COASTAL HAZARD ADAPTATION OPTIONS

A Compendium for Queensland Coastal Councils

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GHD
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Queensland Government
City of Townsville
LGAQ
Australian Government
Department of Climate Change and Energy Efficiency

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List of Acronyms

ABS – Australian Bureau of Statistics

BCA – Building code of Australia

CHAS – Coastal Hazard Adaptation Strategy

CHMA – Cultural Heritage Management Agreement

CHMP – Cultural Heritage Management Plan

CPM Act – Coastal Protection and Management Act

CSIRO – Commonwealth Scientific and Industrial Research Organisation

DERM – Department of Environment and Resource Management

DFL – Design flood level

EWL – Extreme Water Levels

GBR – Great Barrier Reef

GCCM – Griffith Centre for Coastal Management

HCHA – High Coastal Hazard Area

HWM – High Water Mark

IDAS – Integrated Development Assessment System

IPCC – International Panel on Climate Change

LGA Local Government Authority

LGAQ – Local Government Association Queensland

MSL – Mean Sea Level

QCP – *Queensland Coastal Plan*

QDC – Queensland development code

QPP – Queensland Planning Policy

SLR – Sea Level Rise

SPA – Sustainable Planning Act 2009

SPP – State Planning Policy

Executive summary

This Compendium of Coastal Hazard Adaptation Options for Queensland Coastal Councils (the Compendium) is one of the products of the Townsville Coastal Hazard Adaptation Strategy pilot project. The pilot project was partnered by the Queensland Government, the Local Government Association of Queensland and Townsville City Council; funded by the Commonwealth Department of Climate Change and Energy Efficiency under the Coastal Adaptation Decision Pathways program; and executed by GHD and Griffith University.

The Compendium was developed within the framework of the *Queensland Coastal Plan* (QCP), which took effect on 3 February 2012. The QCP seeks to ensure that coastal councils prepare Coastal Hazard Adaptation Strategies (CHAS) for urban high coastal hazard areas (HCHA) as identified in the Queensland Government's (EHP) hazard maps or by more detailed storm tide studies undertaken by local government authorities (LGAs) in accordance with the QCP. The Queensland Government's hazard maps include a nominal allowance for coastal erosion and storm tide inundation, both prepared with consideration of future sea level rise projections.

The *Queensland Coastal Plan Guideline for Preparing Coastal Hazard Adaptation Strategies* (DERM, 2012) identifies the steps needed to develop these strategies, including the identification and selection of adaptation options based on detailed assessments and stakeholder consultation. The Compendium is developed to support this decision process by analysing a wide range of possible options to adapt to coastal hazards, including:

- Regenerative options using soft engineering and environmental restoration;
- Engineering options with hard coastal structures;
- Structural options to improve human settlements resilience;
- Planning options suitable for the Queensland legal and administrative framework.

A set of alternative solutions were identified and analysed based on international and national information on existing adaptation options, stakeholder consultation and specific requirements for Queensland. Each option within the compendium includes:

- A technical description in relation to coastal hazards and management strategies;
- An assessment of potential synergies or conflicts between options;
- A description of the current legal, administrative and planning framework for its implementation in Queensland;
- A description of maintenance requirements, risks of failure and estimated costs; and
- A multi-criteria overview of each option based on climate uncertainty, social, environmental and economic criteria.

The Compendium is intended to be used by coastal councils in Queensland to inform the process of developing a CHAS for high coastal hazard risk areas, however it may also be of interest to other coastal councils throughout Australia. The information provided in the Compendium needs to be considered in conjunction with detailed local knowledge of coastal processes and interpretation of local hazards. The Compendium is not intended to be the sole tool to develop a comprehensive strategy in adapting to current and future coastal hazards; rather a depository of information relevant to the Queensland coast that can be readily used to develop adaptation strategies. As such, the Compendium is recommended to undergo periodic updates to reflect the current understanding of coastal hazards as well as latest advances in climate adaptation.

1. Introduction

Queensland's coastal communities are frequently impacted by significant natural hazards such as tropical cyclones and associated storm tide, and by the constant, long-term dynamics of sandy shores responding to climatic forces. Examples of recent extreme weather events that caused significant damage include tropical cyclones Larry (2006) and Yasi (2011) in Northern Queensland and the East Coast Low of May 2009 in Southern Queensland (BOM, 2012). As a result, short-term extreme erosion (storm scarps), long-term erosion (changes in the shoreline position and beach shape) and occasional inundation from the sea threaten coastal settlements and infrastructure.

Climate variability and change, including sea level rise trends, possible changes in storm patterns and the mean wave climate, will likely lead to additional pressure on coastal communities across the State.

The *Queensland Coastal Plan* (QCP) (DERM, 2011a) acknowledges the risks of climate change and introduces innovative planning elements to reduce risks to coastal settlements and infrastructure. In particular, it provides for coastal councils to prepare Coastal Hazard Adaptation Strategies (CHAS) for urban localities in high coastal hazard areas (HCHA). EHP, with input from the Local Government Association of Queensland (LGAQ) and the LGA working group, has developed the *Queensland Coastal Plan Guideline for Preparing Coastal Hazard Adaptation Strategies* (DERM, 2012), to inform coastal councils on the process and minimum requirements for preparing these strategies.

Further to this, EHP, LGAQ and Townsville City Council have undertaken a pilot project for the Townsville LGA area. The pilot project seeks to provide practical advice to LGAs for the preparation of future Coastal Hazard Adaptation Strategies by testing the relevant policies, tools and processes. The pilot project was funded by the Commonwealth Department of Climate Change and Energy Efficiency's Coastal Adaptation Decision Pathways program.

The Compendium of Coastal Adaptation Options for Queensland Coastal Councils (the Compendium) is a key product of this pilot project, with the main objective to:

> *Inform and support the identification and selection of suitable adaptation options for local governments to consider in the development of coastal hazard adaptation strategies.*

The Compendium provides information on a range of adaptation options, based on currently available information at the national and international level. The selection process and description of adaptation options was undertaken by Griffith University Centre for Coastal Management (GCCM) in consultation with GHD and the project partners. Options include hard and soft engineering measures, water-resilient designs, and a range of environmental and planning mechanisms which can be used to:

- Allow for development intensification by defending the current shoreline position and controlling erosion and storm tide inundation (defend);
- Maintain the current level of use and reduce the risk of storm tide inundation by applying innovative designs when redeveloping or upgrading existing building and infrastructure (accommodate); and/or
- Gradually retreat buildings and infrastructure to safer grounds (retreat).

The Compendium provides a technical description of each adaptation option, with examples of implementation from Australia and internationally. Further details of how each option can contribute to adapting to current and future coastal hazards, and potential synergies and conflicts with other adaptation options are also explored. The current legal and administrative framework for its implementation in Queensland is also reported, together with information related to maintenance requirements, timeframe for review, risk of failure and costs. Finally, a multi-criteria overview is presented to assess each option against climate uncertainty, social, environmental and economic criteria.

Since the commencement of the QCP and Townsville CHAS project, The Queensland Government has begun implementing changes to the *Sustainable Planning Act 2009* framework, including to State planning policies. The QCP policies are being reviewed and will be incorporated into a single State Planning Policy. Readers should check the Department of Environment and Heritage Protection's website to obtain contemporary statements of coastal planning policy and to access associated guidance material.

2. Coastal hazards in Queensland

Climate variability and change (extreme weather events in combination with global sea level rise) are currently challenging coastal communities' resilience around the globe and are likely to increase in the future (IPCC, 2007; Nicholls et al., 2011). With more than 85% of the population concentrated on the coast (ABS, 2002), Queensland is particularly vulnerable to the impacts of chronic (long-term) erosion patterns, extreme (short-term) erosion events and storm tides. In addition, population growth and consequent pressure for development in coastal hazard areas is challenging the capacity of communities and governing institutions to adapt in the future (DCC, 2009). This section outlines the characteristics of the coast of Queensland, the implications of climate change for coastal communities and fundamental concepts for climate change adaptation on the coast.

2.1. Coastal environments, climate variability and climate change

The Queensland coast is diverse, comprising a mix of sandy beaches, rocky headlands, low-lying mud and sand islands, coral atolls and rocky islands. These can host important ecosystems such as coastal dunes, mangrove swamps and coral reefs. The interaction of coastal processes with the various landforms and ecosystems creates a complex and dynamic environment. Hazard impacts such as beach erosion and coastal floods are the result of wind driven processes (waves, surge, currents) and astronomical processes (tides and currents) that combine to form potentially damaging events (DERM, 2011b).

Extreme waves reach the Queensland coast mostly from Tropical Cyclones in North Queensland; East Coast Lows (intense low-pressure systems) and southern ocean swell in Southern Queensland; Northwest Monsoon winds and Tropical Cyclones in the Gulf of Carpentaria; and from seasonal trade winds and even local sea breezes throughout the State. In Southern Queensland, swell waves from the open ocean can travel unimpeded towards the coastline. In Central and Northern Queensland, the Great Barrier Reef (GBR) prevents the majority of swell waves from reaching the coastline, however tropical cyclones can generate extreme waves within the GBR lagoon. Typically, outside of extreme conditions, the Gulf of Carpentaria and areas of the coast protected by the GBR experience waves lower in height, shorter in period and more irregular than those along the Southern Queensland coast (Harper, 2001; DERM, 2011b).

Most of Queensland experiences semi-diurnal tides, that is, two high and two low tides each day, with the tide turning approximately every 6 hours. Queensland's tidal range varies from micro-tidal (tidal range less than 2 metres) in Southern Queensland, meso-tidal (tidal range between 2 and 4 metres) in Northern Queensland and macro-tidal (tidal range over 4 metres) in the Central coast. The Gulf of Carpentaria and Torres Strait have particularly complex tides.

East Coast Lows and especially Tropical Cyclones are responsible for major storm events and storm tides on the Queensland coast.

East Coast Lows are intense low-pressure systems, which often develop during the winter months along the east coast of Australia. They can develop rapidly and are difficult to predict and can cause severe coastal erosion along the Southern Queensland coast. East Coast Lows can occur in clusters, creating long periods of strong winds, which generate high-energy waves that can lead to severe coastal erosion and local flooding.

Tropical Cyclones are intense low-pressure systems with strong winds moving in a clockwise direction around a calm 'eye'. (Note that in the northern hemisphere low-pressure systems move in an anti-clockwise direction). Tropical Cyclones are known to have impacted the entire Queensland coast, particularly in the north where they gain energy from high ocean temperatures. Tropical Cyclones rarely form south of 25˚S which is approximately the latitude of Bundaberg. Tropical Cyclones that do affect Southern Queensland have characteristically travelled from the north and are likely to be of reduced intensity as they enter cooler areas and encounter persistent westerlies. Tropical Cyclones typically occur between November and April. An average of 4.7 Tropical Cyclones per year affect the region, but only some of these make landfall. Tropical Cyclones can generate extreme waves, storm surges and consequent erosion, floods and property damage (Harper, 2001; DERM, 2011b).

Climate change is likely to influence the above mentioned coastal processes through sea level rise and by altering the wave climate and the frequency and intensity of extreme storms. As a consequence of sea level rise, sandy shores may be gradually eroded and the frequency of extreme water levels will gradually increase in the future. The QCP adopts 0.8m sea level rise by the end of this century relative to 1990 levels, subject to review after the release of the next Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) which is due to be released in early 2015. The QCP also adopts an increase of 10% in tropical cyclone peak wind intensity by 2100, based on the best available information at the time of its release.

Two coastal processes will be predominantly worsened by future climatic conditions: coastal erosion and storm tide inundation.

Coastal sediment erosion occurs at different timescales, either as a chronic process caused by imbalances of sediment budgets over a coastal stretch, or as a consequence of extreme events, when the beach realigns to cope with high energy wave conditions. Complex hydrodynamic processes drive erosion and realignment of low-energy muddy coasts in bays and lagoons, with a changing sea level being a major dynamic driver. Climate change is likely to exacerbate both chronic erosion and the beach response to changing extreme events as summarised below:

- As a consequence of sea level rise a beach will naturally realign towards a new equilibrium profile;
- Sea level rise will erode and affect the shape of lower-energy shorelines of bays and lagoons;
- The rate of sediment transport can change as a consequence of changing wave energy and direction reaching the coast, resulting in a new equilibrium profile for a beach; and
- Changes in the frequency and intensity of the occurrence of extreme events can exacerbate the impact on beaches and dune systems.

Higher ocean water levels and consequent short term **storm tide inundation** can be produced in association with the passage of a Tropical Cyclone or can be more persistent over time during East Coast Lows as follows:

- Higher water levels associated with sea level rise can increase the impact of extreme water level events if adequate defences are not in place;
- Storm surges are often accompanied by high waves increasing the localised sea level through the process of breaking wave set-up at the shoreline; and

- Wave run-up, the maximum vertical extent of wave uprush on a beach or structure, is proportional to local wave characteristics, especially height and length, as well as the shoreline interface, adding an additional component to the coastal hazard (Harper, 2001; Harper, 2004).

2.2. Adaptation to coastal hazards on the Queensland coast

Adaptation in coastal areas requires the identification and assessment of specific adaptive responses (referred to here as *adaptation options*). These should be gradually implemented to:

- Decrease the exposure of coastal communities; and
- Improve their resilience to current and future coastal hazards.

This Compendium provides guidance to councils on the types of adaptation options suitable for ensuring sustainable buildings and infrastructure within coastal hazard areas.

Queensland coastal council regions are diverse in terms of coastal processes, coastal hazards and type and intensity of development. For instance, some adaptation options may be suitable for the Gold Coast City Council area, but not the Gulf of Carpentaria. Table 1 provides an overview of coastal processes and hazards most relevant to LGA areas across the State, assuming that sea level rise projections are the same for each region. However, specific advice on the suitability of adaptation options for selected councils can only be given on the basis of detailed technical studies at the local level.

Table 1 Coastal process drivers and hazards for different regions and councils in Queensland

Region and Councils	Coastal process drivers				Coastal hazards		
	Tropical Cyclones	East Coast Lows	Swell Waves	Tides	Storm erosion	Chronic erosion	Storm tide
Southern Queensland incl: Brisbane City Council, Gold Coast City Council, Moreton Bay Regional Council, Redland City Council, Sunshine Coast Regional Council, Gympie Regional Council	✓	✓✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓
Central Queensland incl: Bundaberg Regional Council, Burdekin Shire Council, Fraser Coast Regional Council, Gladstone Regional Council, Isaac Regional Council, Mackay Regional Council, Rockhampton Regional Council, Whitsunday Regional Council	✓✓	✓	✓✓	✓✓✓	✓✓	✓✓	✓✓
Northern Queensland incl: Aurukun Shire Council, Cairns Regional Council, Cassowary Coast Regional Council, Cook Shire Council, Hinchinbrook Shire Council, Hope Vale Aboriginal Shire Council, Lockhart River Aboriginal Shire Council, Mapoon Aboriginal Shire Council, Napranum Aboriginal Shire Council, Northern Peninsula Area Regional Council, Palm Island Shire Council, Torres Shire Council, Townsville City Council, Weipa Town Authority, Yarrabah Aboriginal Shire Council	✓✓✓		✓✓	✓✓	✓✓	✓✓	✓✓✓
Torres Strait incl: Torres Strait Islands Regional Council	✓		✓	✓✓✓	✓✓	✓✓	✓
Gulf of Carpentaria incl: Burke Shire Council, Carpentaria Shire Council, Doomadgee Aboriginal Shire Council, Kowanyama Aboriginal Shire Council, Mornington Shire Council, Pormpuraaw Aboriginal Shire Council	✓✓✓		✓	✓✓	✓	✓	✓✓✓

Note: Relevance is identified from high (✓✓✓) to low relevance (✓)

3. The Compendium

The Compendium provides LGAs with a tool to support decisions on:

- The approach or combination of approaches to adopt for a coastal locality in a HCHA, i.e. whether to *defend* and allow urban intensification, *accommodate* storm tides and sea level rise whilst maintaining current levels of use, or reduce current levels of use and gradually *retreat* from the area; and
- The adaptation options available to pursue these objectives, including an assessment of how the adaptation option can be implemented within the existing legal, administrative and planning regulations.

It is noted here that while providing an overview to all levels of local government on coastal adaptation options, the information within this document is directed at experienced LGA technical officers in both the planning and engineering fields.

3.1. Defend, accommodate or retreat?

Three coastal planning approaches are proposed to address risk in high coastal hazard areas through a CHAS: *defend*, *accommodate* or *retreat*. It is unlikely that any one option will be implemented in isolation. Rather a combination of approaches will normally be implemented within the same LGA area, for instance:

- *Defend* – Protect some sectors of the HCHA with hard coastal engineering structures to avoid storm tide inundation or erosion, allowing the intensification of uses;
- *Accommodate* – Maintain the current level of use in other sectors of the HCHA and allow occasional storm tide inundation (e.g. less than 1 m) or erosion events by means of innovative designs for buildings and infrastructure (e.g. elevating or change in use); and
- *Retreat* – Gradually recover HCHA threatened by severe inundation (e.g. more than 1m depth), permanent inundation or erosion events now and over (say) the next 100 years, where the defence and accommodation would be too expensive, impractical or harmful for the environment.

For the purpose of this Compendium, we formally adopt the following definitions:

3.1.1. Defend

Protect sectors of the coastal hazard area with either hard or assimilating coastal engineering structures to reduce or remove storm tide inundation or erosion risks,. Defend strategies may include maintaining the existing use or intensifying development on the land. Coastal defence may combine long-term strategies for defence and maintenance including regenerative and structural options such as beach nourishment, dune construction, dykes and storm tide barriers.

3.1.2. Accommodate

Maintain the current level of use within coastal hazard areas and raise the tolerance to periodic storm tide inundation or erosion events by means of innovative designs for buildings and infrastructure (e.g. elevating, strengthening or change in use). This entails undertaking actions that will reduce the impacts from coastal hazards to an acceptable level. Actions can generally be broken into two categories:

- Works that will allow the current use to continue (e.g. upgrading drainage works and raising land levels when the existing use is redeveloped); and
- Physical works and legislative amendments that provide for more appropriate future use of the land. For example changing the designated land use to one that can better tolerate the risk (e.g. rezoning land from residential to industrial use), or operational works to raise the height of developable land above the height of potential sea level rise.

3.1.3. Retreat

Includes actions to withdraw from the coastal hazard impacts through relocation or abandonment. The *retreat* option involves removing the vulnerable use from the threatened site which could be achieved through various mechanisms such as relocating the community (e.g. through a land swap arrangement) or abandoning the area (e.g. through buy back mechanisms or rezoning the land to an open space or recreational use).

3.2. Maintain status quo

In the process of assessing possible responses to coastal hazards, taking into account their costs and the views of the community, councils may consider a “maintain the status quo” approach.

Maintaining the status quo allows for continuation of the existing use in an area but prevents any further intensification of those uses. It does not restrict land owners from applying for work on their land to defend (e.g. collaboratively with adjoining landowners) or accommodate the impact of coastal hazards within the existing legislative framework.

A decision to maintain the status quo should be supported by actions such as:

- Planning scheme modifications (e.g. in the strategic framework) to reflect the decision not to intensify land use;
- Ongoing monitoring and review of hazards;
- Targeted public education on hazards;
- A hazard note on property searches;
- Regular review of the emergency plan of the Local and District Disaster Management Group, which recognises the changing risk profile;
- Regular update of the council’s infrastructure plan to reflect longer term intention regarding services and infrastructure in the area as the risk profile changes; and
- Rates review of properties in the area.

In the context of a coastal hazard adaptation strategy, a decision to maintain the status quo demonstrates a clear intention on the part of Council to avoid locating large numbers of additional people in a high coastal hazard area, but without creating community expectation that Council will take any particular action (defend, accommodate or retreat) in the future. When supported by public education on the magnitude of the attendant risks it enables communities to better prepare for potential coastal hazards.

This option may be appropriate where infrastructure and asset investment is currently low and unlikely to increase, and where intensification is undesirable for other reasons, such as the wishes of the community. Alternatively, it may be preferred where other options such as defence or retreat are technically not unfeasible or are not cost effective.

However, with this strategy in place, service providers (Council, key utilities or other services, including emergency services) may at some point make the decision to discontinue services to the area.

3.3. Description of options

The list of coastal hazard adaptation options was identified through a thorough analysis of the existing information at the international and national level in parallel with an extensive consultation process with academic and industry experts, and Queensland Government and LGA representatives.

The adaptation options are divided into:

- **Regenerative options** (Section 4), including beaches, dunes, riparian vegetation and wetlands restoration.
- **Coastal engineering options** (Section 5), including a range of structures for erosion and flood control.
- **Human settlement design options** (Section 6), covering building and infrastructure retrofitting and design, and the raising of land levels.
- **Planning options** (Section 7), including development setbacks, buy-backs schemes, land swap and land-use change.

However, the boundaries between these categories can be ambiguous. For example: Is the construction of a dune more "natural" than the construction of a dyke, when both of them are covered in vegetation? The four category classification system is proposed to assist the end user to easily identify those strategies relevant to the subject LGA area for the development of the future CHAS documents. Accordingly, each adaptation option has been analysed using the following framework:

- A table describing the option's role in the context of a chosen approach, whether it is **defend**, **accommodate** or **retreat (DAR)**;
- A **technical description**, illustrating how the option works and the context in which it can be implemented;
- The option's **role in coastal hazard adaptation**, including discussion on how this option can improve the resilience of coastal settlements and infrastructure under coastal erosion and storm tide inundation scenarios;
- A table assessing the **synergies and conflicts with other adaptation options**, to understand how different adaptation options can be combined to reach the desired outcomes;
- Details on how the adaptation option might work within the **legal and administrative framework** for Queensland's LGAs.
- Information on **maintenance** needs**, timeframes for review** and **costs**, where applicable;
- A **multi-criteria overview**, in terms of climate uncertainty, social and environmental impacts, and costs; and
- **Case study boxes** describing how the option is currently working in place in specific contexts at the international, national or State level.

A semi-quantitative icon scale has been utilised throughout the Compendium to assist the end-user to interpret the analysis of each adaptation option (refer to Table 2).

Table 2 Scale for the assessment of adaptation options

Icon	Defend, Accommodate, Retreat	Coastal Hazards	Synergies and conflicts
✓✓	The option is usually very effective for either D, A or R	The option is very effective for the coastal hazard	The option can have a very positive synergy with the option
✓	The option is usually effective for either D, A or R	The option is effective for the coastal hazard	The option can have a positive synergy with the option
●	The option is usually not used for either D, A or R	The option is not used for the coastal hazard	No interaction
✗	The option is not quite effective for either D, A or R	The option is not quite effective for the coastal hazard	The option can be in conflict with another option
✗✗	The option shouldn't be used for either D, A or R	The option shouldn't be used with the coastal hazard	The option is in conflict with another option

Finally, Section 8 provides information on the **implementation** avenues for each option within the context of LGA planning schemes and other LGA instruments, including potential funding mechanisms.

3.4. Practical advice

The majority of adaptation options described in the Compendium can be combined to pursue the outcomes of a CHAS for a given HCHA, whether the chosen approach is to defend, accommodate or retreat. For example:

- Beach nourishment and dune regeneration programs can be implemented to defend the current shoreline position and provide a buffer against extreme erosion during a storm tide, while the same event can inundate adjacent waterways where accommodation options, such as improved design standards for houses, are in place;
- Environmental restoration such as riparian corridor restoration and generation and/or wetland restoration can be beneficial for defence, accommodation or retreat, depending on the local context;
- Dune regeneration and beach nourishment can be carried out after building and infrastructure removal as part of a retreat and regenerate program; and
- Land buy-back can be applied to retreat from the shore, however under certain circumstances, it can be used to make space for defence infrastructure such as a sea dyke.

In practice, there is no "one-size-fits-all" solution and comprehensive coastal hazard adaptation will only be achieved by combining options at the local scale. In this sense, LGAs are encouraged to consider specifically critical local variables, such as exposure to tropical cyclones, rainfall patterns and long term climate variability, to identify the combination of adaptation options required to develop their CHAS.

A number of elements should be considered when deciding which adaptation option better suits a locality under threat from coastal hazards. These may include, for instance:

- Costs associated with rock armour materials for constructing groynes or seawalls or appropriate sand for beach and dunes generation if materials cannot be sourced locally;
- Unintended consequences. For example, extreme heavy rain can accumulate water behind a dyke or seawall and will need to be managed; and
- A combination of coastal defence options can control coastal erosion and inundation, but worst case scenarios may still occur and the LGA and the community should be prepared to activate emergency procedures, including evacuation.

The Compendium is not an exhaustive listing of all available adaptation options but only those that are currently being implemented or deemed suitable for the Queensland context. Other options, which either are not suitable to the legal and administrative framework of Queensland or not currently under investigation include:

- Bounded approvals;
- Community awareness;
- Emergency planning only solutions;
- Floating buildings and infrastructure;
- Insurance schemes;
- Hazard “full disclosure” clause; and
- Rolling easements.

4. Regenerative options

Regenerative adaptation options usually mimic natural processes and design to either improve or create existing coastal ecosystems and landforms to reduce the risk of coastal hazards on human settlements. This section discusses four regenerative adaptation options:

- Beach nourishment;
- Dune construction and regeneration;
- Riparian corridors restoration and generation; and
- Wetland restoration.

Figure 1 Boondall Wetland Reserve near Nudgee Beach, a Brisbane suburb.
Source: Google Earth, 2012

4.1. Beach nourishment

Beach nourishment is the artificial addition of sand to a beach system, increasing the buffer against erosion or halting erosional losses. Beach nourishment reduces the risk of storm tide inundation when combined with dune creation and vegetative stabilisation.

Table 3 Beach nourishment and coastal planning approaches

	Defend	Accommodate	Retreat
Beach nourishment	✓✓	✓	✓
	Critical in defending the current shoreline position and to protect coastal communities from erosion and inundation	To be used to accommodate current uses and reduce the risk of inundation and erosion	To be carried out as part of an environmental restoration program after retreat from high coastal hazard areas

4.1.1. Technical description

Beach nourishment is used to maintain and/or advance the shoreline position. Sea level rise will require additional sand volumes to counterbalance beach recession (refer Figure 2).

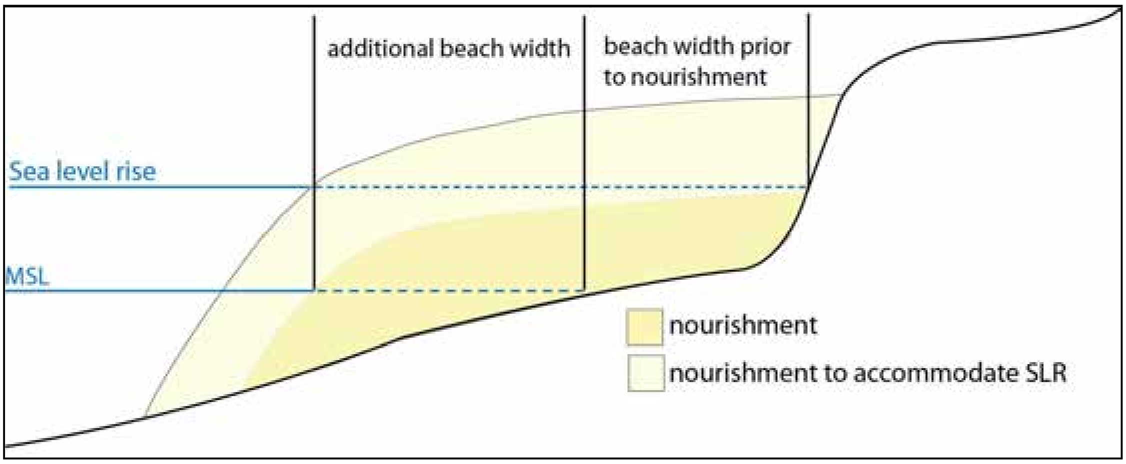

Figure 2 Diagram of typical beach nourishment cross-section.
Source: GCCM

Beach nourishment is a soft engineering approach to coastal protection, which involves the artificial addition of sediment of suitable quality to a beach area that has a sediment deficit or inadequate buffer zone. Beach nourishment can also be referred to as beach recharge, beach fill, replenishment, re-nourishment and beach feeding (Linham & Nicholls, 2010).

Traditionally, beach nourishment has been carried out for two main purposes:

1. To control erosion and create a buffer for settlements and infrastructure (a wider beach system can reduce storm damage to coastal structures by dissipating energy across the surf zone, protecting settlements and infrastructure from extreme events); and
2. To broaden beaches for recreational purposes (beaches are valuable assets for tourism and recreation and economic drivers for coastal communities).

It is important to note that beach nourishment does not halt erosion, but simply provides sediment from an external source in the form of a natural beach, upon which wave and current forces will continue to act.

Beach nourishment can be used to feed existing beaches or to create entirely new beaches by importing sediments from external sources (sourcing only outside the beach system itself) including sand mining, offshore sand deposits, sediments from rivers and river mouths and sand or gravels from quarries. For example, fluvial sand used to fill the pocket beaches on The Strand in Townsville was obtained from the upper Burdekin River west of Townsville, approximately 100 km away from the beaches (Muller et al., 2006). Beach nourishment can also be carried out by sand by-pass systems, which mimic the natural flow of sand on shorelines interrupted by shoreline defences and infrastructure. See, for example, the Tweed River Entrance Sand By-pass, on the Gold Coast (Box 1). Other employed systems include sand back-passing systems designed to retain sand within sedimentary cells (for example, the Noosa Beach Sand Recycling System (SSM, 2004)). However, sand by-pass or back-pass systems are designed to maintain sediment budgets and do not add more sand to the system.

Box 1. Beach Nourishment on the Gold Coast, Queensland

The Gold Coast beaches have experienced periods of severe erosion. In 1967 a series of 11 East Coast Low type storms and remote tropical cyclones removed most of the sand from Gold Coast beaches. Such extreme storms continued to challenge beach resilience until a major beach nourishment programs started in 1974 implementing the recommendations of the so-called Delft Report (DHL, 1970). Starting with 765,000 m^3 of sand from the Tweed River entrance to nourish the southern Gold Coast beaches, the program continued in the following years, sometimes combined with hard defences, such as groynes and seawalls. In 1995 the Tweed River Entrance Sand Bypassing project was initiated by dredging the sand accumulated in the Tweed River. The project continued in 2001 with the implementation of the bypass system that has pumped, , on average, 500,000 m^3 of sand from Northern NSW onto the Gold Coast's southern beaches (Strauss et al., 2009).

Figure 3 Sand bypass system of the Tweed River.

The characteristics of sediments used for nourishment need to be compatible with the natural sand of the beach; the two main parameters of compatibility are grain size (borrowed grain size has to be of the same size or slightly bigger than the natural sand) and colour (it is desirable for imported sand colour to be compatible with the natural sand).

Several methods of beach nourishment can be utilised, including placement by dredge (Figure 4), trucks or piped slurry. Sand can be placed to create a widening of the beach and dune or placed offshore where it can be gradually moved onshore under the normal action of waves. Placement as an underwater deposit may also serve to encourage the dissipation of wave energy, especially storm waves, thereby reducing wave impact at the shore (Linham & Nicholls, 2010). Beach nourishment can require large amounts of sand. For example, creating a 100m wide beach requires approximately 500m^3 per linear metre of coastline, depending on beach slope and grain size. The identification of accessible sand deposits is therefore critical to prepare long-term strategies, especially in the light of the possible impacts of climate change.

