cited in Tan et.al., 2020). However, the relative frequency of La Niña climate events and severe storms have led to some cases where seagrass recovery without intervention is considered unlikely and these conditions are predicted to become more common with climate change (cited in Tan et.al., 2020).

[6] See https://www.goldcoast.qld.gov.au/Services/Projects-works/Damian-Leeding-Memorial-Park-Foreshore-stabilisation-project
[7] https://nesptropical.edu.au/wp-content/uploads/2019/06/NESP-TWQ-Project-2.3.4-Final-Report-Vol-1.pdf

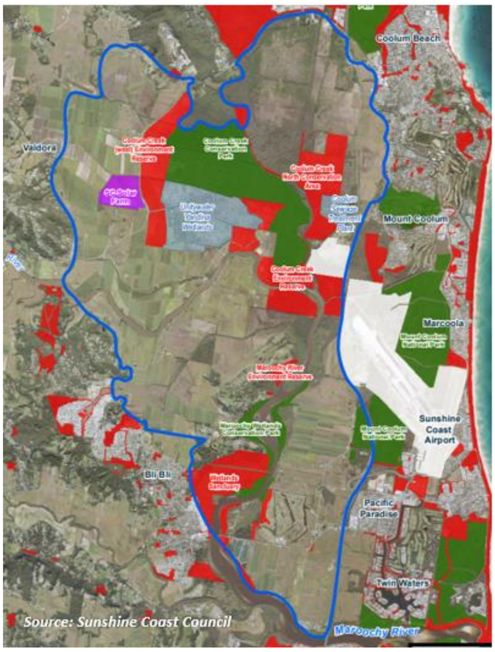
Seagrass restoration is often perceived as expensive with a high risk of failure, however, there are a variety of tools and techniques that have recently been developed to help improve the efficiency, cost effectiveness, and scalability of restoration programs (Tan et.al., 2020). Tan et.al. (2020) provides a review of seagrass restoration successes in Australia, with a focus on emerging techniques, key considerations, and highlights the benefits of increased collaboration, Traditional Owner and stakeholder engagement.

In central Queensland, the construction of a "living seawall" within the Port of Gladstone using dredge spoils to create seagrass and mangrove habitat has recently been assessed. The project has an ecosystem conservation goal with no coastal protection requirement. The case study indicates strong tidal flows at the Port argue for the use of rock groynes to ensure that placed sediments have some erosion resistance for ecosystem establishment (Aiken et.al.,2021). In all but protected coastlines, some matrix of hard structures may be required, at least transiently, to guarantee consolidation of the substrate for seagrass ecosystem (Aiken et.al.,2021).

Saltmarsh and Coastal Wetlands

Saltmarsh and coastal wetland restoration in Qld is typically undertaken to offset impacts associated with land use and coastal development. One of the main causes of saltmarsh loss in the Great Barrier Reef catchment has been the development of ponded pasture and there is increasing focus on restoring some of these areas through the reinstatement of tidal flow to provide fisheries and environmental benefits, such as blue carbon and nutrient storage. There are few documented cases in Queensland where saltmarsh and coastal wetland restoration has been undertaken to specifically address coastal hazards.

The Blue Heart project is a partnership between Sunshine Coast Council, Queensland Government and Unitywater to manage and restore 5,000 hectares of degraded coastal lands on the Maroochy River floodplain for flood hazard management and climate change adaptation[8].



Comprising predominantly agricultural land, the Blue Heart project area has been impacted by increasing tidal inundation and is expected to continue transitioning due to projected sea level rise. The project is enabling the transition of the area to an estuarine wetland complex. Whilst the focus is managing flooding and sea level rise, the project is assisting landholders with the transition, whilst enhancing biodiversity, providing recreation, ecotourism and cultural opportunities, and exploring funding from emerging industries, including blue carbon and nutrient offsets.

Shellfish Reef

Shellfish reefs were once common throughout south-east Qld estuaries but have been severely depleted and degraded. Evidence from southern Australia and internationally show that restoring these ecosystems can enhance biodiversity values, improve water quality and shoreline protection and provide social opportunities. The Nature Conservancy, in partnership with Noosa Shire Council, Traditional Owners and the local community, are working together to restore oyster ecosystems to the Noosa River estuary (see Annex D:case study 6).

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[8] https://www.sunshinecoast.qld.gov.au/blueheart

Coral Reef

Coral restoration research, funding and projects have been rapidly growing in Australia since 2017 with projects focusing more on practical, scalable solutions which enhance coral resilience to a changing climate (McLeod, et al. 2020). Restoration projects are typically long-term, require a multi-disciplinary approach and best applied at the local reef scale. Various techniques include coral gardening, substrate stabilisation, coral repositioning, macroalgae removal and coral larval propagation. The Reef Restoration and Adaptation Program (RRAP) has produced a suite of management interventions and best practice and scalable coral restoration techniques for the GBR (see: https://gbrrestoration.org/resources/coral-restoration-toolkit/.)

Given the vulnerability of coral reefs to changing climate and habitat conditions and the complexities of coral reef restoration, the feasibility of upscaling reef restoration techniques for coastal hazard protection is potentially low. From a local government perspective, the LGAQ Reef Councils' Rescue Plan[9] was developed with the support of the Queensland Government and the Great Barrier Reef Marine Park Authority to implement initiatives to improve water quality to the Great Barrier Reef. Reef councils will develop, pilot and refine initiatives to improve runoff and sewerage treatment plant outflows to deliver better water quality to the Reef and establish effective management measures across councils within the GBR catchment. Such initiatives could indirectly improve coral reef resilience to climate change and ongoing pressures.

Littoral rainforest

Littoral rainforests are federally threatened communities that occur on the coastal fringe of eastern Australia. As well as providing habitat for threatened taxa and recreation and tourism opportunities these communities play a key role in protecting landward areas from the effects of storm surge and sea level rise.

CSIRO[10] in partnership with local organisations are undertaking detailed studies to map littoral rainforest in the Wet Tropics bioregion by their risk or frequency of inundation. 'Leading-edge' rainforest is frequently exposed to inundation and can be critical in protecting coastal assets from the effects of storm-surge, sea-level rise and extreme weather events. The project recommends prioritising management in areas where leading-edge rainforest protects communities and infrastructure. Management actions include assisted ecosystem recovery following inundation and planning mechanisms for landward retreat where feasible.

There is a potential opportunity for local governments to adopt planning scheme overlays and regulations on Matters of Local Environmental Significance (MLES) that protect locally significant ecosystems important for coastal resilience and adaptation, such as littoral rainforest, but also mangroves, saltmarsh, dune vegetation, coastal wetlands and their buffers.

Enhancing Hard Engineering

Whilst traditional hard engineering approaches, such as seawalls, may be the preferred option to address coastal hazards because of the immediacy and level of risk to local coastal assets, there are a variety of techniques available that can increase the environmental and habitat values of existing and new seawalls. The NSW Catchment Management Authority and Office of Environment and Heritage (2012)[11] developed a guideline on techniques, site constraints and considerations for improving the environmental value of seawalls in estuaries (refer Figure 4.2). While the guidelines acknowledge that

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[9] https://www.lgaq.asn.au/downloads/file/197/reef-councils-rescue-plan-cleaner-water-for-the-reef

[10] Factsheet and full report, Mapping to underpin management of tropical littoral rainforest, are available from: www.nespnorthern.edu.au/projects/nesp/mapping-to-underpin-managementof-tropical-littoral-rainforest/

[11] NSW Catchment Management Authority and Office of Environment and Heritage (2012). Environmentally Friendly Seawalls. A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries.

individually some of the techniques may have limited effects, they can have considerable cumulative environmental impact if applied at a broader scale. There are also potential opportunities to incorporate ecological engineering, such as building breakwaters to mimic shallow embayments to enhance the settlement of seagrass.

At the local scale, the Cassowary Coast Council in partnership with research organisations and engineering consultants are currently undertaking a research project within the Great Barrier Reef Marine Park that incorporates 'fish-friendly' design features into rock revetment upgrades (see Annex D: case study 7).

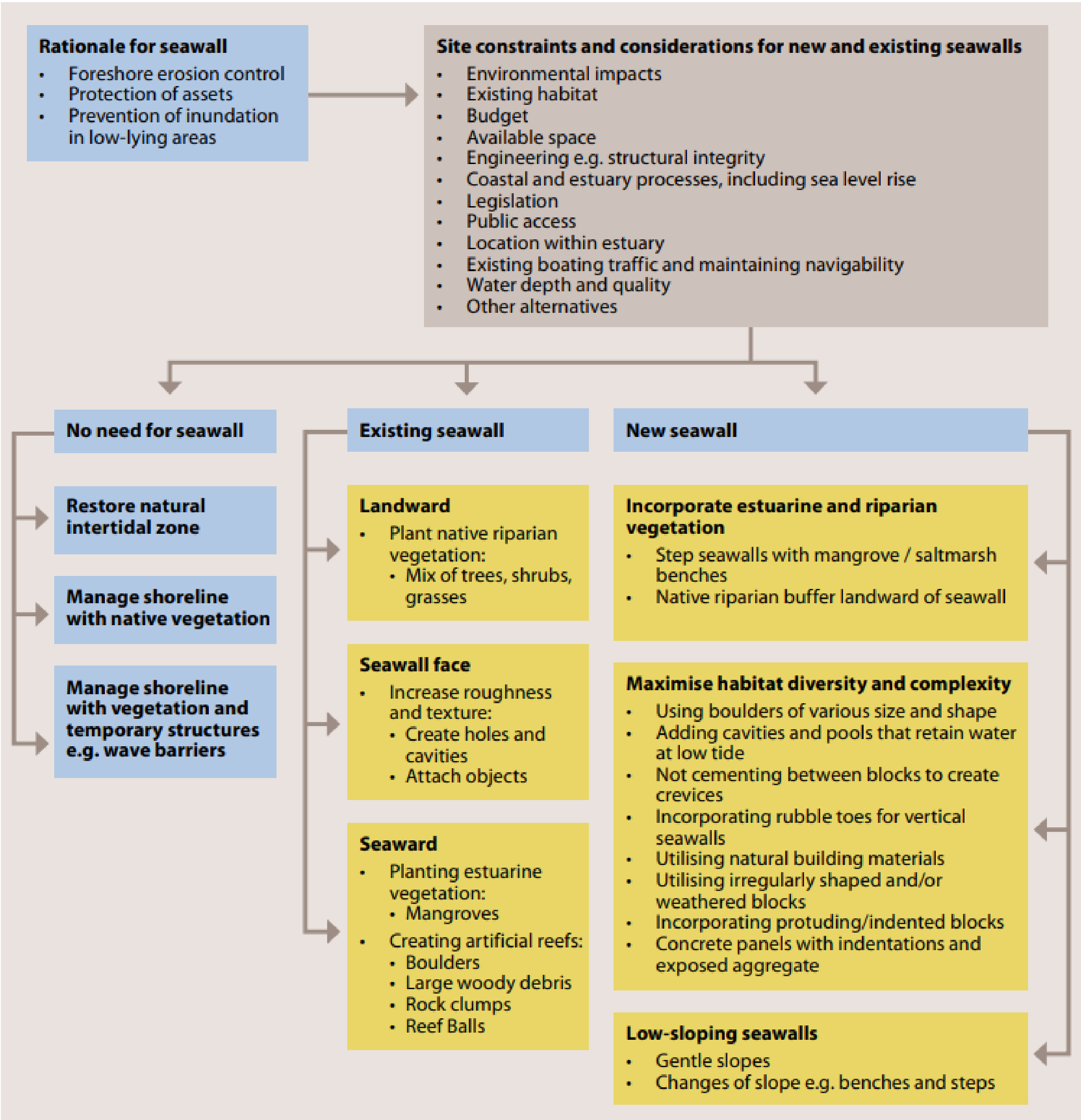

Figure 4.2 Summary guide for building new seawalls or modifying existing seawalls (NSW Catchment Management Authority and Office of Environment and Heritage, 2012)

