Fraser Coast Coastal Hazard Adaptation Strategy (CHAS)

Coastal Futures: Planning Our Changing Coastline

Phase 6 – Adaptation Options Compendium

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1 Introduction

1.1 Background Information

Fraser Coast Regional Council (FCRC) has commenced studies to support preparation of a Coastal Hazard Adaptation Strategy (CHAS) under the QCoast$_{2100}$ program, known locally as the *Coastal Futures: Planning Our Changing Coastline* project. The project has already identified potential risks to the community, assets and values associated with coastal hazards, specifically:

- Temporary flooding of coastal areas due to storm tide;
- Temporary or permanent loss of land due to coastal erosion; and
- Permanent loss of land due to coastal erosion and sea level rise.

1.2 QCoast$_{2100}$ Program

The QCoast$_{2100}$ program has been designed to assist Queensland coastal councils with funding and technical support to progress the preparation of plans and strategies to address climate change related coastal hazard risks. Governed by a Board comprising members from the Local Government Associated of Queensland (LGAQ), Department of Environment and Science (DES) and Department of Local Government, Racing and Multicultural Affairs (DLGRMA), the program is intended to guide decision-making across key areas of local government planning and operations, including:

- Corporate and operational planning and financial planning;
- Land use planning and development assessment;
- Infrastructure planning and management including roads, stormwater and foreshores;
- Asset management and planning including nature conservation, recreation, cultural heritage values and other public amenities;
- Community planning; and
- Emergency management.

The QCoast$_{2100}$ Minimum Standards & Guidelines (MS&G) (DEHP, 2016) provide guidance to local government on preparing a CHAS. The guidelines set minimum requirements that are to be included in a CHAS, as well as providing information on leading practices to facilitate continuous improvement.

The minimum standards set a benchmark for undertaking such studies in Queensland so that coastal hazard adaptation decision-making is approached in a consistent and systematic manner. The MS&G are structured to address the key phases of a CHAS which are illustrated in Figure 1-1. This compendium has been prepared as part of *Phase 6 – identify potential adaptation options*.

1.3 Purpose of the Compendium

This Adaptation Options Compendium provides summaries of potential options to manage coastal hazard risks to the year 2100.

Many of the options have already been implemented by FCRC or are part of routine activities at some localities.

Figure 1-1 QCoast$_{2100}$ Phases (DEHP, 2016)

Other options may represent a significant change to the present-day approach to managing coastal hazard risks. These options will need further consideration through socio-economic analysis (Phase 7 of the project) to determine if they're suitable for Fraser Coast localities.

In some cases, an option presented here will be determined unsuitable and will not be considered further as part of the current project.

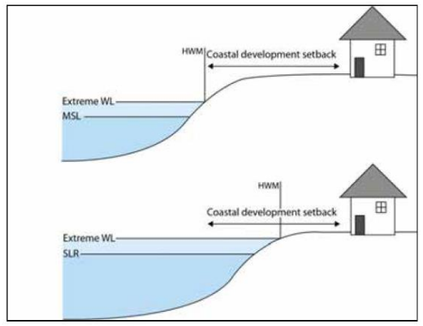
The Compendium describes almost 50 unique options for managing coastal hazard risks. No single option can eliminate the risk and most localities will require a suite of actions to be sequenced over time. Any future options or actions identified as part of the *Coastal Futures* project will need further consideration before implementation. New technologies or approaches to managing coastal hazards risk may also need to be considered in the future.

A preliminary assessment of each option in terms of the 'Period of Effectiveness' and 'Capital Cost' has been made. A simple traffic light colour code system has been applied, whereby:

- Green indicates long term effectiveness or low cost
- Yellow indicates medium term effectiveness or medium cost
- Red indicates short term effectiveness or high cost

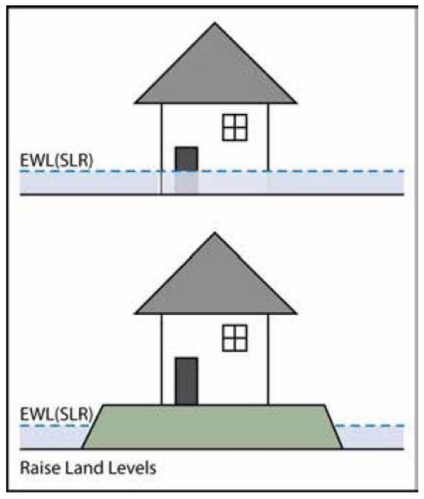
Following this approach options that are effective in the long term and low cost are preferred over those with a shorter period of effectiveness and higher cost. It is noted that this preliminary assessment is indicative and won't be representative across all localities and scenarios.

'Period of Effectives' colour code	Short term	Medium term	Long term
'Capital Cost' colour code	Low	Medium	High

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Avoid									
Community infrastructure planning and management	Avoid locating new important community infrastructure with a long design life in hazard areas. Progressively relocate replacement infrastructure footprint landward over time. Consider opportunities associated with the design life of assets and relocate assets once they are due for replacement.	Planning	✓	✓	✓	Long term	Potential impediment to economic growth and to accommodating population growth. Capital costs may be substantially increased.	Reduces exposure to future risk. Relocating infrastructure can help influence decisions to relocate other services and assets (often non-council) away from hazard areas. Opportunity for Council to lead by example by avoiding hazard areas.	Varies depending on infrastructure interdependencies and land availability
Coastal building lines / development setbacks	Maintain, review and/or implement coastal development building lines to avoid the placement of permanent assets in the hazard area.  *Note: HWM = high water mark; SLR = sea level rise; MSL = mean sea level* **Figure 2 Coastal Development Setbacks**[1]	Planning	✓	✓	✓	Medium - Long term	Reduced area within property boundary for development potential. Existing landowners expect to be able to place infrastructure within the full building envelope.	Minimal cost to public. Prolonged life of development. Reduces risk profile of properties within the hazard area. Can be applied to all hazards, but most commonly to erosion.	Low, but impacts on land values will vary depending on existing land values and length of shoreline. May be in the order of tens of thousands of dollars for some open coast properties

[1] Griffith University Centre for Coastal Management and GHD Pty Ltd (2012) Coastal hazard adaptation options – A compendium for Queensland coastal councils.