Figure 4 Sand dredging as part of the Northern Beach Protection Strategy.
Source: Neumann Contractors www.neumanncontractors.com.au

Figure 5 **Beach nourishment in Queensland. Top: "rainbowing" sand from a dredge at Woorim, Bribie Island, circa 1988.; Bottom: Stabilised beach at Woorim in 2012.**
Source: **Beach Protection Authority and GHD Pty Ltd.**

4.1.2. Role in coastal hazard adaptation

Beach nourishment can be used as a flexible option to cope with coastal hazards in the medium and long term. Noting its simplifying limitations, the so-called Bruun Rule provides a basic understanding of the impacts of gradual sea level rise on a beach profile (Bruun, 1962): depending on beach characteristics and neglecting longshore sediment transport, approximately 50 to 100m of erosion from the shoreline can be expected for 1m sea level rise (CSIRO, 2012).

In addition, potential changes in storm patterns, in particular mean wave direction, can alter beach equilibrium both under rare extreme events and also as a result of changes in the mean wave climate. Beach nourishment strategies can be used to cope with these changes in the short (days to years) and long term (years to decades). Estimations of the impact of erosion due to sea level rise can be used to calculate the sand requirements to maintain the current beach profile and width. Importantly, programs to monitor the shoreline evolution should be put in place to understand where and when beach nourishment should be performed. For example, a recent study estimated that maintaining current beach conditions along 55km of Sydney's northern beaches with 0.9m sea level rise by 2100 would require approximately 53 million m^3 of material, with offshore sand deposits being the only reliable source of sediments in the long term (Gordon, 2009).

Table 4 Beach nourishment and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Beach nourishment	✓✓	✓✓	✓	✓✗
	Nourishment can create a buffer to protect buildings and infrastructure from occasional extreme storm erosion	Ongoing beach nourishment programs or by-pass systems can help counterbalance chronic erosive processes	Nourishment can help maintain coastal defence systems, including dune fields, protecting buildings and infrastructure from occasional storm tide inundation	When buildings and infrastructure are below sea level, beach nourishment can help maintain coastal defence systems, including dune fields, protecting them from storm tide inundation. However retreat can be a better option

Box 2. Large-scale beach nourishment in The Netherlands

Dutch policy is to maintain the coastal foundation present in 1990, being the volume of sand present up to the 20m mark. The deeper part of the coastal profile is thereby considered to be vital for the maintenance of the coast as well. At present, beach nourishment takes place every four to five years. Annual monitoring of the coastal profile is used as input to decide the quantity of sand needed. The average beach nourishment volume in the Dutch coastal system comprises up to 12 million m^3 of sand per year. Inspired by the proposed large-scale increase in annual beach nourishment volumes (Delta Commission, 2008), Dutch coastal authorities presently explore a variety of innovative sand nourishment strategies. One of these is based on the implementation of so-called mega-nourishments. This concept involves the recurrent realisation of large-scale nourishments along the Dutch coast (each typically in the order of 20 million m^3). A surplus of sand is put into the natural system and expected to be re-distributed alongshore and into the dunes through the continuous natural action of waves, tides and wind. In this way mega-nourishments gradually induce dune formation along a larger stretch of coastline over a period of one or more decades, thus contributing to the preservation or increase of safety against flooding over a longer period. Before being fully assimilated into the coastal system, the surplus sand volume temporarily creates added value for nature and recreation; amongst others by providing shoals as rest areas for sea mammals, wide beaches for daily tourism and challenging conditions for the local surfing community.

Figure 6 Beach nourishment techniques.
Source: DHV, 2011

4.1.3. Synergies and conflicts with other adaptation options

Beach nourishment can be combined with other adaptation options as part of a broader coastal defence scheme. Internationally, beach nourishment is often coupled with groynes, detached breakwaters or artificial reefs to reduce the amount of sediment needs or to avoid sediment losses during storms. Whilst it is not a common practice in Queensland, the combination of beach nourishment with hard engineering options should be considered on a case by case basis.

Beach nourishment can be coupled with planned retreat where the strategy includes the rehabilitation of the previously occupied coastal stretch.

Table 5 Synergies and conflicts of beach nourishment

Beach nourishment			
Regenerative options	Dune construction and regeneration	✓✓	Dunes are part of the beach system; these options are mutually beneficial
	Riparian corridors restoration and generation	●	Usually there's no interference
	Wetlands restoration	●	Usually there's no interference
Coastal engineering options	Artificial reefs	✓	Artificial reefs are sometimes associated with beach nourishment for beach stabilisation and salient formation
	Detached breakwaters	✓	Detached breakwaters are sometimes associated with beach nourishment for beach stabilisation and tombolo formation
	Groynes and artificial headlands	✓	Sometimes associated with beach nourishment for beach stabilisation and to reduce the longshore drift of sand
	Sea dykes	✓	Beach nourishment is compatible with sea dykes as it can be carried out on the seaward side of these structures
	Seawalls	✓	Beach nourishment is compatible with seawalls when a large amount of sand is placed in front of the structure. However these structures can sometimes induce further erosion if the water level reaches the base of the structure
	Storm surge barriers	●	Usually there's no interference
Coastal settlements design options	Building retrofitting and design	●	Usually there's no interference
	Flood-resilient public infrastructure	●	Usually there's no interference
	Raise land levels	●	Usually there's no interference
Planning options	Development setbacks	✓	It can be coupled with coastal development setbacks to keep in place the hazard risk line from which the setback is measured
	Land buy-back	✓	It can be carried out to restore recovered coastal space and regenerate its natural functions
	Land swap	✓	It can be carried out to restore recovered coastal space and regenerate its natural functions
	Land-use planning	✓	It can be carried out to restore recovered coastal space and regenerate its natural functions

4.1.4. Legal and administrative framework

Under Queensland legislation, a development approval is required to carry out works affecting beaches and dunes, depending on the nature and scope of the project. The development assessment process is under the *Sustainable Planning Act 2009*, and the Integrated Development Assessment System (IDAS) incorporates the requirements of the *Coastal Protection and Management Act 1995*.

The QCP provides details on the role of beach nourishment in reaching policy outcomes. The plan considers that coastal erosion should be managed through soft protection measures including beach nourishment that involve the augmentation or relocation of natural coastal sediments. The policy specifies beach nourishment as the preferred option to protect settlements and infrastructure, while engineered erosion control structures, such as seawalls and groynes, are only considered where beach nourishment or landward retreat of the infrastructure is not a practical or cost effective option. Where utilised, beach nourishment works are to be undertaken so that:

- The works are suitable for the location; the source sediment is of a suitable quality and is of a type and size which matches that of the native sediment;
- The methods of placement are suitable for the location and do not interfere with long-term use of the locality or environmental values within or neighbouring the proposed placement site; and
- There is sufficient supply of source sediment (DERM, 2011a).

Planning considerations for local government

- What works are required?
- Is coastal protection viable?
- Are there any land tenure considerations?
- What planning and environmental approvals are required?
- Will the works impact on any ecological values, public access and use, cultural heritage values or scenic amenity?
- Are there stakeholders relevant to the project that can contribute?
- What planning outcomes have been identified for the area (i.e. through local or regional plans) and how will the project affect these outcomes?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by beach nourishment works are listed in Table 6. Separate requirements for the dredging of source material have not been considered here.

If the proposed development is considered to be tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- The IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A; and
- Any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* (CPM Act) but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;

- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*; and
- Owners consent for development on private property.

Table 6 Approvals required for beach nourishment

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State **resource) / owners consent**	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land. •	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational works – for removal, destruction or damage of marine plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

Beach nourishment may be required in accordance with an agreed Shoreline Erosion Management Plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

Beach nourishment programs are planned for and funded through an LGA's Shoreline Erosion Management Plan and operational works budget. Examples of LGAs that have previously implemented beach nourishment programs are the Gold Coast City Council and Sunshine Coast Regional Council.

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Beach nourishment is conducted in tidal areas where the tenure is typically unallocated State Land. These areas will not require planning scheme mapping amendments or additional overlays for implementation measures carried out. The only approval triggered under the planning scheme may be operational work for filling and excavation. Other approvals that may be required have been outlined in the sections above.

4.1.5. Maintenance

A long term beach nourishment strategy requires continuous monitoring of shoreline changes to identify timing of renourishment campaigns. Monitoring campaigns are typically carried out annually or in response to significant erosion events. Monitoring campaigns can be conducted with remote cameras or traditional survey techniques. Operational plans to mobilise sand in the short term from strategic sand deposits should be put in place to reduce risks for settlements and infrastructure during emergencies.

4.1.6. Timeframe for review

Beach nourishment is commonly carried out in response to chronic shoreline erosion, while emergency works to cope with extreme storms cannot be considered within fixed timeframes. Depending on the type of intervention, common timeframes for the investment are from 1 to 20 years. For instance, yearly replenishments are commonly used to respond to extreme events and prepare beaches for the tourist season. These are often in the order of the few tens of thousands of cubic metres of sand. Newly constructed artificial beaches combined with hard defence structures, on the other hand, are major investments sometimes involving nourishment in the order of millions of cubic metres. This type of adaptation strategy should have a lifespan of at least 20 years. Where the intervention is a fixed infrastructure such as a by-pass system, continuous operations and performance management will be in place.

4.1.7. Failure risk

Beach nourishment does not stop the natural processes causing erosion, whether it is a lack of natural sand supply or changes in the hydrodynamic conditions. However, failure may be associated with inappropriate design of the intervention (e.g. balance between beach nourishment of the emerged beach and supply of sand to the submerged bar) which can result in apparent loss of sand in the short term. Other risks of failure are related to the broader beach nourishment strategy. For example, when funds are not allocated to cover the needs of long-term programs or sand supply sources are not available.

4.1.8. Estimated cost

The current approximate cost for beach nourishment is $40/m^3; costs can vary depending on distance to the source and quality of sand.

4.1.9. Multi-criteria overview

Table 7 Multi-criteria overview for beach nourishment

Beach nourishment			
Climate uncertainty	Effectiveness	How effective is it for coastal hazard adaptation?	Very effective when there is a ready source of compatible sand, and reasonable costs for mobilisation and operational plans are in place.
	Flexibility	Can it be modified after implementation?	Programs to nourish beaches can be easily modified depending on climatic or beach evolution.
	Reversibility	Is it easy to completely remove?	While sand can't be easily removed, it is a soft engineering solution in balance with natural processes. Removal can occur naturally as a result of sediment transport or storms.
	No regret	Is there any other social or environmental benefit?	Healthy beaches support coastal uses, accessibility and beach ecosystems.
	Decision Horizon	Does it help gaining time for major decisions?	Beach nourishment programs can be put in place until major decisions, e.g. retreat from the shoreline, are taken.
	Synergy with climate change mitigation	Does it help reducing emissions?	Works associated with nourishment operations are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Accessibility is improved.
	Landscape	Does it impact landscape values?	Landscape values are not affected if the size of the beach or the colour of the sand doesn't change substantially.
	Recreational use	Does it affect recreational uses?	Recreational uses can sometimes be detrimentally affected, e.g. established surfing conditions, but generally conditions are improved.
	Property values	Are private property values affected?	Property values can increase as a consequence of a wider and healthier beach.
	Impact on ecosystems	Does it impact coastal ecosystems?	Beach ecosystems can be affected by sand replenishments. However recreating beaches can support ecosystems functions e.g. turtle nesting sites.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high depending on the cost of sand.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance programs can be expensive. Maintenance intervals are difficult to predict, requiring a maintenance funds to ensure ongoing works can be undertaken as and when required.

4.2. Dune construction and regeneration

Sand dunes are wind-formed sand deposits representing a store of sediment landward of the normal high tide mark on natural beaches. Dune construction refers to the creation of artificial dunes to mimic the functioning of the natural system. Dune regeneration refers to the recovery and maintenance of the shape and vegetation of the dune system, reducing the risks of erosion and storm tide inundations whilst improving ecological functions.

Table 8 Dune construction and regeneration and coastal planning approaches

	Defend	Accommodate	Retreat
Dune construction and regeneration	✓✓ Critical in defending the current shoreline position and mitigating erosion and floods while allowing intensification of inland settlements.	✓ To be used to accommodate current uses and reduce the risk of inundation and erosion.	✓ To be constructed and vegetated on the new shoreline after retreat as part of a coastal restoration program.

4.2.1. Technical Description

Dunes are eroded under extreme sea level and wave conditions. Dune regeneration aims at recovering the dune volumes and vegetation cover. Dune regeneration will have to account for sea level rise in the future.

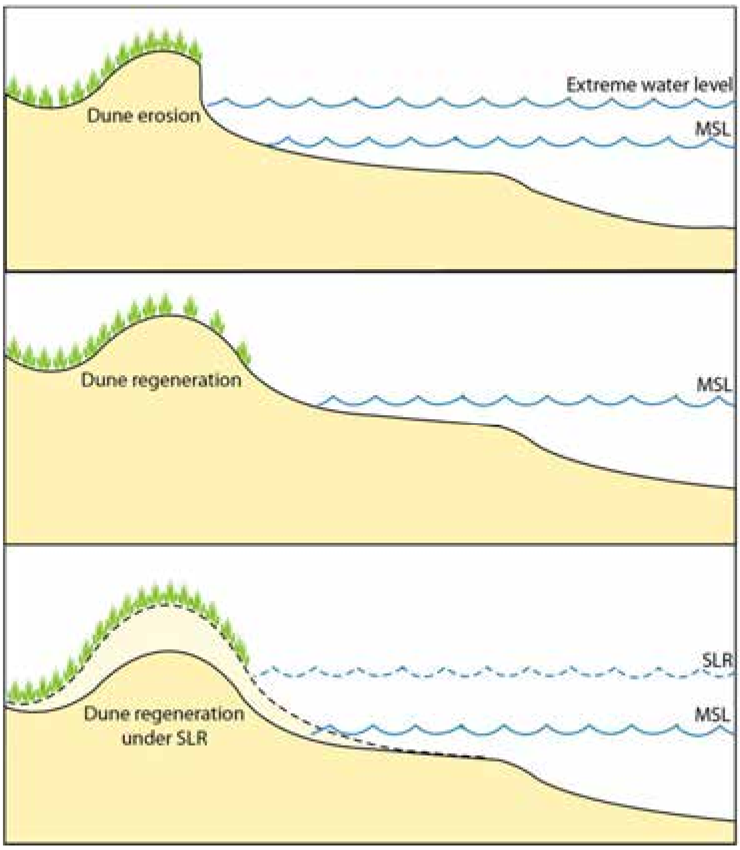

Figure 7 Typical dune construction and regeneration cross-section.
Source: GCCM

Most beaches are backed by vegetated sand dunes that are built up by dry beach sand blown inland and trapped by plants and other obstructions. As sand accumulates, the dunes become higher and wider. Plants play a vital role in this process, acting as a windbreak and trapping the deposited sand. A characteristic of these plants is their ability to grow up through the sand and continually produce new stems and roots as more sand is trapped and the dune grows. Dune restoration and management, including sand replacement and planting of vegetation, has been very successful internationally. LGAs and/or local resident action groups regularly undertake planting of large areas. These revegetated areas enhance 'buffer zones' that naturally protect the coast during storm events.

Dune management can be very successful where a wide dune area is or was previously present and there is an abundant source of sediment. Where only a small width of beach is present, dune management can be applied in conjunction with other coastal protection measures that result in the widening of the beach (DERM, date not specified, b).

During storm surge events dunes act as a dynamic buffer zone; the foot of the dunes can be eroded, protecting the hinterland from erosion and flooding. The eroded material in turn supplies the littoral sediment budget thus minimising general erosion along the entire section of shoreline. During the storm, sand is also transported offshore. Sediment in the resultant sand bar will be returned naturally to the shoreline during calmer periods and will over time replenish the beach dunes.

Artificial dune construction involves the placement of sediment from dredged sources on the beach. The deposited sediment is reshaped into dunes using heavy machinery or other means. Dune construction is most frequently carried out at the same time as beach nourishment.

There are a number of methods of dune stabilisation including:

- Vegetation planting to stabilise natural or artificial dunes. This promotes the accumulation of sand from wind-blown sources around their stems. Over time, this results in dune growth. Planting can be achieved by transplanting vegetative units from nursery stocks or nearby intact dunes. It can be undertaken at the community level using widely available tools; and
- Fences or brush matting on the seaward side of an existing dune to trap sand and help stabilise any bare sand surfaces. This method can also be used to promote dune growth after a structure has been created using heavy machinery. Natural materials such as branches are commonly used for fence construction, as they break down once they have accomplished their sand-trapping objective.

Artificial dune creation and dune restoration can be carried out on existing beaches, beaches built through nourishment, existing dunes, undeveloped land, undeveloped portions of developed areas and areas that are currently fully developed but may be purchased so that dunes can be restored (Linham and Nicholls, 2010).

Box 5. Noosa sand spit restoration

In 1978, an extensive scheme of works successfully relocated and stabilised the Noosa River entrance. The works included construction of a groyne, formation of a new beach–dune system and sand nourishment of the existing beach. Sand placement and pumping associated with the works resulted in the formation of approximately 20 hectares of bare sand consisting of a foredune to prevent wave overwash, and wide, low undulating hind-dune areas. To maintain the height of the foredune and to protect the hind-dune areas, it was necessary to stabilise the bare sand areas against wind erosion. Dune stabilisation works used brush matting and mulch to prevent wind erosion. Sand spinifex grass (*Spinifex sericeus*) was the species best suited to provide ground cover on the exposed foredune. Other species were planted successively, creating a rich ecosystem. The successful completion of the engineering works and the subsequent stabilisation of the dunal areas with vegetation has stabilised the mouth of the Noosa River and resulted in a major extension to the beach at Noosa Heads. An extensive recreational area has also been created. Continued development of the tree and shrub species in the hind-dune areas has led to greater species diversity, increased stability and a self-regenerating vegetative cover. Information gained from this project has been used to plan and assess similar projects in south-east Queensland (DERM, date not specified, a).

Figure 8 Noosa sand spit restoration, 1978
Source: DERM, date not specified, a

Figure 9 Noosa coastline and sand spit, 2011
Source: Google Earth

4.2.2. Role in coastal hazard adaptation

Dune regeneration and construction can be used as a flexible option to cope with coastal hazards in the medium term (years) and long term (decades). Dune systems increase the resilience of the beach providing a source of sediment in the case of extreme erosion. A healthy dune system can therefore reduce the risks for settlements and infrastructure without interfering with the natural dynamics of the coast. Permanent construction on top of the dune system should be avoided in the future.

Maintenance of dune width and height can help adapt to sea level rise and reduce inundation during storm tide events. Increasing the height of the crest of the dune in response to sea level trends is a feasible option where adequate sand deposits are available. Dune rehabilitation and reconstruction can have a role in both defending the current shoreline position and retreating from the shore through environmental restoration and dune construction following retreat.

Table 9 Dune construction and regeneration and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Dune construction and regeneration	✓✓	✓✓	✓	✓
	Dune construction and regeneration can create a buffer to protect buildings and infrastructure from occasional extreme storm erosion.	Dune construction can create an additional sand source to counterbalance chronic erosion, however, this situation should be avoided by maintaining the beach through continuous sand nourishment .	Sand dunes can be designed to cope with occasional storm tide inundation. Dune height and width are the main parameters for design. Maintenance and replacement of the eroded sand should be carried out after any damaging storm.	When building and infrastructure are below sea level, dune construction and rehabilitation can help maintain other coastal defence systems, e.g. dune fields, protecting other unarmoured barrier defences from storm tide inundation. In these cases, retreat may be the more appropriate option.

4.2.3. Synergies and conflicts with other adaptation options

Dune construction and regeneration is typically combined with beach nourishment programs. It can also be undertaken in association with hard engineering structures, such as breakwaters or groynes. Dunes can be generated as part of an environmental restoration program after retreat of vulnerable infrastructure.

Table 10 Synergies and conflicts of dune construction and regeneration

Dune construction and regeneration			
Regenerative options	Beach nourishment	✓✓	Dunes are part of the beach system; these options are mutually beneficial.
	Riparian corridors restoration and generation	•	Typically no interference.
	Wetlands restoration	•	Typically no interference.
Coastal engineering options	Artificial reefs	✓	Can be combined as part of an integrated defence system.
	Detached breakwaters	✓	Can be combined as part of an integrated defence system.
	Groynes and artificial headlands	✓	Can be combined as part of an integrated defence system.
	Sea dykes	✓✗	Can be combined, but are usually on different types of coast.
	Seawalls	✓✗	Can be combined, usually when the seawall is buried under dunes.
	Storm surge barriers	✓✓	Dune construction and regeneration can support the function of storm surge barriers to flood-proof a coastal area.
Coastal settlements design options	Building retrofitting and design	•	Typically no interference.
	Flood-resilient public infrastructure	•	Typically no interference.
	Raise land levels	•	Typically no interference, however dunes can be constructed on the seaward side of the raised land.
Planning options	Development setbacks	✓	Can be combined, usually to protect the dune system.
	Land buy-back	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate natural functions.
	Land swap	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate natural functions.
	Land-use planning	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate natural functions.

4.2.4. Legal and administrative framework

Under the Queensland legislation, approvals are required to carry out works affecting beaches and dunes, depending on the nature and scope of the project.

The QCP provides guidance and policies for coastal dune management and preservation, based on the principle that dunes are to be protected and dune vegetation is maintained and enhanced.

Planning considerations for local government

- What works are proposed?
- Will there be any adverse impacts on coastal process, natural character, the local economy, scenic amenity and public access?
- Has potential impact on ecosystems and habitats been considered (such as habitat for migratory shorebirds and turtle nesting areas)?
- Has the community been consulted regarding the planned works?
- What are the wide benefits to the community from the works?
- Are management plans needed for dune rehabilitation and maintenance?
- How will ongoing works be funded?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by beach nourishment works are listed in Table 11. Separate requirements for the dredging of source material have not been considered here.

Sand dunes are typically located on State land above the high water mark and therefore are not subject to tidal works approval requirements. If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which *Native* Title has not been extinguished*;*

- Preparation of a formal Cultural Heritage Management Plan or a Cultural Heritage Management Agreement under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 11 Approvals required for dune construction and regeneration

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational works – for removal, destruction or damage of marine plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

Dune construction and regeneration may be required in accordance with an agreed Shoreline Erosion Management Plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Dune reconstruction is typically conducted in areas already identified within planning schemes for recreation or open space. These areas will not require planning scheme mapping amendments or additional overlays to be created. The only approval triggered under the planning scheme may be operational work for filling and excavation. Other potential required approvals are outlined above.

Box 6. The Dutch dune system

The safety of large parts of The Netherlands, with approximately 60% of the land below sea level, relies on a combination of dykes and dunes for protection against flooding. The Netherlands employ a defend approach based on the identification of a baseline surveyed in 1990 which sets the line of defence for the country, the so-called Base Coast Line. Based on the assessment of the costs of floods inland, dune systems are therefore designed to withstand storm surges with return periods of up to 10,000 years, corresponding to water elevations of approximately 5m above the mean sea level. Such events can erode up to 300m^3/m of beach, corresponding to approximately 50m of sand width. Dunes are designed to cope with these events and maintain the natural function of coastal ecosystems which are created on the dune system. In this context it is common to find dune fields with a width in the order of hundreds of metres and maximum heights above ten metres (ENCORA, 2009).

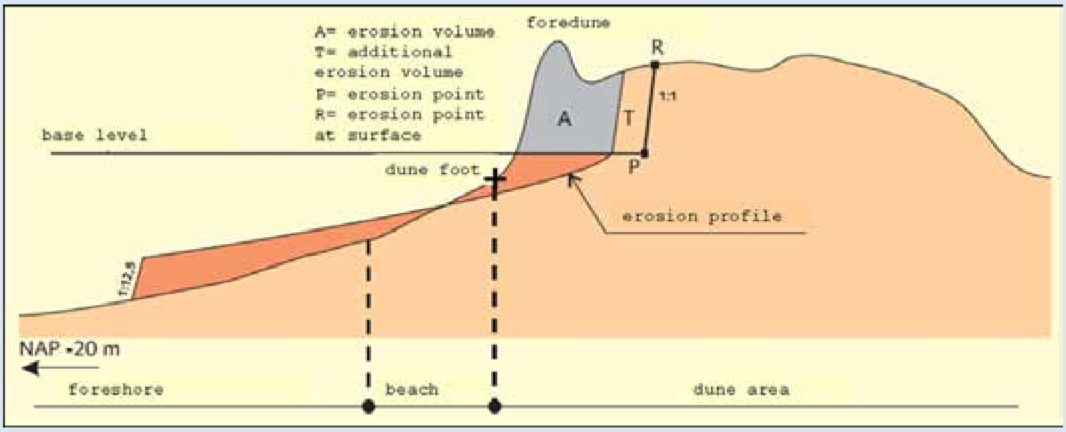

Figure 10 Dune and erosion profile

4.2.5. Maintenance

Sand dunes require monitoring and maintenance to respond to extreme erosion and shoreline changes. Community programs for dune rehabilitation and monitoring have demonstrated successful in managing dune issues. Maintenance of sand dunes requires the identification of adequate sand sources to replenish and reshape the dune profile.

4.2.6. Timeframe for review

Dune construction and regeneration programs should be subject to continuous monitoring after the initial works. No specific time for review can be identified. A funding scheme may be required for ongoing maintenance.

4.2.7. Failure Risk

Dunes are naturally dynamic and can change in response to environmental conditions. Failure of function in dune construction or regeneration is associated with natural or human-induced destruction of the vegetation cover, major storm events and sea level rise. Reduced vegetation cover can reduce the effectiveness of sand capture or resistance to waves. Dunes designed to protect settlements and infrastructure from storm tide inundation should be designed to cope with worst-case scenario erosion events.

4.2.8. Estimated costs

Dune stabilisation can cost in the order of $5,000-$20,000 per ha.

4.2.9. Multi-criteria overview

Table 12 Multi-criteria overview for dune construction and regeneration

Dune Construction and regeneration			
Climate uncertainty	Effectiveness	How effective is it for coastal hazard adaptation?	Fully developed dunes can potentially cope with extreme sea levels and erosion under sea level rise if monitoring and maintenance programs are set up after construction.
	Flexibility	Can it be modified after implementation?	Modification by addition or movement of sand is feasible.
	Reversibility	Is it easy to completely remove it?	Removing the dune is feasible, although can be costly.
	No regret	Is there any other social or environmental benefit?	Coastal dunes create the base for healthy shorelines, flora and fauna.
	Decision Horizon	Does it help gaining time for major decisions?	Dune rehabilitation increases the time available for major decision making, e.g. retreat. Construction of new sand dunes is costly and can be considered as a major decision itself.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions. Planting vegetation can help fix carbon.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Dunes can reduce the access to the shoreline.
	Landscape	Does it impact landscape values?	The impact on landscape is positive although it can reduce sea views from private properties, which causes social conflicts.
	Recreational use	Does it affect recreational uses?	No specific recreational uses are affected as dunes should not be used as a playground.
	Property values	Are private property values affected?	May affect property values (positive and negative).
	Impact on ecosystems	Does it impact coastal ecosystems?	Can have a positive impact on coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Construction and generation is generally expensive. Community involvement can reduce costs.
	Cost of maintenance	Does it need expensive maintenance?	Monitoring and maintenance is required, although not necessarily expensive.

4.3. Riparian corridor restoration and generation

Riparian corridors are vegetated zones acting as a buffer between wetlands, rivers, estuaries, waterways and the land. Riparian corridor restoration and generation reinforce wide and healthy riparian corridors which border tidal water bodies and help mitigate the impact of rising sea levels and storm tide inundation on coastal land by absorbing some of the incoming storm energy.

Table 13 Riparian corridors restoration and generation and coastal planning approaches

	Defend	Accommodate	Retreat
Riparian corridors restoration and generation	✓	✓	✓
	It can increase the effectiveness of defence options.	Useful to reduce the impacts of extreme storms and rising sea levels.	Can facilitate the implementation of gradual retreat policies.

4.3.1. Technical description

The term riparian corridor refers to any land that adjoins or directly influences a body of water. This includes land immediately alongside lakes, rivers, creeks or wetlands, including freshwater and water influenced by tidal variations, such as estuaries and coastal waterways. A riparian corridor can be described as a strip of land covered by riparian vegetation, providing hydrological, ecological, landscape and recreational functions. Where riparian corridors are in contact with tidal waters, restoration and generation functions include:

- Geomorphic stabilisation of watercourses and stream bank stability;
- Maintenance of terrestrial and aquatic biodiversity;
- Filtering of nutrient and polluted runoff;
- Attenuating interface between urban development and tidal water bodies and flood and sea level rise.

Stream bank stability can be maintained by the root systems of trees, shrubs and grasses which bind and hold the soil together. Protection against stream bank erosion in times of strong flow reduces the loss of valuable land, maintains river courses and prevents turbid water conditions and the sedimentation of waterways.

The width of riparian corridors should be defined based on ecological and hydrological criteria. The criteria should allow flexibility to accommodate local characteristics such as the nature of the watercourse, flooding or stormwater issues, geomorphic and soil characteristics, biodiversity constraints, water supply access and public access considerations. Sea level rise and storm surge parameters should be included in the restoration and design of riparian corridors restoration and generation. Current riparian zone widths range from approximately 20m to around 100m (SEQ Catchments, 2011).

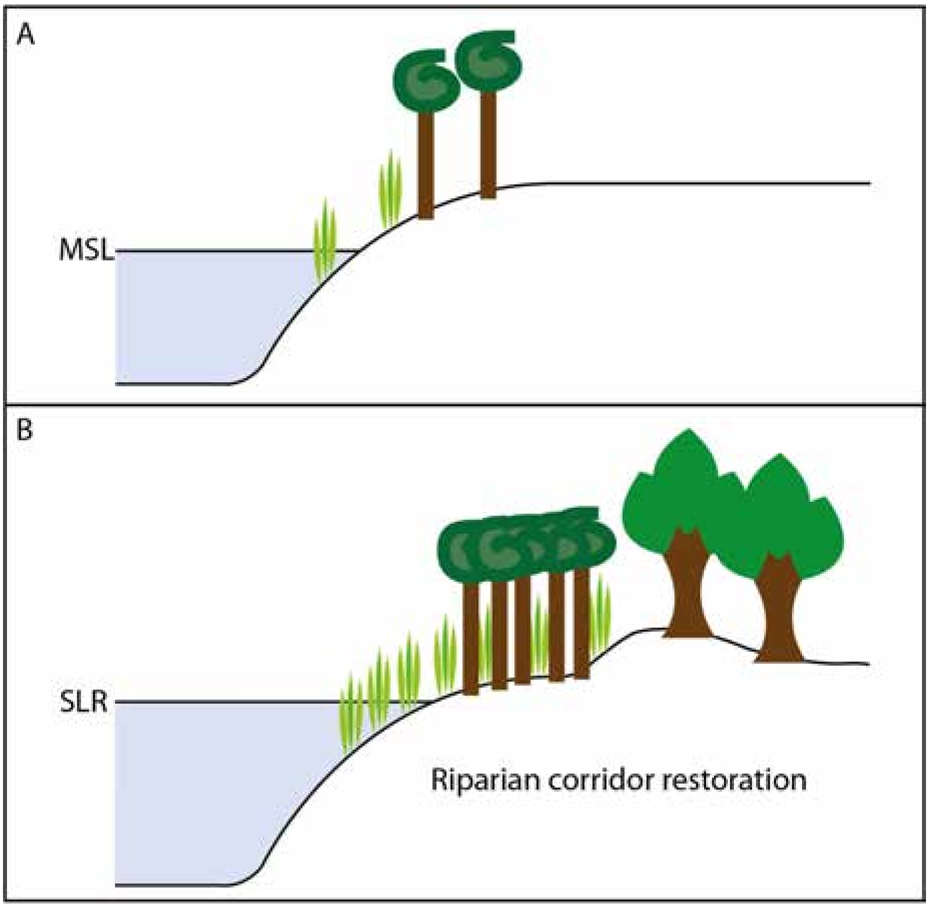

Figure 11 Typical riparian corridor cross-section before and after restoration and generation
Note: MSL= mean sea level; SLR = Sea level rise. Source: GCCM

Restoration activities develop and maintain riparian corridors for the purposes of reducing stream bank erosion, trapping sediments and nutrients, control of temperature and light filtration, thus providing habitat for wildlife and preventing development activity in sensitive areas.