5 Insights from the Literature

There are a growing number of analyses and reviews on the effectiveness of restoring and incorporating coastal ecosystems to improve resilience to coastal hazards. Many of the global reviews focus on estuarine and sub-tidal ecosystems, such as, mangroves, saltmarsh, coral reefs and seagrass/kelp beds, suited for low to moderate energy environments. Beach and dune restoration projects are not consistently considered in reviews of nature-based approaches to mitigating risks from coastal hazards. Narayan et al. (2016) suggests that inclusion of dune and beach habitats would vastly improve the richness of existing global nature-based defence databases. In addition, restoring coastal wetlands to help manage flooding and sea level rise is not consistently considered a NbS for coastal hazard management in the global literature.

The purpose of this section is not to provide a comprehensive review on the published data but to provide a summary of the key issues being assessed.

5.1 Effectiveness

Natural coastal ecosystems have adapted to the highly dynamic coastal zone, influence tidal dynamics and coastal sediment processes and can be adaptable to the changing climate. Morris et. al. (2021) provides a current overview of the physical mechanisms by which most coastal ecosystems in Australia can help mitigate coastal hazards.

Narayan et. al. (2016) analysed field data from 69 global studies on the effectiveness of coastal habitats for wave height reduction. On average, they were shown to reduce wave heights between 35% and 71%, depending on the site and ecosystem type, with coral reefs reducing wave heights by 70%, saltmarsh by 72%, mangroves by 31% and seagrass/kelp beds by 36%.

Chausson et. al., (2020) provides a global literature review on the effectiveness of NbS for addressing the impacts of climate change. Only 13% of the studies reviewed included coastal ecosystems (coral reefs, mangroves, seagrass, saltmarsh, and other coastal ecosystems) and only 39 of the studies (10%) focused on coastal hazards. Although evidence from natural coastal ecosystems shows them to be highly effective at reducing wave heights and energy, the review found few studies investigated the effect of coastal interventions and noted that effectiveness is strongly influenced by site features, such as geomorphology.

Smith et. al. (2020) compiled a database of 46 papers on global living shorelines and while coastal protection was well studied, only 20% of the studies directly compared living shorelines to hardened shorelines. Smith et. al. (2020) also indicated the relatively low level of open data available to coastal managers and the community was one of the biggest challenges for translating NbS science to practice.

If NbS are to be promoted as an alternative, or in parallel, to traditional engineering approaches, more readily accessible data demonstrating how they stabilise sediments, attenuate waves, and protect coastal assets will be required. Any NbS needs to be in response to a well-considered understanding of the hazard mechanisms at a particular location.

5.2 Restoration success

Bayraktarov et. al. (2016) analysed over 200 global studies and over 900 observations on restoration projects for coral reefs, seagrass, mangroves, saltmarshes, and oyster reefs. The success of restoration was reported to be highest for saltmarshes (65%) and coral reefs (65%) and lowest for seagrass (38.0%). However, the study also noted that reported success rates could be biased towards publishing successes rather than failures and as a result many lessons-learned are also likely to go undocumented. Whilst causes of restoration failure were likely to be underreported, unsuccessful restoration was most likely attributable to inappropriate site selection in terms of unsuitable hydrological, substrate and coastal energy conditions for the target ecosystem, as well as stochastic events or human disturbance.

5.3 Monitoring and reporting

Narayan et al. (2016) showed that data from post-project monitoring of the success or failure of restoration projects was not easily available. Bayraktarov et. al., (2016) showed that monitoring was typically only undertaken within the first one to two years after restoration which corresponded to the lifetime of development projects, research grants, or academic theses. The outcome of restoration, success or failure, was also directly related to the period of observation. It was noted that coastal ecosystems can take several years to decades to establish and longer-term monitoring of 15–20 years was considered more appropriate. The majority of studies reviewed also measured success in terms of simple metrics, such as biomass or coverage, and rarely focused on the recovery of other ecosystem functions or services, such as coastal protection.

A global review by Smith et. al. (2020) also indicated that the majority of living shoreline projects reviewed were less than 5 years old and only provided a short-term snapshot of performance. As many ecosystem services require time to fully develop after restoration, longer-term monitoring data was considered critical to fully evaluate the functionality of living shorelines, particularly in the context of rising sea levels.

It is widely reported that NbS require less maintenance compared with traditional structures given their adaptability. Long-term monitoring data would be valuable to determine actual maintenance requirements of NbS approaches, such as substrate replenishment and management of other ecosystem threats, such as pests, diseases and disturbance.

5.4 Cost

Restoration costs are highly site-specific depending on local economies, environmental context, hazard exposure and level of community and research involvement.

The Smith et. al. (2020) global review showed that research on the relative costs of different living shoreline interventions was extremely limited. Bayraktarov et. al., (2016) showed the median reported costs for marine coastal restoration projects were around US$80,000/ha (2010). However, the real total costs (median) were likely to be two to four times higher if both capital and operating costs were included, increasing median costs to US$150 000–400 000/ha (2010). As cost data was not always comprehensively reported, it was not possible to breakdown costs into project components such as planning, purchasing, land acquisition, construction, financing, maintenance, monitoring, and equipment repair/replacement.

The studies reviewed also showed coral reefs and seagrass were among the most expensive ecosystems to restore and were also focused on small-scale, experimental restoration research. Mangrove restoration projects were the largest (up to 120 000 ha) and least expensive per hectare, but not necessarily the most successful. Mangroves were considered the least expensive coastal ecosystem to restore due to the high numbers of community or volunteer-based projects, the availability of mangrove propagules and relative ease of access to restoration sites compared with sub-tidal communities.

Narayan et al. (2016) show that unit restoration costs were lowest for coastal marshes and mangroves, and submerged breakwaters provided by coral and oyster reefs showed higher and more variable costs for the same level of protection. While accurate estimates of NbS costs require detailed information on structure profile, material and labour costs, etc., it was found that water depth is often a critical driver of construction costs and a major influence on cost effectiveness.

Carley et. al. (2017) provides an approximate rate of $10-20 per m^3 for beach nourishment in Australia. Costs are highly dependent on local site factors, particularly project area, degree of site exposure, bathymetry, nourishment volume and technique, distance between sand source and receiving area, type of recharge material, requirement for infrastructure to help retain sand (such as groynes) and the need for ongoing nourishment.

5.5 Cost-benefit

Cost-benefit analyses of NbS for coastal protection can be complex, with difficulties associated with measuring success, long timeframes, limited resources for monitoring and evaluation, and complexities in valuing non-market ecosystem services.

Reguero et al. (2018) compared the cost effectiveness of nature-based and traditional solutions in the Gulf Coast of the US. The results showed that NbS could be among the most cost-effective options but was influenced by location and local site conditions with costs varying significantly where land acquisition and approvals were required. All adaptation measures become more cost-effective over time. The study did not account for the potential adaptability of NbS with changing environmental conditions, such as sea level rise, which could add to their cost effectiveness relative to built infrastructure. In addition, the study did not account for other ecosystem services provided by NbS, such as tourism and recreational services.

Cost-benefit in Queensland will be highly site-specific depending on local economies and the assets at risk. For example, Raybould et al. (2011) estimated the economic value of Gold Coast beaches associated with tourism as high as $300 million per year, with Gold Coast City Council currently spending $30M on beach management and maintenance with additional funds for specific projects[12].

5.6 Site suitability

Whilst it is generally recognised natural coastal ecosystems have the potential to be effective in reducing coastal hazards, whether NbS are appropriate for a site will depend on local environmental context and hazard exposure. NbS typically require long timeframes to establish (in the order of years to decades) and, depending on the ecosystem type, can require large areas of habitat from the coastal fringe to shallow subtidal zones. Landward buffers to allow for ecosystem adaptation to sea level rise may also be required. Coastal assets that are exposed to more imminent and high-risk coastal hazards may also have limited coastal habitat restoration potential and may not be able to accommodate some NbS. Any NbS needs to be in response to a well-considered understanding of the hazard mechanisms at a particular location.

[12] https://apo.org.au/sites/default/files/resource-files/2015-12/apo-nid63213.pdf
https://www.goldcoast.qld.gov.au/files/sharedassets/public/pdfs/brochures-amp-factsheets/city-operational-plan-2021-22.pdf

6 Summary for Decision Makers

This section outlines the key issues arising from the survey and literature review. A summary of key factors that should be considered at the local scale when assessing coastal NbS are provided including approval considerations. Recommendations to improve collective understanding on NbS for coastal hazard management in Queensland are also provided.

6.1 Key Issues

The key issues emerging from the current survey of Queensland local governments are:

- the overall level of understanding of NbS applying to coastal hazard management is low
- cost is considered to be the most important challenge of NbS implementation
- there is uncertainty around NbS effectiveness and efficiencies compared to more traditional approaches
- there is a perception that coastal development and sea level rise limit the opportunities for coastal NbS implementation
- dune and beach ecosystems are considered to provide the greatest opportunities for NbS by local coastal managers
- complex approvals and tenure issues potentially limit opportunities for local governments to implement NbS in marine environments
- strategic planning and education interventions to retain and enhance existing assets are considered to provide the greatest opportunities for local governments, rather than highly intensive ecosystem creation.

The key issues emerging from the literature on coastal NbS are:

- few studies directly compare the effectiveness of coastal NbS against hard engineering solutions
- overall there is a low level of open data available to coastal managers on how NbS can stabilise sediments, attenuate waves, and protect coastal assets
- unsuccessful examples of NbS implementation are often attributable to unsuitable hydrological, substrate and coastal energy conditions for the target ecosystem
- monitoring data is not always reported, is typically short-term (1-2 years) and does not capture maintenance requirements or measure coastal protection effectiveness
- coastal ecosystems can take several years to decades to establish and long-term monitoring is typically required
- restoration costs and cost-benefit are highly site-specific but NbS typically become more cost-effective over time
- it can be difficult to account for other ecosystem services beyond coastal protection which are highly site-specific and can improve NbS cost-benefit
- there is an overall lack of dune, beach and coastal wetland NbS data in the global nature-based defence database.

