LIVING SHORELINES AND NATURE-BASED SOLUTIONS GUIDEBOOK

Bureau of Environmental & Coastal Quality - Division of Coastal Resources Management
Version 1.0

TABLE OF CONTENTS

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ACRONYMS

Area of Particular Concern – APC
Commonwealth of the Northern Mariana Islands – CNMI
Division of Environmental Quality – DEQ
Division of Fish and Wildlife – DFW
US Department of Transportation – DOT
Department of Public Lands – DPL
Division of Coastal Resources Management – DCRM
Federal Emergency Management Agency – FEMA
Historic Preservation Office – HPO
National Fish and Wildlife Foundation – NFWF
National Oceanic and Atmospheric Administration – NOAA
Northern Mariana Islands Administrative Code – NMIAC
Office of Coastal Management – OCM
Systems Approach to Geomorphic Engineering – SAGE
Saipan Shoreline Access and Shoreline Enhancement Assessment – SASEA
United States Army Corps of Engineers – USACE

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Layout design and cover photo are contributions by Kiana Camacho, a 2021 DCRM summer intern. Photo shows natural and man-made infrastructure existing in Wing Beach, Saipan.

DEFINITIONS

Accretion - the accumulation of sand/sediment in an area by sediment transport

Area of Particular Concern – an area included within CRM jurisdiction that is subject to special management because of its unique and important environmental properties, and is subject to specific criteria permit evaluations under part 300 of these regulations

Backshore - the generally dry part of the beach lying between the nearshore and inland area, which is only exposed to waves during storm surge and high tide events

Beach nourishment - the practice of adding large volumes of sand/sediment into an area to combat erosion

Berm - the vertical portion of the beach or backshore formed by the deposition of materials by wave action

Coastal hazards - phenomena under extreme weather and water conditions that threaten infrastructure, property and environment near the ocean

Erosion - the wearing away of land and removal of beach sediments by wave action, tidal currents or drainage

Green infrastructure - vegetative infrastructure system which enhances the natural environment through direct or indirect means

High tide line - the level reaches by the sea on land at high tide

Littoral drift - the movement of sedimentary material within the near-shore zone under the influence of tides, waves, and currents

Living shoreline – a shoreline management practice that provides erosion control benefits; protects, restores, or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural organic materials (e.g. biologs, etc.)

Natural Infrastructure – natural and constructed systems that mimic natural processes and[that] provide effective solutions for minimizing coastal flooding, erosion, and runoff (NOAA)

Nature-based solutions - actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (International Union for Conservation of Nature definition)

Sediment transport - sand/sediment entering and exiting within coastline areas

Shoreline armoring - practice of using physical structures to protect shorelines from erosion

Shoreline morphology - the shape of the shoreline

Storm surge - rising water from the ocean that is pushed towards the shore by the force of winds from a strong storm. Storm surge can damage the shoreline and property.

Stormwater runoff - rain that flows over land or impervious surfaces and eventually drains to the ocean

INTRODUCTION

Beaches connect the ocean and land. Within these ever- changing spaces, residents and visitors recreate while native plants and animals thrive.

Figure 1 - Sandy beaches, such as Managaha, attracts visitors who enjoy its sand and water grounds.

Sand, an overlooked coastal resource, brings great economic and aesthetic value to our island community. The tides and currents of the ocean change how far or close the sandy shoreline appear from the *backshore*. Storms bring strong waves that erode away vulnerable shorelines.
Dependent on how and where the sand shifts, beaches may have more sand leaving the area, experiencing long-term *erosion*. As erosion edges inland, infrastructure along the coastline are at increased risk of *storm surge* damage.

Shoreline armoring is often seen as the quick solution to tackling erosion, yet many coastal areas around the world are beginning to experience beach loss from this traditional approach. Lessons learned from around the nation call for a shift of bulkheads, seawalls, and other hardening structures to living shoreline and nature-based solutions when applicable. Hardened structures are not the only solution to addressing shoreline erosion, and are not always the most effective for a site.

Nature-based solutions are rising in recognition as cost- effective solutions for tackling shoreline erosion and other *coastal hazards*. The CNMI can benefit from these softer environmentally-considerate approaches through increasing wildlife habitat and reducing unwanted shifting in coastal processes.

Figure 2 - Shoreline armoring in Hawaii have resulted in beach loss, bringing forth a "no tolerance" policy towards new seawalls. Photo Credit: Grist/joshuaraineyphotography / Getty Images

DCRM has encouraged the use of living shorelines and other nature-based solutions because they are designed to protect, restore, and enhance natural shoreline habitat that is currently eroding away. Protection can be achieved when site-specific coastal processes and other factors have been assessed in the scoping

"Shoreline protection is most effective and less damaging to natural resources if it is the appropriate kind of structure for the project site and erosion and flood problem, and is properly designed, constructed, and maintained. Because factors affecting erosion and flooding vary considerably, no single protective method or structure is appropriate in all situations. When a structure is not appropriate or is improperly designed and constructed to meet the unique site characteristics, flood conditions, and erosional forces at the project site, the structure is more likely to fail, require additional fill to repair, have higher long-term maintenance costs because of higher frequency of repair, and cause greater disturbance and displacement of the site's natural resources."

- San Francisco Bay Conservation and Development Commission

and planning stage of a stabilization project. Because this concept is new to the CNMI, this guide pulls existing national knowledge and lessons to encourage living shorelines and nature-based solutions for increasing shoreline resilience of our sandy shorelines.

Context for this guidebook was derived from existing guidance and resources produced by other coastal state entities and federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA), US Department of Transportation (DOT), and the US Army Corps of Engineers (USACE). Furthermore, this guidance greatly supplements the DCRM Permit requirements in NMIAC § 15-10-335, which calls for consideration of living shorelines and nature-based solution options when proposing "hard structures" to confront shoreline erosion facing our islands. Updates to this guidance may occur as more research and lessons learned are applicable to the CNMI.

Figure 3 - Beach Road coastline has been relatively stable but its short width is threatened by long-term erosion.

Figure 4 - Mañagaha's northwestern side has a growing dune while its eastern side faces storm-driven erosion. Picture captured by DCRM Enforement.

HOW TO USE THIS GUIDE

This purpose of this guide is to encourage living shorelines and nature-based solutions for addressing our CNMI shoreline erosion issues and inform their assessment, planning and implementation from existing state, federal, and international guidance. Here is a recommended approach to using this guide:

Assessment

1. Interpret your current shoreline environment with key influences (page 8-10, 22).
2. Determine why hardening structures may or may not be suitable for your project (page 23,25).
3. Talk to DCRM Planning and Permitting about your shoreline erosion issue for recommendations of best management practices.
4. Evaluate the living shoreline and nature-based solutions options based on the site assessment, project needs, and what ecosystem services they offer (page 13-22).

Planning

1. Evaluate, determine, prepare what may need for the proposal, such as your budget (page 28-31,32-34,35-38).
2. Develop a design that addresses coastal erosion while providing any necessary ecosystem services (page 22,28). Actual designs must be approved by a certified engineer.
3. Initiate DEQ's One Start permitting process for environmental compliance (page 35-38).
4. Decide which plant species you may want to procure to devise your landscaping plan (page 39-50).

Implementation

1. Begin construction when you have received the appropriate permits and follow permit conditions.
2. After construction, execute your monitoring plan (page 28).

