Ministry of Environment and Energy (MEE), Republic of Maldives

UNDP Maldives

Formulation of Guidelines for Climate Risk Resilient Coastal Protection in the Maldives

Handbook on Climate Risk Resilient Coastal Protection



Project Handbook
February 2013

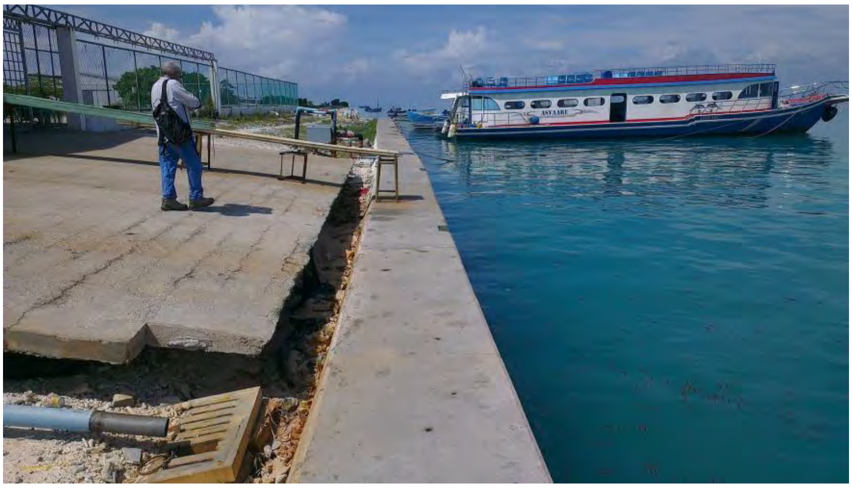

Plate 1 – Quay wall on Thinadhoo (taken October 2012 J Hills)

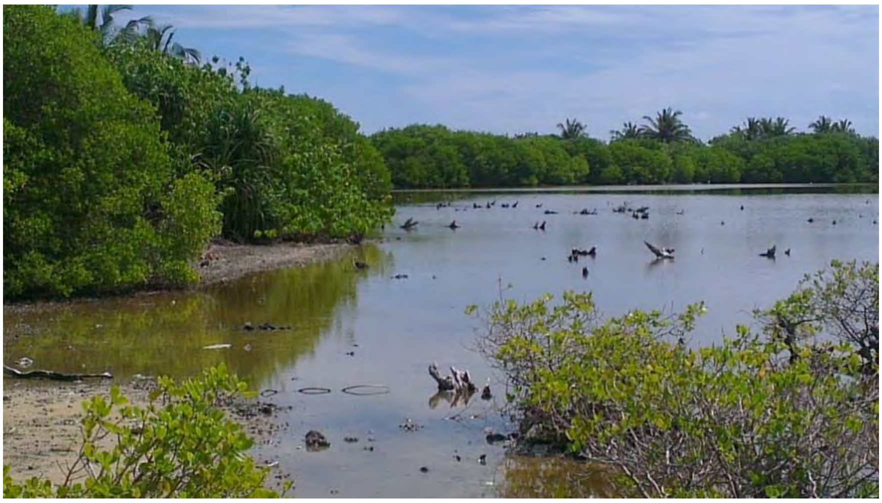

Plate 2: wetland system on Dhidhdhoo (taken in October 2012 J Hills

Plate 3: rock revetment on Khuldhufushi (taken in October 2012 J Hills)

Notice

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Acronyms

AC	Atoll Council
ALWC	Accelerated Low Water Corrosion
DIRAM	Detailed Island Risk Assessment in the Maldives
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EPPA	Environmental Protection and Preservation Act
EPZ	Environmental Protection Zone
GIS	Geographic Information System
GOM	Government of Maldives
IC	Island Council
ICCRRIP	Integrating Climate Change Risk Resilience In Island Planning
IPCC	Intergovernmental Panel on Climate Change
LUP	Land Use Planning regulations
MEE	Ministry of Environment and Energy
MHUDB	Maldives Housing and Urban Development Board
MHI	Ministry of Housing and Infrastructure
MLSA	Maldives Land and Survey Authority
MOTAC	Ministry of Tourism Arts and Culture
MSL	Mean Sea Level
NDMC	National Disaster Management Centre
NDP	National Development Plan
NEAP	National Environment Action Plan
NGIS	National GIS
SIDS	Small Island Developing States
SOE	State of the Environment Report
SoP	Standard of Protection
TRDR	Tourism Resort Development Regulations
TOR	Terms of Reference

"Formulation of Guidelines for Climate Risk Resilient Coastal Protection in the Maldives"

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Contents

Editorial

For the first time, the Republic of the Maldives has a Guidance Manual to help formulate improved decision making on designing and constructing Climate Risk Resilient Coastal Protection in the future. This Manual is very timely as climate change predictions suggest that the Maldives will be experiencing increased coastal pressures from intensive rainfall, storm surges, swell waves, all aggravated through sea level rise and alterations in weather patterns. Since 2006, more than 90 inhabited islands have been flooded at least once, and 37 islands have been flooded regularly or at least once a year.

The Guidance Manual is produced to help increase climate change resilience by initiating:

A) <u>Planning guidelines that provide;</u>

- Qualifying explanation to the requirements of existing EIA and land use planning regulations.

B) <u>Engineering guidelines that cover;</u>

- Performance standards to integrate climate change design into coastal protection structures.
- Performance standards to include required material specifications to "climate proof" coastal protection structures.

C) <u>Guidelines for the monitoring, maintenance and information needs for coastal protection structures</u>

The success of the Guidance Manual will be judged on actual outcomes on the ground. As a result, the onus now lies on all Maldivian stakeholders (regulators and developers) to act in partnership to make this happen. It is designed to be a "living" Guidance Manual and that requires regular planned updates when new data and knowledge on island hydrodynamics and climate change impacts becomes available.

A concerted effort is now needed (initially by the Government of Maldives) to ensure that this takes place and that new information is added to the Manual to help fine tune the performance standards presented within it.

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SECTION 1: INTRODUCTION

1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE GUIDANCE MANUAL

This handbook reflects an overview of the main Guidance Manual produced for this Government of Maldives and UNDP Maldives. A brief overview of the four month piece of work (September 2012 to January 2013 - undertaken by CTL Consult Ltd (UK) on behalf of UNDP Maldives and the Ministry of Energy and Environment (MEE)) is presented. The work has culminated in the production of a brand new set of Guidelines to help the Maldives build climate change resilience into future coastal protection design and construction.

The production of these guidelines represents a 'component' of a larger project entitled "Integrating Climate Change Risks into Resilient Island Planning in the Maldives - ICCRRIP". The purpose of the ICCRRIP project (which is a collaborative effort between the Government of Maldives (GoM), the Global Environment Fund (GEF) and the United Nations Development Program (UNDP)), is to ensure that climate change risks are integrated into resilient island planning in the Maldives and that national, provincial; atoll and island authorities and communities are able to prioritize and implement climate change adaptation measures. Its overall goal is to increase the resilience of the Maldives in the face of the climate change and improve the country capacity to respond effectively to climate related hazards.

The "Formulation of Guidelines for Climate Risk Resilient Coastal Protection in the Maldives" is a core component of the larger ICCRRIP project. The scope of this deliverable is, therefore, to formulate a guidelines document for climate risk resilient coastal protection planning in the Maldives including coastal infrastructure development, dredging and land reclamation, beach replenishment, harbour development, coastal erosion prevention, improvement and creation of access to the islands through reefs, over water structure construction and other coastal developments. Common overarching "themes" considered throughout the guidance manual cover environmental sustainability, economic development and livelihood security.

1.2 WHY IS A GUIDANCE MANUAL NEEDED?

Currently in the Maldives, there are no written guidelines on how to build climate change resilience into existing and future designs for coastal erosion control, land reclamation or harbour development. In addition, Environmental Impact Assessment (EIA) requirements and land use and coastal planning regulations are very generic in terms of the specific engineering and planning guidance advice provided to the private and public sector on "climate proofing" coastal protection structure design. Various studies, such as Detail Island Risk Assessment in the Maldives (DIRAM), make recommendations on good and bad engineering practices, though there is no one report specifically prepared to provide "step by step" advice on how to build, inform on environmental consenting requirements and educate island stakeholders (private sector, regulators and island communities) about how to instill climate change resilience into future planning and contemporary construction practices for coastal protection schemes, harbour structures/design and land reclamation projects.

In addition, the potential to make better use of soft coastal engineering techniques (sand as beach nourishment etc) in the Maldives is required from an economic and environmental sustainability perspective. Within many small island states, there has been increased pressure to introduce more soft engineering schemes, often as part of combined integrated defence systems with more traditional hard techniques. The 2004 tsunami provided significant lessons on the appropriate use of these approaches on different island systems, with mixed success. To this end, a more focussed view on the appropriateness or such techniques is now needed for specific islands as part of a comprehensive set of guidelines.

The focus of this Guidance Manual is therefore on coastal engineering adaptation and resilience of coastal protection infrastructure to climate change, rather than mitigation of climate change effects on the coast through energy efficiency or carbon emissions reduction. It is about ensuring that current and future coastal protection schemes can cope with climatic changes predicted for the future. it is designed to identify ways to ensure that coastal protection techniques (hard or soft) and associated backing infrastructure can be made resilient against climate change threats in a cost-effective way. It will cover the engineering aspects of adaptation, as well as those regulatory and social responses, including expectation management, required to ensure that engineering solutions can be effective.