Summary of Key Issues:

- some uncertainty around NbS beyond beach and dune ecosystems
- overall lack of precedence and open project data
- insufficient project resources allocated to long-term monitoring
- monitoring may not focus on NbS contribution to coastal resilience
- cost-benefit highly site-specific depending on level of risk and co-benefits, which are not always measured
- greatest coastal hazard risk can coincide with lowest availability for ecosystem restoration. Potential opportunities to enhance environmental value of hard engineering solutions
- complex approval process and reliance on technical expertise may reduce appeal of NbS in marine environment
- jurisdictional issues may reduce NbS opportunities in the marine environment for local governments unless significant benefits to local communities

6.2 Site Factors to be Considered

Determining the suitability of coastal NbS must involve assessments at the site scale and must consider the details of local coastal processes and environmental conditions. NbS cost and cost-benefit will also be highly site-specific depending on the coastal hazards and assets at risk, local economies, availability of funding and resources, and the value of other local ecosystem services beyond coastal protection.

A range of criteria will need to be considered when determining the feasibility of NbS for coastal hazard protection, including:

- understanding of the coastal hazard mechanisms at a particular location
- coastal ecosystem function and the physical and ecological habitat requirements of the target ecosystem, including area required for adaptation and recommended buffers
- ecosystem restoration techniques include soft and hard engineering approaches that may be necessary to provide physical habitat requirements and support enduring coastal protection
- realistic timeframes for restoration outcomes (likely to be in the order of years depending on ecosystem type) need to be evaluated against the imminence of the coastal hazard risk
- identification of potential threats and stressors, such as physical damage, pests, poor water quality, sea level rise, that may negatively impact on ecosystems being restored, affect project outcomes, and may incur ongoing maintenance costs
- the range of criteria to measure and monitor the success of the NbS project, including environmental (geomorphological and biological features) and social benefits (such as tourism and job opportunities)
- indicative costs and timeframes for all project stages including monitoring and maintenance
- identification of stakeholders likely to be required in the decision-making process and project implementation including, local government, Traditional Owners, local community, subject matter experts (natural resource managers, ecologists, engineers, planners), NRMs, non-governmental organisations and state/federal government.

  Traditional hard engineering approaches, such as seawalls, may be the preferred option to address coastal hazards because of the immediacy and level of risk and/or the lack of space to accommodate target ecosystems. In these situations, consideration could also be given to incorporate techniques that can increase the habitat value of existing and new hard engineering solutions.

Critical Site Factors to Consider:

- coastal hazard mechanisms
- ecosystem requirements
- need for engineering interventions to support ecosystem and provide coastal protection
- restoration timeframes against changing coastal hazard risk
- local threats and stressors and requirements for project maintenance
- long-term monitoring requirements, including, coastal resilience
- costs for all project stages, including, monitoring and maintenance
- stakeholders and availability of local volunteers
- opportunities to enhance hard engineering methods

6.3 Potential Barriers and Key Considerations

Although the details around coastal NbS projects will be highly site-specific Figure 6.1 summarises the key criteria that generally need to be considered when assessing NbS at the site scale.

There is a general lack of project details available on nature-based techniques employed (successes and failures), monitoring undertaken, approval pathways, indicative costs and timeframes and their effectiveness for improving coastal resilience. This is a common issue across NbS projects globally and more readily accessible data on local projects could assist in the decision-making process particularly around effectiveness and cost-benefit of NbS against traditional methods.

There are strong provisions and local precedence for dune and beach NbS because of their long history of use in Queensland. Tools available include Coastal Dune Management technical notes and the South East Queensland Ecological Restoration Framework Manual. The Reef Restoration and Adaptation Program has also produced a suite of best practice and scalable coral restoration techniques. Guidelines for other Queensland coastal ecosystem nature-based options, such as estuarine wetland restoration, could be beneficial. The NSW government has also developed a guide for improving the environmental value of seawalls and a manual of coastal dune management and rehabilitation techniques.

There are a number of state and federal initiatives to rehabilitate coastal habitats in Queensland through programmes such as the Indigenous Land and Sea Ranger program, National Landcare Program, Riparian and Coastal Recovery Program, Reef Assist Program and the Land Restoration Fund. Ten coastal natural resource management (NRM) bodies also operate in Queensland. Whilst coastal projects delivered through these programs are likely to provide valuable insights on ecosystem restoration outcomes, particularly biodiversity and water quality benefits, they may not necessarily provide data on their effectiveness for improving coastal resilience. Methods and guidelines to measure and evaluate ecosystem effectiveness for coastal protection are required. The Coastal Observation Program – Engineering (COPE) established by the Beach Protection Authority conducted a volunteer program from 1971 to the 1990's to measure basic local coastal processes data across 60 sites in

Queensland[13]. Similar "citizen science" programs could be established to assist with the long-term monitoring requirements of coastal NbS projects.

Cost is considered a significant challenge for NbS. Local council coastal hazard management funding is likely to target high-risk areas in developed or high-use coastal zones where assets are most at risk. Beach nourishment is highly reliant on cost effective, accessible, inactive sand sources. Restoration of mangroves, saltmarsh, reefs and seagrass would be better suited to low to moderate energy locations, such as estuaries and more sheltered environments, and may not be the highest priority for local council coastal hazard management. Restoration of these ecosystems may be more likely associated with projects focusing on biodiversity, fisheries, water quality and carbon offset outcomes rather than coastal hazard resilience. An exception is restoration of coastal wetlands for flood hazard management and climate change adaptation.

Limited council budgets are also unlikely to be used to fund pilot or research projects on small-scale NbS applications that may not offer broadscale coastal protection, such as reef restoration, unless there are significant co-benefits such as tourism opportunities and returns. More comprehensive information on funding opportunities and synergies with other coastal management and investment programs, such as environmental, carbon, blue carbon and nutrient offsets, may be useful to promote NbS for coastal resilience. More open project data and analyses of NbS that incorporate market and non-market benefits in comparison to traditional approaches would also be useful to provide a business case for the use of NbS interventions where suitable.

Potential Barriers

- Lack of precedence around effectiveness to improve coastal resilience
- Lack of NbS cost-benefit data against traditional approaches
- Lack of supporting information on estuarine wetland restoration
- Limited budgets unlikely to fund pilot projects with limited capacity for upscaling or delivery of significant co-benefits

6.4 Approval Considerations

Regulation and management of the coastal zone is often complex and involves multiple stakeholders but there are often additional complexities in estuarine and marine restoration around approvals, tenure and permissibility. Approval pathways may be more straightforward for NbS approaches to coastal hazard mitigation which are supported by environmental guidelines and engineering standards and may assist in decision-making and project planning.

Depending on the nature of activities, NbS projects may trigger different approval requirements due to their interaction with the coastal and marine environment. In particular, works may trigger one or more of the following:

- Development Permit for Tidal Works – this applies for any activities involving construction of a structure within the tidal environment or anticipated to be subject to tidal influences from time to time (e.g., as a result of shoreline erosion). Examples include structures designed to create a more sheltered wave environment to promote rehabilitation, and the construction of habitat features for fisheries values.

[13] https://www.griffith.edu.au/__data/assets/pdf_file/0021/213366/Coastal-Monitoring.pdf

- Development Permit for Works on State Coastal Land – this applies to activities that involve interfering with or changing the morphology of the coastal environment, such as works to build or remove dunes.
  - Allocation of Quarry Material – related to the above, this approval is required for works that bring material from below the high-water mark onshore, such as beach scraping and reshaping of dunes using material that is otherwise in the tidal zone.
- Development Permit For Marine Plant Disturbance – this applies to activities that require the removal or disturbance of marine plant communities, including the collection and movement of dead trees. Marine plants are typically defined as those that are below highest astronomical tide (HAT) and includes species such as mangroves, melaleucas and casuarinas close to tidal influence and saltmarsh but typically does not include dune vegetation.
- Development Permit for Filling and Excavation – this applies to activities involving the movement of material, including bringing in additional fill, in the coastal environment above high water (works below high water are covered by Development Permit for Works on State Coastal Land).
- Marine Park Permit – this applies to works within a marine park, noting that the boundaries for state marine parks (e.g., Great Barrier Reef Coast Marine Park) extend to the high-water mark while the boundaries for federal marine parks (e.g. Great Barrier Reef Marine Park) extend to the low water mark.

For each of these approval types there are different thresholds for when permits are required, depending on the nature of the works. A set of common 'exemptions' are set out in Figure 6.2. Depending on the scale of the works, it may be advisable to design work packages in accordance with these thresholds to reduce the regulatory and financial burden otherwise triggered by approvals.

Further information on these thresholds are set out in the following guidelines:

- EPP/2017/3930 Code for accepted development – For tidal works, or works completely or partly in a coastal management district (DES, 2017)
- EPP/2016/2081 Excluded work (Coastal) _Guideline for coastal development (DES, 2020)
- Accepted development requirements for operational work that is removal, destruction or damage of marine plants (DAF, 2017).

Where approvals are triggered, this typically requires additional assessment to be undertaken and presented to local and state authorities prior to works commencing. This is intended to ensure works align with appropriate policy outcomes and strategic aims.

Approval Considerations

- Site assessments typically required to assess approval requirements
- NbS may trigger permits for:
  - construction within the tidal environment
  - changing coastal morphology
  - re-allocation of material from below high-water mark
  - disturbing marine plants
  - moving material above high water
  - works within a state or federal marine park
- Exemptions may favour staging NbS projects under nominated thresholds
- Approval process may be more straightforward if supported by NbS environmental guidelines and engineering standards

6.5 Recommendations

Based on the results of this assessment, the following recommendations have been made to improve information and collective understanding on NbS for coastal hazard management in Queensland:

- Collectively improve data collation on coastal NbS by developing guidelines to assist coastal managers record key project details, monitoring, approvals, costs, timeframes, effectiveness for improving coastal resilience, delivery of other ecosystem services
- Promote knowledge sharing on coastal NbS. This could build on existing platforms such as the Queensland WetlandInfo project portal[14] which complements the Australian Government on-ground project database MERIT
- Develop restoration guidelines for coastal terrestrial communities and estuarine wetlands and provide links to existing tools such as the Coastal Dune Management technical notes
- Develop guidelines to measure and evaluate NbS effectiveness for improving coastal resilience and encourage co-ordinated volunteer and citizen science programs, such as MangroveWatch and the previous Coastal Observation Program – Engineering (COPE) to assist with long-term coastal monitoring
- Develop guidelines to measure and evaluate NbS outcomes for other ecosystem services such as cultural, biodiversity, carbon capture and water quality benefits
- Provide more comprehensive information on NbS funding opportunities and synergies with other coastal management and investment programs, such as biodiversity, carbon, blue carbon and nutrient offsets
- Develop approval pathways for NbS in the coastal zones to assist coastal practitioners in the planning and decision-making process
- Develop local guidelines on techniques for improving the environmental value of seawalls and other hard engineering options

[14] https://wetlandinfo.des.qld.gov.au/wetlands/resources/tools/wetland-project/

- Identify opportunities for local Councils to implement planning scheme policies or local law to provide more protection and offset regulation on locally significant ecosystems that are important for coastal resilience and adaptation.