Key takeaways of the guide:

- Site assessment with consideration of coastal processes is critical to properly designing any shoreline stabilization project and preventing unintended environmental consequences.
- Living shorelines and nature-based solutions can be selected with ecosystem services in mind and should be considered in assessing options for design before considering hard structures.
- You may need to consult and hire an environmental firm and an engineering firm for the assessment and design of the stabilization project as well as produce any required reports for permitting.
- Federally funded shoreline stabilization and enhancement projects are a possibility when you consult with DCRM or other partnering resource agencies.
- Monitoring the effectiveness of your project will help us build understanding of how living shorelines and nature-based solutions work and how much maintenance would cost.

UNDERSTANDING EROSION AND OTHER COASTAL HAZARDS IN THE CNMI

Shorelines are naturally dynamic, or changing, as they are influenced by how strong the winds are and what direction the winds blow. A general understanding of the layout of a sandy shoreline and sand movement can identify the needs of the project.

General layout of our shorelines

On Saipan, the shallow western lagoon and reef system buffers most of the ocean's wave energies. Saipan's western side beaches have gentle to moderate slopes and are dominated by ironwood and beach morning glory[1].

Further inland is the low-lying coastal plain with economically-valued developed areas that may need coastal protection. The tide plays a big role in the width of dry beach. DCRM uses the *high tide line* to regulate development in the Shoreline Area of Particular Concern in order to prevent exposure to shoreline hazards. The high tide line shows the beach width at high tide, which can also show how close the water could be to infrastructure or property lines. (See Figure 5.)

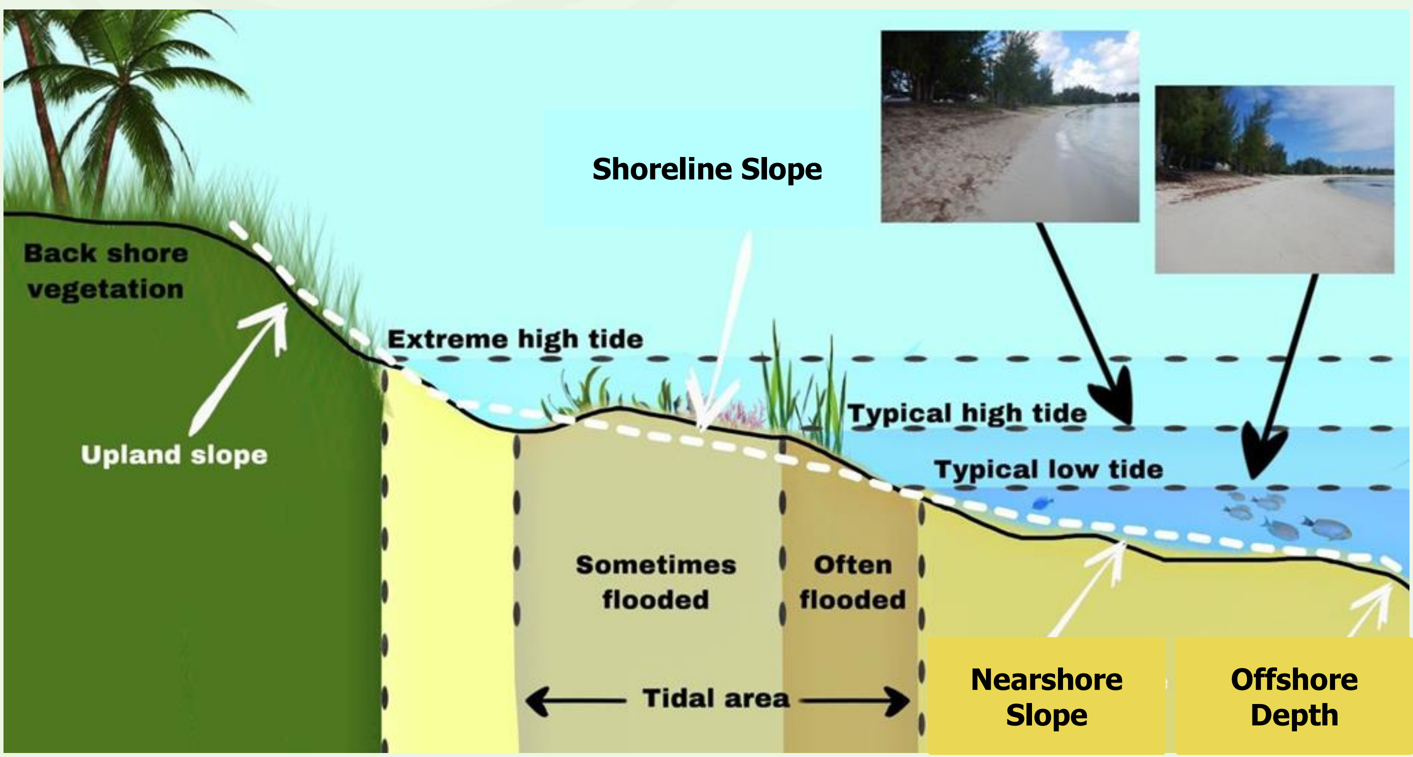


Figure 5 - The tides influence beach width. Two snapshots of the southern Sugar Dock shoreline reveal the tidal range difference. For this reason, DCRM follows the high tide line for the delineation of the Shoreline Area of Particular Concern. Infographic developed by Kiana Camacho.

Sand movement

Naturally, sand can move along a shoreline or underwater. *Littoral drift*, a *sediment transport process*, dictates how the shoreline looks and where sand gets pushed along the shoreline.

Based on interactions with natural and man-made structures along the shore, parts of the shoreline have more sand deposited while others have faster rates of sand leaving than getting deposited.

The strength and direction of currents influence this movement, which change seasonally. North to south seem to be the primary sediment transport direction on Saipan.

Figure 6 - Waves pushes sand up in Tachogna Beach, Tinian

Three States of Shoreline Trends

DCRM monitors shorelines to report out whether they are *accreting*, *eroding*, or *stable* to inform management decisions. Time - whether years or months - should always be factored into the state of a shoreline area. Eroding shorelines concern users and nearby infrastructure, while accretion may signify that a shoreline is receiving extra sand from somewhere.

Accretion occurs where considerable volumes of sand settle.

Figure 7 - Sand has traveled and settled at the northern curve of American Memorial Park, closest to the Smiling Cove Marina taken in 2021.

Erosion occurs where sand continue to be lost. Waves push sand to another section of shoreline or pull sand into underwater grounds as a *sand bar*.

Figure 8 - Notable amounts of sand have been lost along shorelines fronting the Hyatt Regency and Crowne Plaza Resort, possibly traveling and settling around the park facing Smiling Cove in April 2021.

Stable shorelines indicate that the shoreline has a net sediment transport for a certain period of time. The backshore is usually thriving with mature vegetation while the nearshore area has not changed significantly.
Stable shorelines can be damaged by storm surge but they are known to recover pretty quickly through sufficient sediment input.

Figure 9 - The thriving vegetation area in Susupe Beach Park signifies stability since the last storm.

Erosion by typhoon waves

Tropical storms pass through the Marianas Archipelago and bring powerful winds from July through November. Water levels get higher. Strong waves go over the reef and rush water into the sandy shoreline as storm surge, bringing destructive energies.

High energy waves and increased sediment transport processes move the sand during high tide. After the erosion event, some shorelines gain sand back while others do not. Those that do not recover may need a shoreline stabilization approach to protect nearby infrastructure from further wave damage.

The history of sediment movement is an important natural factor to consider in your shoreline stabilization design, because it can impact the effectiveness of your proposed project. Your project could change the way sand moves throughout the coastline.