1.3 DEVELOPMENT OF THE GUIDANCE MANUAL

Information for the guide was obtained from the following sources (see Figure 1.1). The first was from a literature review of other available guidance and documents providing accounts and lessons learnt from the use of hard and soft coastal engineering schemes with particular reference to small island states. The second source was a focused field exercise to 6 Maldivian Islands to learn about the coastal protection challenges on outer islands and the engineering design challenges that contractors are faced with. Thirdly, a practitioner workshop was carried out to obtain information and feedback on the lessons and performance issues associated with climate resilience and coastal protection in the Maldives.

Figure 1.1 – Approach to gathering the information for the Guidance Manual

Note: The above approach has identified that there are no guidance documents (globally) that attempt to do what the Maldives has started in this initiative. The common style of "Guidance Manual" for coastal protection schemes relates to "how to build" or "where to place" schemes. This work is different in that it takes this further by providing some simple structure and recommended standard towards thinking about how to "climate proof" coastal protection.

The following section presents the issues and approaches towards how the Guidance Manual addresses the issue of building resilience into coastal protection structures.

SECTION 2: BUILDING CLIMATE RESILIENCE INTO COASTAL PROTECTION

2 Building Climate Resilience into Coastal Protection

2.1 COASTAL PROTECTION AND CLIMATE RESILIENCE IN THE MALDIVES

Vulnerability on the Maldivian coast

There are a number of drivers which are projected to influence the impact of climate change in the Maldives. The strength of the drivers of change on many Maldivian islands are already manifesting themselves in terms of increased coastal erosion of beaches, changes to reef biodiversity and an increase in the frequency of significant storm events (and hence flood risk). Over the last six years, more than 90 inhabited islands have been flooded at least once, and 37 islands have been flooded regularly or at least once a year. More than 97% of inhabited islands reported beach erosion in 2004, of which 64% reported severe beach erosion. More than 45% of the 87 tourist resorts have also reported severe erosion. As a consequence, building resilience on the coast is a high priority.

Coastal Protection and Engineering Resilience in the Maldives

Coastal protection is an important technique for "engineering" resilience in the Maldives. With most of the inhabitants and much of the infrastructure so close to the sea, then the need to protect people and assets is vital. However, coastal protection often involves modifying (or "manipulating") the effect of the external forces on the system. Selected resistance to these hydrodynamic and meteorological forces is a useful tool but must be used in a planned way and in combination with other approaches to building resilience. If coastal protection is used as the climate change response, rather than one of a portfolio of adaptation responses for islands, then adaptive capacity and resilience can be expected to decrease. Resisting climate change effects just by coastal protection becomes even more precarious when the level of "protection" which it provides is as uncertain as the future climatic conditions.

Coastal protection can help contribute to coastal resilience in the Maldives. However, this is somewhat limited by financial resources: conservative calculations estimate US$1.8 billion for coastal protection of 200 inhabited islands if the entire island is protected and US$1.1 billion if the present settlement areas only are considered[1]. Consequently, any approach to coastal resilience needs to use coastal protection in a selective, sparing and efficient way to maximise benefits at minimum cost. To facilitate this there is also the need to develop appropriate policy and decision-making processes to move towards a trajectory in which lead times are appropriated to allow coherent climate proof investments.

The following represent a series of observed engineering and planning challenges that were highlighted during the course of the production of the Guidelines.

[1] Shaig, A. (2011). Survey of Climate Change adaptation Measures in the Maldives. Report prepared for Integrated Climate Change Risk into Resilient Island Planning in the Maldives Project. Ministry of Housing and Environment and UNDP Maldives.

1 – INADEQUATE FEASIBILITY ASSESSMENT	
Island: Dhidhdhoo	**Structure / location:** Revetment / newly reclaimed area in NW.
	
Rock revetment which stretches in total for ~500m made out of 600kg - 1 tonne imported rock.	End of rock revetment showing erosion, revetment collapse and probably ad hoc boulder placement as groins.

Figure 2.1 – Inadequate Feasibility Assessment

A number of observations have been made from the field assessments and local consultation with contractors, engineers and regulators in the Maldives (Figure 2.1). Inadequate feasibility assessment (at the pre-design stage) appears commonplace. Here at Dhidhdhoo, the new rock revetment is experiencing "end structure" collapse due to poor data gathering (coastal hydrodynamics and sediment transport) at the feasibility stage.

2 – POOR ENGINEERING DESIGN	
Island: Dhidhdhoo	**Structure / location:** Revetment / SW coastline
	
Revetment wall completed within last 6 months which stretches around 31ha newly reclaimed land made from 1-3 tonne important rock.	Revetment showing slumping of wall; this decay process likely to continue and subsequently lead to point failure in the revetment.

Figure 2.2 – Poor Engineering Design

Poor engineering design is apparent often on newly reclaimed parts of islands. Whilst rock size availability and cost are known factors of poor design, the end outcome (as shown here in Dhidhdhoo – Figure 2.2)) is often defence "slumping" which creates obvious weak points in the defence for failure in the future.

3 – POOR ENGINEERING CONSTRUCTION	
Island: Thinadhoo	**Structure / location**: Jetty and harbour wall / east side of island in port.
	
Concrete quay wall topped with concrete beam and slipway to ice plant – note the settlement of backfill and the gap between the end of the slipway and the top of the quay wall.	Settlement of backfill and cracking of concrete beam on top of quay wall; this is likely to be exasperated from water flowing over-ground from the ice plant.

Figure 2.3 – Poor Engineering Construction

Poor construction is linked directly to knowledge and awareness of correct international practices (standards) and also the speed imposed in contractors to construct defences. The end outcome of both limitations is the construction of poor structure which when exposed to the marine environment, will degrade and fail quickly (resulting in a costly repair bill! – see Figure 2.3).

4 – INADEQUATE STRUCTURE MAINTENANCE	
Island: Thulusdhoo	**Structure / location**: offshore breakwater / north and east of island, 20-40m offshore.
	
Degraded offshore breakwater (behind boat) made from rock boulders (picture taken at low water).	Inshore of degraded breakwater showing exposed roots of trees on eroded beach (background) and debris dumping in foreground to reduce erosion.

Figure 2.4 – Inadequate Structure Maintenance

Once a structure is built, there is evidence to show that the lack of a formal structure maintenance programme, that follows international standards, constituting towards poor engineering management and structure failure. The example here at Thulusdhoo (Figure 2.4) shows a degraded offshore breakwater which has impacted on shoreline recession rates and has prompted more ad-hoc “temporary” defence measures (rubbish and rubble dumping) on the foreshore to act as a defence.

5 – INADEQUATE DRAINAGE OF RECLAIMED AREAS

Island: Thinadhoo	**Structure / location**: drainage culvert / new harbour on east side of island.
	
Inadequate drainage culvert in newly reclaimed area by new harbour facilities; evidently the culvert backs-up and overtops the road.	New harbour facility prone to flooding – culvert is by the motor-bikes and culvert drainage holes can be seen in harbour wall (picture taken close to high tide).

Figure 2.5 - Inadequate Drainage of Reclaimed Areas

The lack of or poor design of drainage culverts, especially on newly reclaimed islands, can seriously exacerbate flood drainage problems (Figure 2.5). The irony of reclaimed land is that often, communities become more vulnerable to climate change as a result of reclamation projects, mainly due to the land behind being lower in topography and more susceptible to flooding (especially if culvert design is not correct).

6 – LACK OF CRITICAL "SIGN-OFF" AT COMPLETION

Island: Meedhoo	**Structure / location**: new harbour construction / NW side of island.
	
New harbour facility completed by the contractor approximately 6 months early made with concrete "T- or L-section", capping beam and a brushed concrete slab walkway.	Minimal gap between the concrete walkway slabs which has filled with loose sediment grains; lack of expansion space for the concrete slab is likely to lead to cracking.

Figure 2.6 – Lack of Critical "Sign-off" procedures

Formalising quality assurance and contract delivery (for all contractors in the Maldives – national and international) is required. This ensures the quality of the design and also the contracted expectations are addressed by the contractor. Evidence in Meedhoo (Figure 2.6) demonstrates that engineering "sign off" is not achieved with regard to the placement of concrete slabs and poor demonstration of making space for slab expansion.

1 – LACK OF CONSULTATION AND COMMUNICATION	
Island: Dhidhoo	**Problem:** Lack of engagement with Island Council and local users.
	
Erosion of the beach and fallen palm trees close to housing – the newly reclaimed land is further along the coast and starts just out of the picture.	Beach erosion and rapid deterioration of jetty since the new reclamation was completed.

Figure 2.7 – Lack of Consultation and Communication

With regards to planning, there are noted problems that have been identified on many islands, for example, the impact of a recent programme of land reclamation on Dhidhoo (Figure 2.7) has impacted on island dynamics causing erosion downstream. Better engagement with the Island Councils at the planning stage of the reclamation plus learning from locals about sediment and wave patterns around the island may have improved the decision making process and design of the land reclamation scheme.

2 – FRAGMENTED LAND PLANNING	
Island: Meedhoo	**Problem:** lack of integrated planning reduces coastal resilience for critical infrastructure.
	
SW end of new harbour development showing end of revetment and then eroding area protected by large ~10 tonne concrete blocks.	New diesel storage tanks being built behind revetment (in foreground) and eroding area; highly exposed to coastal flooding and no anti-flood bund.