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Reduce intensity of future development	Implement risk appropriate land use policy and development provisions to maintain/not increase existing risk and future exposure in the coastal hazard area, for example: • change zoning to less intensive uses to avoid future exposure and allow risk appropriate land uses to occur such as open space or conservation • reduce density to maintain/not increase exposure to risk. Consider minimum habitable floor levels to manage risk to property in areas of tolerable risk. Includes partial zoning changes of lots. Covers greenfield and infill development.	Planning	✓	✓	✓	Medium - Long term	Potential impediment to economic growth and to accommodating population growth. Existing land values may reduce. Existing owners would have an investment-backed expectation to be able to develop land. Implementation may require a planning scheme amendment. Risk of landowners not being supportive. May impact on land supply.	Maintains current risk profile by not allowing inappropriate development in current or future hazard areas where the risks are intolerable. Allows risk responsive land use and development that is appropriate for the location and level of risk in the coastal hazard area. Creates / improves buffer between the coastline and other landward development. Reduces exposure to future risk. Reduces long-term exposure to legal and financial risks. Risk of potential compensation to landowners from adverse planning scheme changes can be avoided through the Feasible Alternative Assessment Reporting (FAAR) process. Can be used to signal a clear policy intent to transition land use over time. Provides greater certainty for development and community expectations when zoning and provisions are risk appropriate. Getting the land use strategy right minimises reliance on emergency evacuation as the sole measure to mitigate risk to life and, avoids putting additional burden on existing emergency management resources. Can be applied to all coastal hazards.	Varies depending on land values and length of shoreline. May be in the order of millions of dollars for some open coast properties

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Raise land levels	Manually change land levels on low-lying sites within inundation hazard zones to allow new assets to be located above hazard levels. Often associated with greenfield development or in association with seawall construction  *Note: EWL = extreme water level; SLR = sea level rise* **Figure 3 Raised land levels[1]**	Engineering and Planning	×	✓	✓	Medium - Long term	Large costs on the developer/owner to import fill Potential isolation, drainage, erosion and landscape issues with neighbouring lands May locally increase flood levels or adversely impact on the natural environment. Protection measures can fail and require maintenance over time Unsuitable for existing highly urbanised areas Unsuitable for existing highly urbanised areas and can result in issues with pedestrian connectivity, impacts on streetscape and character	Works can avoid exposure to current and future risks. May increase property values.	Varies depending on location, $20 - $35/m^2 per m raised
Retreat or Planned Transition									
Maintain status quo (no changes to present management approach)	Accept loss of land or assets affected by a hazard event on unprotected shorelines (i.e. once affected, assets or land is not replaced). Allow dunes to recede without intervention, potentially leading to damage of public or private infrastructure Maintain existing structures as per current management arrangements	Ecosystem Management / Engineering	✓	✓	✓	Ongoing	Does not reduce risk exposure	No increase in costs	Existing costs are variable. No change in cost

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Relocate important infrastructure	Relocate important public or community assets to a new location outside of the hazard zone  **Figure 4 Mungo Brush Road relocation overview, Myall Lakes National Park NSW[2]**	Planning / Engineering	✓	✓	✓	Medium - Long Term	Requires suitable alternative locations for the infrastructure Development approvals may be required to facilitate relocation and establishment Substantial additional costs or impacts may be incurred depending on the availability/ characteristics of the alternative site	The coastline and sandy beaches are retained because they can recede naturally Assets are not subject to ongoing impacts and retrofitting/rebuild costs Where possible timing can be aligned to coincide with planned asset renewal Reduces exposure to future risk	Varies depending on asset type and scale. May be in the millions of dollars
Land buy back (no lease back)	High risk private properties are bought at market prices, built infrastructure is demolished and land is used for coastal management purposes (e.g. open space (or similar))	Planning	✓	✓	✓	Long Term	The public (Council/State Govt) must fund full purchase price up-front Coastal property can be very expensive, particularly those with ocean views, large land parcels/houses, apartment blocks etc. Some community members may consider it unfair to spend public funds on private property (including the perception that the public funds are being used to "bail out" wealthy property owners) May require planning scheme changes to signal clear intent that land use will be transitioning over time because of coastal hazard risks May inadvertently increase the market value of remaining properties due to increased rarity Many freehold coastal landowners will not voluntarily accept the arrangement and will prefer to protect freehold land	Private property owners are adequately compensated The public retains a functional beach and gains public land in the medium term Prevents upgrading or intensification of site assets Creates a buffer between the coastline and other landward development once infrastructure is removed Reduces exposure to future risk	Varies depending on market values. May be in the millions for beachfront properties in some locations

[2]NSW Department of Planning, Industry and Environment (2019) Relocating Mungo Brush Road Myall Lakes National Park, accessed 14 April 2020, https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Topics/Parks-reserves-and-protected-areas/M-R/myall-lakes-national-park-mungo-brush-road-construction-overview-map-2019-february-photo.jpg?la=en&h=59%25&w=100%25&hash=720E537051AB3250234DDA777DCEE25176988320

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Land buy back with lease back opportunity	High risk private properties are bought at market prices, then rented out until hazard impacts are imminent (years). When hazard is imminent, built infrastructure is demolished and land is used for coastal management purposes (e.g. open space (or similar))	Planning	✓	✓	✓	Medium - Long Term	Many freehold coastal landowners will not voluntarily accept the arrangement and will prefer to protect freehold land Very costly for coastal properties with high property values Some community members may consider it unfair to spend public funds on private property (including the perception that the public funds are being used to "bail out" wealthy property owners) May inadvertently increase the market value of remaining properties due to increased rarity Council / State government must commit to mortgage arrangements May require planning scheme changes to signal clear intent that land use will be transitioning over time because of coastal hazard risks.	Lease back provides some funding back to contribute towards the purchase costs, or reduces initial purchase cost if lease back is for nominal amount Provides flexibility to allow occupation of the site for as long as it is safe to do so Private property owners are adequately compensated Reduces exposure to future risk The public retains a functional beach and gains public land in the medium term Prevents upgrading or intensification of site assets Creates a buffer between the coastline and other landward development once infrastructure is removed	Varies depending on market values. May be in the millions for beachfront properties