Recommendations:

- Develop NbS guidelines and promote existing technical guidance supported with approval pathways
- Promote open data and knowledge sharing
- Develop monitoring protocols and promote volunteer engagement for long-term coastal monitoring
- Promote information on NbS funding opportunities
- Promote techniques for improving environmental value of hard engineering approaches
- Identify opportunities to enhance protection of locally significant ecosystems important for coastal adaptation

	Terrestrial Coastal Options				Estuarine Coastal Options		Marine Coastal Options		
Ecosystem	**Beaches**	**Dunes**	**Coastal Grasslands to Forest**	**Coastal Floodplain Wetlands**	**Saltmarsh**	**Mangroves**	**Seagrass**	**Shellfish Reef**	**Coral Reef**
Key Site Factors to Consider	-Land availability -Coastal processes	-Land availability -Coastal processes	-Land ownership -Land availability -Topography -Substrate	-Land ownership -Land availability -Topography -Substrate -Hydrology -Groundwater -Tidal inundation -Water quality	-Land ownership -Land availability -Coastal processes -Tidal inundation -Topography -Substrate	-Land ownership -Land availability -Tidal inundation -Substrate -Sediment supply -Topography -Groundwater -Water quality	-Coastal processes -Water quality and depth -Substrate	-Coastal processes -Substrate -Recruitment potential -Water quality	-Water quality -Coastal processes -Substrate
Potential Barriers	-Sediment supply -Requires technical specialists	-Sediment supply -Requires technical specialists - Conflicting land use pressures	-Requires technical specialists - Conflicting land use pressures -Low precedence to improve coastal resilience	-Requires technical specialists - Conflicting land use pressures -Low precedence to improve coastal resilience	-Requires technical specialists - Conflicting land use pressures -Low precedence for coastal resilience	-Requires technical specialists -Low precedence for coastal resilience	-Requires technical specialists -Complex jurisdictional and approvals process -Low precedence to improve coastal resilience	-Requires technical specialists -Complex jurisdictional and approvals process -Limited opportunities for upscaling -Low precedence to improve coastal resilience	-Requires technical specialists -Complex jurisdictional and approvals process -Limited opportunities for upscaling -Low precedence to improve coastal resilience
Major Ecosystem Pressures and Stressors	-Sea level rise -Coastal erosion -Vehicle access and recreational use -Coastal squeeze	-Sea level rise -Coastal erosion -Vehicle access and recreational use -Pests -Coastal squeeze	-Sea level rise -Climate change -Clearing -Fire -Pests and disease -Coastal squeeze	-Sea level rise -Climate change -Hydrological modifications -Clearing -Poor water quality -Pests -Coastal squeeze	-Sea level rise -Climate change -Coastal erosion -Hydrological modifications -Vehicle and pedestrian access -Pests -Coastal squeeze	-Sea level rise -Climate change -Coastal erosion -Water quality -Coastal squeeze	-Sea level rise -Climate change -Coastal erosion -Water quality - Physical damage	-Sea level rise -Climate change -Water quality - Harvesting - Physical damage	-Sea level rise -Climate change -Water quality -Physical damage
Co-benefit Opportunities for NbS	-First Nations -Biodiversity -Cultural, tourism, recreational and aesthetic	-First Nations -Cultural, tourism, recreational and aesthetic -Biodiversity -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Biodiversity -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity -Water quality -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity -Water quality -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity -Water quality -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity -Water quality -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity -Water quality -Carbon sequestration and storage	-First Nations -Cultural, tourism, recreational and aesthetic -Fisheries -Biodiversity
Indicative Timeframe for Effectiveness	1 year	1-10 years	10-15 years	10-15 years	10-15 years	10-15 years	1-10 years	10-15 years	10-15 years
Indicative Construction Costs (AU$ per m^2) ***(Adopted from Morris et.al. 2021)***	$ <100 – 500	$ <100 - 1000	$ <100 - 1000	$ <100 - 1000	$ <100 – 1000	$ <100 – 1000	$ <100	$ <100 – 500	$ <100 – 500

Work type	Threshold	Reference
Minor works on State coastal land undertaken by local government, including: • Work on State coastal land outside the erosion prone area • Native vegetation management and associated fencing, irrigation system or weed control • Fencing or bollards • Reversible or expendable structures with a footprint less than 5 m^2 • Temporary tracks involving earthworks less than 100 m^3 of material where the natural land levels and native vegetation cover is reinstated after the use has ceased or within 12 months • Localised sand pushing for the temporary protection or trees • Dune scarp slope reduction following storm events • Removal of contaminated material, rubble or obsolete or damage structures		Excluded works (Coastal) (DES, 2020)
Minor works on coastal dunes on freehold or leasehold lots	• Lot size $<2,000\ m^2$ • Material disturbance is $<100\ m^3$ average dune crest height is not reduced • No clearing or damage of frontal dune vegetation, vegetation on areas vulnerable to wind erosion or regulated vegetation	Excluded works (Coastal) (DES, 2020)
Beach reprofiling or beach nourishment	• Landward extent of works is erosion scarp or seaward edge of dune vegetation • Reprofiling $<5\ m^3$ per lineal metre of beach • Excavation depth does not exceed 0.5 m • Nourishment $<5,000\ m^3/yr$	ADR Coastal (DES, 2017)
Management of natural waterway mouth across a beach	• Channel relocation <30 m from pre-disturbance profile • Channel relocation to have similar cross-sectional area • No disturbance of mangrove mud, marine clay, coffee rock or other consolidated material • Sand movement $<500\ m^3$	ADR Coastal (DES, 2017)
Fish habitat clean-up activities	• $<10\ m^2$ of marine plant disturbance	ADR Marine Plants (DAF, 2017)
Removal and use of mangrove seeds and propagules for mangrove rehabilitation	• Removal of seed and propagules by hand within 100 km of rehabilitation site • Seeds and propagules are unattached • Works subject to an endorsed project plan	ADR Marine Plants (DAF, 2017)
Fish habitat rehabilitation or restoration work	• Works subject to an endorsed project plan	ADR Marine Plants (DAF, 2017)
Fencing for access control	• Removal of non-tidal saltmarsh plants above HAT only	ADR Marine Plants (DAF, 2017)
Installation of signs	• $<2\ m^2$ of marine plant disturbance per sign	ADR Marine Plants (DAF, 2017)

Figure 6.2 Common exemptions for coastal and marine development works

7 Conclusion

Despite the broad application of coastal ecosystem restoration across Queensland, particularly in beach and dune ecosystems, there is an overall lack of project details available on the effectiveness of NbS for coastal hazard resilience. This is a common issue internationally despite the growing emergence of nature-based approaches.

The optimum solutions for coastal hazard management across Queensland are likely to contain a diverse portfolio of options including engineering interventions, restoration of various local ecosystems, and land use zoning measures. CHAS are effective mechanisms for councils to consider the range of NbS approaches for coastal hazard management. In particular, councils have leverage from a strategic planning approach to protect and enhance coastal ecosystems within their jurisdiction which are important for coastal protection and adaptation. However, environmental guidelines and engineering standards on ecosystem restoration approaches for coastal hazard management are required, including measures to evaluate their effectiveness for coastal protection. More open project data and analyses of NbS that incorporate market and non-market benefits in comparison to traditional approaches would also be useful to provide a business case for the use of NbS interventions where they are suitable.

As NbS for coastal hazards is in the relatively early stages of development, with the exception of dune restoration and beach nourishment, there is an opportunity to develop an inventory of projects and track process and outcomes to provide demonstration case studies for the community and other decision makers. The Australian guide to nature-based methods for reducing risk from coastal hazards (Morris et.al., 2021) is a living document that could be updated with this local information to help expand the global database.

Increasing NbS could be particularly beneficial in Queensland where communities are exposed to coastal hazards and marine and coastal ecosystems play a key role in tourism, recreation and fisheries. However, mainstreaming the consideration and use of NbS will depend on increased evidence of its local suitability and effectiveness for improving coastal resilience.

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Annex A: Survey Questions

	C-CAT NbS Survey 2021
	Please check box with "X" unless otherwise indicated
	Please refer to Attachment 1 for examples of NbS.
1	What best describes your role in coastal hazard management
	engineer
	scientist
	planner
	policy officer
	other (please specify)
2	How many years of experience do you have?
	<5 years
	5-10 years
	10+ years
3	What is your level of understanding of NbS for reducing coastal hazards
	nil
	low

	C-CAT NbS Survey 2021
	medium
	high
4	Indicate how often your organisation has used the following engineering solutions to address coastal hazards in the last 10 years on separate projects. 0 - not used. 1 - 1 to 3 projects. 2 - more than 3 projects.
	sand replenishment
	groynes/training walls
	shoreline armouring with rock
	shoreline armouring with other materials
	other (please specify)
5	Rank in order of importance which ecosystems you think are most suitable for NbS in your region. 1 being most important. NA for not applicable.
	beach
	dune
	saltmarsh
	mangroves
	reefs
	other (please specify)

	C-CAT NbS Survey 2021						
6	Rank in order of use how your organisation use, or plan to use, the following NbS to address coastal hazards. 1 being most frequent use. NA for not applicable. Refer to Attachment 1 for examples of NbS.						
	minimal intervention (planning / ecosystem protection zones)						
	extensive or intensive management (revegetation and management)						
	highly intensive ecosystem management or creation including hybrid systems						
	other (please specify)						
7	Rank in order of importance potential challenges to NbS implementation to address coastal hazards in each of the ecosystem types listed. 1 being most important. NA for not applicable.	beach restoration	dune restoration	saltmarsh restoration	mangrove restoration	reef restoration	other (please specify)
	technical reliability						
	lack of internal/external support						
	approvability						
	cost						
	timeframes						
	public perception						
	potential liability						
	other (please specify)						

	C-CAT NbS Survey 2021						
8	Are your organisation's NbS project/s outcomes being monitored or evaluated?						
	yes						
	no						
	NA						
9	How effective have the following NbS been in terms of expected outcomes. NA for not applicable. Refer to Attachment 1 for examples of NbS.	very good	good	average	poor	very poor	unsure
	beach restoration						
	dune restoration						
	saltmarsh restoration						
	mangrove restoration						
	reef restoration						
	hybrid (please specify)						
1 0	How efficient in terms of time and cost was the NbS intervention relative to more traditional engineering solutions? NA for not applicable. Refer to Attachment 1 for examples of NbS.	very good	good	average	poor	very poor	unsure
	beach restoration						
	dune restoration						
	saltmarsh restoration						
	mangrove restoration						

	C-CAT NbS Survey 2021						
	reef restoration						
	hybrid (please specify)						
1 1	Who is/has been responsible for delivering the NbS in your area?	beach restoration	dune restoration	saltmarsh restoration	mangrove restoration	reef restoration	other (please specify)
	local government						
	NRM						
	local communities						
	state government						
	private						
	other (please specify)						