Figure 2.8 – Fragmented Land Planning

Finally, fragmented land planning is evident on many islands. Downstream erosion of a large harbour development on Meedhoo is now causing erosion problems, but previous planning decisions to locate diesel storage tanks in what is a now “hazard risk” area have not been taken into consideration. This is one of many examples of a fragmented land planning system that does not consider climate resilience.

2.2 THE COASTAL PROTECTION TECHNIQUES CONSIDERED

The focus of the Guidance Manual is on providing a review of all appropriate coastal protection techniques and their capacity to be designed or adapted to address climate change resilience. It relates to a range of possible hard and importantly, soft measures spanning the conceptual cross section of most Maldivian islands (see Figure 2.9). The purpose of this Guidance Manual is not to provide a detailed "text book" narrative review of all coastal protection techniques that are possible in the Maldives. The work of Shaig *et al* (2011) is recommended for review on that regard.

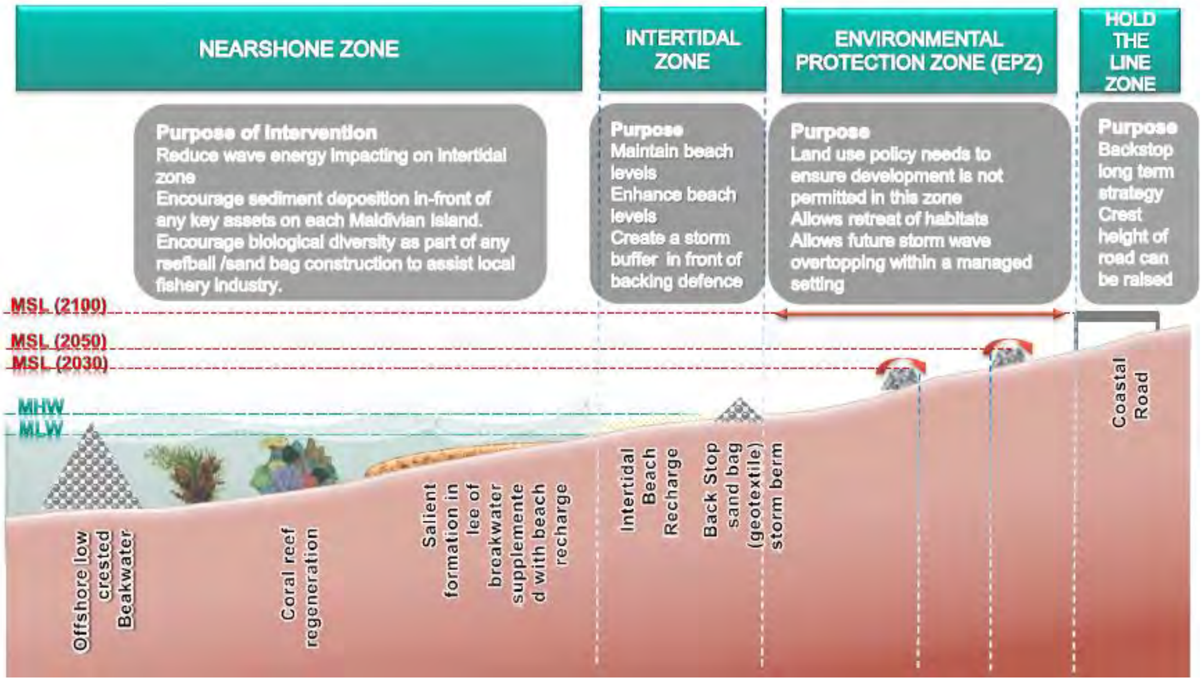


Figure 2.9– Indicative soft coastal protection measures that may (or could) occur on most Maldivian islands

Particular focus is instead provided on presenting a succinct analysis of the climate resilience implications existing and future coastal protection works, so that answers to the following questions may be sought by GoM and private developer contractors for future revisions on this Guidance Manual:

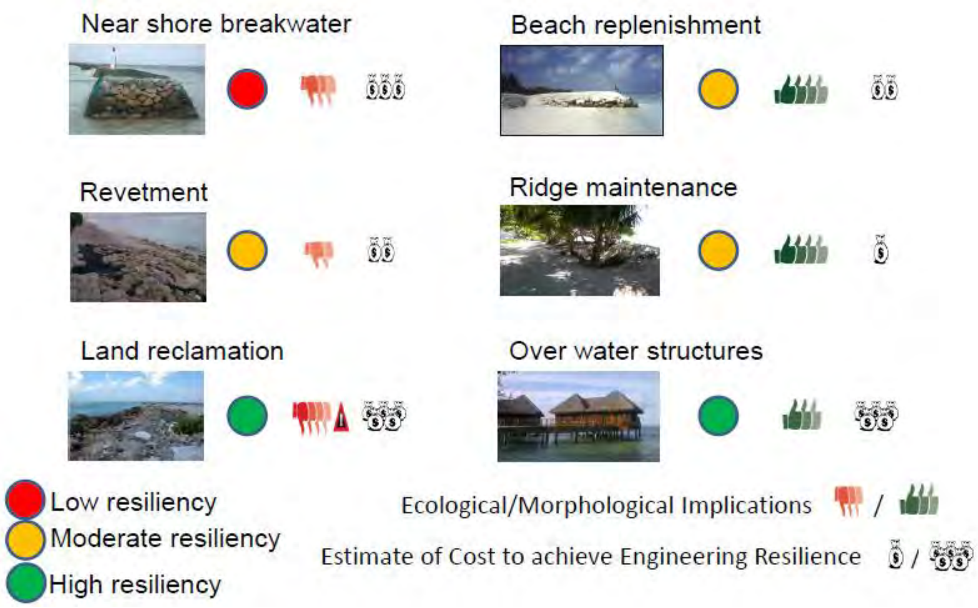
- Can "new build" hard structure approaches be designed as being "climate change resilient"? *(if not, why and what "knowledge" or information is needed to achieve this?);*
- Can "new build" soft structure approaches be designed as being "climate change resilient"? *(if not, why and what "knowledge" or information is needed to achieve this?);*
- Can "new build" hard structure approaches be designed in parallel (or in conjunction) with soft measure approaches to improve "engineering resilience to climate change" *(if so, which measures are most complimentary and achievable in a Maldivian context and why?);*
- What Accommodation Approaches (i.e.: non engineering) are needed to create the necessary enabling environment for the implementation of improved engineering resilience to climate change? *(and over what time-scale is this likely to be achieved in i.e.: 0-5 years and 5-25 years).*
- Linked to the above, can dual-use infrastructure schemes be designed? *(and what studies or research is needed to achieve this?).*

Appendix A outlines in more detail the types of coastal protection techniques that the Guidance Manual considers. An “engineering” resiliency “score” is also provided for each technique to give an indication of the CURRENT technical resiliency of the specific structure to climate change (i.e. how the structure is currently being designed and built). This score is categorised as follows:

- **low engineering resiliency** – regardless of cost, the design has limited capacity to accommodate increased coastal hydrodynamic energy increases (waves/current) without significant design alterations or re-engineering needs and materials commonly used in its design have limited ability to be “adapted” to accommodate change in climatic conditions/seasonal sediment movement patterns with relative ease.
- **moderate engineering resiliency** – the design has potential capacity to accommodate increased coastal hydrodynamic energy increases (waves/current) without significant design alterations or re-engineering needs and materials commonly used in its design have limited ability to be “adapted” to accommodate change in climatic conditions/seasonal sediment movement patterns with relative ease.
- **high engineering resiliency** – regardless of cost, the design is easily able to accommodate increased coastal hydrodynamic energy increases (i.e.: waves/current) and materials commonly used do have the ability to be “adapted” to accommodate change in climatic conditions/seasonal sediment movement patterns with relative ease (i.e.: more material to increase defence crest level or floor “build” levels”.

Figure 2.10 outlines a summary version of Appendix A, showing 6 sample coastal protection techniques, plus an indication of its current engineering resiliency score (i.e.: land reclamation is score as being of “high” engineering resiliency as it is relatively straight forward to engineer a robust scheme that would be resilient to climate change impacts (i.e.: increase its floor level height etc by dredging more material etc). Symbols are also provided to provide a strategic consideration of the techniques environmental resilience (likely long term impacts)) and its estimated cost for construction.

Figure 2.10– Indicative resilience “scores” for 6 coastal protection measuresThe Guidance Manual goes into



detail (in Chapter B3) to declare how easy it could be to adapt its design (as an individual scheme or as part of a collective scheme of a few techniques) to improve the resiliency “score” (i.e.: from a “red” to “amber” score etc). To achieve an improved "score", this may be achieved through adopting one of four "management approach options" as follows:

- **Option 1**: Modification of individual structure design (i.e. pre-construction) to improve individual structure performance *(ie: focus on the structure design prior to construction);*
- **Option 2**: Modification (retrofitting) of existing adjacent hard structures (that are already in situ) to improve overall scheme performance*;*
- **Option 3**: Using soft structure measures to help modify existing *adjacent* structure strategic design to improve overall coastal protection performance *(ie: focus on merging hard with soft measures as part of an integrated scheme);*
- **Option 4** – Modification and review of land use planning *(ie: focus on accommodation measures, strategic placement of key features on an island and to reduce key infrastructure in "at risk" locations).*

The Guidance Manual (Chapter C1) sets out clearly a new set of performance standards to help the delivery of various options and hence the design of new climate resilient coastal protection schemes. It also clearly sets out a series of Standards of Protection (SoP) that should be adhered to that reflect the assets at risk behind the structure being designed. The SoP will be ultimately influenced by the land use and livelihoods (commercial or residential) that the defence is protecting. Chapter D2 addresses this issue with regard to the recommended updates to existing land use regulations in the Maldives and the selection of the most appropriate SoP that should be adhered to.