Typical seasonal conditions

- Northeast trade winds (January to April) - potential for moderate erosion or accretion
- Regular westerly-winds (July to October) - potential for accretion
- Tropical disturbance/typhoon winds (July to November) - potential for strong erosion [2]

Figure 10- Tropical storms have brought erosion events at American Memorial Park shoreline.

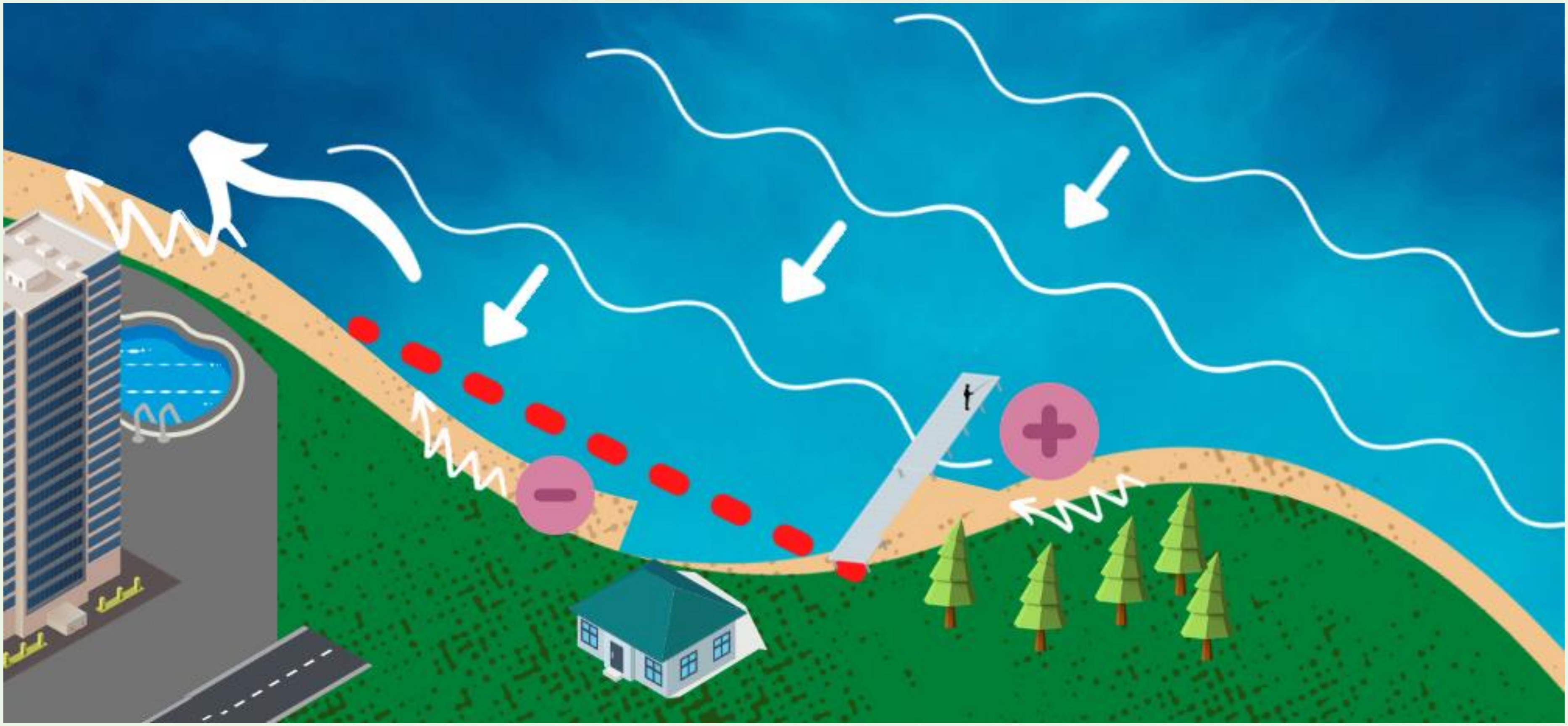


Figure 11 - This graphic illustrates the concept of sand movement along the coast. The dotted red line indicates where the sand was before they were pushed by a current (indicated through the white arrows) during a storm event. The big plus and minus indicate whether the sand has been gained or lost.

Think about how sand moves through your project area. What natural and man-made features do sand interact with? When does erosion seem to happen? Does vegetation help stabilize the area?

In the scenario modelled in Figure 11, sand movement flows from the right side to the left along a fairly developed and disturbed shoreline area. A storm comes in brings strong waves that increases the sediment transport process. Sand gets pushed into the water while others are pushed along the shoreline. A dock exists and acts like a groin, prohibiting sand to pass through the left. This “trapped sand” forms a beach. But unfortunately, the right-hand beach has eroded because all the sand that could have settled there are lost. The one-story house and high-rise building in the backshore become vulnerable to future wave energies if the protective beach width and elevation are reduced and loses its ability to buffer waves.

WHY CONSIDER NATURE-BASED SOLUTIONS?

Figure 12 - Different nature-based solutions options presented in NOAA OCM's Natural Infrastructure web page. Note that oyster beds are not applicable in the CNMI but reef balls and giant clams may have similar benefits.

People and the built environment need existing ecosystems (wetlands, coral reefs, beaches) to thrive. These natural ecosystems provide protection, food, natural spaces (for our recreation and natural beauty), clean water and air, and other societal benefits. 'Nature-based solutions' in the context of this guidebook enhance these ecosystems by mimicking natural processes to address flooding, erosion, and *stormwater runoff*. (See ECOSYSTEM SERVICES FROM NATURE-BASED SOLUTIONS & LIVING SHORELINES.)

Nature-based solutions are interventions for long-term sustainability and hazard mitigation. The *CNMI Smart Safe, Growth Guidance* supports the implementation of smart growth, *green infrastructure*, and hazard mitigation to address the community's vulnerability to multiple hazards, such as flooding, coastal erosion, storm surge, and other coastal hazards. When thinking of solutions, we can design nature to work for us and build our community's overall resilience in the face of climate change.

NATURE-BASED SOLUTIONS

Coral reefs, mangroves, seagrasses, and sandy beaches are nature-based solutions in the CNMI that interact with the ocean's wave energies. These coastal ecosystems can reduce wave heights of up to 71% [3]. Thus, the high value of mitigation and adaptation services of corals justifies their continued protection and enhancement.

Figure 14 - Coral reefs

Coral reefs are the most critical to the CNMI given they are the first line of defense from shore-bound ocean waves. They are highly effective at reducing wave heights and are adapted to high wave exposure. Coral reefs on Saipan, Tinian, and Rota are valued at $104.5 M annually. Coastal protection service from reefs every year to support our built infrastructure and economic activities are at $21.2 M[4].

Figure 15 - Seagrass

Seagrass attenuates remaining wave energy in nearshore waters while filtering pollutants from storm water runoff before they reach our coral reefs.