Revegetation of degraded riparian zones is common practice in riparian restoration. This can be accomplished through active or passive means, or a combination of the two. Common methods for actively restoring vegetation include broadcast sowing of seed and directly planting seeds, plugs, or seedlings. To increase survival rates, young plants may need to be protected with fencing or tree shelters. Reference sites are often used to determine appropriate species to plant and may be used as sources for seeds or cuttings. Reference communities serve as models for what restoration sites should ideally look like after restoration is complete.

Assisted regeneration refers to allowing the site to regenerate naturally by removing the drivers of degradation such as inappropriate land uses, fire regimes and invasive species. This approach has, in general, lower costs than revegetation and restoration. Removal of exotic species is a critical component of riparian zone restoration. This can be accomplished through herbicide application or mechanical removal. When restoration is to be undertaken on long stretches of rivers and streams, it is often useful to begin the project upstream and work downstream to avoid propagation.

Box 11. Boggy Creek Restoration Project, Brisbane

Boggy Creek is a tidal creek system with integral linkages to the broader Brisbane River delta system of braided mangrove streams and channels, and incorporates the valuable habitat of Bulwer Island. This area is vital to the preservation and representation of plant communities and ecosystems. This area also plays an important part of the ecological processes associated with sustaining the Brisbane River Delta and Moreton Bay. A study prepared by the Brisbane Region Environmental Council suggests improving the habitat quality and public amenity through sensible incorporation of remnant vegetation. This would include repairing strips of riparian vegetation and degraded lands in varying stages of regeneration.

Figure 12 Boggy Creek and map of the restoration program.
Source: Brisbane Region Environment Council http://brec.ozecol.org/

4.3.2. Role in coastal hazard adaptation

Restoration of riparian corridor can be part of a strategy to adapt to changing coastal hazards, in particular sea level rise and the impact of storm tide inundation. Sea level rise can gradually erode the banks of wetlands, estuaries and waterways exposed to tidal changes and impact on drainage and groundwater in low-lying coastal floodplains, leading to potential increases in the duration of floods, water logging of soils, salt inundation and more extreme storm surge impacts (Enseby, 2010).

Adaptation activities should focus on the provision of additional buffers within existing or newly generated riparian corridors restoration and generation, to avoid riparian corridor squeeze in the future and provide better protection from storm surge flooding.

Table 14 Riparian corridors and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Riparian corridors restoration and generation	✗	✓✓	✓	✗
	Usually not compatible with the direct impact of storm waves.	Riparian vegetation can help mitigate erosion occurring on riverbanks or waterways as a consequence of rising sea levels .	Riparian vegetation can, depending on the spatial extent, help reduce the impacts of storm tide inundation.	When permanent inundation occurs, riparian vegetation will be flooded, damaged or destroyed and will need to be relocated.

4.3.3. Synergies and conflicts with other adaptation options

Riparian corridor restoration and generation can be coupled with other environmental restoration options such as wetland restoration. Planning options such as land-use change, land swap or acquisition can be utilised to provide for space for the restoration and improvement of riparian corridors.

Table 15 Synergies and conflicts of riparian corridors restoration and generation

Riparian corridors restoration and generation			
Regenerative options	Beach nourishment	●	Typically no interference.
	Dune construction and regeneration	●	Typically no interference.
	Wetlands restoration	✓✓	Synergy in integrated restoration programs.
Coastal engineering options	Artificial reefs	●	Typically no interference.
	Detached breakwaters	●	Typically no interference.
	Groynes and artificial headlands	●	Typically no interference.
	Sea dykes	●	Typically no interference.
	Seawalls	✓	For estuary or waterways, seawalls can be combined with riparian corridors restoration and generation restoration (NSW Government, 2009).
	Storm surge barriers	●	Typically no interference.
Coastal settlements design options	Building retrofitting and design	✓	Synergy in accommodating storm tide inundation .
	Flood-resilient public infrastructure	✓	Synergy in possibly attenuating storm tide inundations
	Raise land levels	●	Typically no interference, unless raising land leads to burying of riparian vegetation.
Planning options	Development setbacks	✓	Coastal development setbacks can provide space for riparian corridors restoration and generation.
	Land buy-back	✓	Compatible when riparian corridors are restored on recovered coastal land.
	Land swap	✓	Compatible when riparian corridors are restored on recovered coastal land.
	Land-use planning	✓	Compatible when riparian corridors are restored on recovered coastal land.

4.3.4. Legal and administrative framework

Under the Queensland legislation, approvals are required to carry out works affecting riparian zones, depending on the nature and scope of the project.

Planning considerations for local government

- What works are proposed?

- Will there be any adverse impacts on coastal process, natural character, the local economy, scenic amenity and public access?
- Has potential impact on ecosystems and habitats been considered (such as habitat for migratory shorebirds and turtle nesting areas)?
- Are management plans needed?
- Will operational works be required?
- What other benefits can be gained through protection of riparian corridors restoration and generation (i.e. ecological, habitat, water quality, scenic amenity etc.)

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by riparian corridor works are listed in Table 16. Separate requirements for the dredging of source material have not been considered here.

Riparian corridor restoration and generation works are typically located on unallocated State Land bordering the high water mark and therefore may be subject to tidal works approval requirements for those components of work e.g. earthworks, that are located below high water mark. If a component of the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* (CPM Act) but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;

- Owners consent for development on private property.
- Revegetation and non-structural activities associated with it, may be considered minor works that do have insignificant impact on coastal management and are reversible and expendable, and therefore fall into the category of excluded work that does not require SPA approval. In that case only land owners consent is required to carry out the work under council local laws.

Table 16 Approvals required for riparian corridors restoration and generation

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational works – for removal, destruction or damage of marine plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies.			
Local government local laws	*Sustainable Planning Regulation 2009* Schedule 26, "excluded work"	Minor work that has insignificant impact on coastal management and is reversible or expendable	*Coastal Protection and Management Act 1995*

Powers available to local government to establish this option and the role of the planning scheme

Riparian corridors restoration and generation may be required in accordance with an agreed shoreline erosion management plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Riparian corridor restoration and generation areas are already likely to be zoned appropriately for this use and even in cases where they are not, revegetation and restoration activities are not likely to require any changes to the planning scheme for works to proceed. Similarly, this strategy is not likely to require any approvals triggered by the planning scheme other than operational works approvals for filling and excavation, depending on the extent of the restoration involved.

4.3.5. Maintenance

Riparian corridor functions and health should be monitored and maintained where required. Specific programs of maintenance can be included in LGA capital works program or community-based initiatives, such as Land care.

4.3.6. Timeframe for review

See maintenance.

4.3.7. Failure risk

While absolute failure is unlikely, there may be more or less effective outcomes. For example, spending heavily to protect or assist a wetland with a limited capability may represent failure through the poor use of resources. In the same way, if rising sea levels are likely to squeeze the wetland in the future, restoration may reap negligible benefits. Another potential source of failure might be if a wetland subsequently becomes a source of disease vector (e.g. due to rising air and sea temperatures) and is seen to be more a source of harm than benefits.

4.3.8. Estimated cost

Costs vary depending on the extent and characteristics of the riparian corridor to be generated or restored.

4.3.9. Multi-criteria overview

Table 17 Multi-criteria overview for riparian corridors restoration and generation

Riparian corridors restoration and generation			
Climate uncertainty	Effectiveness	How effective is it for climate change?	Riparian corridors restoration and generation can help increase the resilience of tidal water bodies and riparian ecosystems to the impacts of sea level rise and storm surges.
	Flexibility	Can it be modified after implementation?	Riparian restoration can be improved and modified after implementation.
	Reversibility	Is it easy to completely remove it?	Riparian vegetation buffers can be easily reduced.
	No regret	Is there any other social or environmental benefit?	Riparian corridor restoration and generation contribute to healthy waterways and coastal ecosystems.
	Decision Horizon	Does it help gaining time for major decisions?	Riparian corridor restoration and generation may be a viable option.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions. Planting vegetation can help fix carbon.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Riparian corridor restoration and generation can reduce accessibility to the shore.
	Landscape	Does it impact landscape values?	Works should improve landscape values.
	Recreational use	Does it affect recreational uses?	Some recreational uses might be excluded.
	Property values	Are private property values affected?	May affect property values (positive and negative).
	Impact on ecosystems	Does it impact coastal ecosystems?	Works can have a positive impact on coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Construction and generation is generally expensive. Community involvement can reduce costs.
	Cost of maintenance	Does it need expensive maintenance?	Extensive maintenance is not typically required after the restoration program has been executed.

4.4. Wetlands restoration

Coastal wetlands are vegetated areas which can be permanently or periodically inundated by tidal waters. Wetlands play an important ecological and regulatory function by providing habitats for flora and fauna and acting as a buffer against storm tide inundations and sea level rise.

Table 18 Wetland restoration and coastal planning approaches

1	Defend	Accommodate	Retreat
Wetland Restoration	✓	✓	✓
	Can increase the effectiveness of defence and hold the line approaches; however wetlands are not defence structures.	Wetland restoration may, depending on the scale, reduce the impact of storm tides, however they don't halt inundation.	Wetland restoration can be performed after retreat from low lying areas.

4.4.1. Technical description

Wetlands can be restored and improved to cope with rising sea levels. Current wetlands will be able to grow and accumulate sediments following sea level trends.

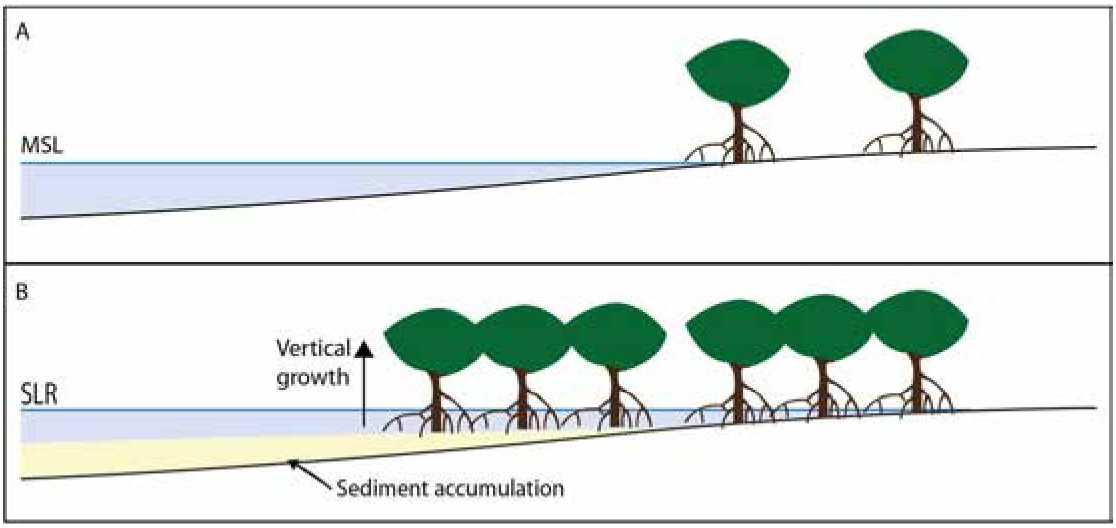

Figure 13 Typical wetland cross-section before and after restoration
Note: MSL= mean sea level; SLR = Sea level rise. Source: GCCM

Coastal wetlands are defined as areas of permanent or periodic/intermittent inundation, whether natural or artificial, with water that is static or flowing, fresh, brackish or salt, including areas of marine water where the depth does not exceed 6 metres at low tide. Typically, wetlands include areas which show evidence of adaptation of soil or vegetation to periodic waterlogging such as intertidal sand flats, mud flats, salt flats, tidal marshes and mangroves; and shallow marine areas, such as seagrass beds or fringing coral reefs (DERM 2011d). Coastal wetlands may be inundated with each high tide (e.g. mangroves), or only occasionally, by particularly high tides or storm surges (e.g. salt marshes). The size of coastal wetlands varies depending on the extension of the low-lying area that can be periodically flooded.

Figure 14 Mangrove wetlands surrounding a coastal community near Redland, Moreton Bay.
Source: Google Earth

Wetland restoration relates to the rehabilitation of previously existing wetland functions from a more impaired to a less impaired or unimpaired state of overall function. Wetland restoration can serve to reduce coastal flooding and erosion. The main benefit of wetland restoration is the reduction of incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone (Gedan et al. 2011). This is achieved by increasing the roughness of the surface over which incoming waves and tides travel. This reduces the erosive power of waves and may help to reduce coastal flood risk by diminishing the inland height of storm surges (Linham and Nicholls, 2010).

4.4.2. Role in coastal hazard adaptation

Wetland restoration can have a relevant role in coastal hazard adaptation, creating a buffer against sea level rise and storm surge impacts. In contrast to hard defences, wetlands are capable of undergoing autonomous adaptation to sea level rise, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level (Fitzgerald et al. 2008). Provided wetlands are not subjected to coastal squeeze, and the rate of SLR is not too rapid to keep pace, wetlands are capable of adapting to SLR without further investments. Typically wetland restoration programs will allow additional protection to contiguous coastal settlements against erosion and storm tide inundation (Gedan et al. 2011).

Table 19 Wetland restoration and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Wetlands restoration	✗	✓✓	✓	✓✗
	Usually not effective in contact with the direct impact of storm waves.	Healthy wetlands can help reduce the impact of chronic erosion and the consequences of rising sea levels through shoreline stabilization.	Healthy wetlands of significant scale can help reduce the impact of storm tide inundation through water flow attenuation.	Wetland growth can match the rate of sea level rise. Wetlands will gradually migrate landward if subject to more frequent inundation.

Box 16. Mangrove restoration in the Sundarbans, Bangladesh

The coastal areas of Bangladesh have a high frequency of tropical cyclones and historic events have caused significant damage, high death tolls and large numbers of casualties. Mangrove forests in the Sundarbans, in the south-west of Bangladesh, protect the local coasts from storm damage. In 1966 a program of mangrove planting was initiated on the seaward sides of protective embankments. The initial objective of the afforestation program was to create a shelter to protect the lives and properties of coastal communities. The early success of these plantings resulted in other positive outcomes such as the provision of forest products for a range of uses; the development of forest shelter belts to protect inland life and property from tidal surges; the production of resources such as timber; the provision of new environments for wildlife. By 1990, approximately 1200km^2 of mangroves had been planted, with funding support from the World Bank (Linham & Nicholls, 2010).

Figure 15 Mangrove restoration in the Sundarbans, Bangladesh.

4.4.3. Synergies and conflicts with other adaptation options

Wetland restoration has positive interactions with most adaptation options and can be carried out together with riparian corridor restoration and generation as part of an integrated program.

Table 20 Synergies and conflicts of wetlands restoration

Wetlands restoration			
Regenerative options	Beach nourishment	●	Typically no interference.
	Dune construction and regeneration	●	Typically no interference.
	Riparian corridors restoration and generation	✓✓	Synergy in integrated restoration programs.
Coastal engineering options	Artificial reefs	●	Typically no interference.
	Detached breakwaters	●	Typically no interference.
	Groynes and artificial headlands	●	Typically no interference.
	Sea dykes	●	Typically no interference.
	Seawalls	✓	For estuary or waterways, seawalls can be combined with wetland restoration (NSW Government, 2009).
	Storm surge barriers	●	Typically no interference.
Coastal settlements design options	Building retrofitting and design	✓	Synergy in possibly attenuating storm tide inundations
	Flood-resilient public infrastructure	✓	Synergy in possibly attenuating storm tide inundations
	Raise land levels	●	Typically no interference, unless raising land results in burying of wetland.
Planning options	Development setbacks	✓	Coastal development setbacks can provide space for wetland restoration and generation.
	Land buy-back	✓	Compatible when wetlands are restored on recovered coastal land.
	Land swap	✓	Compatible when wetlands are restored on recovered coastal land.
	Land-use planning	✓	Compatible when wetlands are restored on recovered coastal land.

4.4.4. Legal and administrative framework

Under Queensland legislation, development approvals are required to carry out works in the tidal zone and coastal management districts, depending on the nature and scope of the project.

Planning considerations for local government

- Is wetland restoration an appropriate coastal hazard adaptation option?
- Will the wetland restoration contribute to wider community benefits such as ecological and nature conservation outcomes, scenic amenity and recreational opportunities?
- What works or activities are required to implement this option?
- What approvals are required?
- Who are the stakeholders?
- Are there sources of funding available to assist?
- Is there a role for community groups?
- Has the community and adjacent landholders been consulted?

Figure 16 Coastal marshes seaward of a dyke in Denmark.
Source: Danish Coastal Authority http://eng.kyst.dk/the-wadden-sea-dikes.html

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by wetlands restoration are listed in Table 21.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;

- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished*;*
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*.

Table 21 Approvals required for wetland restoration

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational works – for removal, destruction or damage of marine plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers Available to Local Government to Establish this Option and the Role of the Planning Scheme

Riparian corridor restoration and generation may be required in accordance with an agreed Shoreline Erosion Management Plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Wetlands are already likely to be zoned appropriately for this use, and even in cases where they are not, revegetation and restoration activities are not likely to require any changes to the planning scheme for works to proceed. Similarly, this strategy is not likely to require any approvals triggered by the planning scheme, with the exception, perhaps of operational work for filling and excavation, depending on the extent of the restoration involved.

4.4.5. Maintenance

Wetland restoration programs do not require specific maintenance, however restoration programs are typically medium-term programs to restore and enhance the ecological functions of wetlands.

4.4.6. Timeframe for review

See maintenance.

4.4.7. Failure Risk

While absolute failure is unlikely, there may be more or less effective outcomes. For example, spending heavily to protect or assist a wetland with a limited capability may represent failure through the poor use of resources. In the same way, if rising sea levels are likely to squeeze the wetland in the future, restoration can be arguable. Another potential source of failure might be if a wetland subsequently becomes a source of disease vector (e.g. due to rising air and sea temperatures) and is seen to be more a source of harm than benefits.

4.4.8. Estimated Cost

Costs vary depending on the extent and characteristics of the wetland to be restored.

4.4.9. Multi-criteria overview

Table 22 Multi-criteria overview for wetlands restoration

Wetlands restoration			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Very effective when wetland restoration is also designed to improve the resilience of coastal communities.
	Flexibility	Can it be modified after implementation?	Yes, but it is unlikely.
	Reversibility	Is it easy to completely remove it?	No.
	No regret	Is there any other social or environmental benefit?	Creation and enhancement of ecosystems; creation of new areas for public use where applicable.
	Decision Horizon	Does it help gaining time for major decisions?	Wetland restoration is itself a major decision
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions. Planting vegetation can help fix carbon.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Accessibility can be reduced.
	Landscape	Does it impact landscape values?	It should improve landscape values.
	Recreational use	Does it affect recreational uses?	Some recreational uses might be excluded.
	Property values	Are private property values affected?	May affect property values (positive and negative).
	Impact on ecosystems	Does it impact coastal ecosystems?	It can have a positive impact on coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Construction and generation is generally expensive. Community involvement can reduce costs.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is normally not required after the restoration program has been executed.

5. Coastal engineering options

Coastal engineering adaptation options are designed to reduce the risk of coastal hazards on human settlements through control of coastal erosion and protection from storm tide inundations. This section discusses the following coastal engineering options:

- Artificial reefs;
- Detached breakwaters;
- Groynes and artificial headlands;
- Sea dykes;
- Seawalls; and
- Storm surge barriers.

Figure 17 Artificial waterways, beaches and groynes near Cleveland, Moreton Bay
Source: Google Earth, 2011.

5.1. Artificial reefs

Artificial reefs are submerged structures designed to reduce wave energy and erosive processes on the coastal foreshore and can be designed to promote recreational amenity such as surfing and diving conditions.

Table 23 Artificial reefs and coastal planning approaches

1	Defend	Accommodate	Retreat
Artificial reefs	✓ ✗	✗	✗ ✗
	Can be effective in localised erosion control, however issues related with design and sea level rise should be thoroughly considered when planning for long-term solutions.	Can be effective in localised erosion control, however issues related with design and sea level rise should be thoroughly considered when planning for long-term solutions.	Use is not suggested if the chosen approach is to retreat from the shoreline.

5.1.1. Technical Description

Submerged reefs function through wave dissipation and wave rotation, which leads to salient growth in the lee of a reef. Wave energy is dissipated on the reef resulting in less energy at the beach in the lee of the reef and the consequent deposition of sediment. Submerged reefs are more effective in areas with small tidal ranges. Future sea level rise can reduce the efficiency of artificial reefs as demonstrated in Figure 18 (B) below. Depending on the chosen construction material, artificial reefs typically have a lifespan of approximately 20 years, therefore, the effects of sea level rise are expected to be minimal.

Recreational and public amenity can be incorporated through surfing, diving, sheltered swimming, water games, fishing and/or marine habitat. The inclusion of amenity, however, requires the amalgamation of different purposes in the reef design and, consequently, can make the design more complex than that which may be required for coastal protection only.

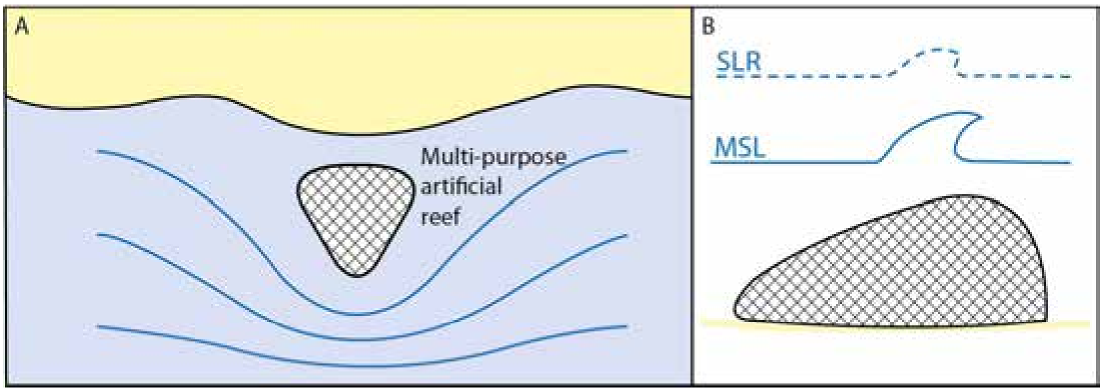

Figure 18 Typical diagram of a multi-purpose artificial reef.
Source: GCCM

It is important to thoroughly understand the local physical processes in order to optimise placement (ASR, 2005). Poorly designed and positioned submerged reefs can accelerate erosion if placed too close to the shore by 'compressing' the surf zone and increasing alongshore currents.

Typically, artificial reefs are constructed with sand filled geotextile bags which are filled inside a split-hull hopper dredge. Once filled, the bags are transported offshore and dropped at pre-determined locations in accordance with the design. In some cases reefs have been constructed with rock or concrete blocks, where units are placed on the seabed according to design specifications using an excavator mounted on a barge.

Box 10. Narrowneck Reef, Gold Coast

Narrowneck Reef is located on the northern beaches of Surfers Paradise on the Gold Coast. It was constructed between August 1999 and December 2000 as part of the Northern Gold Coast Beach Protection Strategy. The aim of the project was to undertake beach widening and to provide an increased storm buffer to reduce the risk of a Nerang River breakout and additional recreational amenity. The project involved a major beach nourishment program (over 1 million m^3 of nourishment), and the positioning of around 400 geotextile sandbags of approximately 150 to 300 tonnes each, following the complex design which was tested using numerical and physical models. The reef extends from a depth of approximately 10m to 1.5m below the lowest astronomical tide. The total cost of $8.4 million was divided between feasibility studies ($0.7 million), construction ($2.1 million) and beach nourishment ($5.6 million).

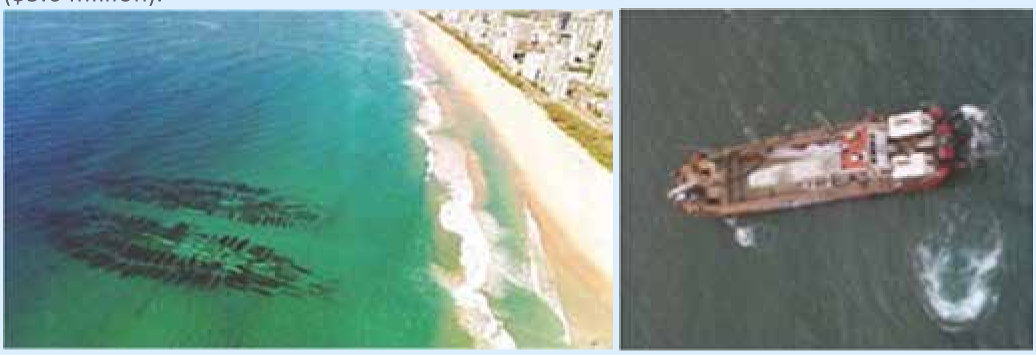

Figure 19 **Narrowneck artificial reef on the Gold Coast**
Source: **GCCM 2007**

5.1.2. Role in coastal hazard adaptation

Sea level rise and changes in the wave climate can affect the efficiency and stability of artificial reefs, in the same way it can affect the efficiency of other emerged or submerged structures for wave energy reduction such as detached breakwaters. A rise in the sea level or substantial changes in the wave energy and direction can alter the reef's role in beach and shoreline stabilisation. Substantial changes in the wave climate can require expensive changes in the design of the structure (e.g. orientation). Artificial reefs can therefore be seen as a measure to control the shoreline position in the medium term (5 to 20 years), but their efficiency as a long term strategy to maintain the current shoreline configuration is limited.

Table 24 Artificial reefs and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Artificial reefs	✓	✓✓	✗	✗
	Can reduce the energy approaching the beach.	Can change beach alignment and erosion patterns.	Not designed to control storm tide inundation or permanent inundation.	Not designed to control storm tide inundation or permanent inundation.

5.1.3. Synergies and conflicts with other adaptation options

Artificial reefs can be combined with other adaptation options as part of a broader scheme. Commonly, artificial reefs are coupled with beach nourishment, dune construction and regeneration or other soft or hard defence engineering options. The combination of artificial reefs with hard engineering options should be considered on a case by case basis.

Table 25 Synergies and conflicts of artificial reefs

Artificial reefs			
Regenerative options	Beach nourishment	✓	Artificial reefs are sometimes associated with beach nourishment for beach stabilisation and salient formation.
	Dune construction and regeneration	✓	They can be combined as part of an integrated defence system.
	Riparian corridors restoration and generation	●	Typically no interference.
	Wetlands restoration	●	Typically no interference.
Coastal engineering options	Detached breakwaters	✓ ✗	Artificial reefs and detached breakwaters are compatible for different locations – they usually don't protect the same coastal stretch.
	Groynes and artificial headlands	✓	Under certain circumstances, artificial reefs and seawalls can be combined.
	Sea dykes	✓	Compatible as protective adjuncts.
	Seawalls	✓	Under certain circumstances, artificial reefs and seawalls can be combined.
	Storm surge barriers	✓	Compatible, however they address different issues - erosion vs floods.
Coastal settlements design options	Building retrofitting and design	●	Typically no interference.
	Flood-resilient public infrastructure	●	Typically no interference.
	Raise land levels	●	Typically no interference.
Planning options	Development setbacks	✓ ✗	Compatible, however when using setbacks to gradually retreat from the shore, artificial reefs are not recommended.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

5.1.4. Legal and administrative framework

Under the Queensland legislation, approvals are required to carry out works in tidal waters in accordance with the provisions of the *Coastal Protection and Management Act 1995.*

Under the QCP, artificial reefs are hard engineered erosion control structures only considered for protection where beach nourishment or landward retreat is not a practical or cost effective option. Where erosion protection structures are necessary, maintaining physical coastal processes outside the area subject to the coastal protection works is required to avoid adverse impacts on adjacent coastal landforms and associated ecosystems. Development that is coastal protection work, including artificial reefs, complies with the QCP only if:

- The development is consistent with a Shoreline Erosion Management Plan; or
- The development protects coastal dependent development; or
- There is a demonstrated need to protect existing permanent structures from an imminent threat of coastal erosion; and
- Abandonment or relocation of the structures is not feasible.

Planning considerations for local government

- What works are proposed?
- Have other options been considered such as beach nourishment etc.?
- Will the structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause a change in coastal processes in other areas (remote from the location)?
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?

Approvals required

The tenure of land under tidal waters is generally unallocated State Land, which is a State resource for the purposes of the *Sustainable Planning Act 2009*.

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by artificial reefs are listed in Table 26.

If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the Coastal Protection and Management Regulation 2003, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district relevant requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994;*
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;

- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 26 Approvals required for artificial reefs

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

Artificial reefs may be required in accordance with an agreed Shoreline Erosion Management Plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Artificial reefs are typically built offshore in tidal areas which are unallocated State Land. These areas will not require planning scheme mapping amendments or additional overlays to be generated

5.1.5. Maintenance

Artificial reefs do not require high levels of maintenance, however extreme storms can damage the structure of sand bags and intervention may be required.

5.1.6. Timeframe for review

Artificial reefs are normally designed to be effective for 20 years under average conditions.

5.1.7. Failure risk

Natural process can result in failure, for example, the base of the reef can be undercut resulting in collapse and (if used) geotextile artificial reef bags can be dislocated by energetic seas. Design and structural failure can be intrinsically connected. Damage due to anchors, propeller strike or knife cuts can undermine the integrity of geotextile fabric. Their effectiveness can be undermined if they are placed in the wrong position with consequences for coastal erosion. The recreational design of the structure can fail when breaking waves are not suitable for surfing. Design should account for sea level rise and wave climate variability.

5.1.8. Estimated cost

Design and construction cost depends on the size and shape of the structure. As a benchmark, the Narrowneck reef structure on the Gold Coast cost approximately $2.1 million.

5.1.9. Multi-criteria overview

Table 27 Multi-criteria overview for artificial reefs

Artificial reefs			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Artificial reefs are a medium term solution and may require upgrades in the long term under sea level rise.
	Flexibility	Can it be modified after implementation?	Modifications of the structure can be carried out, however the costs of works can be high.
	Reversibility	Is it easy to completely remove it?	Removal of artificial reefs is practical where the structure is made of geotextile bags. In other cases it can be very expensive.
	No regret	Is there any other social or environmental benefit?	Creation of shelter and ecosystems, improved surfing conditions, diving and snorkeling.
	Decision Horizon	Does it help gaining time for major decisions?	They are already potentially major decisions for cost and complexity.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Usually not.
	Landscape	Does it impact landscape values?	No major impacts on coastal landscape.
	Recreational use	Does it affect recreational uses?	Positive impacts on surfing conditions, diving and snorkeling. Possible impacts on navigation.
	Property values	Are private property values affected?	It may increase property values.
	Impact on ecosystems	Does it impact coastal ecosystems?	It can create new coastal ecosystems and shelters for species.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is usually not required in normal conditions, but likely in the medium and long term.

5.2. Detached breakwaters

Detached breakwaters are erosion control structures most frequently placed parallel to the coast to reduce wave energy and increase beach stability. Detached breakwaters can create salients and stabilize the shoreline position against erosion.