Option 1 - Modification of individual structure design (pre-construction)

This management approach option relates to the ability to engineer performance improvements (at the design stage) to better address climate resilience. Figure 2.11 outlines a conceptual approach to modifying an individual structure (seawall – hard structure measure) by increasing its SoP from a 1 in 5 year defence standard to a 1 in 50 defence standard through the incorporation of a splash wall "added" to the existing crest of the seawall. The structures SoP is significantly increased with the introduction of floodgates (or de-mountable flood barriers – see Section 2.2.6) in front of the structure.

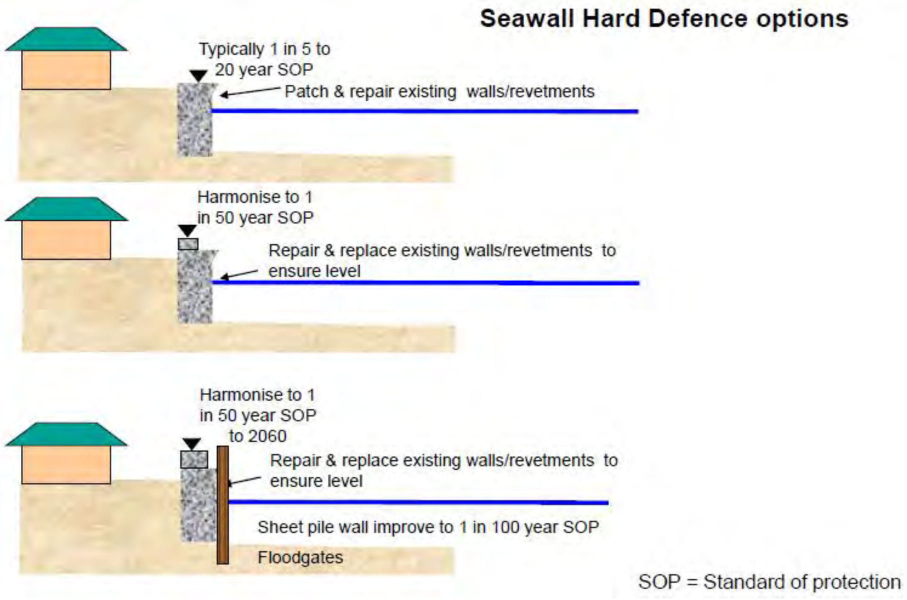


Figure 2.11 – Conceptual cross sections to demonstrate how to increase climate resilience to protect housing

The key message from Option 1 is that once a preferred technique is selected (see Chapter B4), the integration of other supporting techniques or "add-ons" to the design can significantly improve its SoP.

Option 2 - Modification (retrofitting) of existing adjacent hard structures

This management approach option relates to "retrofitting" ADJACENT structures that maybe located close by to the proposed "footprint" site of the new scheme under discussion. Examples could include the re-positioning of a groyne field to better improve sediment drift to new locations. It could also include the example of altering the SoP of a seawall that is adjacent to a newly proposed harbour breakwater that is proposed for construction (i.e.: potential for increased alterations to tidal currents or increased risk of wave overtopping). The example presented in Figure 2.12 is that of a lower cost rock filled gabion basket structure. Gabion basket defences can be "retrofitted" to raise the crest level to improve the SoP (as shown in Figure 2.12), the material (rock) used to place into the baskets can improve resilience, along with the wire mesh that is used and the "angle" at which the gabion baskets are actually placed..

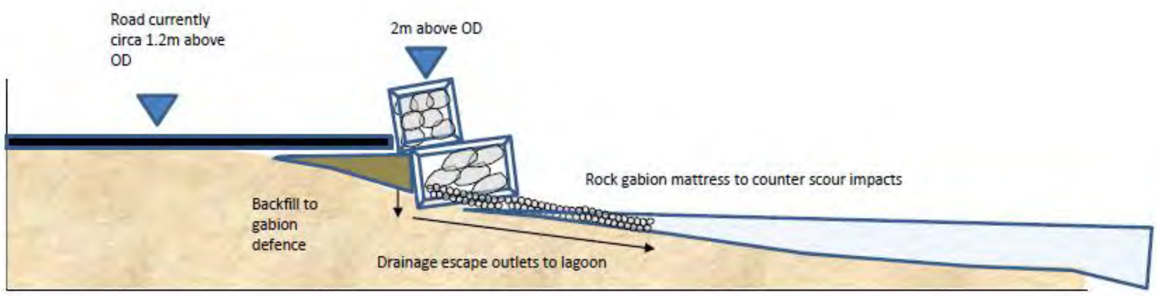


Figure 2.12 – Retrofitting a coral rock gabion structure

Option 3 - Using soft measures to help modify existing *adjacent* structure strategic design

This management approach option relates to the use of soft structure strategic thinking through the modification of adjacent structures. The most appropriate example of this option) with specific relevance to the Maldives) is in the design of individual groynes and groyne "fields". Engineering a resilient approach to this problem is important in the Maldives, and techniques are proposed for consideration and piloting (using modular approaches to groyne construction and design – see Figure 2.13).

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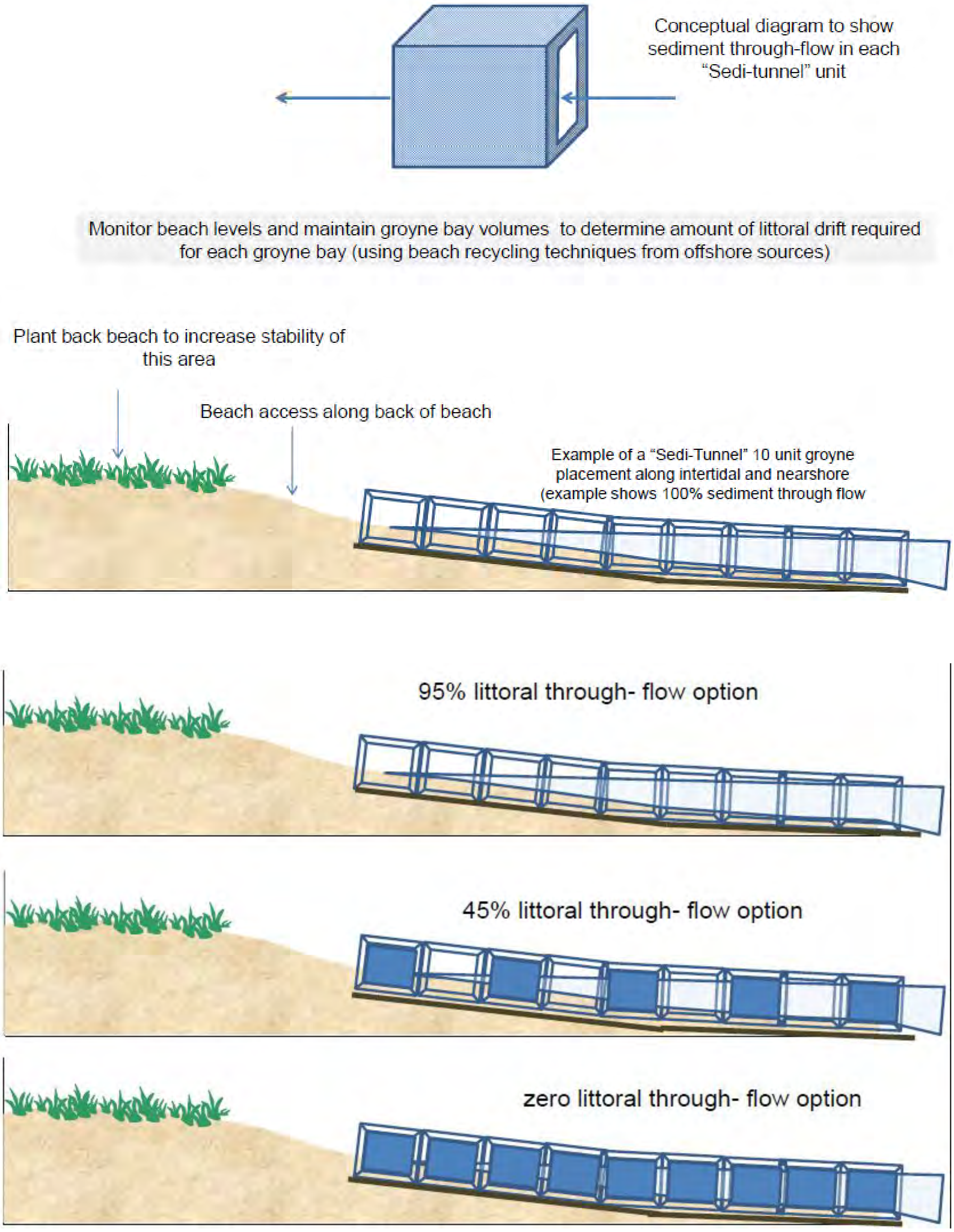

Figure 2.13– Groyne design options to help manage monsoonal sediment movements around islands.

Option 4 Modification and review of land use planning

This management approach option relates directly to planning for a change and is applied in situations where there are no immediate benefits in investing in expensive coastal engineering schemes on an island (or part thereof). Part D (Chapters D2, D3 and D4) of the Guidance Manual are then of relevance for Island Councils and GoM planners to consider with regard to compliance to existing Land Use Planning Regulations in the Maldives and update advisories to current set back policy.