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
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Partial land buy-back	Partial acquisition of privately held freehold land to accommodate coastal management options and be designated as public land	Planning	✓	✓	✓	Medium - Long Term	The public (Council/State Govt) must fund purchase price up-front Unsuited to small, densely developed land parcels. Most suited to large properties adjoined on both sides by public land Some community members may consider it unfair to spend public funds on private property (including the perception that the public funds are being used to "bail out" wealthy property owners) May inadvertently increase the market value of remaining properties due to increased rarity May require planning scheme changes to signal clear intent that land use will be transitioning over time because of coastal hazard risks. Property owners may not accept changes to development provisions that may prevent or limit development potential. Many freehold coastal landowners will not voluntarily accept the arrangement and will prefer to protect freehold land	Property owners retain visual amenity and access to the coastline Reduces exposure to future risk Considerably less expensive than purchasing entire land parcel Improves continuity of public land (and public access) along the shoreline Private property owners are adequately compensated The public retains a functional beach and gains public land in the medium term Prevents upgrading or intensification of site assets in hazard area Creates a buffer between the coastline and remainder of site once infrastructure is removed	Varies depending on market values. May be in the millions for beachfront properties

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Land swap	Exchange high risk private land holdings for replacement public land out of the hazard area. Built infrastructure is demolished on acquired parcels and land is used for coastal management purposes (e.g. open space or similar land use)	Planning	✓	✓	✓	Long Term	Assumes that an available and suitable location exists (difficult in intensively developed coastal areas or those with high levels of visual amenity or conservation values) Expensive for areas with high land values – difficult to provide a nearby substitute location with similar value Alternative land may need to be purchased if existing suitable land is not already in public ownership Landowners are unlikely to accept alternative locations without considerable incentives or compensation Some community members may consider it unfair to spend public funds on private property (including the perception that the public is "bailing out" wealthy property owners) May inadvertently increase the market value of remaining properties due to increased rarity Requires coordinated government response and intervention to be successful Many freehold coastal landowners will not voluntarily accept the arrangement and will prefer to protect freehold land May require planning scheme changes to signal clear intent that land use will be transitioning over time because of coastal hazard risks.	Supports property owners to stay in general area and retains sense of community Reduces exposure to future risk The public retains a functional beach and gains public land in the medium term Creates a buffer between the coastline and other landward development once infrastructure is removed	Varies depending on market values

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Rolling easement	Property boundary is based on a distance to the shoreline, and therefore will move landward as the shoreline does	Planning	✓	✓	✓	Medium Term until hazard becomes immediate and frequent	There is currently no legal mechanism to introduce this style of land title (for existing land parcels or new subdivisions). Private property owners bear the cost of lost land / assets Many freehold coastal landowners will not voluntarily accept the arrangement and will prefer to protect freehold land	Coastline is retained because it can recede naturally Property owners are aware of lifespan of development, therefore no need for compensation resulting in a lower cost to the public Prevents upgrading or intensification of site assets in hazard area Maintains a buffer between the coastline and remainder of site once infrastructure is removed	Varies depending on market values
Trigger related development approvals	Development approvals are lawful until a nominated hazard trigger is reached, e.g. the shoreline comes within a defined distance of the property or infrastructure and the structure or asset needs to be moved further landward or removed from the site entirely. Conditions can also be imposed that trigger a series of certain actions to occur, e.g. Owner commences design of seawall once the shoreline comes within a defined distance. Owner then constructs the seawall once shoreline is within a defined distance.	Planning	✓	×	✓	Medium Term until hazard becomes immediate and frequent	May be difficult to implement for redevelopments where owners have an expectation to have the same rights for a new building as they had with the old building It is possible under the current planning system for applicants to modify the development approval or conditions of approval to have such conditions removed or amended	Coastline is retained because it can recede naturally Well-suited to approvals for infrastructure with a limited lifespan Property owners are aware of lifespan of development approval at the outset, therefore no need for compensation resulting in no cost to the public Prevents upgrading or intensification of site assets in hazard area Maintains a buffer between the coastline and remainder of site once infrastructure is removed	Nil

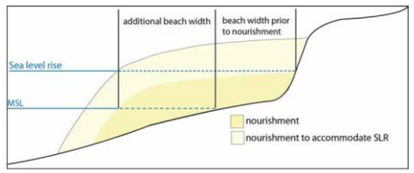
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Build community resilience									
Community education and consultation	Build acceptance and resilience for coastal risk management in the community by providing ongoing information on coastal hazards, risks, monitoring and implementation of actions Actively look for ways to involve the community in coastal, wetland and natural system management Increase signage and activities which help the community and visitors to understand more about climate change, its impacts and solutions  Figure 5 Coastal Futures Project stakeholder engagement, Scarness, November 2019	Community / Education	✓	✓	✓	Ongoing	Requires targeted information and involvement opportunities presented in a way that can be readily understood and embraced by the community	Increases community understanding of hazards and risks and encourages community involvement in mitigation implementation	Costs vary depending on scope of education and consultation undertaken

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Monitoring	Undertake monitoring to determine when risk approaches unacceptable levels and management triggers are reached Monitoring may include: • beach condition, profile and recession rates • mangrove extents recession rates • dune vegetation extents, dune stability • habitat health, connectivity and availability • bathymetric changes (shoaling, scour, channel migration) Involve community where appropriate  Figure 6 CoastSnap photo point Stockton Beach NSW[3]	Data collection / Community / Education	✓	✓	✓	Ongoing	Data collection program needs to be well designed and will need to be implemented over a prolonged time period to allow for monitoring of management triggers Data collection program may be costly depending on type of data collected Requires targeted information and involvement opportunities presented in a way that can be readily understood and embraced by the community	There are opportunities to share costs between state and local governments depending on the type of monitoring (and assessment of monitoring outputs) Monitoring undertaken for purposes other than coastal hazards may also be able to be used to inform coastal management assessments Supports timely implementation of mitigation responses, reducing costs and facilitating risk appropriate uses for as long as possible (pathways approach) Increases community understanding of hazards and risks and encourages community involvement	Varies depending on data type, community involvement and scale
Geotechnical investigation & detailed erosion studies	Undertake detailed geotechnical investigations to determine the erosion potential within foreshore area (requires physical examination down to -2m AHD or below) and likely geotechnical stability of foreshore if the fronting beach or primary dune becomes completely eroded	Data collection	✓	×	×	Ongoing	Investigations and studies may be costly depending on nature and extent	Improves confidence in hazard area interpretation Reduces broader costs of adaptation if geotechnical controls reduce hazard exposure	Varies depending on data sought and scale