Table 28 Detached breakwaters and coastal planning approaches

1	Defend	Accommodate	Retreat
Detached breakwaters	✓ ✗	✓ ✗	✗
	They can be effective in defending the current shoreline position against erosion, however their effectiveness depends on the detailed design of the structure. They are not effective for protection against storm tide inundation.	They should not be used as the main option for an accommodation strategy however they can have a positive role in maintaining the current shoreline.	They should not be used to facilitate retreat, which is usually undertaken to provide more space for natural coastal processes to occur.

5.2.1. Technical description

Detached breakwaters, also known as low crested structures, are emerged or submerged defence structures that are commonly placed nearly parallel to the shoreline. Their objective is to reduce wave energy transmission, long shore current and transport and, as a consequence, reduce erosion and increase the beach width. These structures are commonly made of quarry materials or concrete and have a low crest which allows significant energy transmission. The higher the crest freeboard, the higher the negative aesthetic impact and the lower the wave transmission to the shoreline. Breakwaters for shoreline erosion control are generally constructed with negative crest freeboard (submerged detached breakwaters) or with small positive crest freeboard to minimise the aesthetic impact (ENCORA, 2009).

Sea level rise should be accounted for in breakwater design to ensure they are not unduly submerged into the future.

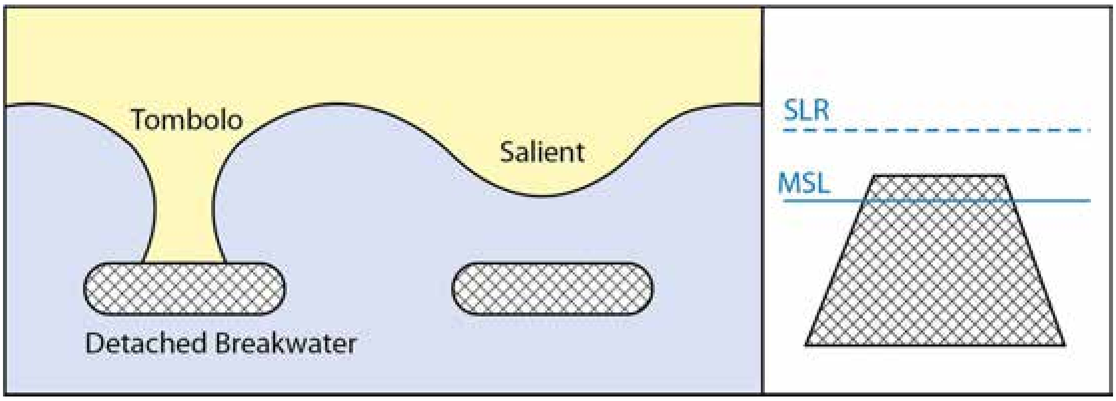

Figure 20 Typical detached breakwaters. Source: GCCM
Note: MSL = mean sea level; SLR = sea level rise.

Crest freeboard, distance to the shoreline, breakwater length and breakwater gap width are the principal factors affecting water flows and the corresponding beach response to segmented detached breakwaters. The higher the breakwater length and crest freeboard, and the lower the gap width and distance to shoreline, the lower the energy transmission, the higher the induced sinuosity of the beach and reduction of longshore sand transport will be. If the induced beach sinuosity reaches the detached breakwater, a tombolo is formed.

Detached breakwaters reduce the longshore transport of sand and may cause or significantly increase erosion in nearby unprotected beaches; therefore, sustainable erosion control schemes should be analysed from a regional point of view in which single or segmented detached breakwaters may be the best solution in a specific coastal area. Detached breakwaters can be constructed from quarry materials or concrete structures, depending on the cost and availability of materials. The use of prefabricated concrete elements may reduce the environmental impact on the beach (USACE, 2002; THESEUS, 2011).

Figure 21 Detached breakwater (bottom right) forming a tombolo in Geraldton, Western Australia, as part of a coastal protection and harbour configuration
Source: Google Earth

5.2.2. Role in coastal hazard adaptation

Sea level rise and changes in the wave climate can affect the efficiency and stability of detached breakwaters. While breakwaters can be efficient in the short term, a rise in the sea level or substantial changes in the wave energy and direction can alter their role in beach and shoreline stabilisation. The crest freeboard can be submerged by rising sea levels, requiring further interventions to maintain their function. Changes in the wave climate can require expensive changes to the design of the structure (e.g. orientation). Detached breakwaters can therefore be seen as a measure to control the shoreline position in the medium term (5 to 20 years) but their efficacy as a long term strategy to maintain the current shoreline configuration is questionable.

Table 29 Detached breakwaters and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Detached breakwaters	✓✓	✓✓	✗	✗
	Can be used to reduce extreme and chronic Storm erosion by reducing wave energy and sand movement and allowing for sand accumulation.	Can be used to reduce extreme and chronic storm erosion by reducing wave energy and sand movement and allowing for sand accumulation.	Not designed to control storm tide inundation or permanent inundation.	Not designed to control storm tide inundation or permanent inundation.

Box 4. Detached breakwaters in Liseleje, Denmark

Liseleje is a coastal community located in Sjaelland, Denmark. The coastline consists both of large cliffs and shallow beaches, with structural erosion caused by a net sediment transport gradient combined with human interference, which was threatening existing summer cottages and beaches, and intensely used for recreational purposes. A combination of breakwaters, nourishment and slope protections was chosen as a solution to existing problems as part of a plan released in the late 1990s. Six new breakwaters with lengths of 40 to 60 m were included in the final plan, together with two small existing detached breakwaters, which were reinforced in 2000 (EUROSION, 2005abc).

Figure 22 Detached breakwaters in Liseleje, Denmark
Source: Google Earth and www.panoramio.com/photo/469209

5.2.3. Synergies and conflicts with other adaptation options

Detached breakwaters are commonly put in place as part of a strategy to reduce wave energy approaching the coast and to widen beaches by forming salients or tombolos. Detached breakwaters can be combined with other hard and soft defence options, in particular beach nourishment.

Table 30 Synergies and conflicts of detached breakwaters

Detached breakwaters			
Regenerative options	Beach nourishment	✓	Detached breakwaters are sometimes associated with beach nourishment for beach stabilisation and tombolo formation.
	Dune construction and regeneration	✓	They can be combined as part of an integrated defence system.
	Riparian corridors restoration and generation	●	Typically no interference.
	Wetlands restoration	●	Typically no interference.
Coastal engineering options	Artificial reefs	✓ ✗	Artificial reefs and detached breakwaters are compatible for different locations but they usually are not used to protect the same stretch of coast.
	Groynes and artificial headlands	✓	Under certain circumstances, groynes and detached breakwaters can be combined.
	Sea dykes	✓	Compatible as protective adjuncts.
	Seawalls	✓ ✗	Compatible, under certain circumstances.
	Storm surge barriers	✓	Compatible, however they address different issues - erosion vs floods.
Coastal settlements design options	Building retrofitting and design	●	Typically no interference.
	Flood-resilient public infrastructure	●	Typically no interference.
	Raise land levels	●	Typically no interference.
Planning options	Development setbacks	✓ ✗	Compatible, however when using setbacks to gradually retreat from the shore, detached breakwaters are not recommended.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

5.2.4. Legal and administrative framework

Under Queensland legislation, approvals are required to carry out works in tidal waters in accordance with the provisions of the *Coastal Protection and Management Act* 1995.

Under the QCP, detached breakwaters are hard engineered erosion control structures only considered for protection where beach nourishment or landward retreat is not a practical or cost effective option. Where erosion protection structures are necessary, maintaining physical coastal processes outside the area subject to the coastal protection works is required to avoid adverse impacts on adjacent coastal landforms and associated ecosystems. Development that is coastal protection work, including breakwaters, complies with the QCP only if:

- The development is consistent with a Shoreline Erosion Management Plan; or
- The development protects coastal-dependent development; or
- There is a demonstrated need to protect existing permanent structures from an imminent threat of coastal erosion; and
- Abandonment or relocation of the structures is not feasible.

Planning considerations for local government

- What tidal works are proposed?
- Are there any access or navigational issues?
- Have other options been considered such as beach nourishment etc.?
- Will the defensive structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause coastal erosion or adverse changes in other areas (remote from the location?)
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?
- Is there a need for long term management plans and strategies for maintenance of structures?

Approvals required

The tenure of land under tidal waters is generally unallocated State Land, which is a State resource for the purposes of the *Sustainable Planning Act 2009*.

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by beach nourishment works are listed in Table 31.

If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and*

Management Act but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 31 Approvals required for detached breakwaters

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

Detached breakwaters may be required in accordance with an agreed Shoreline Erosion Management Plan prepared by the LGA or another coastal management organisation and endorsed by the chief executive administering the *Coastal Protection and Management Act 1995*.

It is unlikely that amendments to the local planning scheme will be required to successfully implement this option. The construction of detached breakwaters is typically conducted offshore and accordingly these do not fall within the jurisdiction of the LGA planning scheme. Accordingly, this strategy will not require planning scheme mapping amendments or additional overlays to be implemented. Statutory approvals required for such structures are the jurisdiction of the State and outlined above.

5.2.5. Maintenance

Detached breakwaters typically do not require high levels of maintenance, however, extreme storms can damage the structures and intervention can be required.

5.2.6. Timeframe for review

Detached breakwaters are typically designed to be effective for (say) 100 years under average conditions, without considering climate change. However, changing climatic conditions can challenge their efficacy and a shorter timeframe for review (5-20 years) should be envisaged.

5.2.7. Failure risk

The base of the breakwater can be undercut resulting in collapse. Energetic seas can dislocate armour units if the size of the blocks is underestimated. Detached breakwaters effectiveness can be reduced if not placed at the optimum distance from the shore when, in some cases, erosion can be exacerbated (Bricio et al., 2012). Design should account for sea level rise and wave climate variability.

5.2.8. Estimated cost

The current approximate cost for detached breakwaters is approximately $10,000 per linear metre of breakwater, but can vary depending on the size of the structure and the availability of building blocks.

5.2.9. Multi-criteria overview

Table 32 Multi-criteria overview for detached breakwaters

Detached Breakwaters			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Can require expensive upgrades in the long term under sea level rise conditions.
	Flexibility	Can it be modified after implementation?	Modifications of the structure can be carried out, however the costs of works can be very high.
	Reversibility	Is it easy to completely remove it?	Removal is . feasible but very expensive.
	No regret	Is there any other social or environmental benefit?	Creation of shelter and ecosystems, reduce wave action and risks for swimmers, however it can create problems for navigation.
	Decision Horizon	Does it help gaining time for major decisions?	They represent a major decision that can have strong impact on the natural system.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Usually not.
	Landscape	Does it impact landscape values?	Can have a negative impact on coastal landscape.
	Recreational use	Does it affect recreational uses?	Negative impacts on surfing conditions and navigation.
	Property values	Are private property values affected?	Protection typically increases property values, however impacts on landscape can decrease values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Water circulation can be alteredbut it can be a shelter for species.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is usually not required in normal conditions, but likely in the medium and long term.

5.3. Groynes and artificial headlands

Groynes are structures built perpendicular to the shoreline that trap sand moving along the coast, causing sand buildup on the downdrift side. A variant of a groyne is an artificial headland which acts in the same manner but has a larger footprint. They can be effective in controlling coastal erosion and longshore transport.

Table 33 Groynes and artificial headlands and coastal planning approaches

1	Defend	Accommodate	Retreat
Groynes and artificial headlands	✓ ✗	✓ ✗	✗
	They can be effective in defending the current shoreline position against erosion. They are not effective for protection against storm tide inundation. They should be combined with sand nourishment to mitigate the adverse effects on coastal processes.	They can be effective in defending the current shoreline position against erosion when used with accommodation methods. They are not effective for protection against storm tide inundation and should be accompanied by beach nourishment to mitigate the adverse effects on coastal processes.	They shouldn't be used to facilitate retreat, which is usually undertaken to provide more space for natural coastal processes to occur.

5.3.1. Technical description

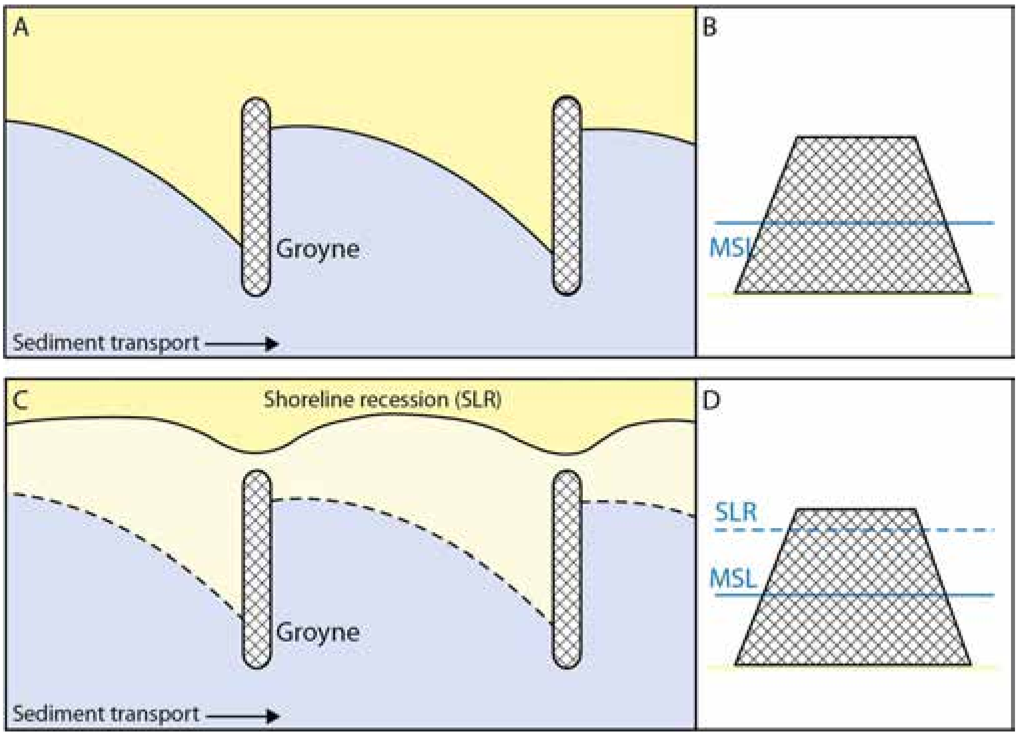

Figure 23 Groynes can be used to control longshore transport and facilitate beach accretion. Sea level rise can affect groynes functionality in the future.
Source: GCCM

A groyne is an active structure extending from the shore into the sea, most often perpendicularly or slightly obliquely to the shoreline. An adequate supply of sediment and existence of satisfactorily intensive longshore sediment transport are the conditions needed for groyne efficiency. The principle functions of a groyne are catching and trapping a part of the sediment moving in the surf zone (mainly in a longshore direction). During weak and moderate wave conditions, the groynes partly dissipate wave energy and lead to sand accumulation in the vicinity of the shore, thus causing accretion. Under storm waves, mainly approaching the shore perpendicularly, the role of the groynes decreases and the beach is partly washed out. Groynes have been frequently used worldwide, however due to the localised erosion that occurs downdrift of the structure, multiple groynes are often constructed along the section of shoreline to be protected. The effectiveness of groynes is enhanced if they are applied together with other soft shore protection measures, like beach nourishment (ENCORA, 2009).

Box 7. Groynes for coastal protection at the mouth of the Maroochy river

The mouth of Maroochy River, on the Sunshine Coast, has historically meandered between extreme positions in the north and south of the estuary and in the 1990s Council's Cotton Tree caravan park on the southern banks of the Maroochy River entrance had been under threat from severe erosion. A working group lead by Council resolved to construct a physical model to determine the best coastal defence configuration for the area. An array of 4 groynes in a splayed finger arrangement on the southern shore of the entrance was found to be the most effective. The first of the four groynes (100m long) was constructed using 5 tonne geotextile bags during 2001 and proved very successful in both protecting the caravan park from the threat of further erosion, and in holding sand on Maroochydore Beach. In conjunction with this work, 100,000m^3 of sand was sourced to renourish Maroochydore Beach. In 2003, Council constructed the additional three groynes to complete the full array of four, and placed 50,000 m^3 of sand nourishment on the southern shores of the estuary. Since construction of the groynes and the placement of sand nourishment, the northern end of Maroochydore Beach has continued to maintain a healthy width and there has been no threat to the caravan park (Restall et al., 2002; O'Keeffe and O'Keeffe 2009).

Figure 24 One of the four geotextile groynes at the Maroochy river mouth, on the Sunshine Coast.
Source: Barbara JH on www.flickr.com

A single groyne, besides its positive influence on the shore, causes numerous side effects, mainly in the form of coastal erosion on the lee side of the structure. In the case of a group of groynes, the above effect appears on the lee side of the whole system. The erosion is also observed in direct vicinity of the structures, particularly when waves approaching the shore perpendicularly predominate. Water circulation cells can develop between groynes, which in turn leads to local erosion of the seabed. During severe storms groynes can be de-stabilised by erosion at the structure while under weak wave conditions they allow sand accumulation and widening of the beach (THESEUS, 2011).

5.3.2. Role in coastal hazard adaptation

Sea level rise and changes in the wave climate can affect the efficiency and stability of groynes. While groynes can be efficient in the short term, a rise in the sea level or substantial changes in the wave energy and direction can alter their role in beach and shoreline stabilisation. The crest freeboard can be submerged by a rising sea level, requiring further interventions to maintain their functions. Shoreline recession can erode the groyne base and reduce its capacity to control longshore transport. Changes in the wave climate can require expensive changes in the design of the structure (e.g. orientation). Groynes can therefore be seen as a measure to control the shoreline position in the medium term (5 to 20 years) but their efficiency as a long-term strategy to maintain the current shoreline configuration is questionable. The likely changes in sediment supply to the coast under climate change; the preferential erosion of some coasts; and the need to conserve available sediment; increase the importance of considering the stabilisation of the shoreline using structures such as groynes.

Table 34 Groynes and artificial headlands and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Groynes and artificial headlands	✓	✓✓	✘	✘
	They can be used to reduce extreme storm erosion by reducing longshore sand movement.	They can be used to reduce chronic erosion by reducing longshore sand movement and stabilizing shorelines.	They are not designed to control storm tide inundation.	They are not designed to control permanent inundation.

5.3.3. Synergies and conflicts with other adaptation options

Groynes and groyne fields are commonly used in combination with beach nourishment to enhance beach stability by reducing long-shore sediment transport. Sometimes they can be found combined with offshore structures, such as breakwaters or artificial reefs. It is an option which should be adopted only if the chosen strategy is to defend, and therefore does not align with options aiming at retreating from the coast.

Table 35 Synergies and conflicts for groynes and artificial headlands

Groynes and artificial headlands			
Regenerative options	Beach nourishment	✓	Sometimes associated with beach stabilisation and to reduce the longshore drift of sand.
	Dune construction and regeneration	✓	They can be combined as part of an integrated defence system.
	Riparian corridors restoration and generation	●	Usually there’s no interference.
	Wetlands restoration	●	Usually there’s no interference.
Coastal engineering options	Artificial reefs	✓	Under certain circumstances, artificial reefs and groynes/artificial headlands can be combined
	Detached breakwaters	✓	Under certain circumstances, groynes and detached breakwaters can be combined
	Sea dykes	✓	Compatible as protective adjuncts.
	Seawalls	✓ ✗	Compatible, under certain circumstances.
	Storm surge barriers	✓	Compatible, however they address different issues - erosion vs floods.
Coastal settlements design options	Building retrofitting and design	●	Usually there’s no interference.
	Flood-resilient public infrastructure	●	Usually there’s no interference.
	Raise land levels	●	Usually there’s no interference.
Planning options	Development setbacks	✓ ✗	Compatible, however when using setbacks to gradually retreat from the shore, groynes/artificial headlands are not recommended.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

Figure 25 Artificial headlands along the Townsville esplanade.
Source: Google Earth

5.3.4. Legal and administrative framework

Under Queensland legislation, approvals are required to carry out works affecting beaches and dunes, depending on the nature and scope of the project. Under the QCP groynes are engineered erosion control structures only considered for protection where beach nourishment or landward retreat is not a practical or cost effective option. Where erosion protection structures are necessary, maintaining physical coastal processes outside the area subject to the coastal protection works is required to avoid adverse impacts on adjacent coastal landforms and associated ecosystems.

Development that is coastal protection work, including groynes, complies with the QCP only if: the development is consistent with a shoreline erosion management plan; or the development protects coastal-dependent development; or there is a demonstrated need to protect existing permanent structures from an imminent threat of coastal erosion; and abandonment or relocation of the structures is not feasible.

Planning considerations for local government

- What works are proposed?
- Have other options been considered such as beach nourishment etc.?
- Will the defensive structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause coastal erosion or adverse changes in other areas (remote from the location?)?
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?

Approvals required

The tenure of land under tidal waters is generally unallocated State Land, which is a State resource for the purposes of the *Sustainable Planning Act 2009*.

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by beach nourishment works are listed in Table 36.

If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district relevant requires assessment against the relevant provisions of the *Coastal Protection and Management Act* (CPM Act) but does not require assessment against the LGA planning scheme

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;

- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 36 Approvals required for groynes and artificial headlands

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. These structures will not require planning scheme mapping amendments or additional overlays/codes to be implemented. The only approval triggered under the planning scheme may be operational work for filling and excavation. Other approvals required and the jurisdiction of the State are outlined in the above section.

Figure 26 A groyne field and a seawall protecting settlements in Brighton, Moreton Bay
Source: Google Earth

5.3.5. Maintenance

Groynes do not require high levels of maintenance, however extreme storms can damage the structures and intervention can be required.

5.3.6. Timeframe for review

Groynes are designed to be effective for (say) 100 years under average conditions, although their effectiveness may be limited under climate change and should be monitored continuously especially given the impacts of sea level rise on their functioning.

5.3.7. Failure risk

Groynes can be physically damaged during extreme events exceeding design specifications or if they are poorly designed or built. With rising sea levels, groynes may become less effective if they are not raised. Cross-shore sediment transport can rapidly add or remove sediment from the groyne field. If the offshore movement of sand is severe the shore will erode far enough that the groynes will flank, and the shore behind the groynes will be damaged.

5.3.8. Estimated Cost

The cost for groynes and artificial headlands construction starts from approximately $5,000 per linear metre.

5.3.9. Multi-criteria overview

Table 37 Multi-criteria overview for groynes and artificial headlands

Groynes and artificial headlands			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	May require expensive upgrades in the long term under sea level rise conditions.
	Flexibility	Can it be modified after implementation?	Modifications of the structure can be carried out, however the costs of works can be very high.
	Reversibility	Is it easy to completely remove it?	Removal is feasible but expensive.
	No regret	Is there any other social or environmental benefit?	Groynes can help stabilise beaches thereby providing public space for the community.
	Decision Horizon	Does it help gaining time for major decisions?	Represent a major decision that can have strong impacts on the natural system.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Usually not.
	Landscape	Does it impact landscape values?	Can have a negative impact on coastal landscape
	Recreational use	Does it affect recreational uses?	Can impact surfing conditions, but can provide a new space for recreational fishing.
	Property values	Are private property values affected?	Protection typically increases property values, however impacts on landscape can decrease values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Can have a negative impact on coastal ecosystems, e.g. by covering seagrass or tidal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is usually not required in normal conditions, but likely in the medium and long term.

5.4. Sea dykes

A sea dyke or levee is an artificially constructed fill or wall commonly designed to regulate water levels and to avoid inundation from storm tides. It is usually earthen, covered with vegetation and parallel to the shore of low-lying coastlines. Sea dykes can be used to control extreme water levels associated with storm tides and in conjunction with sea level rise.

Table 38 Sea dykes and coastal planning approaches

1	Defend	Accommodate	Retreat
Sea dykes	✓✓	✗	✓✗
	Can be used to defend low lying areas from the risk of inundation and erosion provided that they are appropriately armoured on the seaward face.	Would not typically be associated with accommodate.	Shouldn't be used to facilitate retreat, which is usually undertaken to provide more space for natural coastal processes to occur. However, can be considered as part of a planned retreat scheme where the new shoreline position needs a stable defence.

5.4.1. Technical description

Sea dykes can be used to protect human settlements from storm surge floods and sea level rise. However, sea level rise can threaten their efficiency and reshaping and upgrading may be required in the future if not adequately designed.

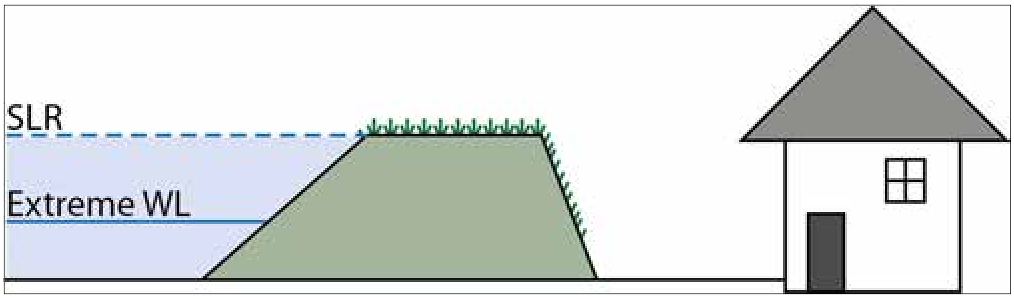

Figure 27 Typical sea dyke configuration.
Note: Extreme WL = extreme water level; SLR = sea level rise

The primary function of sea dykes is to protect low-lying, coastal areas from inundation by the sea under extreme water levels associated with storm tides. These structures have:

- A high volume, which helps to resist water pressure;
- Sloping sides to reduce wave loadings; and
- Crest heights sufficient to prevent or minimise overtopping by flood waters.

Examples of sea dyke application can be found in low lying areas, often associated with deltaic environments, such as within Bangladesh, The Netherlands, Egypt or the USA.

A sea dyke is a typically an earthen structure consisting of a sand core, a watertight outer protection layer, toe protection and a drainage channel. These structures are designed to resist wave action and prevent or minimise overtopping. Dykes have been extensively utilised as flood defences in The Netherlands over the past several hundred years. As a result, the Dutch have extensive experience in their design and maintenance (Linham & Nicholls, 2010) (see example in box 13).

Sea dykes typically have different seaward and landward slopes: on the sea side, a gentler slope reduces wave loadings; on the land side, a steeper slope minimises land take. The cover layer should be impermeable to water to protect the sand core; the sand core provides sufficient volume and weight to resist high water pressures and ensures that water that does enter can drain away; the toe protection is used as supplemental armour to prevent undercutting of the structure; the drainage channel allows any water which does enter the structure to drain away, therefore ensuring the structure is not weakened by water saturation (THESEUS 2011).

Sea dykes require large mass in order to resist high water pressures on their seaward faces. As a result, their construction uses large volumes of building materials including sand, clay and asphalt, which can be costly. A disadvantage of sea dykes is that the shallow slopes applied to facilitate wave energy dissipation cause dykes to have large footprints, i.e. their construction requires significant areas of land. This can increase dyke construction costs and environmental impacts. The construction of sea dykes prevents use of the coastal area for other development, leading to competition for land. Extending dykes seaward may overcome this problem, but costs rise significantly (Linham and Nicholls, 2010). Dykes can create a false sense of security on the landward side of defences, promoting further undesirable development landward.

5.4.2. Role in coastal hazard adaptation

Sea dykes can be an effective measure to reduce the risks of storm tides under sea level rise. However, raising sea dykes in response to sea level rise can cause the area of land required for dyke construction to increase if slope gradients are maintained. The construction and maintenance costs are likely to increase into the future; caused by increases in water depth in front of the structure, which in turn causes increased wave heights and wave loadings on the structure.

Table 39 Sea dykes and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Sea dykes	✘	✘	✓	✓✓
	Sea dykes are usually not designed to cope with storm or chronic erosion.	Sea dykes are usually not designed to cope with storm or chronic erosion.	Sea dykes are designed to cope with occasional inundation hazards.	Sea dykes are the only way to keep permanent inundation at bay without retreat.

5.4.3. Synergies and conflicts with other adaptation options

Sea dykes are, in general, combined with storm surge barriers, dunes or beach nourishment to increase the safety standards and avoid inundation under floods. Sea dykes can be combined with other planning options when these are necessary to make space for defence, such as land buy-back or land swap.

Table 40 Synergies and conflicts of sea dykes

Sea dykes			
Regenerative options	Beach nourishment	✓	Beach nourishment is compatible with sea dykes as it can be carried out on the seaward side of these structures.
	Dune construction and regeneration	✓ ✗	They can be combined, but are usually applied to different stretches of coast.
	Riparian corridors restoration and generation	●	Typically no interference.
	Wetlands restoration	●	Typically no interference.
Coastal engineering options	Artificial reefs	✓	Compatible, however they address different issues - erosion vs floods.
	Detached breakwaters	✓	Compatible, however they address different issues - erosion vs floods.
	Groynes and artificial headlands	✓	Compatible, however they address different issues - erosion vs floods.
	Seawalls	✓	Compatible, however they address different issues - erosion vs floods.
	Storm surge barriers	✓✓	Often combined as part of integrated defence system.
Coastal settlements design options	Building retrofitting and design	✓ ✗	Sea dykes are usually designed to prevent the inundation of buildings. If the dyke is designed to cope only with smaller events, additional changes in coastal settlements might be required.
	Flood-resilient public infrastructure	✓ ✗	Sea dykes are usually designed to prevent the inundation of buildings. If the dyke is designed to cope only with smaller events, additional changes in coastal settlements might be required.
	Raise land levels	✓ ✗	Sea dykes are usually designed to prevent the inundation of buildings. If the dyke is designed to cope only with smaller events, additional changes in coastal settlements might be required.
Planning options	Development setbacks	✓	Coastal development setbacks can provide an additional safety buffer behind sea dykes.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

Box 13. Sea Dykes in The Netherlands

Sea dykes have been continuously built in The Netherlands over the last two thousand years for protecting low lying lands from inundation. Currently, 34 of the 353 km of the Dutch coast are protected by sea dykes, sometime replacing dunes that were too weak or too narrow. This system of dykes is combined with wide dunes and storm surge barriers to withstand water levels during major storm surges from the North Sea, which can reach more than 5 m above the mean sea level. New dykes have also replaced older dykes, now known as "sleeper dykes", which have taken the role of a defence backup. Current dykes are made with a core of sand, covered by a thick layer of clay to provide waterproofing and resistance against erosion. Up to the high waterline the dyke is often covered with carefully laid basalt stones or a layer of tarmac. The remainder is covered by grass and maintained by grazing animals.

Figure 28 Sea dyke in The Netherlands
Source: http://essentialurbanism.wordpress.com

5.4.4. Legal and administrative framework

Under Queensland legislation, a development approval is required to carry out works within a coastal management district, depending on the nature and scope of the project. The development assessment process under the *Sustainable Planning Act 2009* the Integrated Development Assessment System (IDAS), incorporates the requirements of the *Coastal Protection and Management Act 1995*.

Planning considerations for local government

- What works are proposed?
- Have other options been considered such as beach nourishment etc.?
- Will the structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause a change in coastal processes in other areas (remote from the location?)
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by sea dyke works are listed in Table 41. Separate requirements for the dredging of source material have not been considered here.

Reconfiguration of lot and/or material change of use approvals may be required on private property to provide sufficient land for the construction of sea dykes.