2.3 CHOOSING A PREFERRED OPTION

The Guidance Manual provides support to help with decision making on whether to pursue hard of soft coastal protection techniques. Figure 2.14 presents a simplified "decision tree" diagram, tailored specifically for the Maldives..

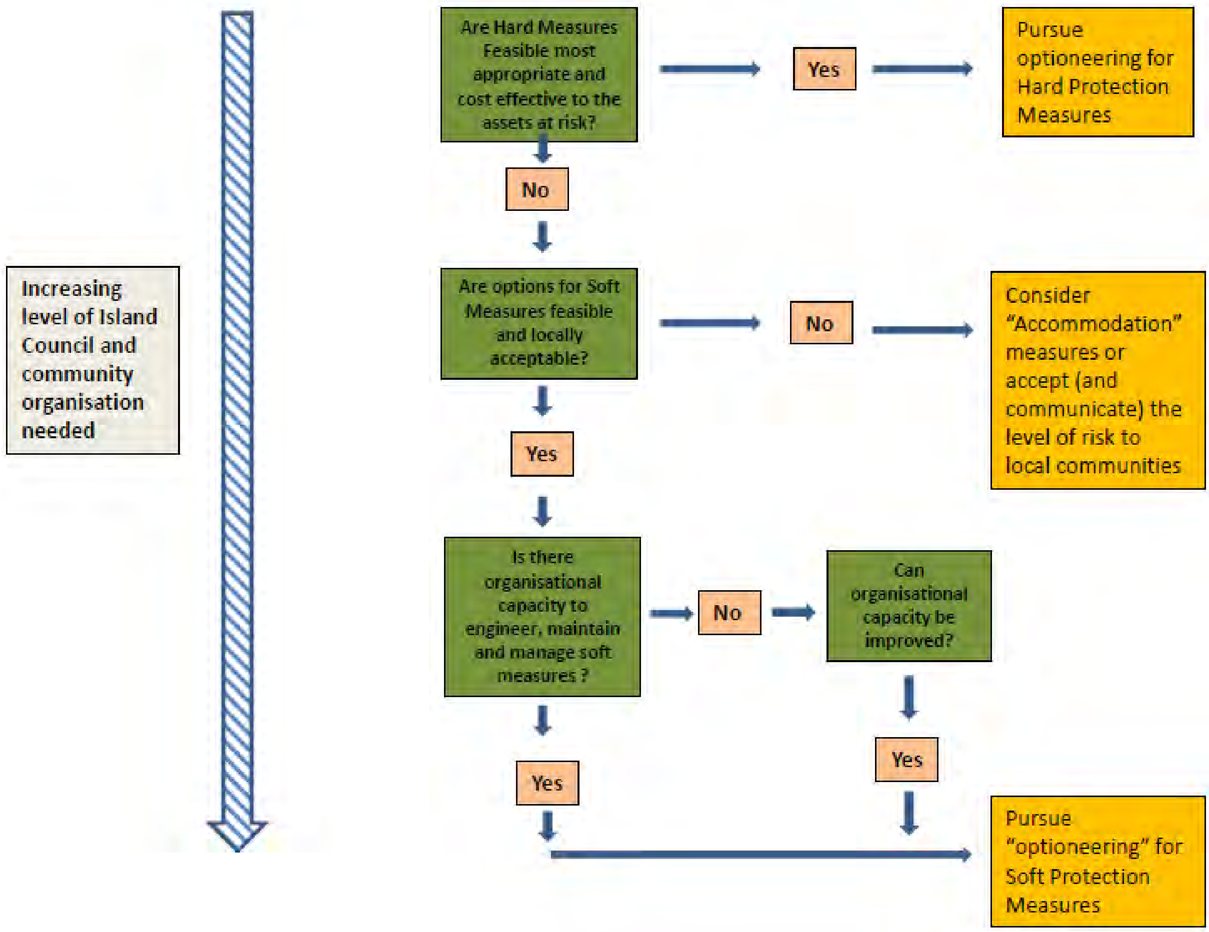

Figure 2.14 – Decision tree to help select between hard and soft option approaches

Once the above Decision Tree has been followed, another is prepared (Figure 2.15) that can be used at a strategic level to help identify the selection of individual coastal protection techniques to address climate resilience for coastal protection on Maldivian islands. Engineering details (performance standards, information requirements, design and material standards associated with these interventions) are then categorised and presented in Part C of the Guidance Manual.

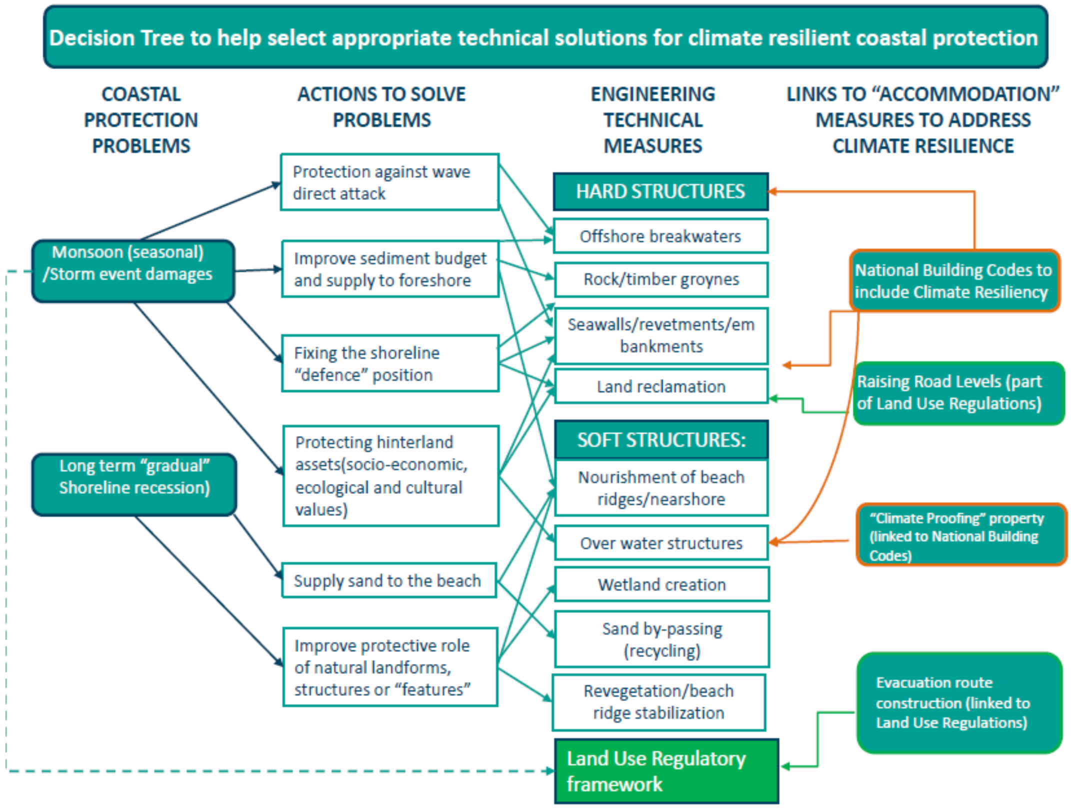

Figure 2.14 Decision Tree for the selection of appropriate technical solutions in the Maldives.

2.4 THE DESIGN AND MATERIAL STANDARDS CONSIDERED

The design of structures for coastal protection should be made in consideration of their intended performance standards. From an engineering perspective, these standards relate to the achievement of the structure purpose such that it has the desired outcome and effect; in this case the provision of coastal protection that confers climate change resilience to islands and their communities. From a planning perspective, performance standards relate to the desired level of protection and the duration protection should be provided for.

Performance *Standards* for climate risk resilient coastal protection structures[2] provide criteria against which the performance of the services they provide can be evaluated in terms of the ***durability*** of the structures and the ***level*** of protection they will provide. The performance standards describe the nature of activities that will be required in order to determine a measure of requirements for durability and level of protection.

The Engineering design performance standards proposed for coastal protection structures in the Maldives are based on those provided by the British Standard, American standard and EN Eurocodes. They are adapted to reflect Maldivian needs and situations (where possible or where available information allows this to be dictated). They have an objective of ensuring a uniform level of building quality to ensure fitness for purpose. The standards that have been used and the resultant recommendations for performance standards of materials and structures are given within Part C of the Guidance Manual.

The two performance standards that the Guidance Manual proposes for application are as follows:

- Design standard details for coastal protection structures (see Chapters C3.1 and C3.2);

[2] For the purposes of this Code, 'coastal protection structures' is deemed to include any form of hard or soft engineering intervention and includes harbour, jetty and overwater structures.

- Material standard details for coastal protection structures (see Chapter C4).

Both fall within the framework of the Environmental Protection and Preservation Act of Maldives (Act No. 4/1993) and the provision contained therein for Environmental Impact Assessment (Environmental Impact Assessment Regulations, 2007).

The performance standards aim to ensure a pre-determined standard of protection (see Chapter B3) to island assets and communities from the increased risk of inundation (flooding) and loss of land presented by climate change scenarios is met.

The performance standards shall be applied to the design, build, monitoring and maintenance (see Part E) of all coastal protection structures constructed to contribute resilience to island assets and communities from the risks presented by climate change. The performance standards shall also apply to all locations where new development (including harbours and land reclamation), takes place and at locations where erosion[3] control/management is required.