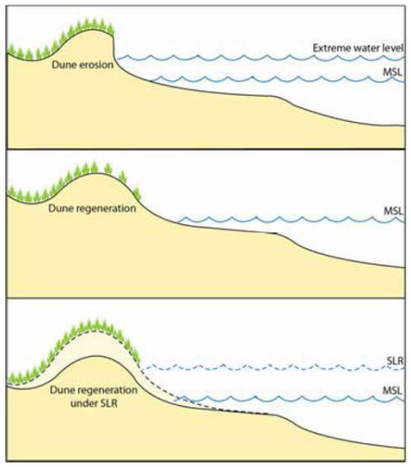
[3]NSW Department of Planning, Industry and Environment (2019) CoastSnap beach monitoring, Accessed 14 April 2020. https://www.environment.nsw.gov.au/research-and-publications/your-research/citizen-science/digital-projects/coastsnap

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Enhance coastline or habitat resilience									
Beach scraping	Manual pushing of a thin (less than 200mm thick) layer of sand from the beach face towards the upper beach to reinforce the dune or reduce risks associated with erosion scarps (such as vertical drops at beach access points). Scraping should only occur above mean sea level, and preferably above the level of high tide.  **Figure 7 Beach Scraping, New Brighton Beach, Byron Shire[4]**	Engineering (Soft)	✓	×	×	Short Term	Unsuitable for locations where there is minimal sand on the beach face Does not prevent erosion but provides a sacrificial buffer for when erosion does occur Needs to be monitored and repeated on an as needs basis – ongoing costs can be hard to predict and plan for, as timing depends on event frequency	Assists to create an erosion buffer and reduce storm damage to landward coastal assets Largely retains beach safety, amenity and access for recreational purposes Relatively inexpensive, can be done using local earthmoving equipment Can be implemented broadly or at localised locations such as at beach access points Can be mobilised quickly, enabling rapid response to manage risks following erosion	$50 to $60 per m beach length

[4] Dowsett,C.(2017) New Brighton beach scraping, Byron Shire Council. Snapshot for CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast, accessed 14 April 2020. *https://coastadapt.com.au/sites/default/files/case_studies/SS63_Beach%20Scraping%20New%20Brighton.pdf*

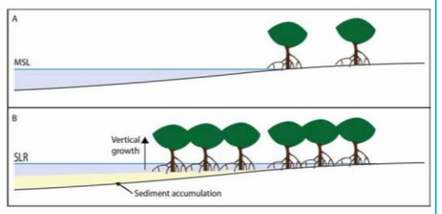
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Small-scale beach nourishment (up to 100,000 m^3)	Manual placement of sand on the beach using either nearshore, estuarine or land-based sand sources to top up the beach and dune system  **Figure 8 Beach Nourishment, Maroochydore[5]**  **Figure 9 Typical beach nourishment cross-section[1]**	Engineering (Soft)	✓	×	×	Short Term	Does not prevent erosion but provides a sacrificial buffer for when erosion does occur Nourishment design influences longevity of benefits as material can be rapidly lost during single storm events, and more slowly lost over time if there is a deficit in sand supply Needs to be monitored and repeated on an ongoing basis – ongoing costs can be hard to predict and plan for, as timing depends on event frequency Sets a community expectation that the beach will always be retained	Assists to create an erosion buffer and reduce storm damage to landward coastal assets Largely retains beach amenity and access for recreational purposes Effectiveness can be increased when teamed with other measures to limit sand loss from the beach, such as groynes Nourishment that widens beaches and raises beach elevations can also assist in reducing inundation impacts on landward areas	Nearshore or estuarine sources may be as little as $30/m^3

[5] Photo courtesy of Matthew Barnes, taken in 2013

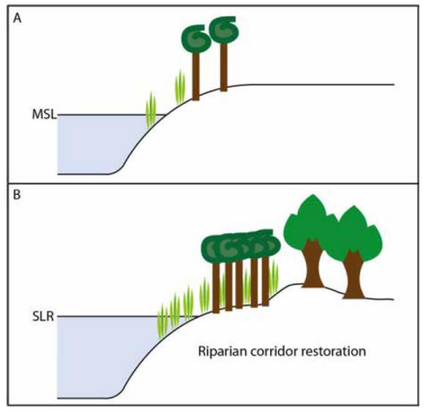
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Dune restoration / augmentation	Increase the crest height or functional integrity of existing dunes through the addition of imported sand from offshore / inactive sand sources. Implement vegetation works to stabilise placed sand (aligned with dune restoration)  **Figure 10 Typical dune constructions and regeneration cross-section[1]**	Engineering (Soft)	✓	✓	✓	Short - Medium Term	Sourcing suitable or sufficient sand may be problematic and costly In heavily populated areas an increase in dune height may affect residential view lines and be opposed by the local community Dune and associated vegetation will still be exposed to damage during storm events Initial revegetation works may be vulnerable to vandalism or trees may be unlawfully lopped/damaged to maintain views. Effectiveness may reduce over time due to increasing frequency of coastal hazard impacts	Provides a natural solution Can be used to restore degraded dunes Supports opportunities to control pedestrian movements to minimise future damage Once established requires the same level of maintenance as similar existing natural dune areas Provides opportunity to involve community partnerships to undertake the revegetation works and monitoring, e.g. Traditional Owners Rangers, residents, environment groups etc.	Sand supply and placement, offshore sand source - $54 to $72/m^3 Revegetation and management over 5 year life, incl weed and vermin control, monitoring, $2200/ha
Dune construction	Reinstatement or artificial construction of new dunes using imported sand from offshore / inactive sand sources. Dunes are positioned at the back of the beach and vegetated to restore natural coastal hazard protection (aligned with dune restoration)	Engineering (Soft)	✓	✓	✓	Medium Term	Sourcing suitable or sufficient sand may be problematic and costly In heavily populated areas any impacts on view lines may be opposed by the local community Initial revegetation works may be vulnerable to vandalism Windblown sand may cause nuisance issues until vegetation establishes Will require periodic maintenance and sand top ups depending on local sediment transport Effectiveness may reduce over time due to increasing frequency of coastal hazard impacts	Provides a natural looking solution Increases coastal habitat and may improve visual amenity Once established requires the same level of maintenance as similar existing natural dune areas	Sand supply and placement, offshore sand source - $54 to $72/m^3 Revegetation and management over 5 year life, incl weed and vermin control, monitoring, $2200/ha