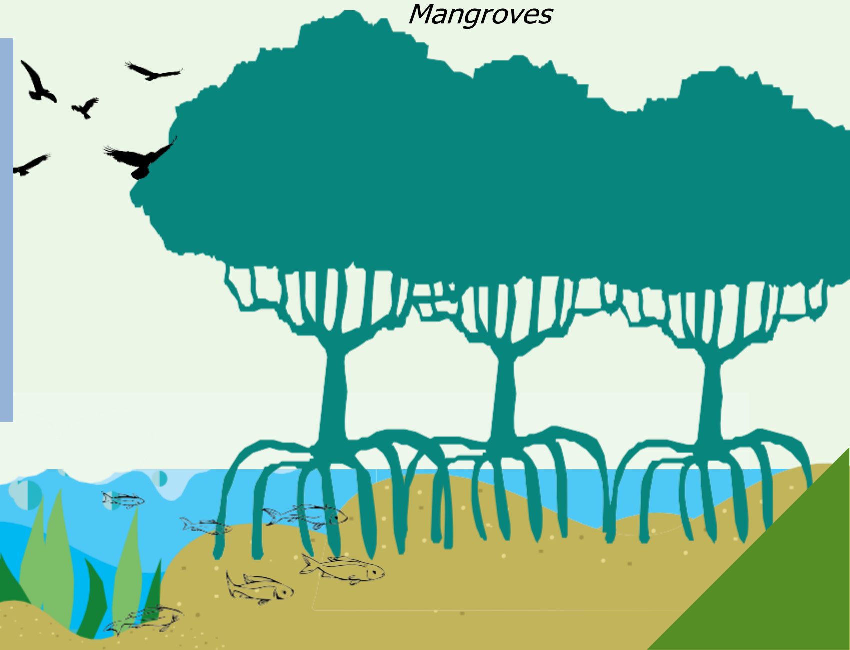
Mangroves have a complex root structure adapted for buffering waves from high storm energy events and even tsunami run up. In other places within the Pacific Region, mangroves are deployed to address storm surge and sea level issues. Restoration or enhancement could increase the magnitude of wave height attenuation with the increase of density and size of the mangrove forest. Studies have shown storm surge attenuation of 0.5 to 2.6 feet per mile of mangrove dependent on density [5].

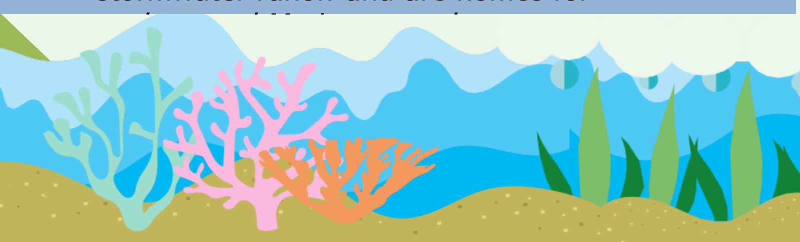
Figure 16 - Mangroves

Figure 13 - Corals, seagrass, and mangroves interact with each other and attenuate energy headed for land.

Sadog Tasi and Tanapag provide $420,650 value annually in shore erosion protection [6].

American Memorial Park wetland and other artifical wetlands infiltrate stormwater runoff and are homes for





Enhancing or restoring coral reefs and mangroves increase their coastal protection ability by increasing their function and coverage within the lagoon. Performance and resilience to sea level rise come as they strengthen over time. One such strategy for reefs is to design a reef or structure with a crest width that is large enough to accommodate additional material to its crest over time. The loss of coral, mangroves, seagrass, or coastal vegetation increase the wave energy damage potential to shoreline and nearshore infrastructure.

Properties with natural shoreline protection measures withstood wind and storm surge from Hurricane Irene (2011) greater than those with seawalls or bulkheads in North Carolina. The storm damaged 76 percent of bulkheads surveyed, while no detected damage occurred on other shoreline types [7].

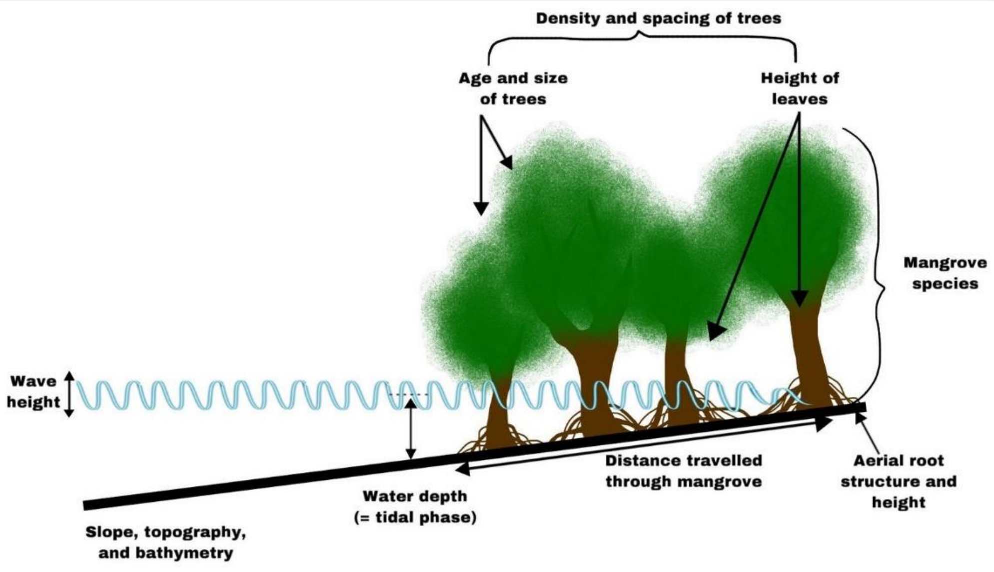


Figure 18 - Mangrove composition can determine its level of coastal protection.

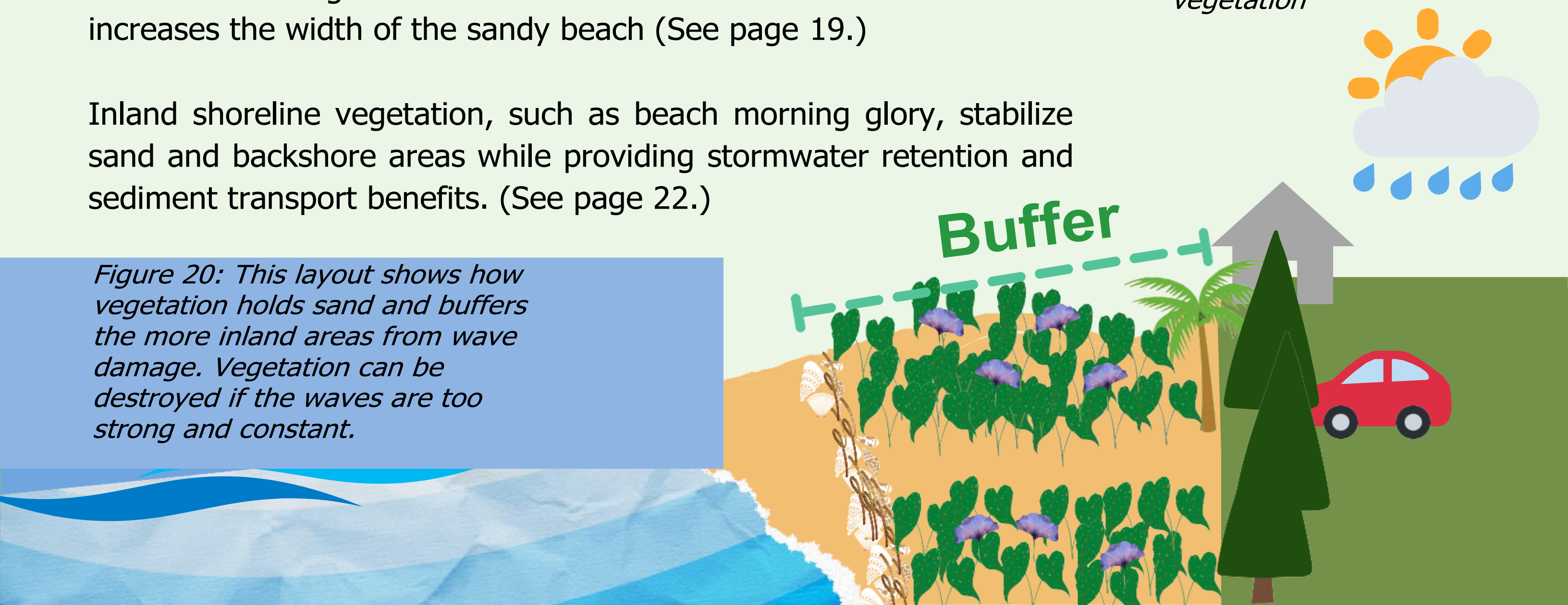
Figure 17 - Sandy beach

Figure 19: Inland vegetation

Sandy beaches are often the last line of defense from wave damage to inland areas given the distance they provide and space to buffer waves. The larger the width of the beach, the better the buffer. The issue arises when the sand loss is large and the sediment entering the shoreline is low to none. *Beach nourishment* increases the width of the sandy beach (See page 19.)