Design Standards have been prepared for the following hard coastal protection measures (see Part C; Chapter 3.2a):

- Land Reclamation Guidelines

- Harbour development (dredging, quay wall and breakwater development)

- Coastal Erosion Protection Guidelines (erosion prevention measures)

- Access improvement to the Islands Guidelines

- Over-water Structure Guidelines

Design Standards have been prepared for the following soft coastal protection measures (see Part C; Chapter 3.2b).

Beach Replenishment Guidelines

Coastal Erosion Protection Guidelines (Soft Measures)

Flood Prevention Structure Guidelines

[3] For the purposes of this Code it is acknowledged that not all erosion is a direct consequence of climate change but it is accepted that climate change will exacerbate existing erosional forces in addition to leading to new erosional pressures.

Material standards are prepared in some detail for the Maldives (see Part C; Chapter 3.3).

- AGGREGATE MATERIAL
- DREDGING AND RECLAMATION
- EROSION AND SEDIMENTATION CONTROL - RIP RAP
- GEOTEXTILES AND IMPERMEABLE BARRIERS
- ROCK AND REVETMENT
- BEACH CREATION
- REINFORCED CONCRETE VERTICAL EDGE STRUCTURES
- CONCRETE FORMWORK
- CONCRETE REINFORCEMENT
- CAST IN PLACE CONCRETE
- PRE-CAST CONCRETE

2.5 PLANNING CONSIDERATIONS

In addition to providing engineering advice, the Guidance Manual focuses on providing updates to existing planning regulations in the Maldives. It presents updates to regulatory text a simple way to incorporate climate change into the existing environmental regulatory structures in the Maldives. This is needed as at present in the EIA process, it is an implicit assumption that the impacts of developments are “static” through the planning horizon. However, projections indicate that climate change will increasingly affect certain aspects of the environment over time and thus this “static” model becomes less valid in some cases. As such, it is proposed to build in estimates of climate change into the assessment of impacts in order to accommodate projections and “climate proof” the EIA process so that future coastal protection selection and their designs become as robust as possible.

The Guidance Manual promotes the use of Vulnerability Assessment (VA) within land use planning for Maldivian islands. The VA should determine erosion/ inundation areas (using specialist advisors with expertise in physical coastal processes. The outcome shall be clearer understanding hazards and their nature and erosion/ inundation area assessments that would comprise of assessing extreme coastal water levels, better understanding current mean sea level heights on each island (critical) and from this, undertake inundation modelling and mapping exercises. The outputs (maps etc) shall be used within future revisions and update to island land use plans).

The Guidance manual also identifies current planning periods for different types of development in the Maldives, and how these planning periods need to consider different expected sea level rise rate scenarios (see Tables below).

TYPE OF DEVELOPMENT	PLANNING PERIOD (BASED ON ANTICIPATED ASSET LIFE
Short-term tourist accommodation	25 years
Residential dwelling, prefabricated structures	25 years
Residential dwelling, concrete structure	40 years
Utility infrastructure	35 years
Industrial building	30 years

Assessment factors for determining flood/erosion prone areas and storm-tide inundation areas.

END YEAR OF PLANNING PERIOD	PROJECTED SEA LEVEL RISE RELATIVE TO 2000 BASELINE
Year 2030	0.2 metres
Year 2040	0.3 metres
Year 2050	0.4 metres
Year 2060	0.5 metres
Year 2070	0.6 metres
Year 2080	0.7 metres
Year 2090	0.8 metres
Year 2100	0.9 metres

Planning period for development to be defended by coastal protection structures.

NB: Note that sea level rise is not predicted to rise on a linear trajectory, but on an exponential trajectory. By using a linear rise of sea level, a 'safety' margin to cover the current high uncertainty of predictions is built into planning process

The following section presents the overview to the structure of the Guidance Manual, how to use the Manual and its likely audience.

SECTION 3: HOW TO USE THE GUIDANCE MANUAL

3 The Guidance Manual

3.1 USERS OF THE GUIDE

A key theme in the development of this Guidance Manual is that integration of efforts across sectors and with various organizations is a prerequisite to building coastal resilience. The Manual is therefore prepared in a manner that allows all stakeholders to make informed choices concerning the selection, design, engineering and build of coastal protection structures. The guide is intended for:

- **technically competent persons** from organisations or groups with responsibilities or need for the planning and design and operation of coastal protection measures, and their advisers. Such users include asset managers, emergency and civil contingency planners and responders, appraisers and designers of coastal protection schemes, island developers and local community groups.
- **developers and contractors** (and other organisations) involved with the development or improvement of coastal protection schemes.

The anticipated users of the Guide (defined as "User Groups"), and why the Guide is to be beneficial to them is set out below in Table 3.1 (a simple flow chart detailing the flow of different users and the relevant parts of the manual associated with each option) and Table 3.2.

Question	If Y	Then
Are you involved in enforcing existing regulations (land use / environment) or building codes?	You are User Group **2**	Focus on Parts **A**, **B**, **C**, **D** and **E**
N ↓ Does your work involve being contracted to design or construct coastal protection schemes?	You are User Group **3**	Focus on Parts **A**, **B**, **C** and **E**
N ↓ Does your work involve having to comply to existing land use and environmental regulations?	You are User Group **4**	Focus on Parts **A**, **B**, **D** and **E**
N ↓ Does your work involve making island or atoll level decisions on policy implementation?	You are User Group **5**	Focus on Parts **A**, **B**, **D** and **E**
N ↓ Does your work have to consider monitoring coastal protection, contracts or outcomes?	You are User Group **2** or **5**	Focus on Parts **C** and **E**
N ↓ Are you a community or an NGO working on islands?	You are User Group **6**	Focus on Parts **A**, **B** and **E**

USER GROUP NUMBER	USER GROUP DESCRIPTION	BENEFIT OF THE GUIDE TO THE USER GROUP
User Group 1	GoM Permanent Secretary (high level decision makers);	Help to provide strategic advice on national island development planning.
User Group 2	GoM technical managers (middle management practitioners);	Help to provide technical guidance on engineering best practice and environmental regulatory compliance to existing laws and building code regulations.
User Group 3	Private sector (engineering contractors);	Help to provide guidance on engineering design delivery, achievability of contract standards (for land reclamations etc) and the preparation of tender specifications.
User Group 4	Private sector (international and national island developers);	Help to provide information on the required regulatory requirements prior to the selection of islands for a specific land use (e.g.: tourism).
User Group 5	Island Councils;	Help to equip Island Councils with the informed knowledge to "when and how" to make correct choices with respect to coastal engineering adaptation and maintenance. For example, Island Councils should (through focused training) be able to better intervene on matters such as i) how to undertake minor maintenance issues; ii)how to adjust groyne field designs or iii) how to move modest quantities of beach sediments.
User Group 6	Community leaders.	Help to advice communities on self-help strategies to address flood risk and also to inform communities on approaches for shoreline change observations and monitoring.

Table 3.2- User Groups and benefits they will receive from the Guidance Manual

3.2 STRUCTURE OF THE GUIDE

The Guidance Manual takes a user through a systematic process from understanding climate resilience in the context of coastal protection decision making and also whether the use of soft or hard engineering schemes systems are appropriate for particular island situations. The Guide presents clear performance standards and design criteria, that should be followed (adhering to international standards) to offer appropriate solutions for specific situations. It then provides guidance on optimising the delivery of improved climate resilience in coast protection designs through proposing updates to existing environmental legislation and taking other local, economic, environmental and whole life management issues into consideration to enable designs to be agreed and finalised.

NB: This Guidance Manual is designed to be a "living document", and one that will need to be updated as new information and experiences are learned from new coastal protection structure performances and improved observations and monitoring of coastal systems around all Maldivian islands. Its design enables specific sections to be updated as more knowledge and data is made available in the coming years along with the opportunity to "Maldivianise" the design and material standards (see Part C) as more experience develops in country.

The Guidelines Manual is presented into a number of colour coded "Parts" and supporting "Chapters" as set out in Figure 3.1 The pages of each Part have an equivalent colour tab on the top right of each page.