Sea dykes are typically located on State coastal land above the high water mark, but may also encroach on the tidal area and/or privately owned properties. If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the Coastal Protection and Management Regulation 2003, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished:
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;

- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 41 Approvals required for sea dykes

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Material change of use	Relevant planning scheme	Land-use change to provide sufficient land to enable construction works	Relevant planning Scheme
Reconfiguration of a lot	*Sustainable Planning Regulation 2009,* Schedule 3, Table 3, Item 1	Reconfiguration of a lot to provide sufficient land to enable construction works	*Land Title Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Sea dykes are typically constructed in tidal areas, which are unallocated State Land. These areas will not require planning scheme mapping amendments or additional overlays to be carried out. Reconfiguration of lot and/or material change of use approvals may be required on private property to provide sufficient land for the construction of sea dykes. The only other approval triggered under the planning scheme would be operational work for filling and excavation. Other approvals required and the jurisdiction of the State are outlined above.

The powers available to LGAs for any potential land take and compensation required to construct a sea dyke are discussed in Section 7.2.4.

Sea dyke construction may reduce the value of land through reduction in views and any required land take for construction. Compensation may be granted under Section 704 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

5.4.5. Maintenance

Sea dykes are typically expensive structures, which can require high levels of maintenance where extreme storms or rising sea levels challenge their efficiency and performance. Maintenance costs are an ongoing requirement for sea dykes to ensure the structure continues to provide design levels of protection. The construction and maintenance costs are likely to increase into the future in response to sea level rise.

5.4.6. Timeframe for review

Sea dykes are typically designed to be effective for at least (say) 100 years under average conditions. Monitoring of dyke performance and maintenance needs should be performed continuously.

5.4.7. Failure risk

Sea dykes can fail if overtopped, when erosion of the top of the dyke can lead to rapidly increasing flows and initiate breaching. If the overtopping occurs early in the flood event, substantial water may enter the protected area and flood to a substantial depth. If the wall fails entirely in one section by breaching, flooding may approach levels that occur in the absence of the dyke or levee.

5.4.8. Estimated cost

Dykes can be extremely expensive, however costs vary depending on the size and length of the dyke. For instance, a recently designed 23km offshore dyke to protect Ho-Chi-Min City in Vietnam had an estimated cost of around $2.5 billion, roughly $100,000 per linear metre.
(Source: http://vietnamnews.vnagency.com.vn/Environment/222312/experts-warn-against-sea-dyke-proposal.html)

5.4.9. Multi-criteria overview

Table 42 Multi-criteria overview for sea dykes

Sea dykes			
Climate uncertainty	Effectiveness	How effective is it for climate change?	Sea dykes are effective measures to protect coastal settlements from future storm tides and sea level rise.
	Flexibility	Can it be modified after implementation?	Modifications of the structure can be carried out, however the costs of works can be very high.
	Reversibility	Is it easy to completely remove it?	Removal is feasible but very expensive.
	No regret	Is there any other social or environmental benefit?	Sea dykes can be arranged as green corridors along tidal waters to be used by coastal communities and be covered with vegetation (see, for example, figure 16).
	Decision Horizon	Does it help gaining time for major decisions?	Dykes represent a major decision that can have significant impacts on the natural system.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions. However vegetation cover can help absorb carbon.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Sea dykes can negatively affect access to the shore.
	Landscape	Does it impact landscape values?	Can have a negative impact on coastal landscape; however vegetation cover can help reduce these impacts.
	Recreational use	Does it affect recreational uses?	Can have impacts on existing recreational uses but can create new recreational space.
	Property values	Are private property values affected?	Protection increases property values but impacts on landscape can decrease values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Can have a negative impact on coastal ecosystems, e.g. by covering wetlands.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	Designed to prevent disasters but if failure occurs may create an unexpected disaster.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is usually continual to ensure the efficacy of the protection but need not be costly.

5.5. Seawalls

Seawalls are structures separating land and water areas designed to prevent coastal erosion and other damage due to wave action and storm tide inundations. Seawalls are normally very large structures as they are designed to resist the full force of waves and storm surges.

Table 43 Seawalls and coastal planning approaches

	Defend	Accommodate	Retreat
Seawalls	✓✓	✓✗	✗
	Are effective in defending the current shoreline position against erosion. Not effective for protection against storm tide inundation as they are often limited in height and may be porous. They should be combined with sand nourishment to mitigate any adverse effects on coastal processes.	Are effective in defending the current shoreline position against erosion to allow accommodation in the lee of the structure.. Not effective for protection against storm tide inundation as they are often limited in height and may be porous. They should be combined with sand nourishment to mitigate any adverse effects on coastal processes.	Shouldn't be used to facilitate retreat, which is usually undertaken to provide more space for natural coastal processes to occur.

5.5.1. Technical description

Seawalls are linear structures constructed at the coastline, at the foot of cliffs or dunes and are put in place to protect the land and associated land-based amenities behind them. While these structures are usually termed coastal protection structures, land protection is most certainly a better description than coastal protection, since they do not address the causes of erosion and in many cases accelerate erosion on their seaward side. In addition, these structures can be aesthetically unappealing and may hinder access to the beach.

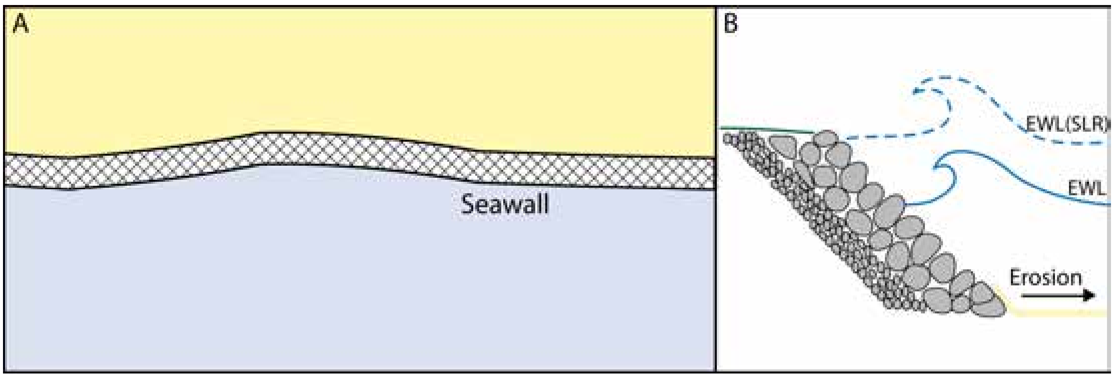

Figure 29 Typical seawall and the effect of sea level rise and erosion.

Source: GCCM

Seawalls are currently in place in many locations around the world. Structurally, a seawall typically comprises a sloping seaward face comprising rubble-mound blocks or concrete, backed by finer material and a filter fabric to prevent leaching. The structure is designed to withstand severe wave action typically in conjunction with storm surge. A rubble-mound revetment often protects the foot of concrete seawalls. Seawalls are often incorporated into a Shoreline Erosion Management Strategy in combination with beach nourishment and dune regeneration to provide a last line of defence under the coastal dune, reducing the risks of erosion and floods (THESEUS, 2011, ENCORA, 2009).

In the past, many nearly-vertical seawalls were constructed that acted to adversely accelerate beach erosion by reflecting much of the incoming wave energy. Hence, exposed seawalls may fix the location of the coastline, but may not arrest the ongoing erosion in the coastal profile. On the contrary, it is quite normal that the beach disappears in front of a seawall and it will most often be necessary, after some years, to strengthen the foot of the seawall with a rubble revetment (ENCORA, 2009).

Seawalls must cover the full length of the littoral cell within which they are located in order to prevent down-coast effects. That is, erosion around the ends of the wall can lead to collapse of the adjacent unprotected coast. In addition, isolated sections of seawall may exacerbate erosion on unprotected sections of a beach by denying sediment down-coast during storms and by deflecting wave energy (ASR, 2005).

Box 14. The Gold Coast sea wall

The City of Gold Coast has approximately 42 km of Pacific Ocean coastline, with popular surfing beaches stretching from Coolangatta to South Stradbroke Island. During the storm erosion that occurred in the 1960s, beach scarps extended landward past the boundaries of many beachfront properties. The extreme waves seriously damaged some building structures and affected the integrity of many other structures. As a response, Gold Coast City Council and many of the residents who owned property adjacent to the beach constructed protective walls along the beachfront in an attempt to protect buildings and other structures. In the majority of cases, these walls were constructed directly on the then existing storm erosion scarp. After detailed studies starting in the 1970s, Council developed a standard design for the construction of protective boulder walls, acknowledging that the dynamic nature of the beach environment means that the boulder wall will be buried in sand during periods of fine weather or following the application of additional beach protection techniques such as nourishment. The boulder wall areas may then be re-exposed during periods of storm conditions. The seawalls were constructed along what is known as the A-line: the line running parallel to the beach along the rear of the primary dune.

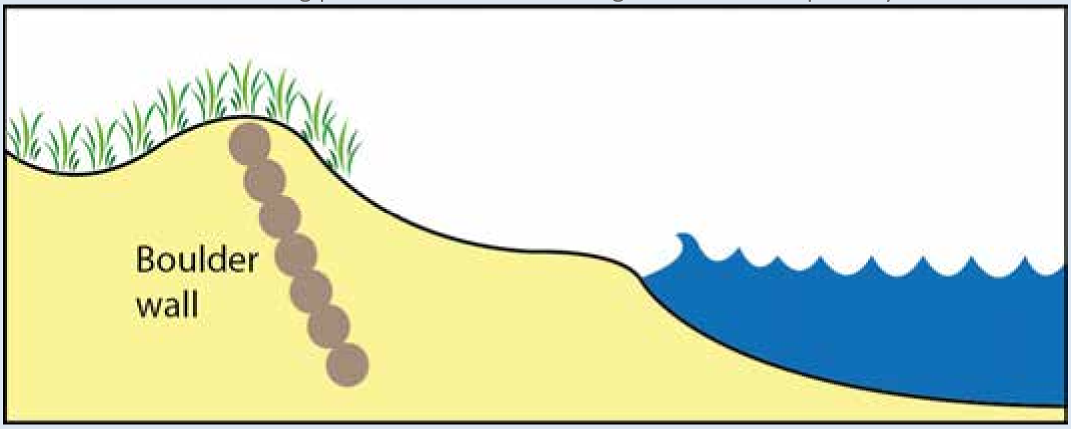

Figure 30 **The Gold Coast seawall (boulder wall) is designed to be buried under vegetated dunes**
Source: **GCCM**

5.5.2. Role in coastal hazard adaptation

Sea level rise creates an issue for seawalls as it raises both the mean normal water level and the height of waves during extreme weather events, during which the present seawall heights may be unable to cope. Changes in the intensity of storms can also challenge the structural resilience. Existing seawalls should therefore be carefully assessed to consider costs and benefits of maintenance and upgrades in the future. Where soft engineering options are not available, new seawalls should be designed considering future sea level rise and possible changes in storm conditions. Innovative design that allows for continuous review and upgrade should be developed to reduce costs of future works. The development of the seawall design criteria is a most important aspect of their design.

Table 44 Seawalls and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Seawalls	✓✓	✗	✓	✗
	Useful to protect coastal settlements from extreme storm erosion.	Not designed to specifically address chronic erosion issues and usually don't develop a beach alignment in equilibrium with sediment transport.	Can protect coastal settlements from occasional storm tide inundations.	If permeable, sea walls are unable to halt permanent inundation.

5.5.3. Synergies and conflicts with other adaptation options

Seawalls can be coupled with hard or soft engineering adaptation options under a defence strategy (e.g. dune construction on top of the seawall, groynes, detached breakwaters, etc.). Seawalls should not be put in place where the strategy is to retreat from the shore; however, in some cases it can be accepted to retreat from the shore and build a seawall to protect some parts of coastal hazard areas. Seawalls can also be used to protect and support reclaimed land.

Table 45 Synergies and conflicts of seawalls

Seawalls			
Regenerative options	Beach nourishment	✓	Beach nourishment is compatible with seawalls when a large amount of sand is placed in front of the structure. However these structures can sometimes induce further erosion when the water reaches the base of the structure.
	Dune construction and regeneration	✓	They can be combined, usually when the seawall is buried under dunes
	Riparian corridors restoration and generation	✓	For estuary or waterways, seawalls can be combined with riparian corridors restoration and generation (NSW Government, 2009)
	Wetlands restoration	✓	For estuary or waterways, seawalls can be combined with riparian corridors restoration and generation (NSW Government, 2009)
Coastal engineering options	Artificial reefs	✓	Under certain circumstances, artificial reefs and seawalls can be combined.
	Detached breakwaters	✓ ✗	Compatible, under certain circumstances.
	Groynes and artificial headlands	✓ ✗	Compatible, under certain circumstances.
	Sea dykes	✓	Compatible, however they address different issues - erosion vs floods.
	Storm surge barriers	✓	Compatible, however they address different issues - erosion vs floods.
Coastal settlements design options	Building retrofitting and design	●	Typically no interference.
	Flood-resilient public infrastructure	●	Normally seawalls do not interfere with flood-resilient public infrastructure.
	Raise land levels	✓	Under certain circumstances, raising land levels can include hard protections on the seaward side of the raised land.
Planning options	Development setbacks	✓	Coastal development setbacks can provide an additional safety buffer behind seawalls.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

5.5.4. Legal and administrative framework

Under Queensland legislation, approvals are required to carry out tidal works including seawall construction. The development assessment process under the

Coastal Protection and Management Act 1995 is aligned with the Integrated Development Assessment System (IDAS) under the *Sustainable Planning Act 2009*.

Under the QCP, seawalls are engineered erosion control structures only considered for protection where beach nourishment or landward retreat is not a practical or cost effective option. Where erosion protection structures are necessary, maintaining physical coastal processes outside the area subject to the coastal protection works is required to avoid adverse impacts on adjacent coastal landforms and associated ecosystems. Development that is coastal protection work, including seawalls, complies with the QCP only if: the development is consistent with a shoreline erosion management plan; or the development protects coastal-dependent development; or there is a demonstrated need to protect existing permanent structures from an imminent threat of coastal erosion; and abandonment or relocation of the structures is not feasible.

Planning considerations for local government

- Are there any land tenure considerations?
- What works are proposed?
- Have other options been considered such as beach nourishment etc.?
- Will the defensive structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause coastal erosion or adverse changes in other areas (remote from the location)?
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by beach nourishment works are listed in Table 46. Separate requirements for the dredging of source material have not been considered here.

Reconfiguration of lot and/or material change of use approvals may be required on private property to provide sufficient land for the construction of seawalls.

Seawalls are typically located on unallocated State Land bordering the high water mark and are thus considered tidal works. If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* (CPM Act) but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 46 Approvals required for seawalls

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Material change of use	Relevant planning scheme	Land-use change to provide sufficient land to enable construction works	Relevant planning Scheme
Reconfiguration of a lot	*Sustainable Planning Regulation 2009*, Schedule 3, Table 3, Item 1	Reconfiguration of a lot to provide sufficient land to enable construction works	*Land Title Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

It is unlikely that amendments to the planning scheme will be required to successfully implement this option. Seawall construction is typically conducted in tidal areas which are unallocated State Land. These areas will not require planning scheme mapping amendments or additional overlays to be carried out. The only approval triggered under the planning scheme may be operational work for filling and excavation.

The powers available to LGAs for any potential land take required to construct the seawall are discussed in Section 7.2.4.

Seawall construction may reduce the value of land through reduction in views and any required land take for construction. Compensation may be granted under Section 704 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

5.5.5. Maintenance

Seawalls do not typically require continuous maintenance, however, extreme storms can damage the structures and intervention can be required.

5.5.6. Timeframe for review

Seawalls can be designed to be effective in the long term under average conditions. However, changing climatic conditions can challenge their efficacy and a reduced timeframe for review of their design should be considered.

5.5.7. Failure risk

Seawalls typically fail by undermining of the seaward face or by water undermining the rear face, either from overtopping waves or land based runoff. Rock revetments may fail due to wave action breaking the rocks or due to waves displacing the rocks (or concrete armour units) reducing their effectiveness. If erosion is allowed to progress behind the sea wall, the wall may become ineffective, standing free of the shore face as an intrusive but ineffective element on the shore. With sea level rise, seawalls will need to be increased in height periodically. This will only be practical if the foundations of the wall have been built sufficiently robustly to allow the extra load. Otherwise the wall may need to be rebuilt.

5.5.8. Estimated cost

The current approximate cost for seawalls is approximately $2,000 to $5,000 per linear metre.

5.5.9. Multi-criteria overview

Table 47 Multi-criteria overview for seawalls

Seawalls			
Climate uncertainty	Effectiveness	How effective is it for climate change?	May require expensive upgrades in the long term under sea level rise conditions.
	Flexibility	Can it be modified after implementation?	Modifications of the structure can be carried out; however the costs of works can be very high.
	Reversibility	Is it easy to completely remove it?	Removal of seawalls is possible but very expensive.
	No regret	Is there any other social or environmental benefit?	Yes, where designed in combination with riparian vegetation and wetlands.
	Decision Horizon	Does it help gaining time for major decisions?	They represent a major decision which can have significant impacts on the natural system.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction and maintenance are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Seawalls can affect the access to the shore where they are not combined with sand nourishment and dune reconstruction.
	Landscape	Does it impact landscape values?	Exposed seawalls can have a negative impact on coastal landscape.
	Recreational use	Does it affect recreational uses?	Exposed seawalls can reduce beach width and opportunities for beach usage.
	Property values	Are private property values affected?	Protection increases property values, however impacts on landscape can decrease values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Can have a negative impact on coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	No specific benefits or impacts identified.
Costs	Initial cost	Is the initial cost high?	Initial costs can be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is usually not required in normal conditions, but likely in the medium and long term.

5.6. Storm surge barriers

Storm surge barriers are hard engineered structures designed to prevent coastal flooding but maintain navigation at other times. They are normally part of a combined system of barriers (dykes, dunes, etc.) preventing storm tide water levels to flood waters within estuaries, lagoons or waterways.

Table 48 Storm surge barriers and coastal planning approaches

	Defend	Accommodate	Retreat
Storm surge barriers	✓✓	✓✗	✗
	Can be used to defend low lying areas from the risk of inundation and maintain navigation, but they can't control erosion.	Can be used in association with staged accommodate strategies.	Shouldn't be used to facilitate retreat, which is usually undertaken to provide more space for natural coastal processes to occur.

5.6.1. Technical description

Storm surge barriers are large-scale coastal defence projects providing a physical barrier that prevents storm surge travelling upstream in navigable rivers, lagoons, inlets or waterways and impacting vulnerable infrastructure. During an extreme event, a storm surge will cause a rise in sea level on the seaward side of the barrier. The closure of a storm surge barrier then prevents elevated water levels penetrating the estuary. As a result, the water level on the landward side remains low. These barriers are usually opened during normal conditions, while failsafe mechanisms are put in place to operate the barrier during extreme events, combined with warning systems to manage the barrier operations. This solution is most frequently applied at narrow tidal inlets, where the length of the structure is not required to be so great and where defences behind the barrier can be reduced in height or length (Linham and Nicholls, 2010).

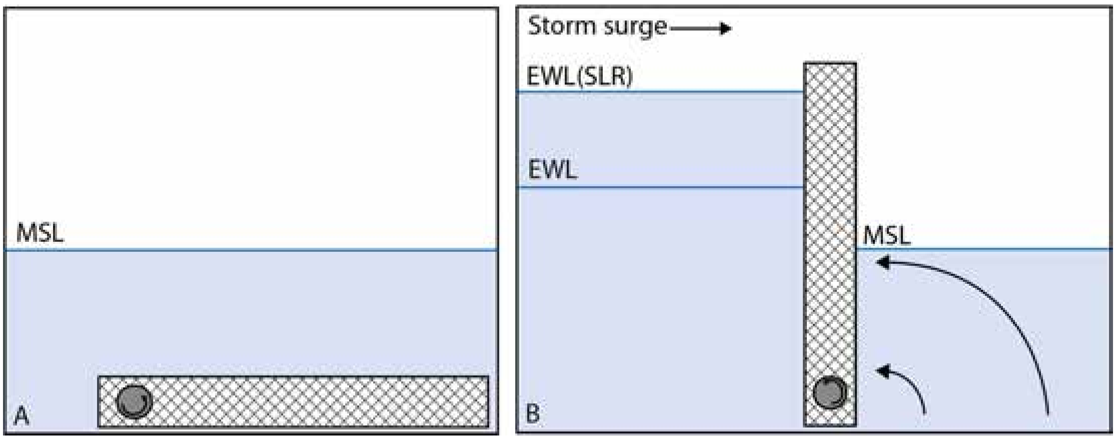

Figure 31 Storm surge barriers.
Source: GCCM

Numerous storm surge barriers are operating around the world, including the Thames Barrier in London (see box 15), the Delta Works in the Netherlands, and the MOSE in Venice, Italy (under construction). Although each of these projects has a similar objective, the designs vary significantly. A common feature is that the barrier usually allows water flow during normal conditions, maintaining ecological functions (e.g. movement of species) and socio-economic activities (e.g. navigation).

Future sea level rise should be considered in the design of storm surge barriers based on their expected lifetime.

Box 15. The Thames Barrier, London

The Thames Barrier (further readings: UK Environment Agency, 2012) is one of the world's largest movable storm surge barriers and is located downstream of central London. Its purpose is to prevent London from being flooded by exceptionally high tides and storm surges moving in from the sea. These occurred, for instance, in 1928 and 1953, with numerous deaths and economic losses for the City of London and across the east coast of England. The barrier needs to be raised (closed) only during high tides; at ebb tide it can be lowered to release the water that backs up behind it from the Thames River. The barrier, designed by the Wallingford Labs, is based on the concept of rotating gates. The site, approximately 10 km east from the centre of London, was chosen because of the relative straightness of the banks, and because the underlying river chalk was strong enough to support the barrier. Work began at the barrier site in 1974 and construction was largely completed by 1982. In addition to the barrier itself, the flood defences for 11 miles down-river were raised and strengthened. Built across a 520 metre wide stretch of the river, the barrier divides the river into four 61 m and two approximately 30m (100ft) navigable spans. The flood gates across the openings are circular segments in cross section, and they operate by rotating the gates at different degrees, controlling water flow upstream. All the gates are hollow and made of steel up to 40 mm thickness. The gates fill with water when submerged and then empty as they emerge from the river. The four large central gates are 20.1 metres high and weigh 3,700 tonnes. Total construction cost was around £534 M (£1.3 B at 2001 prices) with an additional £100 M for river defences.

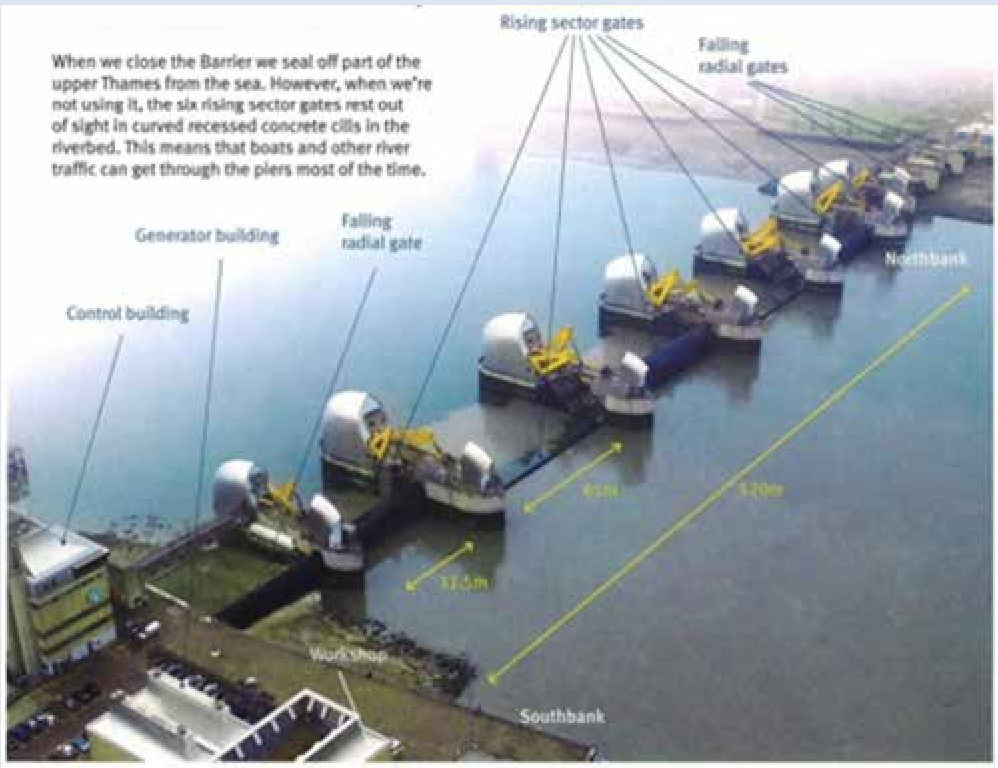

Figure 32 **The Thames storm surge barrier and its operational aspects.**
Source: **UK Environment Agency.**

5.6.2. Role in coastal hazard adaptation

Storm surge barriers are an effective measure to control the risks of floods induced by storm surges affecting vulnerable maritime infrastructure. Design of new storm surge barriers should consider an allowance for sea level rise during the life of the structure. As sea level increases, the return period of extreme water levels will decrease and an increasing number of closing operations will have to be taken into account into the future.

Table 49 Storm surge barriers and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Storm surge barriers	✗	✗	✓✓✓	✓✗
	Storm surge barriers are not utilised to cope with storm or chronic erosion of a shoreline.	Storm surge barriers are not utilised to cope with storm or chronic erosion of a shoreline.	Storm surge barriers are designed to defend against inundation hazards and maintain navigation at other times.	Storm surge barriers can assist in reducing the impacts of permanent inundation.

Figure 33 Storm surge barrier at the Port of Rotterdam, The Netherlands
Source: Netherland Ministry of Water and Public Works www.rijkwaterstaat.nl

5.6.3. Synergies and conflicts with other adaptation options

Storm surge barriers are used to close navigable waterways during extreme water level events. To effectively waterproof land, storm surge barriers must be combined with sea dykes and dunes and could require land reclamation. Options to retreat from the coast (land swap, rolling easements, etc.) are normally not combined with storm surge barriers. However, coastal development setbacks may be used to maintain an additional safety buffer.

Table 50 Synergies and conflicts of storm surge barriers

Storm surge barriers			
Regenerative options	Beach nourishment	●	Usually there's no interference.
	Dune construction and regeneration	✓✓	Dune construction and regeneration can support the function of storm surge barriers to protect a coastal area.
	Riparian corridors restoration and generation	●	Usually there's no interference.
	Wetlands restoration	●	Usually there's no interference.
Coastal engineering options	Artificial reefs	✓	Compatible, however they address different issues - erosion vs floods.
	Detached breakwaters	✓	Compatible, however they address different issues - erosion vs floods.
	Groynes and artificial headlands	✓	Compatible, however they address different issues - erosion vs floods.
	Sea dykes	✓✓	Often combined as part of an integrated defence system.
	Seawalls	✓	Compatible, however they address different issues - erosion vs floods.
Coastal settlements design options	Building retrofitting and design	✗✗	Storm surge barriers are utilised to avoid the need for accommodation against floods on human settlements and infrastructures
	Flood-resilient public infrastructure	✓✓	Storm surge barriers are utilised to avoid storm tide inundation, however this can be combined as an additional safety measure.
	Raise land levels	✓	Under certain circumstances, with hard protections on the seaward side of the raised land.
Planning options	Development setbacks	●	Coastal development setbacks are unlikely to bet applied behind storm surge barriers.
	Land buy-back	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land swap	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Land-use planning	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.

5.6.4. Legal and administrative framework

Under Queensland legislation approvals are required to carry out tidal works as defined by the *Coastal Protection and Management Act 1995*, including storm surge barrier construction.

Storm surge barriers are not considered under the QCP, however they can be considered in accordance with hard engineering erosion control structures that are only considered for protection where beach nourishment or landward retreat is not a practical or cost effective option and there is a need to maintain navigation. Development of storm surge barriers that is coastal protection work, in this case, complies with the QCP only if: the development is consistent with a shoreline erosion management plan; or the development protects coastal-dependent development; or there is a demonstrated need to protect existing permanent structures from an imminent threat of coastal erosion; and abandonment or relocation of the structures is not feasible.

Planning Considerations for Local Government

- What works are proposed?
- Have other options been considered such as beach nourishment etc.?
- Will the defensive structure have adverse effects on coastal processes, natural character, the local economy, scenic amenity and public access?
- Would the option cause coastal erosion or adverse changes in other areas (remote from the location?)
- Would there be an expectation that the structures would be maintained forever?
- Will the public continue to accept the maintenance costs for the structures in the future?
- What would happen if protection structures fail?

Approvals required

The tenure of land under tidal waters is generally unallocated State Land, which is a State resource for the purposes of the *Sustainable Planning Act 2009*.

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by storm surge barrier works are listed in Table 51.

If the proposed development is considered tidal works in a LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district relevant requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Works within a declared fish habitat area under the *Fisheries Act 1994*;

- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

5.6.5. Failure risk

Storm surge barriers may fail if overtopped in the long term and especially if sea level rise is not fully considered. They may also effectively fail if other parts of the barrier system are breached and the barrier is outflanked.

Storm surge barriers can also be subject to failure to close, or close completely, during a storm surge, either due to a mechanical failure or a failure of the control system or operator.

5.6.6. Estimated cost

Costs vary depending on the size of the barrier; however costs are expected to be in the order of hundreds of millions of dollars for very significant projects. For instance, today's construction cost for the Thames Barrier in London would be more than $2 billion. Smaller barriers however may still be economically feasible in certain situations.

Table 51 Approvals required for storm surge barriers

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Operational Works – for Removal, Destruction or Damage of Marine Plants	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 8	Removal or destruction of marine plants.	*Fisheries Act 1994*
Building work	*Sustainable Planning Regulation 2009,* Schedule 3, Table 1, Item 1	Building work	*Building Act 1975*
Building work – declared fish habitat area	*Sustainable Planning Regulation 2009,* Schedule 3, Table 1, Item 2	Building work within a declared fish habitat area	*Fisheries Act 1994*
Any relevant local planning scheme policies			

Powers available to local government to establish the option and the role of the planning scheme

Storm surge barriers are typically constructed across river/delta mouths with infrastructure extending from bank to bank. Consequently, infrastructure works will be required both above and below the high water mark. It is unlikely that amendments to the local planning scheme will be required to successfully implement this option if works are on unallocated State Land. However, ancillary infrastructure requirements will likely be required on adjacent land that may require zoning change.

The powers available to LGAs for any potential land take required to construct the storm surge barrier are discussed in Section 7.2.4.

5.6.7. Maintenance

Storm surge barriers are expensive structures, which may require high levels of maintenance to ensure the structure continues to provide design levels of protection when needed. The construction and maintenance costs are likely to increase into the future in response to sea level rise.

5.6.8. Timeframe for review

Storm surge barriers are designed to be effective in the long-term under average and extreme conditions. Monitoring of storm surge barriers performance and maintenance needs should be performed on a continuing basis.

5.6.9. Multi-criteria overview

Table 52 Multi-criteria overview for storm surge barriers

Storm surge barriers			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Storm surge barriers are more effective to protect from storm tide inundations, with a more limited role in controlling the risks of sea level rise.
	Flexibility	Can it be modified after implementation?	Modifications can be carried out with potentially costly interventions.
	Reversibility	Is it easy to completely remove it?	Removal of storm surge barriers is possible but likely quite expensive.
	No regret	Is there any other social or environmental benefit?	There's no specific environmental benefit identified.
	Decision Horizon	Does it help gaining time for major decisions?	They represent a major decision which can have significant impacts on the natural system.
	Synergy with mitigation	Does it help reducing emissions?	Works associated with construction are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Is designed to facilitate access for navigation.
	Landscape	Does it impact landscape values?	Can have a negative impact on coastal landscape.
	Recreational use	Does it affect recreational uses?	Storm surge barriers, when opened, should not interfere with recreational activities.
	Property values	Are private property values affected?	Protection increases property values, however impacts on landscape can decrease values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Can have a negative impact on coastal ecosystems, however water circulation is maintained.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	Designed to prevent disasters.
Costs	Initial cost	Is the initial cost high?	Costs may be extremely high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance is essential to maintain function.