	If Interested in Providing Project Details, Please Fill Out Following Template:
	Check box with "X" unless otherwise indicated
1	LGA:
2	Project Name:
3	NbS Category:
	planning and protection zones
	beach restoration
	dune restoration
	saltmarsh restoration
	mangrove restoration
	reef restoration
	hybrid (please specify)
4	Project Timeframe:
	start year
	end year
	expected end year
5	Project Area:

	If Interested in Providing Project Details, Please Fill Out Following Template:
	<10ha
	10-50ha
	50-100ha
	>100ha
6	Assets Vulnerable to Coastal Hazard:
	private property
	public property
	combination
	other (please specify)
7	Stakeholder consultation involvement:
	internal
	public
	state regulators
	federal regulators
	research
	NRM groups
	other (please specify)
8	Project approvals required:

	If Interested in Providing Project Details, Please Fill Out Following Template:
	local
	state
	federal
	other (please specify)
9	Project funding:
	local government
	state government
	federal government
	community grants
	research grants
	private investment
	other (please specify)
10	Estimated full project cost prior to implementation:
	<$10,000
	$10,000-$50,000
	$50,000-$100,000
	>$100,000
	>$500,000

	If Interested in Providing Project Details, Please Fill Out Following Template:
11	Actual full project cost:
	<$10,000
	$10,000-$50,000
	$50,000-$100,000
	>$100,000
	>$500,000
12	Please use the following box to provide any further information you consider relevant, such as:
	intended versus actual outcomes and benefits of the project
	has the project/s had any unintended negative effects (e.g loss of landuse/poor environmental outcomes etc.)
	challenges including engineering and scientific factors and political and community influence on decision-making
	lessons learned
	knowledge gaps for further research
	expected outcome for the area if the NbS had not been implemented
13	Are you happy to be contacted for project reports, site maps, photos and monitoring data to be used as a case study.
	yes
	no

Annex B: Survey Recipients

Brisbane City Council

Bundaberg Regional Council

Burdekin Shire Council

Burke Shire Council

Burnett Mary Regional Group

Cairns Regional Council

Carpentaria Shire Council

Cassowary Coast Regional Council

City of Gold Coast

Cook Shire Council

Douglas Shire Council

Fitzroy Basin Association

Far North Queensland Regional Organisation of Councils

Fraser Coast Regional Council

Gympie Regional Council

Healthy Land and Water

Hinchinbrook Shire Council

Isaac Regional Council

Livingstone Shire Council

Logan City Council

Mackay Regional Council

Mapoon Aboriginal Shire Council

Moreton Bay Regional Council

Napranum Aboriginal Shire Council

Noosa Shire Council

Northern Peninsula Area Regional Council

Pormpuraaw Aboriginal Shire Council

Redland City Council

Sunshine Coast Council

Terrain

The Nature Conservancy

Torres Shire Council

Torres Strait Regional Authority

Townsville City Council

Weipa Town Authority

Whitsunday Regional Council

Yarrabah Aboriginal Shire Council

Annex C: Survey Results

	C-CAT NbS Survey 2021						
	Please check box with "X" unless otherwise indicated						
	Please refer to Attachment 1 for examples of NbS.						
1	**What best describes your role in coastal hazard management**						
	engineer	4					
	scientist	5					
	planner	3					
	policy officer	1					
	other (please specify)	manager (3), resilience officer (1), technical officer (2), project delivery (1)					
2	**How many years of experience do you have?**						
	<5 years	4					
	5-10 years	3					
	10+ years	13					
3	**What is your level of understanding of NbS for reducing coastal hazards**						
	nil						
	low	8					
	medium	9					
	high	3					
4	**Indicate how often your organisation has used the following engineering solutions to address coastal hazards in the last 10 years on separate projects. 0 - not used. 1 - 1 to 3 projects. 2 - more than 3 projects.**						
	sand replenishment	1.2 (0/NA:8,1:3,2:9)					
	groynes/training walls	0.6 (0/NA:11,1:6,2:3)					
	shoreline armouring with rock	0.9 (0/NA:7,1:8,2:5)					
	shoreline armouring with other materials	0.7 (0/NA:11,1:4,2:5)					
	other (please specify)	pile fields, dune fencing					

5	**Rank in order of importance which ecosystems you think are most suitable for NbS in your region. 1 being most important. NA for not applicable.**	*Value in bracket is average rank after substituting 5 for NA*					
	beach	2 (2.5)					
	dune	1 (2.0)					
	saltmarsh	4 (3.6)					
	mangroves	3 (3.5)					
	reefs	5 (4.2)					
	other (please specify)	coastal wetlands, riverbank stabilisation, rocky reefs					
6	**Rank in order of use how your organisation use, or plan to use, the following NbS to address coastal hazards. 1 being most frequent use. NA for not applicable. Refer to Attachment 1 for examples of NbS.**						
	minimal intervention (planning / ecosystem protection zones)	1 (1.5)					
	extensive or intensive management (revegetation and management)	2 (2)					
	highly intensive ecosystem management or creation including hybrid systems	3 (2.5)					
	other (please specify)	behavioural/community-based marketing					
7	**Rank in order of importance potential challenges to NbS implementation to address coastal hazards in each of the ecosystem types listed. 1 being most important. NA for not applicable.**	**beach restoration (*rank, average score, count of NA in brackets*)**	**dune restoration (*rank, average score, count of NA in brackets*)**	**saltmarsh restoration (*rank, average score, count of NA in brackets*)**	**mangrove restoration (*rank, average score, count of NA in brackets*)**	**reef restoration (*rank, average score, count of NA in brackets*)**	**other (please specify)**
	technical reliability	2- 3.7 (6)	4 - 3.9 (7)	3 - 3.8 (8)	4 - 4.1 (6)	5 - 4.4 (12)	
	lack of internal/external support	3- 4.1 (3)	3 - 3.9 (4)	2 - 2.9 (5)	2 - 3.0 (5)	3 - 3.3 (10)	
	approvability	6 - 4.4 (6)	7 - 5.2 (6)	4 - 4.2 (7)	3 - 3.9 (6)	2 - 3.1 (11)	
	cost	1 - 2.0 (3)	1- 2.2 (4)	1 - 2.4 (6)	1 - 2.3 (5)	1 - 1.9 (11)	
	timeframes	5 - 4.3 (6)	5 - 3.9 (6)	6 - 4.3 (7)	6 - 4.5 (6)	4 - 4.2 (11)	
	public perception	4 - 4.3 (4)	2 - 3.9 (5)	5 - 4.3 (8)	5 - 4.3 (7)	7 - 5.8 (11)	
	potential liability	7 - 4.9 (5)	6 - 5.1 (5)	7 - 6.3 (8)	7 - 6.2 (7)	6 - 5.3 (11)	

	other (please specify)	Decisions driven by public perception and/or ignorance, sourcing suitable type and increasing volume of sand, potential impact on wildlife - invertebrates, turtle nesting, nature based or soft engineering mitigating impacts from development / hard assets, fish habitat areas, marine protection zones	Persistent hard assets/ modification and encroachment limiting feasibility in developed areas and limiting landward migration of beach-dune systems with sea level rise, ongoing encroachment / unlawful clearing to provide views, decisions driven by public perception or ignorance, fish habitat area, marine protection zones	Responsibility	suitable sites, responsibility		Riverbank restoration, retreat (most NBS available)
8	**Are your organisation's NbS project/s outcomes being monitored or evaluated?**						
	yes	**15**					
	no	**3**					
	NA	**2**					
9	**How effective have the following NbS been in terms of expected outcomes. NA for not applicable. Refer to Attachment 1 for examples of NbS.**	**very good**	**good**	**average**	**poor**	**very poor**	**unsure (NA)**
	beach restoration	**3**	**4**	**3**	**3**		**7**
	dune restoration	1	8	5	1		5
	saltmarsh restoration		1	2	1		16
	mangrove restoration		2	2	2		14
	reef restoration	1	1	1	2		15
	hybrid (please specify) - pile field method for estuary restoration - pile fields + reveg	pile field method for estuary restoration - pile fields + reveg	green seawalls				
10	**How efficient in terms of time and cost was the NbS intervention relative to more traditional engineering solutions? NA for not applicable. Refer to Attachment 1 for examples of NbS.**	**very good**	**good**	**average**	**poor**	**very poor**	**unsure**
	beach restoration	**2**	**3**	**2**	**4**		**9**

	dune restoration	5	4	1	1		9
	saltmarsh restoration	1	1	1	1		16
	mangrove restoration	1	1	2	2		14
	reef restoration	2			2		16
	hybrid (please specify) - pile field method for estuary restoration - pile fields + reveg	pile field method for estuary restoration - pile fields + reveg		green seawalls			
11	**Who is/has been responsible for delivering the NbS in your area?**	**beach restoration**	**dune restoration**	**saltmarsh restoration**	**mangrove restoration**	**reef restoration**	**other (please specify)**
	local government	16	16	5	7	0	1
	NRM	4	9	3	4	0	1
	local communities	4	9	1	2	0	0
	state government	1	2	1	4	0	0
	private	2	2	0	1	0	0
	other (please specify)	Traditional owners	Traditional owners	Traditional owners	Traditional owners		

Annex D: Queensland Case Studies

D.1 Beaches

Case Study 1

Case study: Replicating Natural Coastal Processes

The dynamic nature of Sandhills Creek Estuary was posing an erosion risk to adjacent coastal assets and Rose Bay Beach.

Whitsunday Regional Council assessed a range of options to manage the erosion risk. Relocating the estuary mouth to a historical position further south was preferred over a hard engineering approach due to cost and amenity benefits.

Though it has been acknowledged that the mouth may need to be relocated over time, particularly following extreme events, the works are proving to be effective four years since relocation. Ongoing monitoring will be undertaken to assess the need for further follow up works.

Sandhills Creek estuary is located south of the township of Rose Bay, Bowen, in the Whitsunday region. In 2012 it was recognised the northern migration of the mouth posed an erosion risk to adjacent coastal assets including a road, housing and a council sewer pipeline. The northern-most location of the entrance was also considered to have the potential to increase the erosion threat to the foreshore fronting Rose Bay Beach.

Coastal processes studies were undertaken to assess erosion management options to protect assets which may be threatened by the northern location of the entrance. A review of aerial imagery from the 1940's to 2009 indicated the estuary is highly dynamic with the entrance predominantly located in the central and southern parts of the embayment.

Although it was considered there was some potential for the mouth to naturally migrate southward in the short to medium term, there was also a recognised risk that the mouth could persist in its location or continue to migrate northward which could directly threaten coastal development, particularly during extreme events.

The following broad management options were considered by Whitsunday Regional Council.

Protection Works: construction of a revetment wall along the northern bank of the estuary. This hard engineering approach was considered the least preferred option because of cost (estimated in 2012 at $225,000 for 90m long revetment), amenity impacts and the potential requirement for ongoing beach nourishment.