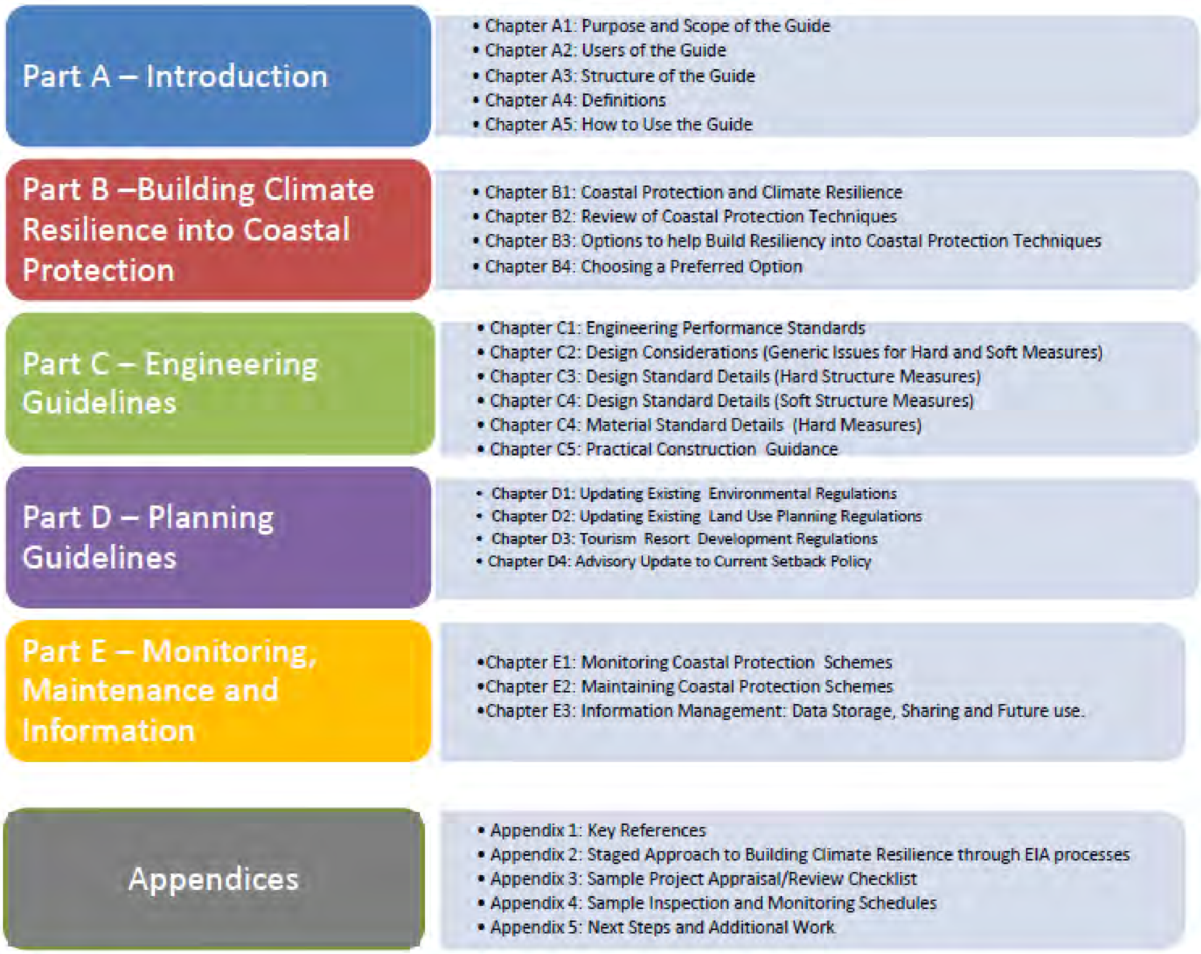

Figure 3.1 Structure of the Guidelines

The intention is that the Guide will help in the "next step" implementation of the following ICCRIP demonstration projects

- Kulhudhuffushi – Strengthen natural ridge system 2.5km and redesign drainage system to reduce flood risks
- Thinadhoo – Restoration of 1.2km of natural ridge system. Re-vegetation of 47,000sq.m of EPZ. Redesign drainage system to reduce flood risks.

APPENDIX A – BUILDING ENGINEERING RESILIENCE INTO COASTAL PROTECTION SCHEMES

Hard and Soft Measure Approaches (Erosion Mitigation Measures)

MEASURE TYPE	MEASURE HEADING	KEY PURPOSE	RESILIENCY IMPLICATION (0-5 YEARS)	RESILIENCY IMPLICATION (5-25 YEARS)	RESILIENCY "SCORE"	OPTIONS TO IMPROVE RESILIENCY SCORE (SEE CHAPTER B3)	IMPACT ON ISLAND DYNAMICS	COST
Seawall/bulkhead 	Hard	Armouring structure	Assessment of overtopping frequency (averaging 0.5 – 1m above high tide) and from this, maintain standard of protection levels as dictated by the backing land use or assets at risk. Immediate actions may include engineering a crest splash wall of circa 0.3m height.	Likely upgrade to the standard of protection afforded by the structure (increase crest level height – circa 0.5m). Possible re-setting of sheet piles if being undermined.		Option 1 Option 3		
Foreshore Breakwater (rock, concrete filled barrels or nylon geo-bags) 	Hard	Shore stabilisation	Possible increase in crest height (usually designed to be circa +2m in crest height) which may be an extra level of geo-bag or rock. Decision likely to be based on an assessment of the sediment accretion volumes generated by the structure and whether accreted sediment is making the structure more robust (i.e: part buried etc).	Depending on material used for breakwater. Rock being more resilient to wave energy than nylon bags). Possibly removal, relocation or re-design of the structure to better afford protection to assets at risk. Possible sediment recycling/redistribution if structure is proving too effective in accreting sediment volumes. Geo-bag (nylon bags) revetment most likely have to be upgraded with new bags.		Option 1 Option 2 Option 3		
Near shore breakwater 	Hard	Shore stabilisation	Commonly used in high energy zones. As a result, short term resiliency is dependent on material used for construction (geo-bag, rock, coral boulder, sand cement plastered bags etc). Mesh likely to require replacement on coral boulder breakwaters on ocean side within 5 years). Design impacts on wider hydrodynamic regime make this structure poor in terms of wider resilience to the coastal environment.	With no formal design criteria, there is a high risk of toe failure within this time period and so structure resiliency is predicted to be weak and in need of structure re-build. Crest height will need re-designing to counter water level fluctuations and to improve performance. Whilst structure can be designed to be robust, its wider impact on sediment dynamics over longer time scales makes this not a preferred option form climate resilience unless properly constructed and designed at the outset.		Option 1 Option 2 Option 3		

Revetment 	Hard	Armouring structure	Sand cement bag revetments (e.g.: on Hulumale showing signs of "blow out" see image) will need constant maintenance. Concrete interlocking "S" or "Z" block revetments are more modular in their design and hence more resilient to accommodate change. Maintaining standard of service is dependent upon revetment material being available on island (resiliency of structure may therefore be jeopardised as a result if material is needed via importation). The success of the structure on Hulumale is partly due to the "space" being available for the structure. This doesn't apply to many smaller islands foreshores.	Modular "block" type revetments (not made of coral boulders or sand) are more durable and robust and hence more resilient to climate change. Increasing slope angle or crest height may be required in this time epoch depending on fronting beach condition. Replacement of geotextile membrane likely (see image opposite) within this time epoch. Lack of "side" protection will reduce the resiliency of any revetted structure and hence will require engineering intervention at some time in the future (if not present at the start).		Option 1 Option 2 Option 3		
Groynes 	Hard and Soft (depending on materials used)	Shore stabilisation	Depending upon material used for construction, short term resiliency can be accommodated into regular maintenance programmes. The initial groyne field spacing strategy is most likely "ad-hoc" and not strategically planned on any island. Short term beach volume impacts are most likely the result of poor groyne field placement on most islands.	Coral boulder groynes can be re-designed to capture more sediment transport around islands by extending their length into the house reef area. Availability of material is dependent upon this strategy. The longer term impact of this approach is likely to result in downsteam beach erosion especially if sediment budgets are in a net loss phase. Sand (moveable) groynes are less resilient to storms, but provide a better "shoreline management" resilient approach.		Option 1 Option 2 Option 3		
Adhoc Reclamation 	Hard	Erosion control/prevention	Continued use of solid waste or reclamation "spoil. Often this is never consolidated and is easily dispersed by high tides. Not a resilient coast protection option	No inherent resilience associated with this option long term.		Option 3		

3.2.1 Hard and Soft Measure Approaches (Island Access Infrastructure)

MEASURE TYPE	MEASURE HEADING	KEY PURPOSE	RESILIENCY IMPLICATION (0-5 YEARS)	RESILIENCY IMPLICATION (5-25 YEARS)	RESILIENCY "SCORE"	HOW TO IMPROVE RESILIENCY SCORE (SEE CHAPTER B3)	IMPACT ON ISLAND DYNAMCS	COST
Quay Wall 	Hard	Access infrastructure	As this structure is built purposely for access needs, issues surrounding short term resilience have to be directly linked to maintaining its standard of service to wave overtopping. In the short term, this refers to regular maintenance of the structure and any engineering modification needed to ensure its performance (to continually ensure island access) is maintained. Their impact on wider island geomorphological processes (exacerbating coastal erosion) has to be linked to the mitigation measures set out in the EIA. Methodological "standards" taking forward more strategic shoreline management should be implemented prior to its construction.	As a structure (in this time epoch) it is likely to be resilient to climate change, assuming this is made of robust materials that can be replaced/added to as part of a regular maintenance schedule. The fact that it is a "fixed" feature, also equally makes this of "low resilience" to climate change. Its resilience as a strategic measure to counter wider climate impacts is questioned though has to be linked to the mitigation measures set out in the EIA. Methodological "standards" taking forward more strategic shoreline management should be implemented prior to its construction.		Option 1		
Harbour Breakwater 	Hard	Access infrastructure	As this structure is built purposely for access needs, issues surrounding short term resilience have to be directly linked to maintaining their standard of service. In the short term, this refers to regular maintenance of the structure and any engineering modification needed to ensure its performance (to continually ensure island access) is maintained. Their impact on wider island geomorphological processes (exacerbating coastal erosion) has to be linked to the mitigation measures set out in the EIA. Methodological "standards" taking forward more strategic shoreline management should be implemented prior to its construction.	As a structure (in this time epoch) it is likely to be resilient to climate change, assuming this is made of robust materials that can be replaced/added to as part of a regular maintenance schedule. The fact that it is a "fixed" feature, also equally makes this of "low resilience" to climate change. Its resilience as a strategic measure to counter wider climate impacts is questioned though has to be linked to the mitigation measures set out in the EIA. Methodological "standards" taking forward more strategic shoreline management should be implemented prior to its construction.		Option 1 Option 4		
Entrance Channel Protection	Hard	Access infrastructure	As this structure is built purposely for access needs, issues surrounding short term resilience have to be directly linked to maintaining their standard of service. In	As a structure (in this time epoch) it is likely to be resilient to climate change, assuming this is made of robust materials that can be		Option 1 Option 4		

			the short term, this refers to regular maintenance of the structure and any engineering modification needed to ensure its performance (to continually ensure island access) is maintained. Their impact on wider island geomorphological processes (exacerbating coastal erosion) has to be linked to the mitigation measures set out in the EIA. Methodological "standards" taking forward more strategic shoreline management should be implemented prior to its construction.	replaced/added to as part of a regular maintenance schedule. The fact that it is a "fixed" feature, also equally makes this of "low resilience" to climate change. Its resilience as a strategic measure to counter wider climate impacts is questioned though has to be linked to the mitigation measures set out in the EIA. Impacts on nearshore reef habitats (footprint of protection placement)etc are most likely impacted upon over the longer term.				