Inland shoreline vegetation, such as beach morning glory, stabilize sand and backshore areas while providing stormwater retention and sediment transport benefits. (See page 22.)

Figure 20: This layout shows how vegetation holds sand and buffers the more inland areas from wave damage. Vegetation can be destroyed if the waves are too strong and constant.



NATURE-BASED SOLUTIONS IN ACTION

Native shoreline vegetation planting has proven useful to dune restoration in an eroding stretch of beach at the Bellows Air Force Station in the windward coast of O'ahu, Hawai'i. The Air Force and community acted on the erosion by removing ironwood trees and planting native shoreline vegetation, such as beach morning glory, to capture wind-blown sands and allow them to settle on the beach. They noted that the layer of ironwood tree needles prevented the growth of native dune growing plants. In addition, they addressed the upland storm water runoff through temporary irrigation systems. The Air Force involved the community by hosting volunteers to plant native vegetation throughout the year to foster connection to the land [8].

Figure 21- Native plants stabilize the Bellows Air Force beach and buffers wave damage.

Beach nourishment has been implemented in the Pacific. Some beaches on Saipan, such as parts of Beach Road shoreline, were said to be filled on a smaller scale using dredged sand that buried boat ramp at Sugar Dock, but these were not formally reported. One documented example of a nourishment project to take erosion is in Fongafale Island, Tuvalu. Coral gravel and sand were the materials the government used to build eroded beaches. Adjacent to this nourishment were existing groins and sea walls. Residents felt that this enhanced the environment and recreation in the area [9].

Figure 22 – Tuvalu's government strategically dredged and placed gravel and sand on Fongafele Island.

In late 2002, the Cayman Beach Marriott Resort began installing a **reef ball breakwater** to address the continued erosion of beach along their hotel. Seven Mile Beach would erode from May to November but recover from December to April. Three months after installation, the beach grew by 15 m and reached 25 m. Wave heights were reported to be reduced by ~60%. However, the reef ball breakwater was reported to enable some erosion in storm conditions with continuous winds. In 2004, Hurricane Ivan slightly eroded Seven Mile Beach. Erosion was mitigated due to the short- lived windy nature of the storm [10].

Figure 23 - Reef balls were installed on the waters near Seven Mile Beach.

LIVING SHORELINES

Influenced by nature, living shorelines are engineered to improve shoreline function and habitat. DCRM defines living shoreline as "a shoreline management practice that provides erosion control benefits; protects, restores, or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural organic materials." Living shorelines mimic and enrich the natural environment by integrating natural material to meet one or more of the following: attenuate wave energy; allow natural sediment movement; absorb storm water; filter storm water pollutants; and defend from storm surge and high wave energy. For a successful living shoreline project, proper landscaping and/or engineering design must account for site-specific coastal processes and intended functionality of the shoreline.

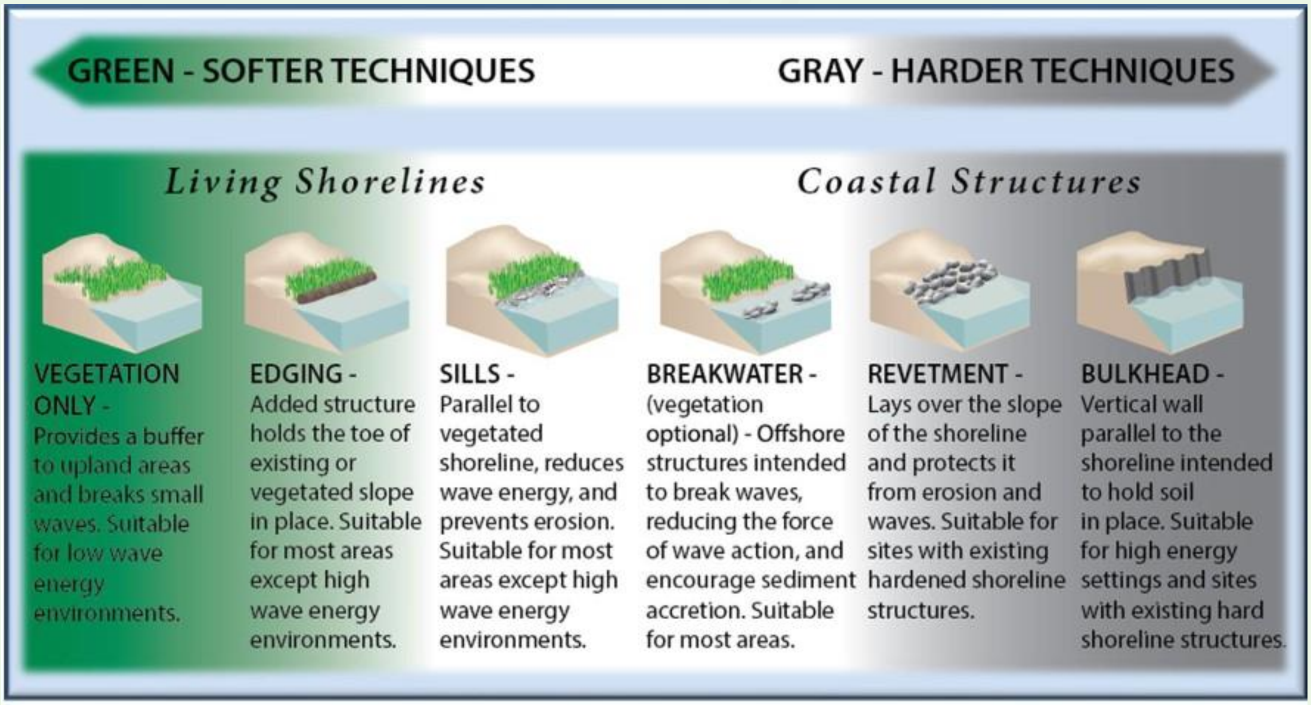


Figure 24: Stabilization techniques with greener, living shorelines to on the left to the gray, coastal infrastructure on the right.