6. Coastal settlements design options

6.1. Building retrofitting and improved design

Building retrofitting and improved design is the combination of measures to improve the resilience of current buildings or to apply new design standards for future developments. This can include measures to waterproof buildings or accommodate water flows through the building while preventing major damages to structures and facilities. It is a mitigation measure against the impacts of sea level rise, associated storm tide inundation, riverine flooding and wind and not related to measures to limit coastal erosion.

Table 53 Building retrofitting and design and coastal planning approaches

1	Defend	Accommodate	Retreat
Building retrofitting and design	✓✗	✓✓	✗
	Defence strategies aim to minimise the risk of inundation; in these cases, investing in house retrofitting and design should be proportional to the level of protection provided by the defence system.	It is a way to mitigate the impacts of storm tide inundation when defence is not feasible.	It should not be undertaken if the chosen strategy is to retreat from the high coastal hazard area.

6.1.1. Technical description

Residents may choose to remain living in communities that have historically developed in high coastal hazard areas, despite the threat from storm tide inundation and associated risks. As storm tide intensity and frequency is expected to increase in the future in association with rising sea levels, existing buildings could be made more resilient by retrofitting or applying new design standards through redevelopment.

During storm tides, houses experiencing impacts may suffer damage caused by:

- Seawater inundation;
- Water currents that break through walls or move whole buildings off their foundations;
- Water currents and high winds that drive debris into the building;
- Breaking waves; and/or
- Landslide.

In addition to the damage caused by storm tide waves as they wash ashore, the sea water will cause further damage as the storm tide subsides and the water recedes back into the ocean. The flow of this 'ebbing' water is guided by the shape of the land, the roadways, houses and other structures in its path. As a result, the direction of water flow may be quite different to that of the initial storm tide as it erodes new channels and applies different forces to houses and buildings (QRA, 2011a). The saline sea water may also cause damage through ongoing corrosion of building materials.

Different types of flood characteristics determine how to retrofit houses for floods in hazard prone areas. These include hydrostatic (e.g. lateral on walls or vertical on floors) and hydrodynamic actions induced by the flow of water above ground level.

Erosion and scour can affect the stability of the foundation and can increase the flood actions on buildings. The usual methods to mitigate the effects of erosion and scour are to increase the depth of the foundation embedment. Erosion protection measures should be undertaken if potential for erosion due to flood actions is deemed serious. Foundations must be designed to maintain the necessary support for the structure during a flood situation and in particular must be designed to prevent flotation, collapse or movement. Flood hazard areas may restrict the construction option of a single storey house with a concrete slab-on-ground. Alternative construction methods, such as an elevated house would need to be considered. This may require consequential planning or building control changes, for example to increase applicable building heights restrictions (ABCB 2011).

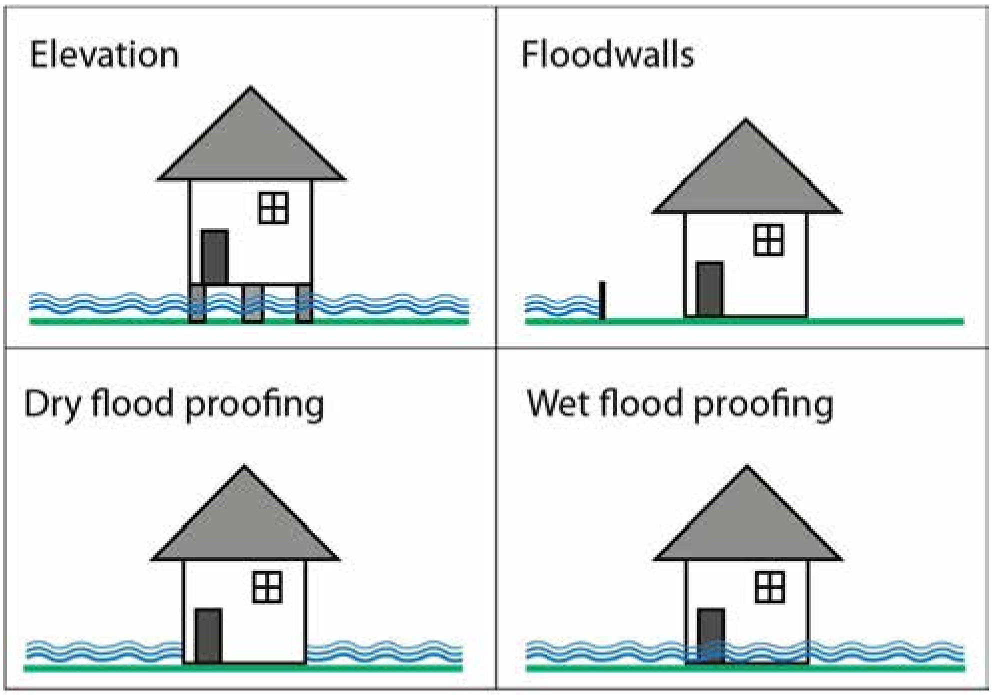

Figure 34 Building retrofit and design to accommodate flood
Source: GCCM, adapted from Andjelkovic, 2001.

'Wet flood-proofing' allows floodwaters to enter and leave the enclosure to equalize the hydrostatic pressure on both sides of the external walls. The holes in the walls must be large enough so as not to become easily blocked by debris. Items such as decks and patios must be structurally adequate so as not to cause failure of the main building they are attached to. The structural materials used below the design flood level (DFL) must therefore be water resistant to minimise the resulting damage. Designers and building owners can choose to select water resistant, non-structural materials for wall linings etc. (ABCB 2011; QRA 2011a).

For 'dry flood-proofing', the building or relevant parts of the building envelope are made substantially impermeable to flood water. If this method is proposed, it would need to be considered on a case by case basis under the performance requirements. If this method is used, care must be taken to ensure the structural adequacy of the building envelope to carry the differential hydrostatic pressure (in addition to the hydrodynamic action) created by the flood waters. This pressure is quite severe and could cause major structural damage if not properly accounted for (ABCB 2011).

Utilities and associated equipment, if exposed to flood water (i.e. located below the DFL) should be designed, constructed and installed to prevent floodwater from entering and accumulating within the system. Utilities and associated equipment should also be anchored to resist the forces generated by the flood (such as buoyancy) and should not be mounted on items or structures that could break away during the flood. Electrical service conduits and cables below the DFL should be waterproofed. Underground service conduits and cables should be buried at a depth sufficient to prevent damage caused by erosion and scour. Meters and switches should be mounted above the DFL and made accessible during the flood (ABCB 2011).

During a flood event, especially one exceeding the DFL, it may be necessary for emergency services or other persons to rescue people trapped in a house by flood waters. Means of exiting the house must be available to allow rescue. The exit route could be from a balcony, veranda, deck, door or window of sufficient size (ABCB 2011).

6.1.2. Role in coastal hazard adaptation

Building retrofitting and new design standards should incorporate climate change projections for the lifetime of the building. In Queensland coastal areas the combination of sea level rise and changing tropical cyclone patterns may increase intensity and frequency of extreme storm tide events over the next 100 years. In this context, retrofitting and design standards for houses in storm tide threatened regions should consider including future sea level rise scenarios. For instance, Annex 3 of SPP3/11 provides planning periods based on asset life and projected sea level rise for those planning periods.

Table 54 Building retrofitting and design and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Building retrofitting and design	✗✗	✗✗	✓✓	✓✗
	Under storm or chronic erosion where defence is not feasible the best option is likely the removal of the building.	Under storm or chronic erosion where defence is not feasible the best option is likely the removal of the building.	For new development or redevelopment, retrofitting or targeted design considerations can be used to mitigate storm tide inundation.	Likely to be practicable only in specific circumstances (see for instance, floating houses, section 9)

6.1.3. Synergy with other adaptation options

Retrofitting and improved design standards can work in synergy with other accommodation options such as flood-resilient public infrastructure and do not interfere with other options to defend the current shoreline position. However, it is normally not coupled with retreat options such as land purchase, swap or changing land-use.

Table 55 Synergies and conflicts of building retrofitting and design

Building retrofitting and design			
Regenerative options	Beach nourishment	●	Interference unlikely.
	Dune construction and regeneration	●	Interference unlikely.
	Riparian corridors restoration and generation	✓	Synergy in accommodating storm tide inundations.
	Wetlands restoration	✓	Synergy in accommodating storm tide inundations.
Coastal engineering options	Artificial reefs	●	Interference unlikely.
	Detached breakwaters	●	Interference unlikely.
	Groynes and artificial headlands	●	Interference unlikely.
	Sea dykes	✓ ✗	Sea dykes are usually designed to avoid the inundation of buildings. If the dyke is designed to cope only with smaller events, additional mitigation measures might be required.
	Seawalls	●	Interference unlikely.
	Storm surge barriers	✗ ✗	Storm surge barriers are normally designed to avoid accommodation and floods on human settlements and infrastructure.
Coastal settlements design options	Flood-resilient public infrastructure	✓ ✓	They should be combined to accommodate storm tide inundations
	Raise land levels	✓	They can be combined in the future if the raised land will be at risk from storm tide inundations under sea level rise
Planning options	Development setbacks	✗	Usually not combined, however it can be an option for redevelopment within erosion prone areas
	Land buy-back	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure
	Land swap	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure
	Land-use planning	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure

6.1.4. Legal and administrative framework

The *Sustainable Planning Act 2009* specifies that a planning scheme must not include provisions about building work, to the extent the building work is regulated under the *Building Act 1975*.

Planning considerations for local government

- What building design codes and provisions could be implemented within the Planning Scheme?

- What is the likely cost of these design improvements?
- What sources of funding could be accessed to assist home owners in implementing this option?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by house retro-fitting works are listed in Table 56.

Table 56 Approvals required for building retrofitting and design

Approval	Reference	Requirement	Applicable Legislation / Codes
Building work	*Sustainable Planning Regulation 2009*, Table 1, Item 1	Building works as defined under the *Building Act 1975*	*Building Act 1975*
Material Change of Use	*Sustainable Planning Act 2009*	Planning scheme code compliance for multi-unit dwellings.	Local planning scheme
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

The planning scheme is limited in how it can implement design standards within single detached dwellings. Design standards for these structures are typically dealt with in the *Queensland Development Code* (QDC) and the *Building Code of Australia* (BCA). This is currently reflected within the planning scheme to the extent that the majority of houses are deemed as either exempt or self-assessable development. For attached housing or apartment style dwellings, the planning scheme has more scope to regulate design. Design requirements for these types of uses are more easily regulated via the planning scheme. Therefore for these types of uses, amendments to codes to incorporate appropriate design and siting requirements may be an option.

Part 3 of the *Building Regulation 2006* prescribes matters that a local planning instrument may designate for the BCA or matters that the LGA may make or amend in a provision of a local law or planning scheme or a resolution. The Regulation provides for land designated as bush fire prone or liable to flooding. The *Building Act 1975* currently provides for building development approvals for an erosion prone area under the *Coastal Protection and Management Act 1995*. No provision is made in either the Act or Regulation for works within the coastal zone as defined under the Coastal Plan.

6.1.5. Maintenance

The initial cost of a house retrofit may be quite high but need not require increased maintenance. Costs should be assessed on a case-by-case basis.

6.1.6. Timeframe for review

The appropriateness of retrofitting options should address the lifespan of the retrofit option and the economic cost. If the payback time exceeds the economic cost of implementing retrofitting options then other climate adaptation methods should be considered.

6.1.7. Failure risk

Failure of retrofitted measures will occur when the level of protection afforded is exceeded by the actual flood event, which will likely have a finite probability over the life of the facility.

In the case of emergency intervention measures for flood protection of infrastructure (e.g. temporary floodwalls or levees), failure can be associated with delays in deploying such a system in time. Failure associated with design includes underestimation of flood height or speed or other modes of failure associated with the specifically deployed measure.

6.1.8. Estimated cost

The estimated cost is variable, depending on the type and size of infrastructure.

6.1.9. Multi-criteria overview

Table 57 Multi-criteria overview for building retrofitting and design

Building retrofitting and design			
Climate uncertainty	Effectiveness	How effective is it for climate change?	Effective when addressing specific storm tide and sea level rise scenarios and levels of risk.
	Flexibility	Can it be modified after implementation?	Yes, however modifications may be expensive
	Reversibility	Is it easy to completely remove it?	Probably not.
	No regret	Is there any other social or environmental benefit?	Social benefits may include increased community resilience during and after extreme events.
	Decision Horizon	Does it help gaining time for major decisions?	Can be a temporary solution until a major decision, e.g. when retreat from the shoreline has to be taken.
	Synergy with mitigation	Does it help reducing emissions?	Use of energy efficient measures will reduce emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Depending on methods, access to shore should not be restricted.
	Landscape	Does it impact landscape values?	Probably not.
	Recreational use	Does it affect recreational uses?	Probably not.
	Property values	Are private property values affected?	May affect property values both positively and negatively depending on situation.
	Impact on ecosystems	Does it impact coastal ecosystems?	Shouldn't impact ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	Can improve emergency procedures (e.g. emergency exit from the roof).
Costs	Initial cost	Is the initial cost high?	Initial costs may be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance needs similar to normal.

6.2. Flood-resilient public infrastructure

Flood-resilient public infrastructure refers to techniques combining measures to improve the resilience of current buildings or by applying new design standards for future developments. This can include measures to waterproof infrastructure or accommodate water flows whilst preventing major damages. It is a mitigation measure against the impacts of sea level rise and associated storm tide inundation and not related to measures to limit coastal erosion.

Table 58 Flood-resilient public infrastructure and coastal planning approaches

1	Defend	Accommodate	Retreat
Flood-resilient Infrastructure	✓✗	✓✓	✗
	Defence strategies aim to minimise the risk of inundation; in these cases, investing in flood-resilient infrastructure should be proportional to the level of protection provided by the defence system.	It is a way to mitigate the impacts of storm tide inundation when defence is not feasible.	It should not be undertaken if the chosen strategy is to retreat from the high coastal hazard area.

6.2.1. Technical description

The projected increased occurrence of coastal flooding events represents a potential risk to some public infrastructure, including transport and communication networks, energy and water supply and social infrastructure (such as schools and hospitals). In Queensland, such assets are often concentrated in potentially vulnerable coastal areas, supporting human settlements functions (DERM, 2011b).

The elevation of transport infrastructure enables the movement of goods and people during a flood event. As such, it decreases flood vulnerability. The use of elevated walkways could improve accessibility between houses and important public buildings, such as flood shelters, during such events. Flood damage to water supply systems is likely to be concentrated at the intake points and locations where the main supply crosses riverbeds and the like. During floods, the quality of potable water in conduits can be affected by silting and pollution and can be addressed by locating pipes above specific flood levels. Similar avoidance strategies can be applied, for example, to electrical supplies, sewer pipes and telephone lines (Andjelkovic, 2001).

Flood-resistant techniques can be classified on the basis of the type of protection as follows (Andjelkovic, 2001; MRC, 2009):

- Permanent measures (always in place, requiring no action if flooding occurs);
- Contingent measures (requiring installation prior to the occurrence of a flood); and
- Emergency measures (improvised at the site when flooding occurs).

Permanent flood-resisting measures are most effective when used in areas that are subject to frequent flooding, relatively high flood depths, or where insufficient flood warning time is available to implement contingent flood proofing measures. These measures include closures and sealants, watertight cores, floodwalls (Section 5) and levees, and elevation of structures. These measures will be most effective when used in areas that are subject to frequent flooding, relatively high flood depths, or where flood warning time is insufficient to apply contingent measures.

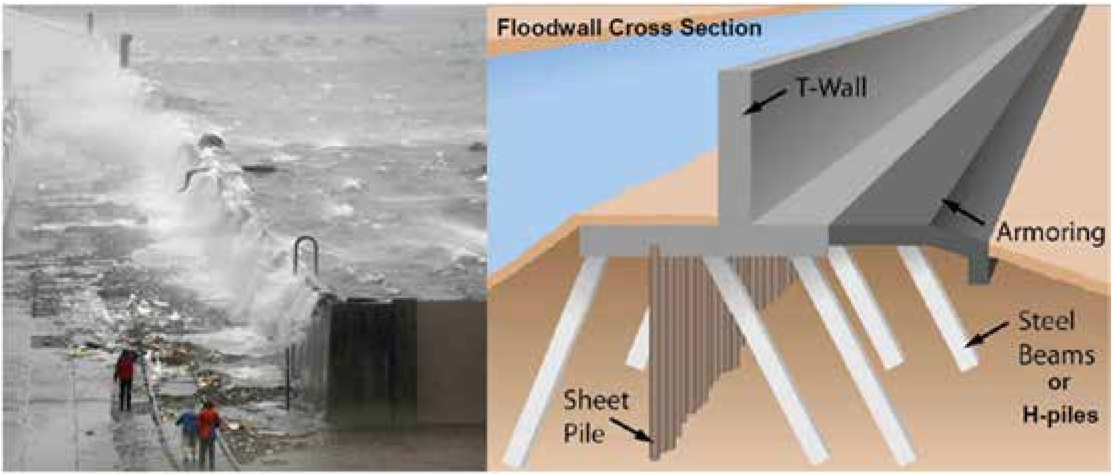

Figure 35 **Hurricane Gustav's surge impact on New Orleans on a floodwall (tampabay.com) and a cross section of the floodwall**
Source: **US Army Corp of Engineers, New Orleans www.mvn.usace.army.mil**

Contingent flood-resisting measures are those that require some type of installation, activation, or other preparation immediately prior to the occurrence of a flood. These measures may include flood shields, watertight doors, and moveable floodwalls.

Emergency flood-resisting measures are characterised by their ability to be initiated at relatively short notice using previously obtained and stored materials. Sand and timber are the primary materials. These methods are most effective in flood areas where water velocities are low and depths are shallow, and where flood waters rise slowly. These measures include sandbag levees, retaining walls and stop log barriers.

Some of the advantages of flood-resisting measures are the following:

- They avoid the need to elevate, demolish or relocate structures and as a result, are often a much more cost effective approach to reducing flood risk (Kemp, 2009); and
- They can be more affordable than the construction of permanent flood protection works such as storm surge barriers and dyke systems (FEMA, 2007).

However, the application of flood-resisting measures does little to minimise damage caused by high velocity flood flow and wave action (FEMA, 2007). Clearly if the flood level exceeds the pre-deployed protective elevation then these measures will be completely ineffective.

6.2.2. Role in coastal hazard adaptation

When accommodating rare extreme water levels is the chosen approach, the improvement of the flood-resiliency of public infrastructure will be effective in reducing the community impact of storm tides. Depending on the lifetime of the asset, sea level rise expectations should be included in the design of new infrastructure and in any upgrade.

Table 59 Flood-resilient public infrastructure and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Flood-resilient public infrastructure	✗✗	✗✗	✓✓	✓✗
	Under storm or chronic erosion where defence is not feasible the best option is likely infrastructure removal and relocation.	Under storm or chronic erosion where defence is not feasible the best option is likely infrastructure removal and relocation.	For new development or redevelopment, retrofitting or targeted design considerations can be used to mitigate storm tide inundation.	Likely to be practicable only in specific circumstances

6.2.3. Synergy with other adaptation options

Development of flood-resilient public infrastructure would not interfere with measures dealing with short-term or long-term erosion and should be coupled with measures applied to retrofit or improve design standards of buildings in areas at risk.

Table 60 Synergies and conflicts of flood-resilient public infrastructure

Flood-resilient public infrastructure			
Regenerative options	Beach nourishment	●	Interference unlikely.
	Dune construction and regeneration	●	Interference unlikely.
	Riparian corridors restoration and generation	✓	Synergy in accommodating storm tide inundations
	Wetlands restoration	✓	Synergy in accommodating storm tide inundations
Coastal engineering options	Artificial reefs	●	Interference unlikely.
	Detached breakwaters	●	Interference unlikely.
	Groynes and artificial headlands	●	Interference unlikely.
	Sea dykes	✓ ✗	Sea dykes are usually designed to avoid the inundation of infrastructure. If the dyke is designed to cope only with smaller events, additional mitigation measures might be required
	Seawalls	●	Interference unlikely.
	Storm surge barriers	✓✓	Storm surge barriers and dykes are designed to avoid storm tide inundation; however they can be combined as an additional safety measure.
Coastal settlements design options	Building retrofitting and design	✓✓	They should be combined to accommodate storm tide inundations.
	Raise land levels	✓	They can be combined in the future if the raised land will be at risk from storm tide inundations under sea level rise.
Planning options	Development setbacks	✗	Can be an option for redevelopment within erosion prone areas.
	Land buy-back	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Land swap	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Land-use planning	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.

6.2.4. Legal and administrative framework

To date, flood-resilience measures for infrastructure have not been widely embraced by government organizations as a flood damage mitigation measure. This may be due to the absence of a suitable design code. The results of CSIRO testing of the effects of saltwater immersion on building materials could potentially form the basis of a flood-resilience building code (CSIRO, 1999). When suitable information is available, government organizations could consider incorporating flood-resilient requirements in building regulations for flood-prone areas.

Planning considerations for local government

- What changes could be made within planning schemes to encourage flood-resilient infrastructure?
- How vulnerable is Council's existing infrastructure?
- What funding is required to improve the resilience of core infrastructure?
- Can retrofitting of public infrastructure be undertaken to increase social disaster resilience (e.g. retrofit school for additional use as a cyclone shelter)?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by flood-resilience works are listed in Table 61.

If the proposed development is considered tidal works in an LGA tidal area, it will need to be assessed against the following relevant provisions:

- the IDAS code in the *Coastal Protection and Management Regulation 2003*, schedule 4A;
- any applicable planning scheme, temporary local planning instrument, master plan or preliminary approval to which section 242 of the Act applies.

Development that is defined as tidal works in a coastal management district requires assessment against the relevant provisions of the *Coastal Protection and Management Act* but does not require assessment against the LGA planning scheme

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992*;
- Clearing of assessable vegetation under the *Vegetation Management Act 1999*;
- Works within a Queensland Marine Park in accordance with the *Queensland Marine Parks Act 2004*;
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975*;
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994*;
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished*;*
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003*;
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992*;
- Owners consent for development on private property.

Table 61 Approvals required – Flood-resilient public infrastructure

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational work – for tidal works (prescribed tidal works)	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is tidal works completely within a single LGA tidal area.	*Coastal Protection and Management Act 1995*
Operational work – for work within a coastal management district	*Sustainable Planning Regulation 2009* Schedule 3, Table 4, Item 5	Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark	*Coastal Protection and Management Act 1995*
Building work	*Sustainable Planning Regulation 2009*, Table 1, Item 1	Building work as defined under the *Building Act 1975*	*Building Act 1975*
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

For new and important public infrastructure, implementation could be via development of a new code or amendment of an existing code within the local planning scheme that stipulates design and siting criteria to provide for flood resilience or even immunity. However, it cannot be used to retrospectively enforce the flood-resilience of public infrastructure. A development application would need to be triggered via the planning scheme for LGAs to be able to enforce this measure. Therefore, a separate mechanism would need to be investigated in these instances.

Infrastructure may also need to be constructed on a reactive basis for temporary or permanent purposes in response to disaster/emergency circumstances. Each LGA must prepare a Disaster Management Plan under Section 57 of the *Disaster*

Management Act 2003, which must include provision for disaster mitigation and response.

Under section 20B of the *Disaster Management Act 2003*, the chairperson of the State disaster management group may give written notice to an LGA stating that the deemed approval provisions do not apply to a development application.

Emergency development including operational work or use, or including operational work that is tidal works, is exempt from assessment under Section 584 and 585 of the *Sustainable Planning Act 2009*.

A landowner may seek compensation for reduced property values in association with restrictions reduced property values associated with flood-resilient public infrastructure e.g. flood-walls. Compensation may be granted under Section 704 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

6.2.5. Maintenance

Whilst permanent flood-resilience measures might require low levels of maintenance (e.g. floodwalls) other contingent and emergency flood-proofing measures might require specific materials and trained personnel for installation.

6.2.6. Timeframe for review

Review of the efficiency of flood-resilience measures should be carried out periodically, based on a specific revision plan, after flood events; and when investigations using new climate change projections are undertaken.

6.2.7. Failure risk

Failure of retrofitted measures will occur when the level of protection afforded is exceeded by the actual flood event, which will likely have a finite probability over the life of the facility.

In the case of emergency intervention measures for flood protection of infrastructure (e.g. temporary floodwalls or levees), failure can be associated with delays in deploying such a system in time. Failure associated with design includes underestimation of flood height or speed or other modes of failure associated with the specifically deployed measure.

6.2.8. Estimated cost

The estimated cost is variable, depending on the type and size of infrastructure.

6.2.9. Multi-criteria overview

Table 62 Multi-criteria overview for flood-resilient public infrastructure

Flood-Resilient public infrastructure			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Effective when addressing specific storm tide and sea level rise scenarios and levels of risk.
	Flexibility	Can it be modified after implementation?	Yes, however modifications may be expensive
	Reversibility	Is it easy to completely remove it?	Probably not.
	No regret	Is there any other social or environmental benefit?	Social benefits may include increased community resilience during and after extreme events.
	Decision Horizon	Does it help gaining time for major decisions?	It may help gaining time before deciding to retreat to higher grounds
	Synergy with mitigation	Does it help reducing emissions?	Use of energy efficient measures will reduce emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Probably not.
	Landscape	Does it impact landscape values?	It may sometimes impact landscape values
	Recreational use	Does it affect recreational uses?	It may sometimes impact recreational uses
	Property values	Are private property values affected?	It may increase property values.
	Impact on ecosystems	Does it impact coastal ecosystems?	It may sometimes impact coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	It is intended to improve disaster and emergency procedures.
Costs	Initial cost	Is the initial cost high?	Initial costs may be high.
	Cost of maintenance	Does it need expensive maintenance?	Maintenance may be an issue.

6.3. Raise land levels

Raising land levels is the combination of measures to elevate the surface level of human settlements. Land can be raised to avoid inundation of new developed land or redevelopments within high hazard areas. Projected sea level rise and storm tide hazard should be considered based on the development's expected lifetime.

Table 63 Raise land levels and coastal planning approaches

	Defend	Accommodate	Retreat
Raise land levels	✓✓	✓✓	✗
	Avoids inundation of former low-lying areas; suitable for large areas.	Avoids inundation of former low-lying areas; suitable for single parcels/buildings.	Would not be used for retreat.

6.3.1. Technical description

Raising the level of low lying land above an expected storm tide inundation level can be an effective response to mitigate current and future coastal hazard risks. While building new structures with floor levels above expected flood heights would reduce damage, raising the land levels around the development further reduces risks and maintains access and use of the property across the areas even during specific storm tide events. Issues related to high water tables could also be alleviated.

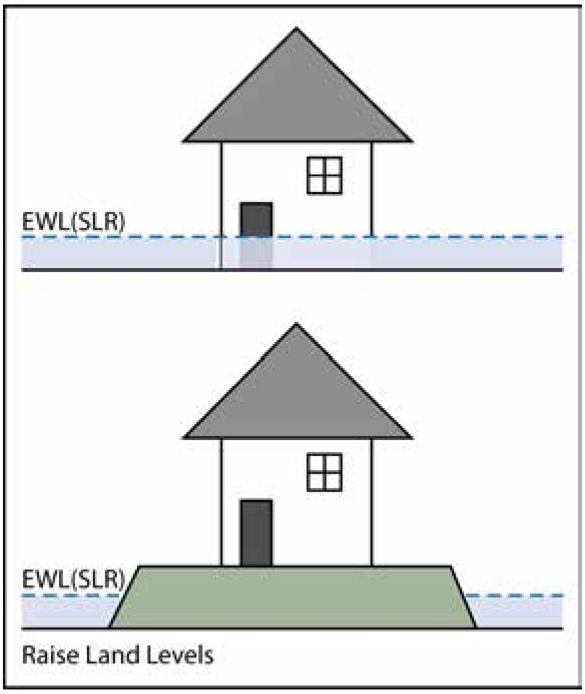

Figure 36 Raised land levels
Source: GCCM

Typically the edge of the raised land may need protection from erosion. This may be an existing sand dune system maintained by beach nourishment or by a seawall, dyke or other erosion-resistant face along a shore with no beach or dunes. This edge may change the character of the shoreline. This measure should be designed to allow rainstorm runoff and drainage. For existing structures, it may be possible to raise the structure and rebuild the foundation underneath if the structure is of high value and lifting costs are acceptable. More often, it would be more cost effective not to reinvest in older structures for a period of time and rebuild when the building structure and fabric have reached the end of their normal service life. The approach can be most readily applied for new development in low lying areas. This option can be harmful to remnant flora and fauna if applied in undisturbed areas. The impact of filling will depend on the methodology enacted. If the filling is undertaken in stages, or property by property rather than on a widespread scale, some flora and fauna may recolonize the filled area from adjacent areas.

Where a new area is being developed on low-lying land, a more widespread approach to filling would likely be adopted. This approach would allow for the slopes and drainage lines to be well planned.

It is unlikely to be cost effective to fill areas that are not intended for reasonably intense development.

Land may be filled repeatedly as sea levels rise, typically with each redevelopment of a structure or renewal of roads, keeping fill levels above expected inundation levels. However, such an approach may have the effect of making the area feel quite 'transient' and disrupted if rapidly rising sea levels made filling a frequent or even constant activity in the area.

6.3.2. Role in coastal hazard adaptation

In the future, the main benefit of raised land levels will remain the additional land, but under a rising sea level, coastal defence benefits should also be considered. As mentioned above, the two main methods for raising land levels are:

- Enclosing and defending shore or near-shore areas; and
- Filling shore or near-shore areas, often using the same techniques used in beach nourishment.

While adapting to climate change, raising land levels using fill methods is perhaps more appropriate as it does not carry a great flood risk.

Table 64 Raise land levels and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Raise land levels	●	●	✓✓	✓✓
	Typically raising land levels is not designed to address storm or chronic erosion.	Typically raising land levels is not designed to address storm or chronic erosion.	Raising land levels can mitigate both storm tide and permanent inundation.	Raising land levels can mitigate both storm tide and permanent inundation.

6.3.3. Synergies and conflicts with other adaptation options

Raised land level is commonly combined with hard or soft engineering measures to protect the claimed area (seawalls, sea dykes) or to enhance environmental quality around the claimed land (beach regeneration, dune regeneration).

Table 65 Synergies and conflicts of raise land levels

Raise land levels			
Regenerative options	Beach nourishment	●	Interference unlikely.
	Dune construction and regeneration	●	Interference unlikely, however sometimes dunes can be constructed on the seaward side of the raised land.
	Riparian corridors restoration and generation	●	Interference unlikely unless raising land has to cover riparian vegetation.
	Wetlands restoration	●	Interference unlikely unless raising land has to cover the wetland.
Coastal engineering options	Artificial reefs	●	Interference unlikely.
	Detached breakwaters	●	Interference unlikely.
	Groynes and artificial headlands	●	Interference unlikely.
	Sea dykes	✓ ✗	Sea dykes are usually designed to avoid the inundation of buildings. If the dyke is designed to cope only with smaller events, additional mitigation action might be required.
	Seawalls	✓	Under certain circumstances, raising land levels can include hard protections on the seaward side of the raised land.
	Storm surge barriers	✓	Under certain circumstances, with hard protections on the seaward side of the raised land.
Coastal settlements design options	Building retrofitting and design	✓	They can be combined in the future if the raised land will be at risk from storm tide inundations under sea level rise
	Flood-resilient public infrastructure	✓	Can be combined in the future if the raised land will be at risk from storm tide inundations under sea level rise
Planning options	Development setbacks	✗	Usually not combined, however it can be an option for redevelopment within erosion prone areas and high coastal hazard areas.
	Land buy-back	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Land swap	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Land-use planning	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.