3.2.2 Hard and Soft Measure Approaches (Measures to reduce land shortage and coastal flooding)

MEASURE TYPE	KEY PURPOSE AND MEASURE TYPE	RESILIENCY IMPLICATION (0-5 YEARS)	RESILIENCY IMPLICATION (5-25 YEARS)	RESILIENCY SCORE	HOW TO IMPROVE RESILIENCY SCORE (SEE CHAPTER B3)	IMPACT ON ISLAND DYNAMICS	COST
Land Reclamation 	Reduced land shortage (Hard measure)	Actual engineering effort to make land higher is relatively simple, assuming appropriate materials are available at suitable costs. However, unless formal "protection" measures are provided to the newly reclaimed land, the resiliency of the operation (even in the short term) is likely to be reduced (ie: edge treatment works etc).	Assuming protection measures are provided to the land reclamation area (i.e. measures identified in Section 3.3.2) then the resiliency of the land reclamation exercise (to climate change) is high. Otherwise, the short term epoch implication will be reduced.		Option 1 Option 4		
Bridge / causeway	Reduce land shortage / coastal flooding Hhard measure)	Assuming causeways are built to enable water flow (i.e.: on piers/with ducts) then the short term resiliency of the structure AND the impact on adjacent islands is reduced (though not classified as "low"). If the causeway is solid, thus impacting on natural hydrodynamics, then the ability to engineer resilience basically means the causeway is built to a higher crest level, though at major negative impact on the natural water flow around the island.	Assuming causeways are built to enable water flow (i.e.: on piers/with ducts) then the short term resiliency of the structure AND the impact on adjacent islands is reduced (though not classified as "low"). If the causeway is solid, thus impacting on natural hydrodynamics, then the resiliency of the structure is low (as per the short term epoch outcome).		Option 1 Option 2 Option 3 Option 4	(if a solid structure).	

3.2.3 Hard and Soft Measure Approaches ‘Quick fix’ measures (short-timeframe)

MEASURE TYPE	KEY PURPOSE AND MEASURE TYPE	RESILIENCY IMPLICATION (0-5 YEARS)	RESILIENCY IMPLICATION (5-25 YEARS)	RESILIENCY “SCORE”	HOW TO IMPROVE RESILIENCY SCORE?	IMPACT ON ISLAND DYNAMICS	COST
Beach replenishment 	Shore stabilisation (Soft Measure)	Very popular and often effective short term measure. Its resiliency in the short term is linked to the sediment budget of the island in question. If the island experiences a net negative sediment budget, then even short term re-nourishment programmes can have wider impacts on island dynamics.	As re-nourishment programmes often last up to 10 seasons (ie: circa 5 years), the resiliency of the approach has to be proven during the first time epoch (ie: a demonstrated success). If the island experiences a net negative sediment budget, then even short term re-nourishment programmes can have wider impacts on island dynamics. If sediment budgets are “neutral” though sediment recycling is adopted (accreting areas replenishing eroding areas), then resiliency of the approach can be high so long as no other dredging or man induced activity takes sediment out of the sediment budget “system”.		Option 1 Option 2 Option 3		
Temporary seawalls and groynes 	Erosion control/prevention (Soft and/or Hard Measure)	The temporary nature of these structures, coupled with the fact there is no formal design model to follow, renders the structures of being of low resilience to climate change in the short term. Despite this the “ad hoc” nature to these structures makes then able to be quickly built to address an urgent or immediate need.	These structures play no role in providing a long term resilient defence approach. It is common for such structures to have a residual life of possibly 2 seasons (1 year). Bolstering sand bagged seawalls with concrete or placing a sand/concrete mix within sandbags may enhance the residual life of such structures, though the failure of the nylon bags (cheaper than geotextile) often results in structure failure during storm conditions.		Option 1 Option 2 Option 3		
Demountable Flood Barriers (urban areas)	Hard measure – de-mountable flood barrier build into the design of existing or future roads	Retrofitting such designs are more challenging than when designing a new road.			Option 1 Option 2 Option 4		Depending upon technique chosen

						
Multi-purpose Flood Barriers 	Hard measure (flood protection) – built into the design of existing roads or properties	An alternative approach would be to build “speed humps” that double up as flood barriers and are in place at all times		Option 1 Option 4		
Recreational Area “multipurpose” infrastructure  	Hard measure (flood protection)	Multi-purpose seating along promenade/quay areas that can be used as flood barriers		Option 1 Option 4		
Coastal vegetation retention	Shore stabilisation (soft measure)	Preserving existing “green belt” vegetation is a clear resilient measure to adopt on islands that have enough littoral space and are large enough to accommodate this. It is not a resilient measure if the island is too small to retain a suitable natural vegetation line. It becomes a good resilient measure in Maintaining the necessary landforms for sustained vegetation growth is paramount over the long term. Linking this to ridge maintenance is key is resiliency of this option is to occur. It is more useful in “high exposure” islands and undertaken in tandem with other soft engineering schemes.		Option 1 Option 3		

		the short term if a natural vegetative zonation is prevent on an island. Pioneer vegetation is only likely to initially “take hold” during this time epoch.					
Ridge Maintenance 	Shore stabilisation	This technique inherits best practices of natural resiliency with regards to “using nature” to enable natural coastal geomorphological ridge formation to develop. Short term resiliency measures may include artificially bolstering storm ridge integrity.	Longer term planning to design artificial “ridge crests” may be introduced in areas to improve the longer term resiliency of the ridge. This is likely to involve sediment recycling or re-nourishment operations in addition to vegetation planting programmes (see above). This technique needs to be promoted more on inhabited islands for long term implementation.		Option 1 Option 3		
Artificial reefs 	Erosion control/prevention	Establishing the platform and environment to create artificial reefs can be relatively simple. Using pre-cast units (i.e.: Reef Balls – see image) is one effective way of setting this approach up (though expensive). Their resilience to storms depends on how they are anchored to the seabed.	Longer term resilience of artificial reefs depends on the water quality conditions to enable reef colonisation to occur on the platform used (or pre-cast units). It is often not considered as a long term solution to dealing with erosion on islands due to poor strategic planning and commitment to monitoring and adaptation of design.		Option 1 Option 2 Option 3 Option 4		
Coastal structures on stilts 	Reduce land shortage / coastal flooding	The lack of design guidance regarding pile distance and crest design heights makes short term resilience difficult to quantify, however, assuming initial structure height is appropriate, then resilience to climate induced storms in this time epoch is deemed as high.	The lack of design guidance regarding pile distance and crest design heights makes long term resilience difficult to quantify, however, assuming initial structure height is appropriate, then resilience to climate induced storms in this time epoch is deemed as high. Should design height not be appropriate, then retrofitting the height of the construction is challenging and hence its resilience to climate change is very much		Option 1 Option 4		

			dependent upon its original design.				
Submerged sand filled geotextile tubes 	Erosion control/prevention	Commonly used in high energy zones. As a result, short term resiliency is dependent on material used for construction (geo-bag, sand cement plastered bags etc). Geotextile bags (poor quality) may require replacement in high energy wave environments within 5 years). Design impacts on wider hydrodynamic regime make this structure poor in terms of wider resilience to the coastal environment.	With no formal design criteria, there is a high risk of toe failure within this time period and so structure resiliency is predicted to be weak and in need of structure re-build. Crest height will need re-designing to counter water level fluctuations and to improve performance. Whilst structure can be designed to be robust, its wider impact on sediment dynamics over longer time scales makes this not a preferred option form climate resilience unless properly constructed and designed at the outset.		Option 1 Option 2 Option 3 Option 4		
Seagrass / mangrove planting 	Erosion control/prevention	Short term resiliency is dependent upon the level of protection that is given to enable the growth of the seagrass or mangrove seedlings. The main factors to consider when planting mangroves are the spacing of the propagules, number of propagules planted together, time of year when propagules are planted, handling of propagules prior to planting and the frequency of inundation. Often sand bag structures/defence blocks are needed to ensure that suitable protection is afforded to the newly planted mangrove propagules.	Long term resilience of this approach is dependent upon the long term maintenance and management of the "protection" afforded to the propagules in the short term epoch. If this is undertaken, and mangrove/seagrass beds are encouraged in suitable quiescent locations, then this has a good longer term resilient potential.		Option 1 Option 2 Option 3		

NB: Chapter C3.1 and C3.2 should be viewed for design performance standard details for most of the above techniques.

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