<u>Natural Living Shoreline</u>

- Techniques: Vegetation only, edging
- Wave Energy Conditions: Low

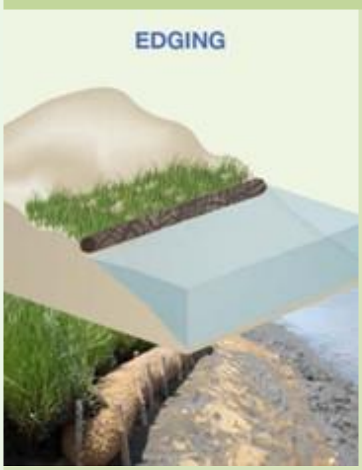
<u>Hybrid Living Shoreline</u>

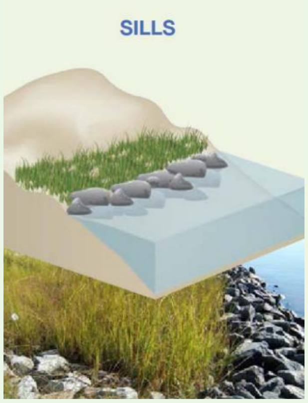
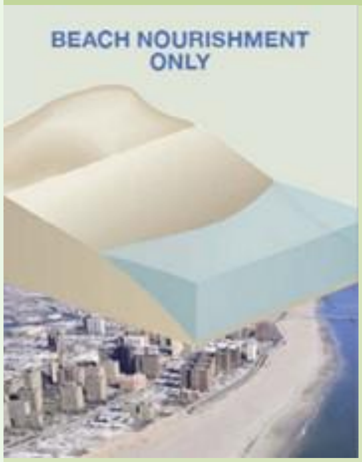
- Techniques: Sills, breakwater
- Wave Energy Conditions: Low to medium

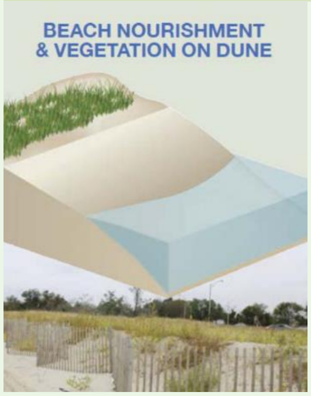
<u>Structural Living Shoreline</u>

- Techniques: Coastal structures with native vegetation
- Wave Energy Conditions: Higher (Still provides some ecological function)

All Nature-Based Solutions require monitoring and maintenance of vegetation to ensure efficiency. The first years are crucial for the vegetation to establish and strengthen. Replanting and repairs must occur periodically if juvenile vegetation is damaged from a major storm. Consult with DCRM to see if you need a permit.

Technique	Description	Benefits	Issues
	Vegetation only integrates salt-tolerant native shoreline plant species to buffer wave energy. Nearshore and backshore areas can be landscaped to buffer erosion Suitable for: Low wave energy environments Material Options: Salt-tolerant native plants	• Dissipates wave energy • Slows inland water transfer • Increases natural storm water infiltration • Stores flood water • May hold trash headed for the ocean	• No storm surge reduction ability • Appropriate in limited situations • No high water protection • Uncertainty of successful vegetation growth • Competition with invasive species
Average cost: $150 per linear foot [2a] Maintenance cost: less than $100 per linear foot			
	Integrates anchored natural material (such as coir logs or wood) that retain the toe of existing vegetated slope in place Suitable for: Most areas except high wave energy environments Material Options: Salt-tolerant native plants, snow fencing, erosion control blankets, Geotextile tubes, living reef (oyster/mussel), rock gabion baskets	• Dissipates wave energy • Slows inland water transfers • Increases natural storm water infiltration • Toe protection helps prevent loss of edge • May hold trash headed for the ocean • No high water protection	• High physical footprint of project • Uncertainty of successful vegetation growth • Competition with invasive species
Average cost: $117-$603 per linear foot [1a] Maintenance cost: less than $100 per linear foot annually [1a]			

Technique	Description	Benefits	Issues
 	Sills integrate riprap, gabion baskets, or clean broken concrete and native vegetation to stabilize shoreline. A gapped sill approach may allow habitat connectivity, greater tidal exchange, and better waterfront access Suitable for: Most areas except high wave energy environments Material Options: Stone, sand breakwaters, living reef (oyster/mussel), rock gabion baskets	• Provides habitat and ecosystem services • Dissipates wave energy • Slows inland water transfer • Increases natural storm water infiltration • Toe protection helps prevent loss of edge	• Requires more land area • No high water protection • High physical footprint of project • Uncertainty of successful vegetation growth and competition with invasive species
Average cost: $457-$996 per linear foot [1a]		Maintenance cost: less than $125 per linear foot annually [1a]	
 	Beach nourishment only is fill from an outside source into the site area and graded to elevations capable of buffering anticipated waves Suitable for: Low-lying oceanfront areas with existing sources of sand and sediment Material Options: Sand	• Expands the usable beach area • Dissipates wave energy • Lower environmental impact than hard structures • Flexible strategy • Redesigned with relative ease • Provides habitat and ecosystem services	• Requires continual sand resources for renourishment • No high water protection • Appropriate in limited situations • Consider sediment transport since there are no possible impacts to regional sediment transport • Needs another stabilization practice to retain sand over time • May encroach on existing seagrass beds
Average cost: $117-$603 per linear foot [1a] Maintenance cost: less than $100 per linear foot annually [1a]			

Technique	Description	Benefits	Issues
	Beach nourishment & vegetation on dune integrates salt-tolerant native shoreline plant species to buffer wave energy. Nearshore and backshore areas can be landscaped to buffer erosion Suitable for: Low wave energy environments Material Options: Salt-tolerant native plants	• Expands the usable beach area • Dissipates wave energy • Lower environmental impact than hard structures • Flexible strategy • Redesigned with relative ease • Provides habitat and ecosystem services	• Requires continual sand resources for renourishment • No high water protection • Appropriate in limited situations • Consider sediment transport since there are no possible impacts to regional sediment transport • Needs another stabilization practice to retain sand over time • May encroach on existing seagrass beds

Average cost: $1,150 per cubic yard of sand and vegetation [1a]
Maintenance cost: 15% of total cost per year [1a]

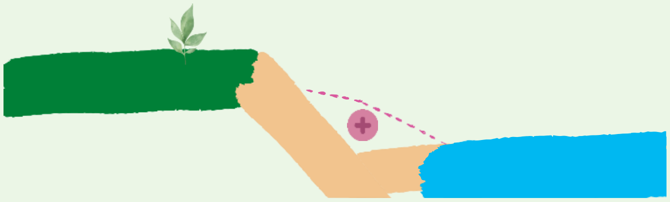
Beach nourishment

Beach nourishment is applicable for environments with existing sources of sediment. It is a widely popular option globally given its widening of the sandy beach, often included in design plans. Additional features may be incorporated. Beach nourishment is expensive especially when it requires off-shore dredging. A USACE permit is required [11]. Careful construction with best management practices should be implemented to avoid impacts to wildlife (like burrowing crabs). Assume that the beach may receive replenishment regularly to retain its width. In the past, some beaches have received nourishment after the dredging of Sugar Dock. *The CNMI does not currently have a beach nourishment or sediment management plan in place.* Navigating through the local and federal permitting system consulting DCRM.

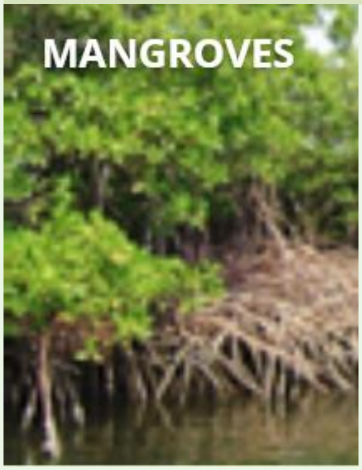
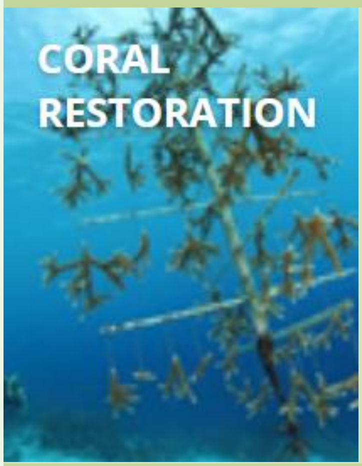
Tips:

- Littoral drift is an important factor in estimating the lifespan of nourishment, given that the sediment leaves the area over time.
- Making slopes gentle could dissipate wave energy and reduce abrasion (See Figure 25).
- Grain size can drive appropriate design slopes and may affect the success of a nourishment project – some jurisdictions such as Hawaii require similar grain sizes to the receiving beach that may ensure the success of a beach nourishment project and avoid water quality impacts.