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Active dune and habitat management including vegetation planting and management	Continue to implement and support natural dune processes through dune care / habitat management programs, including consolidation of informal beach access Fencing of dune management areas until habitat re-established and to encourage natural dune building processes  **Figure 11 Vegetation planting at Kemp Beach, Rosslyn[6]**	Ecosystem management	✓	✓	✓	Short Term	May be cost effective in short term, but dunes don't provide an engineering solution to a chronic erosion or a receding coastline over the long term (dunes will erode) Significant reinstatement works may be required after major damage occurs to maintain protective functionality	In short term, provides a store of sand to buffer from storms and reduce risk of erosion Intact dune systems can limit inland inundation penetration on the open coast Provides complementary ecological and amenity benefits Supports maintenance and enhancement of natural values expressed by stakeholders. Vegetated dunes are cooler than non-vegetated dunes Can form part of other long term or interim solutions (e.g. stabilising nourished sands) and increases the time available for major decision making Relatively low cost in areas where erosion is not chronic Provides an opportunity to educate and involve the community in managing risks and undertaking monitoring	Varies, may be in the order of thousands of dollars annually depending on condition
Land management to support habitat migration	Actively encourage temporary, low impact uses and/or habitat maintenance on land fringing coastal habitats to support progressive habitat migration. This may also include assisted colonisation to enable distribution shifts of important species	Ecosystem management	✓	✓	✓	Medium - Long Term	Short term community opposition by people whose activities may be affected May need changes to land use planning policy and development provisions to help implement	Long term viability of habitat and wildlife corridors Long term habitat availability for community and visitors who appreciate natural values.	Varies depending on location and use of adjoining land

[6] Livingstone Shire Council (2019) *Yeppoon State High School Planting at Kemp Beach*, Accessed 14 April 2020. https://www.livingstone.qld.gov.au/images/CivicAlerts/5/Yeppoon-State-High-School-Planting-at-Kemp-Beach-1.gif

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Freshwater and saltwater wetland restoration	Actively restore degraded wetlands to improve natural hazard management function. Planting of wetland vegetation enables sediment to accumulate. It may, depending on the scale, reduce the impact of storm tide inundation through water flow attenuation and assist with adapting to SLR  **Figure 12 Typical cross-section before and after restoration[1]** *Note: MSL=mean sea level; SLR=sea level rise*  **Figure 13 Mangrove rehabilitation works on the Shoalhaven Rover, south coast of NSW[7]**	Ecosystem management	×	✓	✓	Short - Medium Term	Costs vary, but depending on scale, can be substantial May have other environmental impacts where existing vegetation/ecological values occur	Maintain significant values expressed by stakeholders including Traditional Owners May assist with attenuating inundation Provides co-benefits of ecological improvements and carbon sequestration Provides an opportunity to educate and involve the community in monitoring and managing wetlands Carbon sequestration potential may provide an avenue to attract investment.	Varies depending on condition and scale. May be in the tens of thousands of dollars
Establish buffers around wetlands	Establishing buffers around wetlands enables them to migrate landward as sea-levels rise and reduce potential for coastal squeeze	Planning and ecosystem management	×	×	✓	Short Term	May require rezoning and/or land purchase	Supports long term viability of important community assets Complementary benefits include retention of fish habitat, carbon sequestration potential and flood mitigation	Varies depending on land values and adjoining land uses

[7]NSW Department of Primary Industries (2008) Primefact 746: Mangroves. Accessed 14 April 2020 http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/236234/mangroves.pdf

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Green belts and riparian corridors	Rows of trees and other native habitat, preferably riparian Plant riparian buffers along estuary foreshores  **Figure 14 Typical riparian corridor cross section before and after restoration[1]**	Ecosystem management	✓	✓	×	Short - Medium Term	Cost varies depending on scale Could cause issues with nearby residents who may lose water views.	Establishes a buffer devoid of built assets to accommodate wave action and erosion, and attenuate storm tide inundation Increases the stability of estuary banks at creek mouths to reduce the likelihood of erosion Added benefits of provision of shade and animal/fish habitat Creates shading and heat management Carbon sequestration Increases ecological connectivity and wildlife movement	Revegetation and management over 5 year life, incl weed and vermin control, monitoring, $2200/ha
Reduce extents of hard surfaces	Reduction in the coverage of impenetrable surfaces to increase infiltration and decrease runoff	Planning and ecosystem management	✓	✓	✓	Medium Term	Cost varies depending on scale Difficult to implement in highly developed areas	Reduce runoff and therefore localised erosion Has additional risk mitigation potential such as reducing flood risk Can improve water quality Planning scheme can incorporate water sensitive urban design provisions for new development	Varies depending on nature of hard surface coverage
Adapt or accommodate									
Allow foreshore recession	Accept erosion of the foreshore at some locations that are less critical from a tourism / community / asset perspective	Ecosystem management	✓	×	×	Long Term	Private landholders are not compensated for the loss of land or property The community may lose public facilities or land temporarily or permanently Ongoing replacement costs for low-cost, easily replaced infrastructure Criticism from some parts of the community over the loss of minor assets and lack of intervention	Particularly suitable for park land and low-cost facilities (e.g. access ways, walkways) Establishes community expectations about highly valued infrastructure from a broad community perspective Supports risk-appropriate usage of hazard area	No to low cost

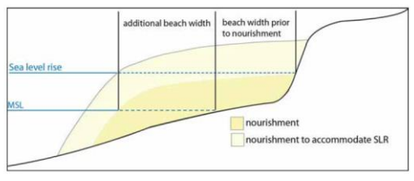
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Emergency management planning (e.g. alternative route provision)	Accept inundation impacts where suitable alternative infrastructure exists to service community needs during / following an event	Emergency response	×	✓	✓	Medium - Long Term	Infrastructure is still exposed to inundation hazards, with resultant repair/maintenance costs There may be minor inconvenience to a small number of directly affected private properties Relies on existing alternative infrastructure availability	Alternative infrastructure is in place to meet community needs (i.e. redundancy is built into the system) Overwhelming majority of community is able to continue to function while any assets are impacted or being repaired	No cost
Emergency management response	Monitoring and warning systems including evacuation strategies and community engagement	Emergency response and Planning	✓	✓	✓	Short - Medium Term	Initial capital outlay for new systems and processes Requires continuing investment in coordination and education that must be trialled and updated Implementation is in conjunction with other strategies Emergency evacuation response should not be relied upon as the sole measure for mitigating risk to life for new development New development in higher risk areas creates an additional burden on existing emergency management capabilities and resources	If effective, can reduce or eliminate risk of loss of life Pre-warning and education can help to minimise loss of property	Cost varies depending on scale
Insurance	Taking out insurance coverage of Council assets in current and future hazard areas	Planning	✓	✓	✓	Short Term (or as long as can be insured)	Premiums will increase over time with increasing numbers of claims or areas may become uninsurable Risk that insurance definitions do not cover event that causes damage (e.g. 'storm' compared with a 'flood') Will still need to be done in conjunction with other strategies	If able to be insured, assets can be re-built as a result of claims or payout can fund the relocation landward or redesign	Varies depending on asset and risk exposure
Development master planning	Master planning or structure planning of new developments to avoid placing any vulnerable uses within the hazard extent	Planning	✓	✓	✓	Medium - Long Term	Site coverage may not be able to be used as initially intended by developer Potential impediment to form of accommodating population growth Existing owners would have an investment-backed expectation to be able to develop land to achieve a certain return	Reduces exposure to future risk Opportunity to maintain or enhance natural ecological function of hazard area Supports risk-appropriate usage of hazard area Provides greater certainty for community and development expectations	Minimal, as should be done as part of good practice development planning