Channel Relocation: excavation and fill works to re-establish the creek mouth in the central to southern section of the estuary. Though it was acknowledged that works may need to be repeated over time, particularly following extreme events, channel relocation was the preferred management option adopted as it replicated natural coastal processes of the area.

In May 2017, the Whitsunday Regional Council lodged a development application with the State government to seek approval to re-locate Sandhills Creek mouth.

The development approval was issued to the Council in August 2017 (SDA-0617-040074 and Council approval 20170335). As the site is also within the Great Barrier Reef Marine Park a marine park approval was also lodged and issued (MPW2017/GBRC0065).

The earthworks associated with the Sandhills Creek project commenced on the 4th of September 2017 and were completed on Friday the 8th of September 2017.It is estimated that approximately 5,500m3 of sand was re-located during the construction period at a cost of $25,000.

Sources of Information:

Report on: Beach Erosion and Creek Channel Migration at Rose Bay, Bowen. Department of Environment and Resource Management, Natural Resources and Environment Division. Unpublished internal DERM report. 26th March 2012.

Sandhills Creek Entrance: Assessment of Erosion Management Options. Prepared by Coastal Engineering Solutions for Whitsunday Regional Council. 20th April 2012.

D.2 Dunes

Case Study 2

Case study: Nature-based Approach for Dune Resilience

The Burdekin coastline supports significant environmental and recreational areas that are vulnerable to coastal erosion and storm tide inundation. In 2020 Burdekin Shire Council adopted a Dune Management Strategy to address local coastal management challenges and to create a more resilient coastline.

The strategy focuses on the principles of nature-based actions, education and working with the community to protect and enhance coastal dunes. Cost-benefit and multi-criteria analysis showed the strategy would have environmental and social benefits. These include: increased dune resilience to erosion, better conservation outcomes, and improved conditions for recreation. The strategy highlights the importance of community collaboration and education to address coastal hazards and pressures over the long-term, and the value of volunteer contributions in coastal restoration projects.

Background

The Alva, Wunjunga and Beachmount Reserve in the Burdekin region collectively cover 10km of coastal dune systems that are under increasing pressure from recreational use and coastal hazards. Based on the findings of the local Coastal Hazard Adaptation Strategy and community and stakeholder consultation, a 10-year strategy was adopted by Council to improve dune resilience and environmental and social values.

The Strategy

The Strategy adopts the principles of using nature-based actions rather than 'hard' infrastructure and promotes community stewardship and partnerships. The actions focus on restoring and protecting dunes to increase coastal resilience to erosion, enhance habitat conditions for migratory birds and marine turtles, protect adjacent coastal wetlands, and improve conditions for dune recreation.

Actions

Commencing in 2021, the strategy will deliver a range of actions, including:

- partnerships with Gudjuda Aboriginal Corporation and indigenous land and sea rangers, local residents, Wunjunga Progress Association, Lower Burdekin Landcare group, North Queensland Dry Tropics, Great Barrier Reef Marine Park Authority and Queensland Parks and Wildlife
- revegetation of approximately 12ha of disturbed dunes using locally propagated native species
- installation of sand fences in severe blowouts
- installation of fencing to protect vulnerable dunes and rehabilitation areas including the use of native thorny shrubs to discourage access
- education through local schools on coastal processes and dune management
- installation of educational signage including:
    - ‘wetlands to coast theme’ at the entrance of important environmental areas
    - ‘dune systems theme’ describing the role of dunes in providing habitat, helping to mitigate coastal hazards and the importance of community engagement in dune management
    - ‘Beach driving and dunes theme’ to describe the importance of local beaches for migratory birds and turtles and the need for vehicle restrictions to protect these values
- installation of regulation signs targeting recreational vehicles in dunes
- monitoring of recreational areas
- formalising, improving and monitoring primary beach accessways.

Approvals

The strategy was designed to have a beneficial impact on coastal processes and the following management actions are considered accepted development under State and planning approvals:

- restoring dune vegetation
- controlling vehicle and pedestrian access
- improving access conditions
- minor dune works for public safety or local restoration.

Costings

Costs for dune restoration and protection depend on the landform and vegetation condition and also the level of volunteer support.

Strategy actions have been costed over a ten-year period with priority works amounting to $150,000 (without fencing) to $530,000 (with fencing) based on the following estimates (excl. GST):

- dune revegetation: $10,000/ha for enhancement planting and $25,000/ha for revegetating bare sites
- signage $150-$570 per item
- fence maintenance $40/m for a wire fence to $120/m for log and post fencing
- annual site inspections $100 / per inspection.

Timing

The Dune Management Strategy was adopted by Council in December 2020 and the Coastal Hazard Adaptation Strategy was endorsed by Council in 2021. Implementation of the Dune Management Strategy commenced in 2021 with seed propagation with the aim of dune revegetation, signage and fencing to commence in Alva at the end of 2021 and in 2022 for Wunjunga.

Outcomes

Ongoing monitoring between local partnerships will report on the environmental and social outcomes of the strategy.

Sources of Information: JBP (2020) Dune Management Strategy for Alva, Wunjunga and Beachmount Reserve

https://www.burdekin.qld.gov.au/beach-dune-protection

Case Study 3

Case study: Whole of Coast Approach

Mackay Regional Council in partnership with Reef Catchments has developed the Mackay Coasts and Communities Program to provide a strategic approach to coastal management and to increase coastal resilience to erosion and land-use pressures.

Various Local Coastal Management Plans have been developed under the program that outline site-specific actions to protect and rehabilitate coastal vegetation; provide recreational assets such as beach accesses; deliver local education and promote community participation in coastal management.

The program was initiated in 2008 with the development of Coastal Management Guidelines for Mackay, which set the strategic intent for managing coastal areas across the region.

Background

The Mackay Regional Council area covers approximately 320 kilometres of mainland coastline. The coastal zone is characterised by a diverse range of natural features including sandy beaches, rocky headlands, extensive intertidal flats, and substantial areas of coastal wetlands.

These coastal areas are under increasing pressure from development, population growth, recreational use and climate change and are prone to severe storm events and tropical cyclones.

The Mackay Coasts and Communities Program was developed to provide a strategic and coordinated approach to manage the regions coastal zone. Delivered by Mackay Regional Council and Reef Catchments, and supported by the state and federal government, 21 local management plans have been developed under the scheme to date.

Coastal Management Plans

The plans provide site-specific recommendations for individual coastal units based on best-practice principles.

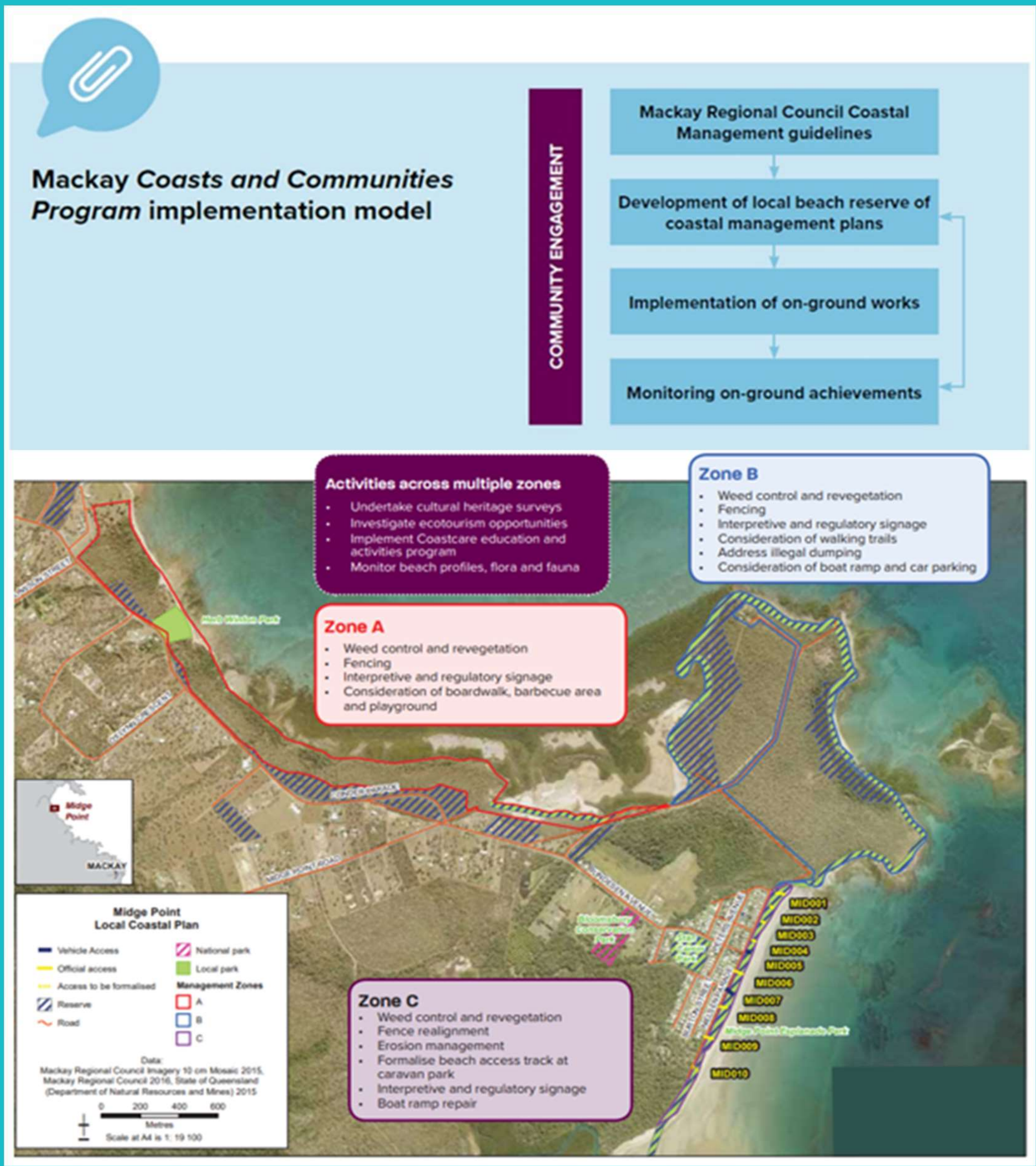
Following community consultation, on-ground activities are prioritised and undertaken strategically as resources become available.

The plans provide a suite of management actions to address local coastal erosion and pressures including:

- improving and maintaining coastal vegetation through revegetation and weed control
- installing fencing to formalise beach access and reduce impacts on sensitive coastal habitats
- formalisation of boat ramps
- installation of regulatory, cultural and interpretive signage to help reduce impacts on sensitive coastal habitats
- monitoring beach profiles
- opportunities for local education programs on coastal ecosystem processes.

Implementation

Implementation of priority activities in many of these areas is now underway, including coastal fencing, weed control and revegetation. Community engagement is recognised as critical to the delivery and successful outcomes of these on-ground works.



Sources of Information:

https://www.mackay.qld.gov.au/environment/natural_environment/coastal_management

D.3 Mangroves

Case Study 4

Case study: Mangrove Restoration on Eroded Riverbanks

The *Logan River Vision 2017 to 2067* sets a vision for the Logan River as being a world class environmental asset that is accessible to everyone, is celebrated, and will connect people and places along its length.