Figure 25: This graphic visualizes how a steep slope could be made gentle. Sand could be added where



Technique	Description	Benefits	Issues
	Reef balls integrate hardened material such as pH neutral concrete, and are designed to grow coral species and dissipate wave energy along the seaward slope. They can be materials for a breakwater or sill structure. Suitable for: Within the lagoon, where tidal range is not higher than 9 feet or 2 meters Material Options: Fiberglass, 3-D printed, pH neutral concrete	• Expands the usable beach area • Provides habitat for marine life • Stimulate coral growth (pH neutral concrete could encourage this)	• Material may have to be imported • Placement in design is determined by the level of wave and current reduction needs • Possible impacts to regional sediment transport • Potential of sand transportation out over rock sill and into deeper parts of the lagoon
Average cost: Up to $800 for mold size with additional $23,500 in deployment and bottom survey and monitoring expenses [3a]			
	Constructed wetlands are water treatment systems that use wetland vegetation and soils Suitable for: Low wave energy environments and drainages Material Options: Salt-tolerant native plants	• Dissipates wave energy • Slows inland water transfer • Increases natural storm water • Infiltrates and stores flood water • May hold trash headed for the ocean	• No high water protection • Appropriate in limited situations • Uncertainty of successful vegetation growth • Competition with invasive species
Average cost: $15,200 per acre [1a] Maintenance cost: Unknown			
	Seagrasses plant integrate native seagrass into shallow sandy bottom Suitable for: Low wave energy Environments Material Options: *Enhalus acoroides* and *Halodule*	• Dissipates wave energy • Slows inland water transfer • Increases natural storm water infiltration	• Requires planting expertise
Average cost: $38,000-$2.8 million per acre [1a]			

Technique	Description	Benefits	Issues
	Mangroves are integrated to dissipate wave energy at the shoreline Suitable for: Areas with natural freshwater drainage into the ocean Material Options: Bruguiera gymnorrhiza, Heritiera littoralis, Xylocarpus moluccensis	• Dissipates high wave energy that reaches the coast • Slows inland water transfer • Provides habitat • Increase natural storm water infiltration	• Requires planting expertise • space dedicated to migrate inland due to sea level rise • Requires natural freshwater input
Average cost: $15,500 per acre to restore hydrologic flow [1a] Maintenance cost: Unknown			
	Corals naturally reduce wave energy. Coral nurseries provide corals for transplant at areas needing coral restoration. Suitable for: Sandy ocean bottoms within the western lagoon of Saipan	• Dissipates wave energy • Slows inland water transfer • Provides habitat	Requires coral reef expertise. Consult with DCRM and private firms specialized in this work, such as Johnston Applied Marine Sciences.
Average cost: $0 - $25 million per acre [1a] Maintenance cost: See DCRM or Johnston Applied Marine Science			

[1a] NOAA's appraisal based on US mainland sources extracted from the Green Infrastructure Effective Database. Given the CNMI's remote geographic location, costs may be higher especially for concrete or imported materials.

[2a] GASAS 2017 cost estimate for a nourishment width of 70 ft.

[3a] Reef Ball foundation pricing webpage: https://reefballfoundation.org/pricing-2/

Actual costs may be realized from local projects that have undergone construction.

ECOSYSTEM SERVICES FROM NATURE-BASED SOLUTIONS & LIVING SHORELINES

Identify what ecosystem services are needed to stabilize and address stormwater issues at your site by comparing to a healthy shoreline.

Wave attenuation - reducing and absorbing wave energy headed for the shore, such as seagrasses and corals

Sediment transport - allowing of natural sediment movement that build up the coastline, such as seagrasses

Stormwater retention - storing and absorbing of stormwater runoff from inland, such as beach vegetation. Great for sites with or close to roads and drainages.

Coastal buffering - protecting from storm surge and high wave energy, such as coral reefs

Stormwater infiltration - filtering of pollutants from stormwater runoff from inland, such as beach vegetation. Great for sites with or close to roads and drainages.

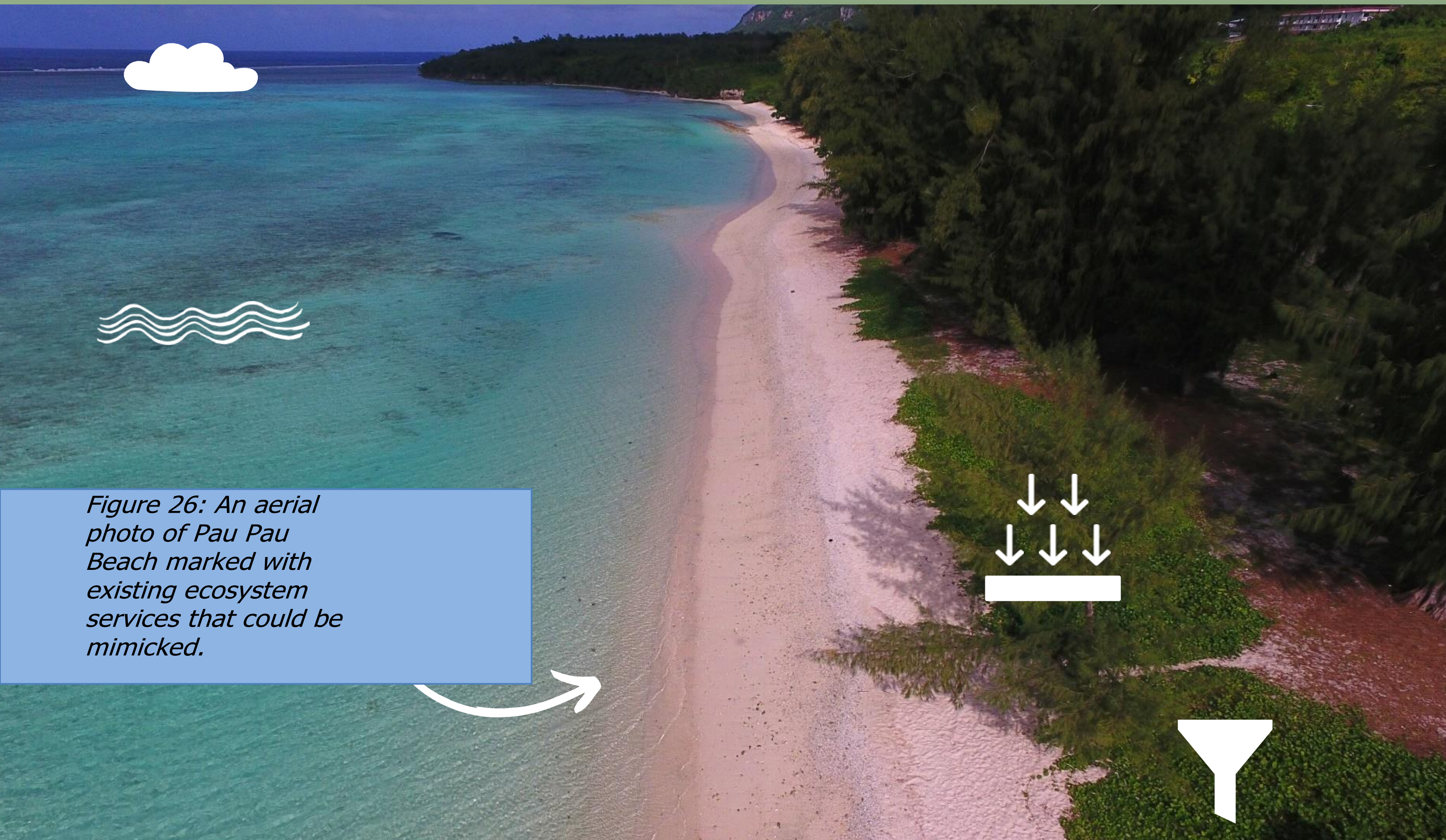


Figure 26: An aerial photo of Pau Pau Beach marked with existing ecosystem services that could be mimicked.