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Build redundancy into network systems	Provide alternative connections to network assets (such as sewer, water, roads etc) at high risk locations to minimise impacts on asset interdependency	Engineering	✓	✓	✓	Medium - Long Term	Existing infrastructure is still exposed to inundation hazards, with resultant repair/maintenance costs There may be minor inconvenience to a small number of directly affected private properties	New alternative infrastructure is in place to meet community needs (i.e. redundancy is built in to the system) Overwhelming majority of community is able to continue to function while any assets are impacted or being repaired Supports staging of relocation of critical infrastructure as infrastructure with high risk exposure may eventually be able to be removed	Cost varies depending on scale and asset type
Manual creek mouth management to protect public assets	Actively limit creek mouth meandering into dune areas seaward of critical public infrastructure. Requires active monitoring for implementation  **Figure 15 Currimundi Lake entrance management, Sunshine Coast, December 2019**	Engineering / Ecosystem management	✓	×	×	Short Term	Requires active management and interference May affect local waterway ecology Will require statutory approvals Erosion from high creek flows during major flooding can still occur	Reduces localised risks from wave erosion reaching the dune Supports natural growth and stabilisation of dunes May benefit water quality and discourage breeding of pest species (e.g. biting midge) by increasing flushing of waterway	Low if easily accessible
Manual creek mouth management to protect private assets	Actively limit creek mouth meandering into dune areas seaward of private assets. Requires active monitoring for implementation	Engineering / Ecosystem management	✓	×	×	Short Term	Requires active management and interference May affect local waterway ecology Will require statutory approvals May attract criticism that public funds are being used to protect private assets Erosion from high creek flows during major flooding can still occur	Reduces localised risks from wave erosion reaching the dune Supports natural growth and stabilisation of dunes May benefit water quality and discourage breeding of pest species (e.g. biting midge) by increasing flushing of waterway	Low if easily accessible

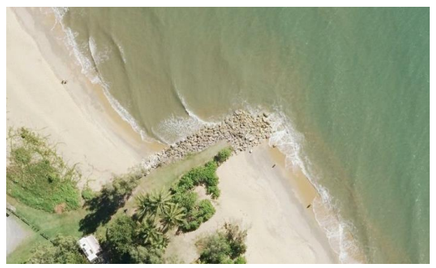
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Hazard resilient design for new/ upgraded public infrastructure	Where new or replacement public infrastructure is necessary within the hazard extent and the risk is deemed 'tolerable', infrastructure is designed to accommodate temporary inundation, be sacrificial or be relocatable. Includes setting or amending floor levels  **Figure 16 Flood resilient toilet, Lismore NSW[8]**	Planning / Engineering	✓	✓	✓	Ongoing	May increase construction costs in hazard areas Relies on availability of replacement infrastructure (if sacrificial), nearby receiving space and resources to relocate (if relocatable) Design may not be able to fully reduce risk and may be expensive (i.e. retreat or accept damage may be a cheaper option)	Reduces exposure to future risk Design modification can support an extended life for the asset Relocatable or sacrificial designs are well-suited to infrastructure with a short design life Effective in the short to medium term to accommodate storm-tide and SLR; effectiveness dependent upon design parameters, hazard categories and overall risk Encourages innovative design practices Greatest benefits when new builds or renovations are occurring	Varies depending on infrastructure type and construction costs

[8] Modus Australia n.d. *Toilet building for busy flood prone city centre accessed 14 April 2020.* https://www.modusaustralia.com.au/projects/toilet-building-for-busy-flood-prone-city-centre

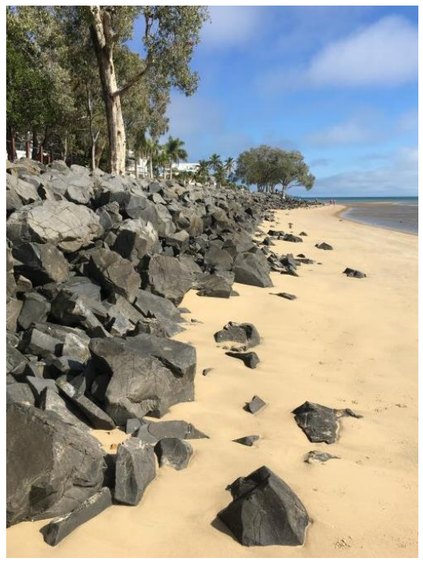
Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Hazard resilient design for new/ upgraded private infrastructure	Where new or replacement private built assets are proposed within the hazard extent, infrastructure is designed to accommodate temporary inundation, be sacrificial or be relocatable. Includes setting or amending floor levels	Planning / Engineering	✓	✓	✓	Ongoing	May increase construction costs in hazard areas Design may not be able to fully reduce risk and may be expensive (i.e. retreat or accept damage may be a cheaper option) Sacrificial or relocatable designs unlikely to be palatable to owners for dwellings or major infrastructure Relies on availability of replacement infrastructure (if sacrificial), nearby receiving space and resources to relocate (if relocatable) May place restrictions on future development for existing owners Transfer of ownership may change the owner attitude to acceptability Issues for ongoing access if the built assets are isolated as a result of hazard impacts on surrounding land	No cost to public Reduces exposure to future risk Opportunity to educate community on future hazards Design modification can support an extended life for the asset Relocatable or sacrificial designs are well-suited to infrastructure with a short design life Effective in the short to medium term to accommodate storm-tide and SLR; effectiveness dependent upon design parameters and overall level of risk i.e.: may not be appropriate in higher risk areas or where the depth of inundation is high Encourages innovative design practices Greatest benefits when new builds or renovations are occurring Supports progressive increase in resilience throughout hazard areas	Varies depending on infrastructure type and construction costs
Contaminated site management	Identify contaminated sites that are within hazard zones to establish clean-up procedures or implement options that reduce exposure	Planning	✓	✓	✓	Ongoing	Potential local contamination during clean-up May be costly depending on contaminants and volumes	Reduces the risk of harm to waterway and human health Reduced litigation risk	Varies depending on site specific contaminants and volumes
Urban design	Increase tidal inundation management capacity using water sensitive urban design including onsite detention	Planning	×	✓	✓	Ongoing	Needs supporting policy Likely to be problematic for coincident flooding and tidal inundation	Can reduce the penetration of tidal inundation onto private property	Varies depending on site