6.3.4. Legal and administrative framework

Under Queensland legislation, approvals are required to carry out operational work within a coastal management district. The development assessment process under the *Coastal Protection and Management Act 1995* is aligned with the Integrated Development Assessment System (IDAS) under the *Sustainable Planning Act 2009*.

Planning considerations

- Are there any land tenure issues that need to be considered?
- Will the works trigger any other interests or approvals for such works within a State Marine Park?
- Will the works significantly impact on the rights of persons with an interest in land in proximity to the filling?
- What works are proposed?
- Will there be any adverse impacts on coastal processes, natural character, the local economy, scenic amenity and public access?
- Has potential impacts on ecosystems and habitats been considered (such as habitat for migratory shorebirds and turtle nesting areas)?
- Has the community been consulted regarding the planned works?

Approvals required

Schedule 3 of the *Sustainable Planning Regulation 2009* outlines works requiring development assessment in Queensland. Development assessments likely to be triggered by the filling of land above the high water mark are listed in Table 66.

Other approvals that may be required include:

- Operational work that is interfering with quarry material as defined under the CPM Act on State coastal land above high water mark;
- Clearing of native plants (rare and threatened) under the *Nature Conservation Act 1992;*
- Clearing of assessable vegetation under the *Vegetation Management Act 1999;*
- Works within the Great Barrier Reef Marine Park in accordance with the *Great Barrier Reef Marine Park Act 1975;*
- Works within strategic port land or airport land in accordance with the approved land-use plan under the *Transport Infrastructure Act 1994;*
- Native title suppression pursuant to 24KA of the *Native Title Act 1993* where works are proposed on lands on which Native Title has not been extinguished;
- Preparation of a formal Cultural Heritage Management Plan (CHMP) or a Cultural Heritage Management Agreement (CHMA) under Section 23(1) of the *Aboriginal Cultural Heritage Act 2003;*
- Development on a Queensland Heritage Plan under the *Queensland Heritage Act 1992;*
- Owners consent for development on private property.

Table 66 Approvals required for raising land levels

Approval	Reference	Requirement	Applicable Legislation / Codes
Resource entitlement (State land or State resource) / owners consent	*Sustainable Planning Regulation 2009* Schedule 14	• DNRM for unallocated State land; • DNRM for road, esplanade reserves etc under the Land Act; • DNRM for leased State land under the Forestry Act; • EHP for land subject to tidal works under the CPM Act; • Trustee for State land reserved under the Land Act; and • Owner of freehold land.	*Land Act 1994* *Coastal Protection and Management Act 1995*
Operational works-Clearing of Native Vegetation	*Sustainable Planning Regulation 2009*, Schedule 3, Table 4, Item 1	Clearing assessable vegetation	Vegetation Management Act 1999
Any relevant local planning scheme policies			

Powers available to local government to establish this option and the role of the planning scheme

If this strategy is introduced, amendments to flood overlay mapping within planning schemes will be required to accurately reflect new flood levels. If land that was previously deemed flood prone can now be developed for different uses, some planning scheme mapping amendments may also be required to reflect these changes. In addition to the State approvals outlined above, an operational works application for filling and excavation will also most likely be triggered by the planning scheme.

6.3.5. Maintenance

Raised land levels do not require continuous maintenance, which can be limited to the defence structures enclosing the landfill.

6.3.6. Timeframe for review

Raised land levels are designed to be long-term investments and long-lasting infrastructure. Reviews should be considered following updates in sea level rise rates.

6.3.7. Failure risk

The main risk of failure is if the acceptable flood height is underestimated, in which case a damaging flood will still occur. Depending on the planned horizon for the works, higher water levels should be considered under sea level rise scenarios. Erosion at the perimeter can also occur.

6.3.8. Estimated cost

The cost of raising land levels will depend on the availability and cost of suitable fill. Sometimes fill material may be available for free. Costs of placing and grading may be quite modest, with higher costs for the load bearing area under the structure where consolidation and suitable material is required. An indicative cost to raise land level by up to 1 m may be \$10 - \$30/m^2.

6.3.9. Multi-criteria overview

Table 67 Multi-criteria overview for raise land levels

Raise land levels			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Raise land levels can be an effective measure to cope with specific sea level rise scenarios.
	Flexibility	Can it be modified after implementation?	This option can't usually be modified after implementation.
	Reversibility	Is it easy to completely remove it?	No.
	No regret	Is there any other social or environmental benefit?	No.
	Decision Horizon	Does it help gaining time for major decisions?	It is usually a major decision.
	Synergy with mitigation	Does it help reducing emissions?	Works are a source of carbon emissions.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Usually not.
	Landscape	Does it impact landscape values?	It can change coastal landscapes and will change borrow areas.
	Recreational use	Does it affect recreational uses?	It can sometimes impact recreational uses.
	Property values	Are private property values affected?	It may increase property values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Yes, where it covers valuable ecosystems or they are affected by borrow pits.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	It can reduce the risks and improve disaster and emergency procedures.
Costs	Initial cost	Is the initial cost high?	Costs can be extremely high.
	Cost of maintenance	Does it need expensive maintenance?	No.

7. Planning options

Planning adaptation options are designed to reduce the risk of coastal hazards on human settlements by controlling development in high hazard risk areas and reducing the current urban footprint on high hazard risk areas.

The following planning options are described:

- Coastal development setbacks;
- Land buy-back;
- Land swap; and
- Land-use planning.

Figure 37 Wooli Village Draft Coastal Management Plan land swap proposal
Source: Clarence Valley Council, NSW

7.1. Development setbacks

Development setbacks establish fixed distances from a designated boundary (i.e. the mean sea level) to the property line in which development is restricted, prohibited or regulated by specific design requirements to provide a safety buffer against extreme storms and future sea level rise. In Queensland, development setbacks from the highest watermark are imposed on development by means of the identification of coastal hazard areas, including erosion prone areas and high and medium coastal hazard areas.

Table 68 Development setbacks and coastal planning approaches

	Defend	Accommodate	Retreat
Development setbacks	✓✓	✓	✓✗
	Setbacks can be part of a defence strategy, providing an additional safety margin to settlements at risk, or as a condition to limit intensification.	Setbacks can be part of an accommodation strategy, providing an additional safety margin to settlements at risk.	Setbacks can be included as part of a planned retreat strategy, however major changes in the current legislation would be required.

7.1.1. Technical description

A coastal development setback is defined as a prescribed distance from the permittable property boundary to a specific base line in which development is restricted, prohibited or regulated by specific development controls. The designated base line can be the high water mark, a hazard risk line, a defence line, or another specific line determined by the legislative framework.

Coastal development setbacks provide protection to properties and infrastructure against coastal flooding and erosion by ensuring that buildings are not located in an area susceptible to these hazards and that those structures which are susceptible are appropriately designed to mitigate against the risk. Coastal development setbacks can also be imposed to specify locations in which existing developments may not be rebuilt or improved following damage.

In general two types of setback can be implemented:

- Elevation setbacks to deal with flooding; and
- Lateral setbacks to deal with erosion.

Setback distances are determined either as:

- A fixed setback, which prohibits development for a fixed distance landward of a reference feature; or
- A floating setback, which uses dynamic, natural phenomenon to determine these distances case by case.

Building setbacks allow coastal processes, such as erosion, to continue naturally along strategic sections of the coast while ensuring that intensification of development in at-risk areas is restricted. Setback boundaries can be adopted on the basis of historical erosion rates, extreme water level rise predictions and sea level rise figures (Linham & Nicholls, 2010).

In Queensland, LGAs commonly include coastal setbacks in planning scheme development assessment codes. For example, *Our Living City: Gold Coast Planning Scheme 03* includes a constraint code for Ocean Front Land (Part 7, Division 3, Chapter 11) which requires a compulsory setback of 8.1m from the A-line (the boulder seawall protecting the Gold Coast beachfront houses) for development triggered by Overlay Map OM12 – Foreshore Seawall Line and Building Setback Line from Ocean Beaches.

In accordance with the *Queensland Planning Provisions* (QPP), LGAs must include the provisions of the QCP in future planning schemes and planning scheme updates. Planning schemes must reflect the coastal hazard adaptation strategy for the relevant coastal hazard areas, such as through overlay codes. LGAs may opt to carry out more detailed studies following the Guidelines to better determine the extent of the coastal hazard area at the local scale and consider at a localised scale the use of prescribed setbacks.

In general, coastal development setbacks should be calculated from the highest water mark (HWM) and related to the extreme water levels (EWL) and can vary in width depending on local criteria. Sea level rise will compress the buffer width while the HWM will migrate landward.

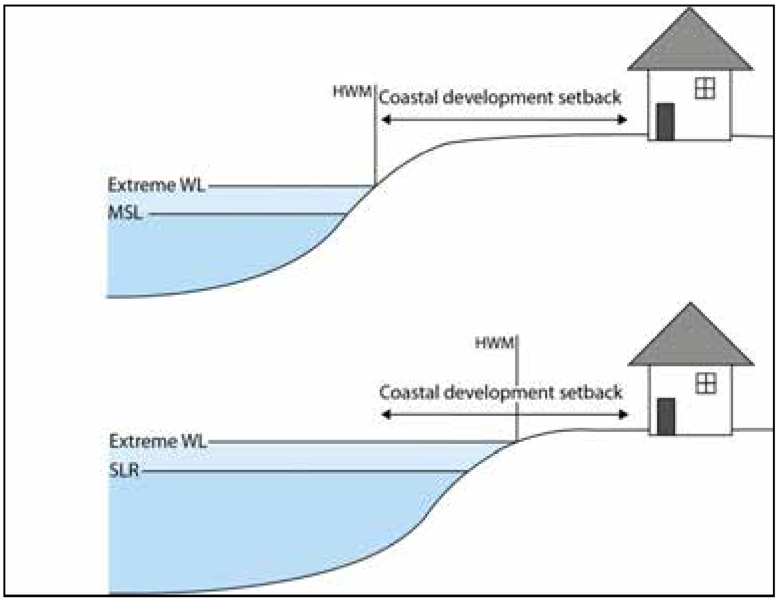

Figure 38 Coastal development setbacks.
Source: GCCM
Note: HWM = high water mark; SLR = sea level rise; MSL = mean sea level

7.1.2. Role in coastal hazard adaptation

Coastal development setbacks can be an effective measure to address projected climate change and sea level rise risks within the coastal zone. Sea level rise will cause a gradual inland movement of the shoreline at rates determined by the rates of rising sea levels. The implementation of coastal setbacks can reduce the risks of hazards to coastal settlements and communities.

Table 69 Development setbacks and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Development setbacks	✓✓ Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.

7.1.3. Synergies and conflicts with other adaptation options

Coastal development setbacks are compatible with most adaptation options analysed here; they provide a safety buffer under a defence strategy, which may entail hard or soft engineering measures; and create an opportunity to facilitate the execution of planned retreat strategies in the long term, by removing settlements and infrastructure within the buffer zone.

The width of a coastal development setback needs to be sensitive to the local topography to be an effective measure.

Table 70 Synergies and conflicts of development setbacks

Development setbacks			
Regenerative options	Beach nourishment	✓	It can be coupled with coastal development setbacks to keep in place the hazard risk line from which the setback is measured.
	Dune construction and regeneration	✓	They can be combined, usually to protect the dune system.
	Riparian corridors restoration and generation	✓	Coastal development setbacks can provide space for riparian corridors restoration and generation.
	Wetlands restoration	✓	Coastal development setbacks can provide space for riparian corridors restoration and generation.
Coastal engineering options	Artificial reefs	✓ ✗	Compatible, but not recommended when using setbacks to gradually retreat from the shore.
	Detached breakwaters	✓ ✗	Compatible, but not recommended when using setbacks to gradually retreat from the shore.
	Groynes and artificial headlands	✓ ✗	Compatible, but not recommended when using setbacks to gradually retreat from the shore.
	Sea dykes	✓	Coastal development setbacks can provide an additional safety buffer behind sea dykes.
	Seawalls	✓	Coastal development setbacks can provide an additional safety buffer behind seawalls.
	Storm surge barriers	●	Coastal development setbacks are usually not applied behind storm surge barriers.
Coastal settlements design options	Building retrofitting and design	✗	Usually not combined, however it can be an option for redevelopment within erosion prone areas
	Flood-resilient public infrastructure	✗	Usually not combined, however it can be an option for redevelopment within erosion prone areas.
	Raise land levels	✗	Usually not combined, however it can be an option for redevelopment within erosion prone areas and high coastal hazard areas.
Planning options	Land buy-back	●	Usually not combined.
	Land swap	●	Usually not combined.
	Land-use planning	●	Usually not combined.

7.1.4. Legal and administrative framework

Coastal development setbacks are an intrinsic part of Queensland's coastal management policy. In Queensland, coastal building lines may be imposed on coastal management districts in accordance with Section 66 of the *Coastal Protection and Management Act 1995*. Currently however, implementation of this

framework has been inconsistent across the coast. In some cases projected sea level rise has been included in design and development principles without details on specific setback areas. More recently, LGAs are including setback policies into their planning schemes and local plans.
Coastal setback can be applied through the identification of coastal hazard areas, which, in practice, set back future intensification of development from areas at risk, while allowing current levels of use as long as exposure and risks are not increased from the current conditions.

Planning considerations for local government

- What buffer zone distance is required to protect assets and infrastructure?
- Are there any land tenure considerations?
- What are the wider benefits to the community from the setback i.e. public access, amenity, ecological etc.?
- What town planning mechanisms are available for achieving setback requirements?
- Who are the stakeholders and have they been consulted?

Approvals required

No operational works or building works are required for the implementation of coastal development setbacks.

One mechanism for implementing coastal development setbacks is through material change of use or reconfiguration of lot applications within the coastal management control district. Setbacks may be conditioned as part of the development approval in a number of ways:

- Building setbacks in accordance with local planning scheme codes and overlays
- Land surrender to either State or Local Government
- Acquisition of land

Powers available to local government to establish this option and the role of the planning scheme

In Queensland, the LGA planning scheme will make provisions for setbacks, depending on whether the application is self, code or impact assessable (see e.g. Gold Coast City Council, 2011). The QCP provides specific detail on what development may be allowed seaward of the coastal building line and within coastal hazard areas through the development assessment process. The use of land surrender conditions within the coastal management district can also serve to establish and maintain setbacks through the development assessment process. The LGA or State government may also choose to enforce powers of acquisition to establish setbacks in already established areas outside of the development assessment process.

Building setbacks can be imposed through local planning scheme requirements as a condition of development, but can only be sought at the development approval stage. This adaptation option would be likely to require a number of planning scheme amendments, including code amendments and overlays. Triggers for level of assessment would also need to be revised. Land-use zoning changes are unlikely to be required. The planning scheme amendment process is described in Section 8.1.

The *Coastal Protection and Management Act 1995* (s. 110) provides that a land surrender condition may be imposed on a development situated within an erosion prone area in the coastal management district involving reconfiguring a lot.

Surrendered land would be dedicated as a reserve for coastal management purposes. The establishment of setbacks through land surrender can only be sought at the development approval stage.

An LGA or the State may acquire land for 'works for the protection of the seashore and land adjoining the seashore' in accordance with Part 2 (Taking of land), Section 5 (Purposes for which land may be taken) of the *Acquisition of Land Act 1967*. Building setbacks through land acquisition can be sought at any time.

A landowner may seek compensation for reduced property values in association with restrictions to development potential resulting from coastal setbacks. Compensation may be granted under Section 704 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

7.1.5. Maintenance

Coastal setbacks do not require maintenance other than day-to-day management requirements for open space areas.

7.1.6. Timeframe for review

Coastal hazard risk areas should be reviewed with the release of the *IPCC Fifth Assessment Report* due in 2015, and likely subsequent reports, or under the making of an Australian intergovernmental agreement or policy. Where a more detail setback is in place at the local scale, a review should be triggered by erosion or inundation events questioning the effectiveness of the current setback.

7.1.7. Failure risk

Failures of coastal development setbacks policies can be associated with inaccurate assessment of the necessary setback distance or a lack of legal or technical backup to support the policy. Generally, coastal setbacks are calculated from base risk lines which, in turn, are identified by considering the return period of extreme water levels (e.g. 100 years has been commonly adopted but there is no universal criteria). If the risk line calculation uses a relatively low return period for events (e.g. 10 years) or does not consider sea level rise, the setbacks can be ineffective in the longer term. In the same way, if the coastal setback policy does not have a strong legal backup, it can fail in court after expensive legal battles.

7.1.8. Estimated cost

Costs for implementing coastal setbacks include the initial cost of the study and any requirements for land resumption to enforce the policy within already developed areas (e.g. relocating settlements and infrastructure within areas at risk). Costs for an effective and reliable initial technical study should be in the order of $50,000 to $500,000, depending on data availability, length of the shoreline, etc. Costs for policy implementation vary depending on urban density and assets at risk.

7.1.9. Multi-criteria overview

Table 71 Multi-criteria overview for development setbacks

Development setbacks			
Climate uncertainty	Effectiveness	How effective is it for climate change?	They can be very effective if well devised.
	Flexibility	Can it be modified after implementation?	They can be changed, although seaward change will be easier than landward.
	Reversibility	Is it easy to completely remove it?	They can be removed completely.
	No regret	Is there any other social or environmental benefit?	They can provide space for coastal ecosystems and improve public use and accessibility to the shoreline.
	Decision Horizon	Does it help gaining time for major decisions?	They can be put in place until major decisions, e.g. retreat from the shoreline, have to be taken.
	Synergy with mitigation	Does it help reducing emissions?	Yes, if it is coupled with revegetation programs.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	It can improve access to the shoreline.
	Landscape	Does it impact landscape values?	Coastal landscapes can be positively affected.
	Recreational use	Does it affect recreational uses?	Usually not.
	Property values	Are private property values affected?	It can impact property values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Coastal ecosystems are not affected.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	It can have indirect benefits.
Costs	Initial cost	Is the initial cost high?	Direct costs are not high.
	Cost of maintenance	Does it need expensive maintenance?	No.

7.2. Land buy-back

Land buy-back can be implemented by government either for hazard mitigation or environmental protection. When addressing coastal hazards, government may purchase land to remove or prevent development thus allowing space for erosion, storm tide inundation or coastal defence structures.

Table 72 Land buy-back and coastal planning approaches

	Defend	Accommodate	Retreat
Land buy-back	●	●	✓✓
	Typically not combined with a defence strategy. However, sometimes it can be necessary to buy back land to allow for coastal protection.	Purchasing land for public safety can provide space to accommodate sea level rise or storm surge hazard.	An effective approach to gradually retreat buildings and infrastructure from areas at risk.

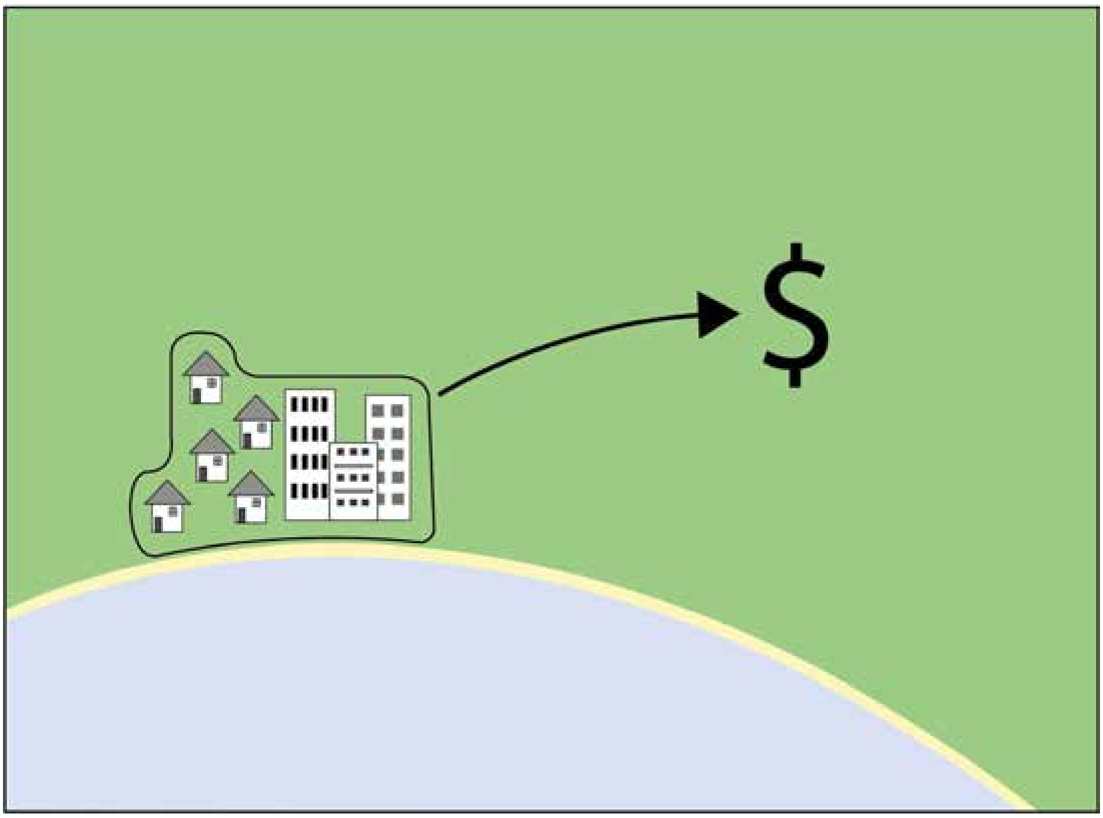

Figure 39 Land purchase provides LGAs with the opportunity to purchase land or property in hazard prone areas.
Source: GCCM

7.2.1. Technical description

Buy-back can be used to take ownership and control of coastal land under threat from sea level rise and floods, such as the high coastal hazard areas identified by the QCP. In particular, land purchase is a voluntary mechanism where a government purchases the land from the landholder whereas resumption is a compulsory acquisition process with associated compensation provisions. The most common purpose for land resumption is for public utilities, highways and railroads, but is also increasingly implemented for public safety (Tricket, 2000).

7.2.2. Role in coastal hazard adaptation

Land buy-back can be used to create a buffer in high coastal hazard areas under threat from storm surge, erosion or and sea level rise.

Table 73 Land buy-back and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Land buy-back	✓✓	✓✓	✓✓	✓✓
	Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.	Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.

7.2.3. Synergies and conflicts with other adaptation options

Land buy-back is typically undertaken to 'lock-up' the most vulnerable land and protect it from further development thus allowing natural coastal processes to continue and provide a buffer for other existing or new development against sea level rise and storm surge. In this context, the option should not typically be combined with hard defence structures but rather with options to retreat from the shore and restore the environment (e.g. wetland restoration, riparian corridors restoration and generation).

Table 74 Synergies and conflicts of land buy-back

Land buy-back			
Regenerative options	Beach nourishment	✓	Can be carried out to restore recovered coastal space and regenerate its natural processes.
	Dune construction and regeneration	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate its natural processes.
	Riparian corridors restoration and generation	✓	Compatible when riparian corridors are restored on recovered coastal land.
	Wetlands restoration	✓	Compatible when wetlands are restored on recovered coastal land.
Coastal engineering options	Artificial reefs	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Detached breakwaters	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Groynes and artificial headlands	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Sea dykes	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Seawalls	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Storm surge barriers	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
Coastal settlements design options	Building retrofitting and design	✗	Land management options promote a gradual retreat from areas at risk of damage to buildings and infrastructure.
	Flood-resilient public infrastructure	✗	Land management options promote a gradual retreat from areas at risk of damage to buildings and infrastructure.
	Raise land levels	✗	Land management options promote a gradual retreat from areas at risk of damage to buildings and infrastructure.
Planning options	Development setbacks	●	Usually not combined.
	Land swap	✓✓	Compatible under a planned retreat strategy to recover coastal land.
	Land-use planning	✓✓	Compatible under a planned retreat strategy to recover coastal land.

7.2.4. Legal and administrative framework

The *Sustainable Planning Act 2009* refers to the *Acquisition of Land Act 1967* which states the purposes for which land may be taken:

- "Where the constructing authority is the Crown, for any purpose set out in the schedule; or
- Where the constructing authority is an LGA, for any purpose set out in the schedule which the LGA may lawfully carry out; or
- For any purpose, including any function of the LGA, which the LGA is authorised or required by a provision of an Act other than this Act to carry out."

Planning considerations for local government

- What are the land tenure issues that need to be considered?
- What will the land be used for?
- Has the community been consulted regarding the proposal?

Approvals required

No operational works or building works are required for land purchase or resumption.

The mechanisms available to an LGA for land buy-back are discussed in the section below. These include:

- Land surrender
- Acquisition of land

Powers available to local government to establish this option and the role of the planning scheme

Land acquisition is not explicitly provided for in local planning schemes, however, it may be accompanied by planning scheme modifications to change the designation of land to public use.

Property buy-backs differ from compulsory resumption programs in that the owner willingly sells his or her property to the LGA or State government. Formal programs have been implemented by some Queensland LGAs in association with floodplain management strategies. Land may be used for non-residential purposes e.g. public park or drainage easements.

The *Coastal Protection and Management Act 1995* (s. 110) provides that a condition of land surrender may be imposed on a development approval for works situated within an erosion-prone area involving reconfiguring a lot. Surrendered land would be dedicated as a reserve for coastal management purposes. The establishment of setbacks through land surrender can only be sought at the development approval stage.

An LGA or the State may acquire land for 'works for the protection of the seashore and land adjoining the seashore' in accordance with Part 2 (Taking of land), Section 5 (Purposes for which land may be taken) of the *Acquisition of Land Act 1967*. Building setbacks through land acquisition can be sought at any time.

A landowner may seek compensation for reduced property values in association with restrictions to development potential resulting from planning scheme changes. Compensation may be granted under Section 704 and 705 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land. Some LGA submissions to the *Queensland Floods Commission of Inquiry* (2012) suggested that the entitlement to compensation should be limited where a planning scheme is changed to meet the impacts of climate change, implicitly arguing it would seem that the original development approvals were not able to have been informed by scientific projections at the time.

7.2.5. Maintenance

Not applicable

7.2.6. Timeframe for review

Not applicable

7.2.7. Failure risk

Land buy-back strategies can fail in case of lack of funding for purchasing land and assets, lack of legal backup to purchase land or strong opposition from the community.

7.2.8. Estimated cost

The estimated costs for land buy-back is highly dependent on the size of the land parcel, the location and the characteristics and value of associated assets.

7.2.9. Multi-criteria overview

Table 75 Multi-criteria overview for land buy-back

Land buy-back			
Climate uncertainty	Effectiveness	How effective is it for climate change?	Recovering space in erosion prone areas is an effective measure for climate adaptation.
	Flexibility	Can it be modified after implementation?	Not a flexible option, although it can be reversed.
	Reversibility	Is it easy to completely remove it?	Yes.
	No regret	Is there any other social or environmental benefit?	Recovering space allows for the creation of new public areas and ecosystems.
	Decision Horizon	Does it help gaining time for major decisions?	It is a major decision.
	Synergy with mitigation	Does it help reducing emissions?	Yes, if it is coupled with revegetation programs.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Can improve access to the shoreline.
	Landscape	Does it impact landscape values?	Coastal landscapes can be positively affected.
	Recreational use	Does it affect recreational uses?	Can provide space for new recreational purposes.
	Property values	Are private property values affected?	Can impact property values, either positively or negatively.
	Impact on ecosystems	Does it impact coastal ecosystems?	Can create space for coastal ecosystems.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	Can reduce reliance on emergency and disaster procedures.
Costs	Initial cost	Is the initial cost high?	Costs can be extremely high.
	Cost of maintenance	Does it need expensive maintenance?	No.

7.3. Land swap

Land swap involves the exchange of private land to relocate buildings and infrastructure to safer ground. Land swaps are important to consolidate land ownership and to mitigate the impacts of coastal erosion and storm tide inundation.

Table 76 Land swap and coastal planning approaches

	Defend	Accommodate	Retreat
Land swap	●	✓	✓✓
	Typically not combined with a defence strategy. However, sometimes it can be necessary to swap land to allow for coastal protection.	Swapping land for public safety can provide space to accommodate sea level rise or storm surge.	It is an effective approach to gradually retreat buildings and infrastructure from areas at risk.

7.3.1. Technical description

Land swap involves the exchange of private land to relocate buildings and infrastructure to safer ground. The land that has been swapped acts as a hazard buffer and mitigates the risks of coastal hazards.

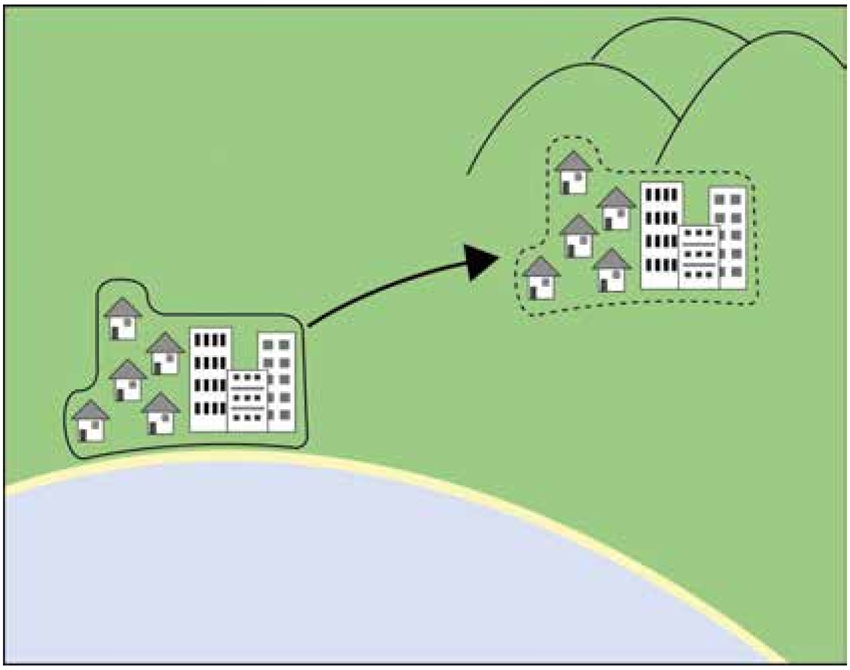

Figure 40 Land swap.
Source: GCCM

While there are a number of examples of land swap being applied overseas to deal with coastal hazards, there are few examples of implemented or proposed programs within Australia. One example is the *Wooli Village Draft Coastal Management Plan* (Clarence Valley Council, 2010) on the north coast of New South Wales which considers land swap as a potential option to relocate approximately 40 properties to safer ground within the village, at a high cost for the LGA and the community. This proposal has not yet been implemented and it is encountering strong community opposition. However, alternative solutions for the long term are not clear as the sand spit of the Wooli Wooli River, where the village sits, will likely face major morphological changes in the future, including possible breaching to the ocean.

The most relevant and only known example of land swap in Queensland is the program implemented in the flood-devastated town of Grantham in the Lockyer Valley following the extreme flooding experienced in February 2011 (see box 8 for details).