Erosion is prevalent throughout much of the Logan River due to a reduction in riparian vegetation and flooding.

Logan City Council in partnership with Healthy Land and Water and Ozfish Unlimited are undertaking local projects to restore fish habitat including mangrove restoration within eroded reaches of the river.

The Logan River Parklands Bank Stabilisation project commenced in 2019 to rehabilitate significant erosion along approximately 480m length of the Logan River Parklands. Erosion was exacerbated by flooding and increased usage and was impacting a number of significant trees and access pathways and resulted in a safety issue for park users.

A number of options were investigated to stabilise and restore the riverbank, including installation of heavy rock batter. State Approvals for the final detailed design took approximately 4 months to complete with construction commencing in February 2021.

Construction involved the installation of log pile fields for long term substrate stabilisation to promote mangrove recruitment and the installation of log root balls to enhance fish habitat values.

Approximately 1,000 native tube stock were also planted along a 90m length of the riverbank by volunteers. Interpretive signage was installed for public education purposes.

Initial inspections show sedimentation with mangrove recruitment has occurred. The site will be monitored for a period of two years.

The approximate project cost for planning, approvals, construction, maintenance and signage was $250,000.

The project was funded by Logan City Council's Environmental Levy and supported by Healthy Land and Water, Ozfish Unlimited and the Australian Government.

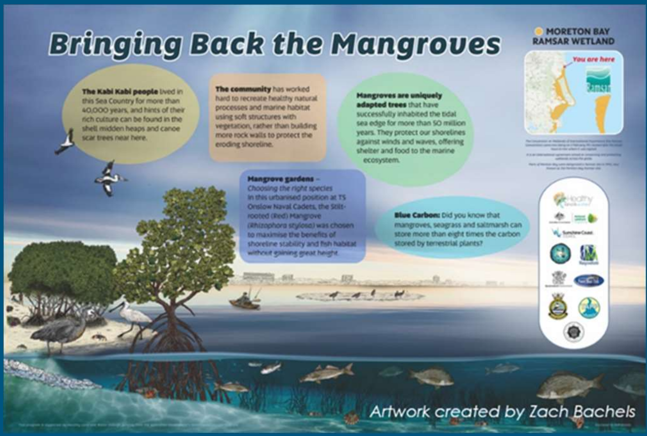
It is hoped the project will deliver solutions that can be upscaled at other locations along the Logan River.

Information provided by Logan City Council

Case Study 5

Case study: Restoring Mangroves in an Urban Coastal Area

This community-driven project was undertaken to restore a section of urbanised foreshore at Golden Beach within the Pumicestone Passage. Involving partnerships between, Healthy Land and Water, Take Action for Pumicestone Passage, Professor Norm Duke of MangroveWatch and James Cook University, Bunya Bunya Country Aboriginal Corporation, local businesses and government agencies, almost 100m of eroding shoreline has been stabilised with soft engineering elements with mangrove and foredune plantings.



Monitoring results indicate the project has stabilised the foredune, promoted sediment deposition, has had a high success rate for foredune and mangrove plantings and shows high resilience to storms and erosion. Although relatively small in scale, the project provides a model for rehabilitation of natural and highly modified coastal sites in urbanised environments.

Background

The reclaimed foreshore fronting the TS Onslow Naval Cadets site is highly vulnerable to coastal erosion. Concrete blocks were installed along the foreshore between the 1980's to 2009 to protect adjacent land uses and reclaim marginal foreshore lands. However, these structures provided a public safety risk, exacerbated foreshore scour, created instream channelling, provided conditions unsuitable for local foredune and mangrove habitat and were required to be removed as they contravened coastal management policies.

Various management options were investigated for the site including re-construction of the revetement wall. However, most options involved high costs and provided limited amenity and habitat values. Given the limited resources available, environmental sensitivity of the location, and intended private and public land-use purposes, a soft engineering approach with nature-based solutions was the option proposed by the community.

Project Details

The project involved a staged approach using a combination of substrate stabilisation measures, including novel techniques, sand nourishment and revegetation.

Stage 1

August to November 2014: community consultation; project management plan; approvals

December 2014 to 2016 - on-ground works including:

- surveys of tidal height range for target mangrove habitat
- installation of protective fencing and informative signage
- installation of coir logs in a novel 'fish-scale' design
- bank battering and installation of gravel and rubble anchors
- sand nourishment
- mangrove seed collection and propagation
- mangrove and foredune planting
- addition of gravel to stabilise surface around mangroves
- photo monitoring and site inspections every 6 months
- corrective measures: installation of silt fencing to divert overland flow following extreme erosion events; infill planting following vandalism to some mangroves.

Outcomes: the novel configuration of coir logs proved effective in withstanding high tides, waves and longitudinal current and protecting mangrove seedlings which showed a high success rate following planting (70%).

Stage 2

Though the outcomes of Stage 1 were successful, the foreshore to the north scoured with Cyclone Oma in 2019, with Stage 1 effectively acting like a groyne. Scouring is characteristic in this part of the Passage. Stage 2 was undertaken to expand restoration works to address the erosion along the northern foreshore.

Works included:

- community consultation
- extensive local and state government approvals which included a full Development Application and a Marine Parks permit
- installation of protective fencing and informative signage
- installation of coir logs at toe of bank parallel to the shoreline
- over 400 foredune plantings
- sand nourishment
- surveys of sand nourishment tidal height range
- installation of coir logs in a 'fish-scale' pattern between lowest and highest astronomical tide
- installation of biodegradable, inter-lockable mesh sheets (BESE made in the Netherlands) within the intertidal zone to stabilise the surface
- installation of interlocking concrete modules at low tide mark to help dissipate wave energy and provide invertebrate habitat
- seed collection and propagation of 400 lower growing *Rhizophora stylosa* and 100 *Avicennia marina* between the high and low water tide levels
- monthly photo monitoring
- regular drone footage
- regular monitoring on planting survival rates.

Outcomes

An independent engineering assessment of the project in 2019 concluded that the design helped to dissipate wave energy resulting in sediment deposition within the site. Native plantings showed high survival rates (90%).

The site shows signs of high resilience with all elements of the project withstanding very high tides, severe storms and flooding in December 2020.

Issues and Challenges

- limited resources available
- highly dynamic coastal zone
- multiple approvals required across local and state government departments
- some initial community resistance to mangrove plantings, including some damage and removal of planted seedlings
- continuing foot traffic damaging substrate sheeting and mangrove seedlings
- inability to add gravel (which effectively stabilised surface in Stage 1) during Stage 2 works due to permitting issues.

Lessons Learned

- staged, long term and adaptive approach required to successfully restore habitats in dynamic coastal zone
- local knowledge and vigilance, community interest and energy, and multi-disciplinary team help deliver cost effective and positive social and environmental outcomes
- raise awareness and educate local residents on the need and benefits of the works early in the planning phase
- fish-scale design of coir logs placed in rows with the tidal regime, in combination with gravel placement for substrate stabilisation, gave mangroves the best chance of success
- need to manage overland flow contributions to foreshore erosion
- need to establish long-term maintenance and monitoring program to assess shoreline profiles and mangrove restoration.

Cost Estimate

$80,000 for on-ground works only, does not include costs for design drawings, approvals, monitoring and reporting. In-kind support received for installations, planting and adaptive management which was invested at a ratio of 4:1 on-ground cost. The blended finance from local businesses to the National Landcare Program broadened project ownership and attracted significant in-kind support.

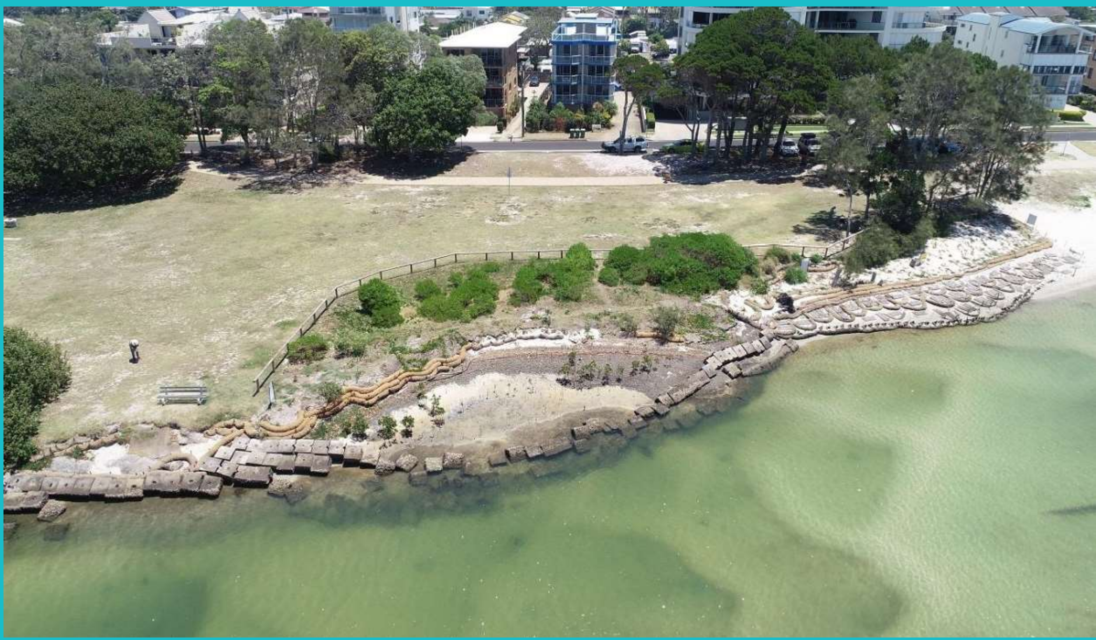


Photo Source: Airborne Insight

Sources of Information:

AirBorn Insight (2019). Onslow Shoreline Management Project – Stage 2: Project assessment, recommendations and approval.
Australian Wetlands Consulting (2011). Onslow Street Foreshore Rehabilitation Options Report
Omtrek (2018). Bank Stabilisation Stage 2 – TS Onslow Naval Cadets, Golden Beach
Healthy Land and Water (2019). TS Onslow Shoreline Management Project Report for Department of Agriculture and Fisheries
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D.4 Shellfish Reef

Case Study 6

Case study: Restoring Shellfish Reefs in South-east Queensland

Oyster-dominated shellfish reefs were once common throughout south-east Qld estuaries but have been severely depleted and degraded. Restoring these ecosystems has been shown to provide social and environmental benefits including, improvements in water quality, shoreline protection, enhanced biodiversity, and opportunities for education, research and recreation.

For the last 18 months The Nature Conservancy in partnership with Noosa Shire Council, the Thomas Foundation and Noosa community, including Kabi Kabi Traditional Owners, have been working to identify opportunities to restore shellfish reefs to parts of the Noosa River estuary. Funding is also provided by the Australian Government's Reef Builder program.