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Floating development	Allow structures to move with changing water levels  **Figure 17 Floating restaurant, Lakes Entrance**	Planning	×	✓	✓	Ongoing	Only effective in areas not subjected to wave action	Manages the uncertainty of sea levels	Varies depending on infrastructure type and construction costs
Protect									
Large-scale beach nourishment (greater than 100,000 m^3)	Manual placement of sand on the beach using marine source (offshore inactive preferred)  **Figure 18 Beach Nourishment, Woorim, Bribie Island[9]**  **Figure 19 Typical beach nourishment cross-section[1]**	Engineering (Soft)	✓	×	×	Medium-Long Term	Can be very expensive, particularly when a suitable and economical sand source is not located close to the placement site Does not prevent erosion but provides a sacrificial buffer for when erosion does occur Nourishment design influences longevity of benefits as material can be rapidly lost during single storm events, and more slowly lost over time if there is a deficit in sand supply Sets a community expectation that the beach will always be retained	Assists to create an erosion buffer and reduce storm damage to landward coastal assets Largely retains beach amenity and access for recreational purposes Effectiveness can be increased when teamed with other measures to limit sand loss from the beach, such as groynes Nourishment that widens beaches and raises beach elevations can also assist in reducing inundation impacts on landward areas	Offshore sand source and delivery could be up to $45 to $60/m^3

[9] Webb, T., 2016: Engineering solutions for coastal infrastructure. CoastAdapt Information Manual 7, National Climate Change Adaptation Research Facility, Gold Coast.

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Artificial reef	Construction of a submerged offshore structure designed to reduce the energy of waves approaching the adjacent coastline  **Figure 20 Narrowneck artificial reef, Gold Coast[1]**	Engineering	✓	×	×	Medium Term	Very expensive to build and maintain ($ millions) Effectiveness reduced as sea levels rise, allowing waves to pass without being attenuated May reduce sediment transport supply to adjacent downdrift beaches Will only impact on a short section of shoreline	Effectiveness can be increased when teamed with other measures to increase beach width such as beach nourishment Supports beach widening and retention of a natural beach environment by slowing sediment transport along the adjacent shoreline Appropriate design may increase surfing opportunities Creates calmer wave environment for recreational uses such as swimming May locally increase biodiversity of marine species by increasing habitat Can increase recreational amenity (fishing opportunities)	Expensive, $10 to $20 million+ depending on size and location
Groyne and artificial headlands	Construction of an artificial barrier perpendicular to the beach to trap and hold beach sediments  **Figure 21 Short rock groyne at Bramston Beach[10]**	Engineering	✓	×	×	Medium - Long Term	Can be expensive to build ($ millions) if groynes are built into the surf zone or estuary. Require ongoing maintenance Loss of beach amenity from natural conditions - numerous groynes may be required along a beach to be effective Erosion effects at end of groyne field due to interrupted sediments not reaching downdrift areas Unlikely to be effective for long term sea level rise (groynes don't increase sediment budget for beach) Do not assist with storm tide inundation	Effectiveness can be increased when teamed with other measures to increase beach width such as beach nourishment Retains a sandy beach in current position In some scenarios, can provide recreational amenity (fishing) Can be used as a temporary measure if constructed using geobags or similar	From $2000 to $5000/m length, subject to groyne height and materials used. Artificial headlands are more expensive

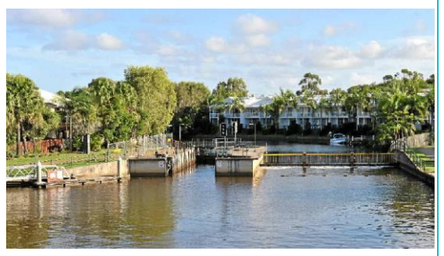
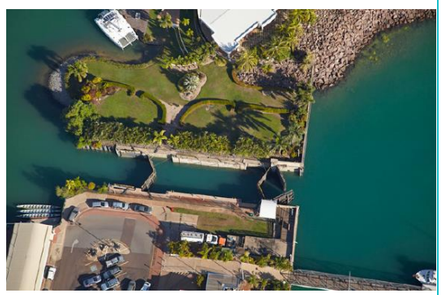
[10] Image from Queensland Globe, Accessed 13 September 2018 https://qldglobe.information.qld.gov.au/

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Seawall to protect public assets	Protect public assets by constructing major protection works seaward of valued community infrastructure. Typically constructed from rock or concrete along the dune line parallel to the beach  **Figure 22 Rock Revetment Seawall, The Esplanade, Hervey Bay**	Engineering (Hard)	✓	×	✓	Medium - Long Term	Expensive capital outlay (can be $ millions depending on site) plus ongoing maintenance after storm events to maintain integrity Existing seawalls may need to be re-designed or augmented to account for sea level rise Beach lowering immediately seaward of the wall will occur at seawall sites experiencing chronic long-term erosion, resulting in no high tide beach and a loss of recreational and visual amenity Government protection of private property can be controversial and evoke equity issues Accelerated erosion can occur at the ends of seawalls. Wall ideally should be built as contiguous lengths/major segments along the beach but can be staged for future risks Can have significant negative impacts on landscape character and loss of access and beach amenity. 'Ugly' seawalls that dominate or don't blend with the landscape or result in loss of sandy beaches may not support community values.	Holds shoreline in current position (i.e. the land behind the beach is protected, often at the expense of the beach) The crest height of a seawall may also be sufficient to locally protect against sea level rise on the ocean frontage, but may not be high enough to limit storm tide inundation Alternative materials such as geobags may be suited to locations with smaller wave climates where a structure with a shorter design life is desired Provides opportunity for seawalls to be designed to 'look good' and have multiple design objectives beyond only their engineering function. Seawalls that 'blend with the landscape' and character of a place and allow public access, provide better urban design and public realm outcomes	$2000 to $5000/m length, subject to seawall height and proximity to suitable materials