Box 8. Land swap in Grantham, Lockyer Valley

Following the disastrous floods of February 2011 the Lockyer Valley Regional Council purchased parcels of freehold, elevated land, covering an area of approximately 378 ha, to enable the voluntary relocation of displaced residents. The land swap program allowed eligible property owners to swap their land for part of the newly purchased council land. The program is governed by a council policy (Lockyer Valley Regional Council, 2012), stating that landowners who meet the eligibility criteria participate voluntarily; the council offers residential allotments to eligible landowners at no cost in exchange for their transferring ownership of their land to council blocks of comparable size are offered, up to 10,000 m^2; if a landowner elects to take a smaller block than his or her existing one, no compensation is paid for the difference; landowners are responsible for meeting the cost of building their homes on the new blocks. The Lockyer Valley Regional Council's land swap program is a unique use of a planning measure to guard against the repetition of a similar disaster, enabling the collective relocation of a community, which carries social benefits as well as achieving floodplain management goals (Queensland Floods Commission of Inquiry, 2012).

Figure 41 Purchased parcels allocated to the land swap program in Grantham.
Source: Lockyer Valley Regional Council, 2012.

7.3.2. Role in coastal hazard adaptation

Land swap is an effective way to manage retreat from high coastal hazard areas where the desire for land swap is mutually agreed upon by both parties. By establishing land swap agreements along threatened coastlines, protective works do not need to be implemented and coastal ecosystems are benefited.

Table 77 Land swap and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Land swap	✓✓ Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.	✓✓ Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.

7.3.3. Synergies and conflicts with other adaptation options

Land swap facilitates removal of development from high at-risk areas and allows the natural functions of the area to recover and provide a buffer against sea level rise and storm tide inundation. In this context, the option should not be combined with hard defence structures but rather with options to gradually retreat from the shore and restore the environment (e.g. wetland restoration, riparian corridors restoration and generation).

Table 78 Synergies and conflicts of land swap

Land swap			
Regenerative options	Beach nourishment	✓	Can be carried out to restore recovered coastal space and regenerate its natural functions.
	Dune construction and regeneration	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate its natural functions.
	Riparian corridors restoration and generation	✓	Compatible when riparian corridors are restored on recovered coastal land.
	Wetlands restoration	✓	Compatible when wetlands are restored on recovered coastal land.
Coastal engineering options	Artificial reefs	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Detached breakwaters	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Groynes and artificial headlands	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Sea dykes	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Seawalls	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
	Storm surge barriers	✗	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and retreat.
Coastal settlements design options	Building retrofitting and design	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Flood-resilient public infrastructure	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Raise land levels	✗	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
Planning options	Development setbacks	●	Usually not combined.
	Land buy-back	✓✓	Compatible under a planned retreat strategy to recover coastal land.
	Land-use planning	✓✓	Compatible under a planned retreat strategy to recover coastal land.

7.3.4. Legal and administrative framework

There is no legal framework for land swap in Queensland; however, the recent relocation of the Grantham community following the 2011 floods demonstrates the administrative process required. Land swap programs are voluntary and are provided for within the *Acquisition of Land Act 1967* as discussed below.

Planning considerations for local government

- What are the land tenure issues that need to be considered?
- What will the land be used for?
- Has the community been consulted regarding the proposal?

Approvals required

No operational works or building works are required for land purchase or resumption.

Incidental approvals that may be required in association with land swap programs include reconfiguration of a lot and material change of use in order to appropriate land for transfer. Planning scheme modifications may also be required to provide suitable land for land swap.

Powers available to local government to establish this option and the role of the planning scheme

Section 21 of the *Acquisition of Land Act 1967* provides for the transferring of land in satisfaction of compensation. Subsection (1) notes 'the constructing authority and the claimant may agree that the constructing authority will grant the claimant, in satisfaction wholly or partly of the claimant's claim for compensation, any easement, right of way, lease or other right of occupation, or any other right, privilege or concession in, upon, over or under the land taken or any other land in the property of the constructing authority'.

The *Queensland Reconstruction Authority Act 2011* provides for the declaration of declared reconstruction areas in locations directly or indirectly affected by a disaster event and those necessary for the protection, rebuilding and recovery of affected communities (Section 42).

Land in a declared reconstruction area may be declared as acquisition land whereby the owner must not dispose of the land other than to the constructing authority and the authority must purchase the land upon notice that the owner intends to sell the land. There are no known similar provisions for land outside of a declared reconstruction area.

The Queensland Reconstruction Authority was granted powers to make a development scheme (Section 62) including the ability to make provision for particular assessable developments (Section 64).

In circumstances outside of declared disaster events, the provision of suitable land for land swap, including required approvals for reconfiguration of lot, material change of use, operational works and construction would be undertaken through the processes detailed in the *Sustainable Planning Act 2009* under the responsibility of local or State government.

Modifications to the local planning scheme, including land-use change and new local plans may be required to provide suitable land for swap and to identify those areas designated for future land swap.

7.3.5. Maintenance

Not applicable.

7.3.6. Timeframe for review

Not applicable.

7.3.7. Failure risk

Land swap strategies can fail in the case of lack of funding for purchasing land and assets, lack of legal back up to purchase land, failure in the identification of suitable land or strong opposition from the community.

7.3.8. Estimated cost

The estimated costs associated with land swap are highly dependent on the size of the subject land, property values in the local area and the characteristics of associated assets.

7.3.9. Multi-criteria overview

Table 79 Multi-criteria overview for land swap

Land swap			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Recovering space in erosion prone areas is an effective measure for climate adaptation
	Flexibility	Can it be modified after implementation?	Not a flexible option, although it can be reversed
	Reversibility	Is it easy to completely remove it?	Yes, however costly
	No regret	Is there any other social or environmental benefit?	Recovering space allows for the creation of new public areas and ecosystems
	Decision Horizon	Does it help gaining time for major decisions?	It is a major decision
	Synergy with mitigation	Does it help reducing emissions?	Yes, if it is coupled with revegetation programs
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	It can improve access to the shoreline
	Landscape	Does it impact landscape values?	Coastal landscapes can be positively affected
	Recreational use	Does it affect recreational uses?	It can provide space for new recreational purposes
	Property values	Are private property values affected?	It can impact property values
	Impact on ecosystems	Does it impact coastal ecosystems?	It can create space for coastal ecosystems
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	It can decrease pressure on emergency and disaster procedures
Costs	Initial cost	Is the initial cost high?	Costs can be extremely high
	Cost of maintenance	Does it need expensive maintenance?	No

7.4. Land-use planning

Changes in land-use, for example from residential to recreational purposes, can be considered as part of a strategy to mitigate future development from exposure to risks from coastal erosion and storm tide inundation. Changes to land-use designation should be considered as a preventative mechanism to ensure that the distribution and intensity of future uses are compatible with identified risks in high coastal hazard and erosion prone areas.

Table 80 Land-use planning and coastal planning approaches

	Defend	Accommodate	Retreat
Land-use planning	●	✓	✓✓
	Typically not combined with a defence strategy. However, sometimes it can be necessary to recover space to allow for coastal protection.	Changing land-use for public safety can provide space to accommodate sea level rise or storm surges.	It is an effective approach to gradually retreat buildings and infrastructure from areas at risk.

7.4.1. Technical description

LGAs play a key role in land-use decisions and can use a variety of policy tools to influence the rate of land-use change or to permanently protect open space (Sims and Schuetz, 2007). Land-use planning is one of the instruments used by LGAs to manage development and land-use maps and codes are usually integrated in the planning and development assessment process and are a component of the planning scheme. Changes in land-use can be carried out to reduce the intensification within coastal hazard areas; mechanisms for land-use change have been urgently identified as a consequence of the 2011 floods and reflected in specific guidelines for land-use transition in coastal floodplains (Queensland Floods Commission of Inquiry, 2012; QRA 2011c). Such guidelines would also be effective to provide land-use transition within coastal hazard areas to reduce exposure and risks to human settlements. Proposals for land-use change should be supported by a broad stakeholder consultation process.

Exposure of coastal settlements to coastal hazards can be reduced through a gradual land-use transition.

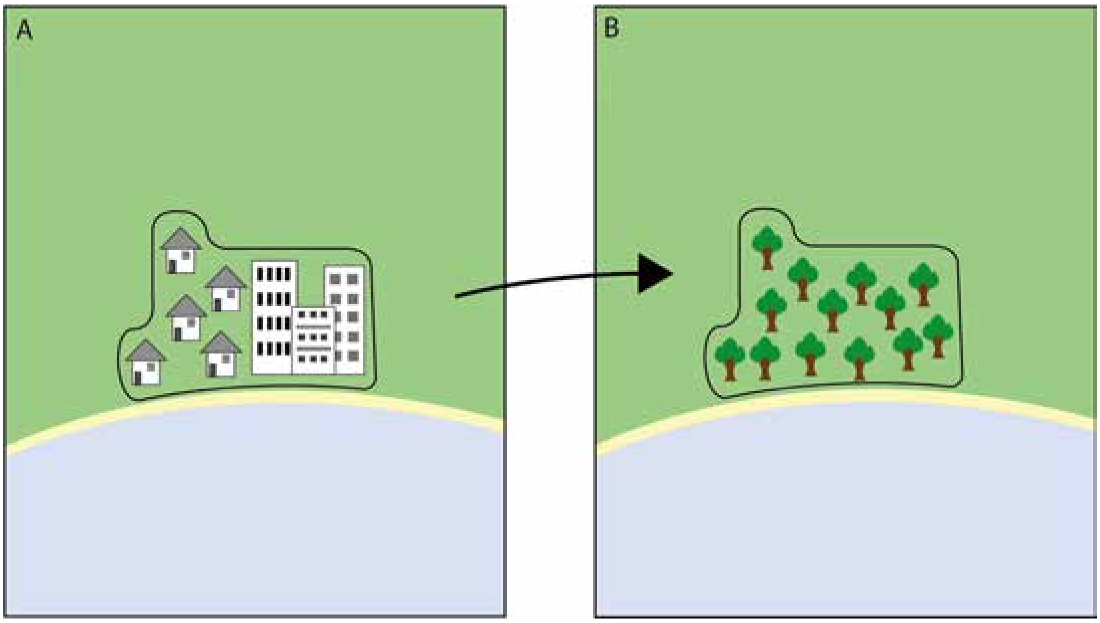

Figure 42 Land-use change to reduce hazard risk.
Source: GCCM

7.4.2. Role in coastal hazard adaptation

Land-use change can mitigate the impacts of coastal hazards, including erosion, sea level rise and storm tide inundation, by changing the designation of future land uses in areas at risk from those with low resilience (e.g. residential) to those with high resilience (e.g. public space).

Table 81 Land-use planning and coastal hazards

	Storm erosion	Chronic erosion	Storm tide inundation	Permanent inundation
Land-use planning	✓✓	✓✓	✓✓	✓✓
	Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	Useful to create a buffer between areas at risk from storm or chronic erosion and coastal settlements.	Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.	Useful to create a buffer between areas at risk from storm tide inundation or permanent inundation and coastal settlements.

7.4.3. Synergies and conflicts with other adaptation options

Land-use planning amendments to respond to coastal hazards ensures that proposed future land uses are compatible with the natural functions of the area, provide a buffer from the hazard to high risk uses, and provides suitable land for the development of any defensive infrastructure required. Accordingly, land-use change is compatible with defence, retreat and accommodate strategies.

Table 82 Synergies and conflicts of land-use planning

Land-use planning			
Regenerative options	Beach nourishment	✓	Can be carried out to restore recovered coastal space and regenerate its natural functions.
	Dune construction and regeneration	✓	Dune construction and regeneration can be carried out to restore recovered coastal space and regenerate its natural functions.
	Riparian corridors restoration and generation	✓	Compatible when riparian corridors are restored on recovered coastal land.
	Wetlands restoration	✓	Compatible when wetlands are restored on recovered coastal land.
Coastal engineering options	Artificial reefs	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
	Detached breakwaters	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
	Groynes and artificial headlands	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
	Sea dykes	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
	Seawalls	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
	Storm surge barriers	✘	Hard protection works should not be carried out when the chosen management strategy is to recover coastal space and reduce the urban footprint.
Coastal settlements design options	Building retrofitting and design	✘	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Flood-resilient public infrastructure	✘	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
	Raise land levels	✘	Land management options promote a gradual retreat from areas at risk of buildings and infrastructure.
Planning options	Development setbacks	●	Usually not combined.
	Land buy-back	✓✓	Compatible under a planned retreat strategy to recover coastal land.
	Land swap	✓✓	Compatible under a planned retreat strategy to recover coastal land.

7.4.4. Legal and Administrative Framework

LGAs within Queensland have the responsibility to implement land-use planning policies and disaster management as a way to mitigate and adapt to hazardous events. The *Sustainable Planning Act 2009* is a key tool for implementing land-use planning and development reform in Queensland.

Section 7.4 provides a discussion on the mechanisms for land-use planning as a coastal hazard adaptation tool.

Planning Considerations for Local Government

- What are the land tenure issues that need to be considered?
- What will the land be used for?
- Has the community been consulted regarding the proposal?

Approvals Required

No operational works or building works are required for land purchase or resumption. If the planning scheme modification process is used, a preliminary approval to override the planning scheme will not be required to change land use.

Powers Available to Local Government to Establish this Option and the Role of the Planning Scheme

The process for undertaking planning scheme modifications is discussed in Section 8.1.

Compensation may be granted under Section 704 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

7.4.5. Maintenance

Not applicable.

7.4.6. Timeframe for review

Reviews of zoning should be carried out as part of the planning scheme update and amendment at the local level.

7.4.7. Failure risk

Land-use change strategies can fail due to a of lack of legal back up to change the use of the land, failure of the identification of the right use for the land or strong opposition from the community.

7.4.8. Estimated cost

No additional costs will be required above that associated with the already required planning scheme revision process.

7.4.9. Multi-criteria overview

Table 83 Multi-criteria overview for land-use planning

Land-use change			
Climate uncertainty	Effectivenes s	How effective is it for climate change?	Changing land-use from high intensity to other uses reduces the risks in hazard prone areas.
	Flexibility	Can it be modified after implementation?	Not a flexible option, although it can be reversed.
	Reversibility	Is it easy to completely remove it?	Yes.
	No regret	Is there any other social or environmental benefit?	Creation of public space can benefit both society and the environment.
	Decision Horizon	Does it help gaining time for major decisions?	Land-use change can be implemented until another major decision, e.g. retreat from the shoreline, is required.
	Synergy with mitigation	Does it help reducing emissions?	Yes, if it is coupled with revegetation programs.
Social and environmental impacts	Accessibility	Does it affect the access to the shore?	Can improve access to the shoreline.
	Landscape	Does it impact landscape values?	Coastal landscapes can be positively affected.
	Recreational use	Does it affect recreational uses?	Can provide space for new recreational purposes.
	Property values	Are private property values affected?	Can impact property values.
	Impact on ecosystems	Does it impact coastal ecosystems?	Coastal ecosystems can benefit from new public spaces.
	Emergency procedures	Is there any benefit for disaster and emergency procedures?	Can reduce reliance on emergency and disaster procedures.
Costs	Initial cost	Is the initial cost high?	Direct costs are not high.
	Cost of maintenance	Does it need expensive maintenance?	No.

8. Implementation

8.1. Adaptation of planning schemes

Planning schemes can be modified to manage or mitigate the effects of development in areas that are at high risk to coastal hazards. Modifications to a planning scheme can include changes to existing land-use designations, zone codes, use codes, overlay maps and codes, level of assessment tables and planning scheme policies.

Overlays identify spatial areas within an LGA area that may:

- Be sensitive to the effects of development;
- Constrain land for development;
- Be subject to valuable resources; or
- Present opportunities for development.

Overlays can be developed to spatially identify areas at risk to coastal hazards with the relevant LGA area including (but not limited to) sea level rise, erosion and storm surge. Assessable development proposed in coastal hazard areas is identified on an Overlay Map trigger assessment against the provisions of a corresponding Overlay Code. The proposed development must demonstrate compliance with the provisions of the Overlay Code to be considered for approval by Council.

Planning scheme modifications support the intent of the *Queensland Coastal Plan* as follows:

Table 84 QCP policies relevant the modifications of the planning scheme

State Planning Policy 3/11: Coastal Protection	State Policy for Coastal Management
Policy 1 Allocating areas for urban development avoids or minimises the exposure of communities to the risk of adverse coastal hazard impacts, maximizes the conservation of coastal resources and preferentially allocates land on the coast for coastal-dependent development. Policy 1.1 Consolidation through infill and redevelopment. Policy 1.2 Nodal settlement pattern. Policy 1.3 Reflect high and medium coastal hazard areas as a constraint. Policy 1.4 Avoid allocating new areas for urban purposes within a coastal hazard area. Policy 1.8 Local planning instruments are to appropriately reflect the adaptation strategy. Policy 1.11 Allocate coastal-dependent land uses adjacent to tidal water in preference to other uses.	No specific policies. Rather, planning scheme modifications would be used as an implementation mechanism across a breadth of policies.

The process for modifying an existing planning scheme is detailed in Chapter 3, Part 5 of the *Sustainable Planning Act 2009* (SPA) which states that LGAs must follow the process stated in a guideline made by the Minister and prescribed under the *Sustainable Planning Regulation 2009*. The guideline makes provision for LGAs to carry out public consultation for 30 business days. The LGA must consider and provide a summary of all the properly made submissions received during the public consultation period. The planning scheme amendments will then be provided to the Minister for approval and notified in the gazette if approved. For LGAs in the process of drafting new planning schemes, there is an opportunity to include provisions for Coastal Hazards through the Standard Planning Scheme Provisions under Chapter 2, Part 5 of SPA. The purpose of the Standard Planning Scheme Provisions is "to facilitate consistency across schemes and greater certainty for users who interpret local planning schemes" and to provide a further opportunity to "effectively integrate State interests".

The Standard Planning Scheme Provisions take the form of the *Queensland Planning Provisions* (QPP). The QPP is a State planning instrument under the SPA and mandates a consistent form of planning schemes across Queensland through standardized structure, format, land-use and administrative definitions, zones, levels of assessment, overlays, infrastructure planning provisions, development assessment codes and other administrative matters. The QPP (draft version 3) includes *Queensland Coastal Plan* provisions such as the identification of coastal protection in the standard suite of overlays.

Whilst predominantly standardized, the QPP also makes provision for LGAs to incorporate local content and variation to reflect the context of the LGA areas. On this basis, LGAs along the Queensland coast can incorporate provisions to assist with mitigating and managing areas at high risk to coastal hazards.

Chapter 3, Part 6, Division 1 of SPA grants the Minister power to direct an LGA to take action about local planning instruments to protect or give effect to a State interest. The direction may be as general or as specific as the Minister considers appropriate. Section 128 of the SPA further provides that if the LGA does not take the action directed by the Minister under sections 126 and 127, the Minister may take the action. In consideration of policy 2.5.2(b) below, the Minister will consider making necessary directions in accordance with sections 125 and 126 of the SPA should an LGA not implement policy 1.8 above within the time period specified.

The Queensland Floods Commission of Inquiry (Chapter 5) noted that Queensland LGAs take a conservative approach in publishing information about the possible effects of climate change and amending planning schemes to mitigate against risks of compensation provisions and the exposure to liability.

One submission to the Floods Commission of Inquiry was for introduction of a legislative exemption from liability for reasonably based LGA decision-making modelled on Section 733 of the *Local Government Act 1993* (NSW).

A landowner may seek compensation for reduced property values in association with restrictions to development potential resulting from planning scheme changes. Compensation may be granted under Section 704 and 705 of the *Sustainable Planning Act 2009* for a change to the planning scheme that results in reduced value of the land.

8.2. Adaptation of other council instruments

Coastal hazard adaptation options must be reflected in the local planning instruments for relevant high coastal hazard areas. However, it is also recommended to incorporate the CHAS results into emergency, community, financial, infrastructure and corporate plans. The following table provides an informal guidance on the relevance of each option to a range of planning instruments.

Table 85 Council instruments' relevance to CHAS

Instrument	Regulated by	Implementation mechanism
Asset Management Plan	*Local Government Act 2009*	*s104(6)(a)* - A long-term asset management plan is a document that outlines the LGA's policies and strategies for ensuring the sustainable management of local assets and infrastructure during the period of the plan
Community Plan	*Local Government Act 2009*	*s104(4)(a)* - A long-term community plan is a document that outlines the LGA's goals, strategies and policies for implementing the local government's vision for the future of the LGA area
Corporate Plan	*Local Government Act 2009*	*s104* - A Corporate Plan sets out a Council's broad strategies and vision for all aspects of its operation for a given period. Corporate plans must be prepared to allow enough time for preparation of a budget before the start of its first financial year.
Emergency and Disaster Management Plans	*Disaster Management Act 2009*	*s57(1)* - A disaster management plan incorporates the strategic policy framework for disaster management for the State, and the LGA's policies for disaster management within the jurisdiction of the relevant LGA area. The plan includes provisions for any events likely to occur in the area and the roles and responsibilities of entities involved in disaster management strategies.
Planning Scheme	*Sustainable Planning Act 2009*	*s84* - Planning Schemes advance the purpose of the Sustainable Planning Act by appropriately reflecting standard planning scheme provisions and facilitating the achievement of strategic outcomes for the relevant LGA area.
Shoreline Erosion Management Plans	*Coastal Protection and Management Act 1995*	Shoreline erosion management plans (SEMPs) are the State's preferred method for Councils to address shoreline erosion issues at the local level. SEMPs enable LGAs and their communities to develop effective and sustainable erosion management strategies. In general, SEMPs serve to identify significant coastal erosion issues, develop options for erosion management and ensure erosion management measures are consistent with the QCP.

8.3. Funding mechanisms

8.3.1. Local Government Revenue Raising

LGAs have specific legislated authority to raise revenue or require construction of certain infrastructure through a limited range of rates and charges, under the Local Government Act 2009 and the Sustainable Planning Act 2009. These are the primary mechanisms for funding and provision of local government services and infrastructure.

Table 86 Local Government revenue raising

Funding Mechanism	Description	Authority
Rates and charges	Special Rates are a possible funding mechanism. *The Local Government (Finance, Plans and Reporting) Regulation 2010* expressly authorises the use of special rates to fund a project spanning more than one year for construction or provision. A key concept is that of the "overall plan". This is a relatively detailed description of the project in terms of its scope, location, overall cost and overall timing. Councils would have to very closely follow the requirements for establishing such a special rate for coastal works - with clear plan of works covered by the rate and properties benefitting from the works.	Local Government
Environmental Levies	Further to the 'Special Rates and Charges' described above, Local Governments may impose environmental levies to landholders as a part of annual rate collection. The funds collected from these levies are designated specifically to environmentally relevant projects and are held separately from Council's general revenue. Specific examples of such levies are: • Bushland Preservation Levy – *Brisbane City Council*; and • Environment Levy – *Sunshine Coast Regional Council*. Such levies also enable Local Governments to acquire land which supports significant ecosystems to be turned into conservation reserves. Similar initiatives can be undertaken to facilitate the restoration and regeneration of riparian systems or for dune regeneration etc.	Local Government
Developer contributions and Infrastructure agreements	Local Governments may impose conditions upon development applications which require contributions for the provision of infrastructure relating to the project. Developer contributions are upfront user charges for future infrastructure services, which are generally required prior to construction. These contributions are applicable only to 'trunk infrastructure' as defined under the *Sustainable Planning Act 2009* and are imposed as conditions to an approval for a particular development. The relevant charges are controlled by the State and capped at a maximum value unless "out of sequence development" is proposed where a Priority Infrastructure Plan is in place. Infrastructure agreements are generally associated with larger developments and comprise agreements between a developer and the local government to provide necessary infrastructure in lieu of infrastructure charges. The agreement may require the proponent to provide for works and/or a land dedication in lieu of some, or all of the relevant infrastructure contributions. The infrastructure agreement between the proponent and the local government will confirm the obligations of both parties in regard to such issues as the timing and extent of land dedication, construction works and payment of monetary contributions as applicable. Local Governments may apply for either one mechanism (i.e. Developer contributions\ Infrastructure agreements) or the other, not both.	Local Government

8.3.2. External Funding Sources for Local Government

A number of external funding sources are available to LGAs; however, these funding sources or programs can be provided for very limited purposes and are dependent on the ongoing availability of funds from the body administering the program. The availability of funds and eligibility of the applicant must be investigated on a case by case basis.

Table 87 External funding source for Local Government

Funding Mechanism	Description	Authority
Natural Disaster Relief and Recovery Arrangements	The Natural Disaster Relief and Recovery Arrangements (NDRRA) is a disaster response and recovery assistance program designed to assist LGAs to restore essential public assets to their pre-disaster standard in accordance with the current engineering standards and building codes, while maintaining the same asset class and immunity level. In 2007, an additional funding mechanism – commonly referred to as the 'betterment provision' – was added to the NDRRA Determination to encourage rebuilding or restoration of assets to a higher standard of disaster resilience than their pre-disaster state. In order for the Commonwealth to fund a betterment proposal under the NDRRA, it is necessary for the State or LGA to demonstrate that the project is cost-effective and increases the asset's disaster resilience, thereby mitigating against future impacts. At the time of writing only one betterment proposal across Australia has been successfully developed and implemented under this provision. However, it is anticipated that an upcoming review of the NDRRA will address impediments to making an application for betterment funding under NDRRA. https://www.smartservice.qld.gov.au/services/grants/grantdetails.action?grantId=40289b8c1b9e1cbe011b9e1cfd6b0004	Department of Local Government and Planning Queensland Reconstruction Authority (REPA component)
Government borrowing	Issuing of long-term debt, typically in the form of various bonds through the Queensland Treasury Corporation, can provide LGAs with funds to undertake works in the short-term. However, it must be recognised that this will require additional revenue raising through means such as special rates or levies in order to service the debt.	State Government
Growth Area Bonds	Issue of bonds to finance infrastructure enhancement that are tied to a specific area repaid through future tax revenues collected in a defined area (promoted by Property Council of Australia)	Private Sector
Business Improvement Districts	Stakeholders within a defined boundary make a collective contribution towards the maintenance and promotion of an area (promoted by Property Council of Australia)	Private Sector
Local Government Grants and Subsidies Program	From 2012-13 the Queensland Government has committed $45 million per year, under the Local Government Grants and Subsidies Program (LGGSP), to provide financial support for LGAs that demonstrate that they have a limited capacity to self-fund an identified priority project, as evidenced by a financial sustainability evaluation undertaken by the department. The LGGSP program, which incorporates the Climate Ready Infrastructure Initiative, aims to provide funding assistance to councils in Queensland to deliver projects that: • are identified community needs • support the ongoing sustainability of their communities • protect natural and built environments • enhance the quality of life of people living in rural communities by improving recreational, tourist or cultural facilities, or improving security measures in public places • enhance the social, economic and environmental health of communities • support delivery of State, local government and community priorities • promote collaboration between neighbouring LGAs to deliver regional priorities • ensure that greenhouse gas reduction and climate change adaptation are key factors in planning and design • promote and provide opportunity to increase Indigenous employment. http://www.dlgp.qld.gov.au/grants-and-funding/local-government-grants-and-subsidies-program.html	State Government

Funding Mechanism	Description	Authority
Caring for our Coasts	The Australian Government's Caring for our Coasts policy includes: • $25 million over five years to help coastal communities prepare and adapt to the impacts of climate change including through initiatives such as the National Coastal Risk Assessment • consultation with coastal councils, coastal Natural Resource Management (NRM) groups, capital city mayors, academics, community groups and State and territory governments to develop a blueprint for coastal cities and towns to meet current and future climate challenges • updating and improving the Australian Disaster Mitigation Package to take into account severe weather and storms due to climate change • $100 million for a five year, Community Coast Care Program to better protect our precious coastal environment, and • $200 million in a five year Great Barrier Reef Rescue Plan to help secure the Reef from climate change and declining water quality. http://climatechange.gov.au/government/initiatives/caring-for-coasts.aspx	

8.3.3. Funding Sources and Programs for Community Initiatives

A limited number of funding sources are available to community groups; however, these programs are dependent on ongoing funding and will often have very limited relevance to coastal hazard adaptation responses, such as coastal dune regeneration efforts. The availability of funds and eligibility of the applicant must be investigated on a case by case basis.

Table 88 Funding Sources and Programs for Community Initiatives

Source / Program	Description	Authority
Local Government Environmental Grants	Many LGAs provide grants to community groups to undertake environmental initiatives that address regional, local or citywide environmental issues. Such schemes may involve regeneration of dune and riparian zones.	Local Government
Environmental stewardship	The Environmental Stewardship Program offers funding rounds through which eligible private land managers can apply to provide a range of agreed management activities to protect, rehabilitate and improve particular ecological communities. Eligible land managers include farmers, Indigenous communities, and other managers of private freehold and leasehold land. http://www.nrm.gov.au/funding/stewardship/index.html	Australian Government
Free plant and rehabilitation program	Many councils in Queensland offer free plant programs. The number of plants available will vary and usually a greater number of free plants are given to community groups.	Local Government
Financial assistance for voluntary conservation agreements	Some LGAs in Queensland offer financial assistance to landholders with a voluntary conservation agreement. The financial assistance is usually made to help landholders complete on-ground works that are part of their management plan.	Local Government
Private sector grants	Many private companies/organisations provide one-off grants for environmental improvement projects. These may be entered into as voluntary programs or be required as part of development approvals/environmental impact approvals. Several grant programs are offered throughout the State for undertaking environmental projects; some specific examples include but are not limited to the following: • Conditions of development approval on specific developments; • ANZ Staff Foundation Grants; • Energex Sustainability and Environment Fund; • Ergon Energy Envirofund. • Etc.	Private sector

9. Conclusion and next steps

This Compendium of Coastal Hazard Adaptation Options has been prepared to support Queensland coastal councils in preparing Coastal Hazard Adaptation Strategies to reduce the risk to human settlements within coastal hazard areas. The Compendium reviews a range of options, including:

- Regenerative options using soft engineering and environmental restoration;
- Engineering options incorporating hard coastal structures;
- Structural options to improve human settlements resilience; and
- Planning options suitable for the Queensland legal and administrative framework.

These options can be assessed and combined to pursue the strategy objective for specific areas at risk, whether it is to:

- Defend the area from coastal hazards impacts and maintain the current level of development or allow for further intensification;
- Accommodate coastal hazards, such as episodic storm tide inundations, by improving the design of buildings and infrastructure; or
- Gradually retreat buildings and infrastructure from areas at risk.

The Compendium is a valuable resource for coastal councils, and can be used together with:

- The Queensland Coastal Plan;
- Queensland Coastal Plan Guideline for Preparing Coastal Hazard Adaptation Strategies;
- The Coastal Hazard Adaptation Strategy for Townsville, a practical example of how to prepare a CHAS at the local scale.

In addition, a number of other technical documents are available to support an LGA's understanding of the need for reliable coastal hazard investigations and the essential role of risk-based decision-making, in particular:

- Harper B.A. (2004) *Queensland climate change and community vulnerability to tropical cyclones – ocean hazards assessment – Synthesis Report*, Queensland Government. http://www.longpaddock.qld.gov.au/about/publications/vulnerabilitytocyclones/index.html
- NCCOE (2012) *Guidelines for responding to the effects of climate change in coastal and ocean engineering – 2012 Update*. Engineers Australia, National Committee on Coastal and Ocean Engineering.

The use of these documents will allow an LGA's planners, engineers and asset managers to understand the CHAS process and to organize its preparation and implementation. Each adaptation option includes a broad range of information to support LGA staff in a preliminary assessment of its suitability for specific locations. However, professional advice should be sought to select the most effective option, including detailed study of its performance and impacts under a range of current and future conditions. In the same way, LGAs should inform the public of the known level of risk, possible options for a specific location, including its social, economic and environmental costs.

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