After extensive community feedback, scientific analysis and government consultation, four sites have been selected that meet ecological, engineering, social and regulatory requirements. Active habitat restoration will start in Summer 2021. The recovery process is expected to take 5 to 10 years until self-sustaining shellfish reefs are returned to the estuary.

Background

Shellfish reefs were widespread in estuaries and low energy foreshores across southern Australia. As a result of overharvesting, dredging, disease and poor water quality, oyster beds became functionally extinct throughout most of their range by the early 1900's. Shellfish reefs are now considered one of Australia's most critically endangered marine ecosystems.

Evidence from NSW, Victoria, Western Australia and around the world show that restoring these ecosystems can:

- improve water quality
- enhance biodiversity values
- protect shorelines from coastal erosion
- enhance sediment deposition
- provide opportunities for education, research and recreation (noting oyster restoration is not for human consumption).

Noosa Oyster Ecosystem Restoration Project

Oyster reefs were once common in the Noosa River estuary but have become severely depleted due to over-harvesting and dredging. Despite improvements to local water quality and coastal management, natural restoration of shellfish reefs in the estuary has been inhibited by low recruitment and loss of available settlement areas.

The Nature Conservancy, Noosa Shire Council, the Thomas Foundation and Noosa community, including Kabi Kabi Traditional Owners, with funding also provided by the Reef Builder program, are working together to restore oyster ecosystems to the estuary.

The project is located on Kabi Kabi Sea Country and is guided by Traditional Owner elders who provide cultural knowledge and collective memories of the Noosa River and advise on the restoration works.

Restoration Process

After extensive stakeholder engagement and local research including historical studies and ecological and geomorphological surveys, four sites have been selected within the estuary that meet ecological, engineering, social and regulatory requirements.

Site selection, interim design and pilot projects were undertaken between 2020 and 2021. Sites were selected based on historical evidence of oyster reefs; connectivity to seagrass, mangroves and other reefs; sediment characteristics; seabed mobility; water quality and depth; coastal infrastructure; estuary and foreshore use; public safety; river access and navigability; cultural heritage, and stakeholder and community consultation.

Reef-base designs were developed to be cost-effective and to meet engineering and ecological specifications and regulatory requirements relating to coastal processes, fisheries habitat, reef stability, safety, biosecurity and environmental impacts.

Pilot restoration is planned for summer 2021 with full restoration to follow in the spring of 2022. The process will involve the placement of local rock and, in places, a composite of local rock and recycled oyster shells to create reef bases. At each restoration site these bases will be shaped into a series of oyster reef patches which promote oyster ecosystem restoration, afford some protection to the adjacent shoreline, and ensure easy fish passage and natural river flow. Depending on natural recruitment rates, juvenile oysters may also be introduced to the sites. Educational signage will be installed to raise public awareness and help minimise impacts to oyster beds and private and public infrastructure and estuary uses.

Outcomes

The project will be continually monitored and evaluated. It is anticipated it will take 5-10 years to restore self-sustaining shellfish reefs to the estuary.

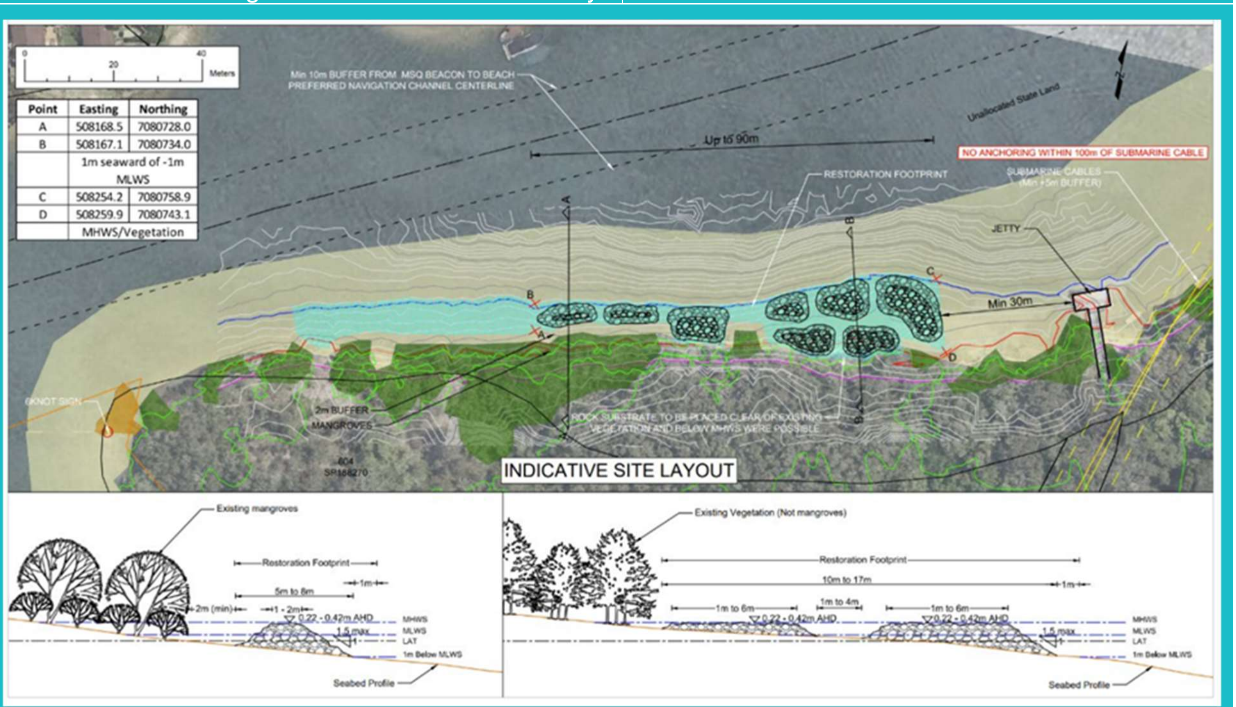
Budget

The project has a budget of $3.6m including in-kind support from the Nature Conservancy, Thomas Foundation and Australian Marine Conservation Society; Noosa Shire Council's environment budget and funding from the Australian Government Reef Builder Project.

Challenges

As this was one of the first projects of this kind in south-east Queensland, there were some challenges in the process. Reef restoration design requires a multi-disciplinary approach with subject matter experts including engineers, ecologists, historians, planners and surveyors.

Common to most projects in the highly dynamic and regulated coastal zone, there were complexities and long timeframes in the approvals and permitting process and extensive consultation was required to ensure all social and environmental issues were considered.



Sources of Information:

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D.5 Enhancing Hard Engineering

Case Study 7

Case study: Cassowary Coast Fish Friendly Seawall

Cassowary Coast Council in collaboration with SMEC, James Cook University's TropWATER and Horton Coastal Engineering, developed the Flying Fish Point Seawall Renewal project. The project resulted in the upgrade of over 600m of rock revetment incorporating 'fish-friendly' design features to enhance local marine habitat. The project was the first of its kind within the Great Barrier Reef Marine Park and aims to provide a case study and source of research for future projects on coastal protection with habitat enhancement features.

Background

Flying Fish Point located north of the Johnstone River in North Queensland has a history of shoreline erosion which has required significant investment in rock revetments to protect landward property and infrastructure.

Due to degrading conditions and poor performance, some revetments required remediation. Cassowary Coast Council took this opportunity to investigate the incorporation of 'green engineering' principals as part of the upgrade process to provide a robust and resilient coastal protection asset that also provided environmental benefits, community values and research opportunities.

Involving the local community and subject matter experts, the resulting design included shaping the rock armour and incorporating 'Reef Balls' within the revetment to enhance fish-friendly habitat features. Reef Balls are made of inert, marine-grade concrete, are free of steel reinforcements and potential contaminants, and have a pH of seawater and surface texturing that aid in organism settlement. The structures have a local design life of 50 years, are stable and can be readily removed and relocated.

Native vegetation was also established along the revetment crest to enhance the foreshores local amenity values.

Project Details

All works obtained Commonwealth, State and local approvals; were constructed in accordance with engineering standards for tidal works; were designed to be stable during a 1 in 50-year storm event; and received Registered Professional Engineer of Queensland (RPEQ) certification.

Commencing in 2017, the project included the following elements:

- Stakeholder workshops and project design
- Community consultation
- Approvals
- Development of Construction Environmental Management Plan, Operational Environmental Management Plan, Monitoring Program, Emergency Response Plans and Sinking Placement Plan
- Construction (April – July 2018):
  - installation of 2 layers of secondary rock armour over existing revetment surface
  - installation of 2 layers of primary rock armour over secondary armour layers
  - installation of Reef Balls at the toe of the rock revetment above Lowest Astronomical Tide
  - native vegetation plantings along revetment crest
- Independent engineering inspection
- Regular monitoring of seawall integrity
- Baseline and three-year monitoring program to assess fish and other marine habitat features.

Project Outcomes

The project has been successful from a time and cost perspective, including direct contributions to the local economy and has provided a significant improvement to the protection and amenity of the foreshore. On-going monitoring will evaluate the long-term impacts of the fish friendly features on local marine biodiversity with the final technical report expected in December 2021.

Project Benefits

Compared with more traditional rock revetment designs, the Flying Fish Point seawall upgrade:

- increased sand recovery compared with traditional style sea walls
- increases structural complexity of intertidal habitat to provide greater opportunity for marine biodiversity
- provides research opportunities to enhance habitat values of coastal protection infrastructure
- involved community participation
- has improved aesthetic values for the local community
- provided cost efficiencies due to reduced requirements for excavation

Issues and Challenges

- design process required extensive consultation to ensure desired environmental outcomes of habitat complexity did not compromise structural function, performance and statutory tidal works requirements
- complex approval process within the Great Barrier Reef Marine Park, however, approvals were obtained within 6 months

Cost Estimate

Total expenditure for all stages of seawall was $6,170,000

Sources of Information:

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Annex E: Examples of Nbs Resources

Australian Coastal Restoration Network: https://www.acrn.org.au/

Coral Restoration Database: https://www.icriforum.org/restoration/coral-restoration-database/

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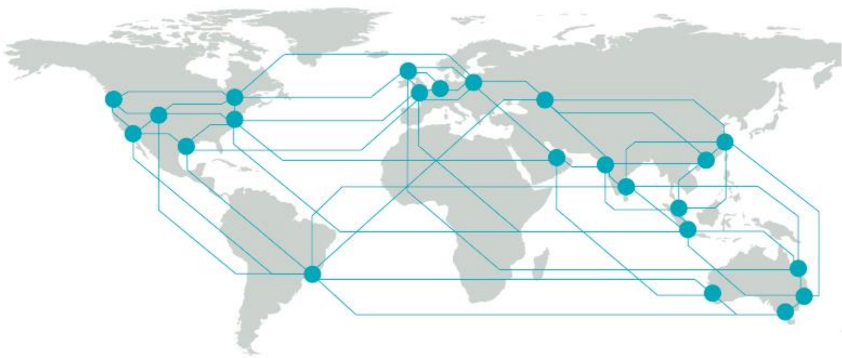

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