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Scour protection to protect public assets	Protect public assets by constructing low-level protection works along waterways to protect valued community infrastructure  **Figure 23 Scour protection at public boat ramp and stormwater drain outlet, Poona**	Engineering	✓	×	✓	Medium - Long Term	Costs vary, but depending on scale, may be substantial May have adverse environmental impacts where high ecological values occur, especially during construction Design will need to integrate with other measures for flood protection	Works can employ a variety of materials, including softer materials such as coir logs or vegetative solutions etc. Softer materials or low-key works may be able to be implemented by community groups. Crest level may also be sufficient to locally protect against sea level rise inundation, but may not be high enough to limit storm tide inundation	$50 to $250/m^2, subject to access restrictions and materials used

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Seawall / scour protection on private land to protect private assets	Allow private asset owners to construct major or low-level protection works to protect private assets  **Figure 24 Scour protection Sunshine Coast[11]**	Engineering / Planning	✓	×	×	Medium Term	Expensive capital outlay in isolation, savings can be made when private property owners combine resources to fund (economies of scale) All owners may not maintain seawalls to the approved design standard, particularly following ownership changes Private asset owners often seek to construct individual walls rather than protecting a longer section of coastline, leading to discontinuous standards of protection and alignment. Erosion is accelerated on unprotected properties Many private properties have already built close to seaward property boundaries and there is often insufficient space to fully or partially contain a suitably designed seawall on the private property, or space to undertake seawall maintenance Beach lowering immediately seaward of the wall will occur at seawall sites experiencing chronic long-term erosion, resulting in no high tide beach and a loss of recreational and visual amenity. This can sever access along the beach on public land Crest height to accommodate wave overtopping can sometimes obscure sea views from natural ground level Protection works can impact on beach amenity and adversely impact on natural coastal environment values, processes and functions	Holds shoreline in current position (i.e. the land behind the beach is protected, often at the expense of the beach) The broader community does not fund the capital or maintenance costs of protecting private property There is no exclusive use of public land for private benefit Design criteria can vary depending on owner's willingness to pay The planning scheme can provide clear policy direction for where new private asset protection works are supported, or not envisaged. Development provisions can be included to achieve consistency in design outcomes and criteria	As for scour protection and seawalls for public assets

[11] Sunshine Coast Council (2014) Resident's handbook: Artificial waterways. Accessed 14 April 2020 https://assets.website-files.com/5cf9d1a3e1b6580b4593f70d/5d003b9d11b2dbf534012a0b_Sunshine%20Coast%20Artificial%20Waterways%20Handbook.pdf

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Tidal barrage / gates / surge barriers	Construction of a physical barrier across a waterway to prevent elevated water levels from penetrating into upstream areas. Can be designed to be movable to optimise water level and water quality management  **Figure 25 Noosa Waters lock and weir system[12]**  **Figure 26 Tidal lock, Cullen Bay Marina, Darwin, NT[1]**	Engineering	×	✓	✓	Long Term	Very high capital and maintenance costs Often requires ancillary structures and works to maintain effectiveness (e.g. training walls to affix the gates to and a sand bypassing system if placed close to a river mouth) Can adversely impact on riverine flooding extents if storm tide is coincident with flood peaks	Allows natural riverine and coastal functions including navigation to continue while barrier is not in operation (i.e. when the gates are closed) Can assist in reducing the impacts of storm tide inundation and sea level rise by being deployed only when elevated water levels are expected Assists with disaster management	Expensive. Can be in the millions of dollars depending on the width and depth of barrier required

[12] Sunshine Coast Daily (2014) *Noosa residents could finally get their canal repair wish*, accessed 14 April 2020 https://www.sunshinecoastdaily.com.au/news/canal-residents-get-a-windfall/2493319/

Adaptation Option	Adaptation Option Description	Adaptation Option Type	Relevant hazards			Period of Effectiveness	Drawbacks	Benefits	Capital Cost
			Erosion	Storm Tide Inundation	Sea Level Rise				
Levees / dykes	Construction of a permanent, physical barrier on land to prevent inundation of landward areas  **Figure 27 Dyke at Petten, the Netherlands[13]**	Engineering and Planning	×	✓	✓	Medium Term	Expensive capital outlay (can be $ millions depending on site) plus ongoing maintenance after storm events to maintain integrity Existing levees may need to be re-designed or augmented to account for sea level rise One breach of the levee can render the entire system redundant Crest height to accommodate inundation levels can sometimes obscure sea views from natural ground level Once a levee is overtopped, the water is trapped behind levee (cannot drain back into the sea / estuary) unless there is a pumping system Implementation can be challenging due to the potential involvement of multiple landowners Implications of stormwater management or coincident flooding need to be considered to avoid worsening of inundation	Prevent flooding (estuarine and riverine) into landward areas Can be used to formalise open space and public access along a shoreline Most effective along estuaries where wave action is minimal	Can be expensive depending on exposure to wave action and required height above ground level. $5000 to $10 million /m length for rock structures. $600/m for low earthen bunds
Tide flaps and valves on stormwater pipe network	Installation of valves or tide flaps on the existing stormwater network to permit one-way flow only and avoid penetration of salt water upstream into the pipe network  **Figure 28 Duckbill Valve[14]**	Engineering	×	✓	✓	Short - Medium Term	Flow control devices need to be installed on all affected outlets in the area to avoid provide broad immunity from inundation Flow control device cost depends on device type, size of pipe, accessibility and difficulty to retrofit Does not prevent inundation overtopping local land levels and entering the stormwater network upstream of the flow control device Effectiveness depends on device type, hydraulic head in system, sensitivity to sedimentation levels etc.	Highly suited to retrofitting in existing developed areas Able to provide a localised solution anywhere within the network	Varies depending on pipe size and mechanism type, from hundreds to tens of thousands of dollars

[13] Dutch Water Sector (2013) *Boskalis and Van Oord to reinforce coastline by creating beach in front of sea dike, the Netherlands*, accessed 14 April 2020, https://www.dutchwatersector.com/news/boskalis-and-van-oord-to-reinforce-coastline-by-creating-beach-in-front-of-sea-dike-the
[14] Measurit Technologies Ltd (2020) *Tideflex check valves are free draining* Accessed 14 April 2020 https://www.measurit.com/tideflex-benefits/tideflex-valves-are-free-draining