COMPARING TO AN ALL COASTAL STRUCTURAL APPROACH

When beaches are impacted by erosion, land owners and government entities are compelled to protect land and critical infrastructure along the shore. As shoreline loss continues to encroach on private property and sea level rises, stabilization measures are more than likely to be pursued. In the CNMI and worldwide, it is widely accepted to harden the shoreline using coastal structures, commonly seawalls, despite their unintended consequences. For decades, research in places with armored coastlines, such as Hawaii and Puerto Rico, found that shoreline hardening increased beach narrowing and beach loss.

Naturally, a beach will retreat landward. With a coastal structure, such as a sea wall, sand cannot move inland and can get completely lost [10]. Groins can lead to accretion on the up-drift side but erosion down-drift, shifting overall littoral drift.

The U.S. Army Corps of Engineers (USACE) is a federal agency involved in regulating tidal waters and non-tidal waters of the US such as our shoreline areas. They conducted studies to protect infrastructure from storm-induced damage and erosion of Beach Road. Garapan Area Shoreline Assessment Study (2017) recommended T-groins with beach nourishment estimated to $21.3 M for its estimated 50-year lifespan [10].

Consideration of coastal processes could help in preventing any unwanted consequences. Unlike hardened structures, living shorelines and nature-based solutions may encourage accretion and comprehensively fix many environmental issues within the site, such as stormwater runoff.

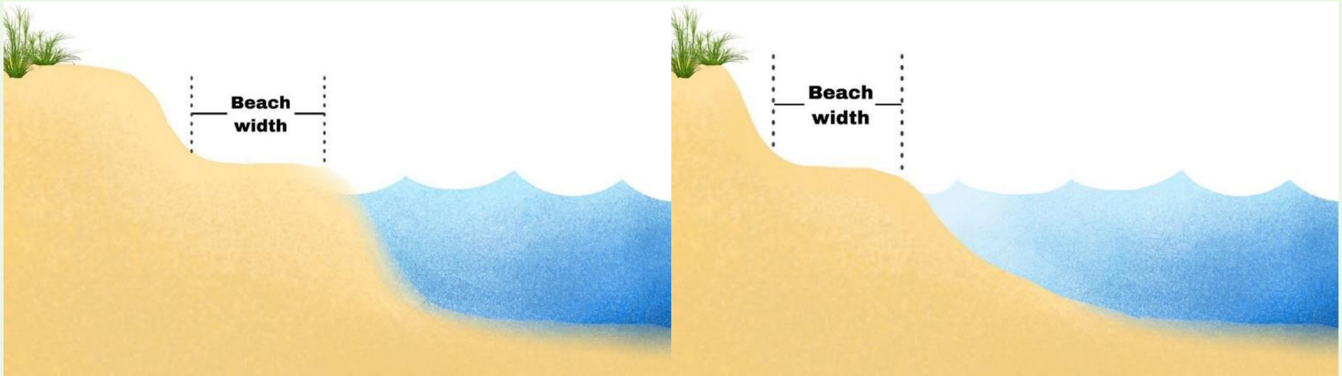
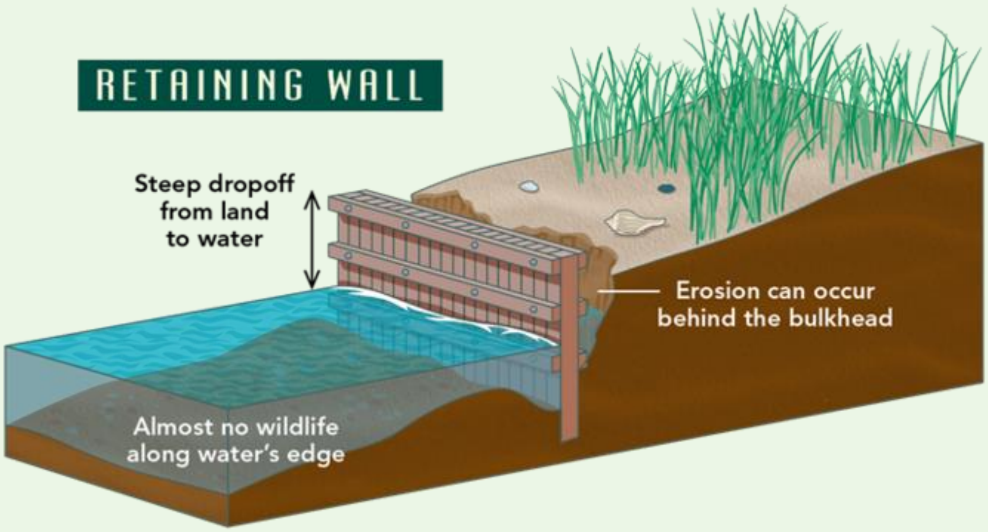


Figure 27: Natural beach retreat happens with erosion and sea level rise. Hardening the shoreline will prevent the beach from retreating inland and result in loss of beach.

COMPARING TO AN ALL COASTAL STRUCTURAL APPROACH



'Hard' infrastructure like retaining walls abruptly severs the ecological connection between the coast and water.

- Reflects energy which can cause scouring and even damage to nearby seagrass and coral
- Steep drop-off cuts off land and sea for wildlife
- Rigid and does not change Best for high energy wave conditions
- High initial first cost and low maintenance throughout lifespan

Not only do Living Shorelines defend land against destructive waves, but they also provide crucial habitat for fish and wildlife.

- Absorbs and dissipates energy
- Gentle slope connects land and sea for wildlife (design for fish, birds, crabs, etc.)
- May adapt to sea level rise
- Suitable for low to medium energy wave conditions
- Lower cost for implementation and regular maintenance throughout lifespan

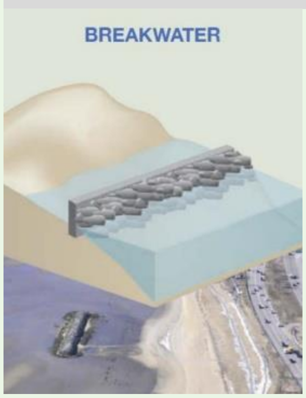
COASTAL STRUCTURES

Coastal structures, or shoreline armoring, may require less time and money on maintenance. They are rigid and fixed once developed so they reflect the incoming wave energies and could get damaged during its lifespan. Repair or complete replacement are comparatively costlier options.

Coastal structures can be integrated into hybrid living shoreline designs in a way that creates wildlife habitat. The design must identify the targeted wildlife that would benefit, and how the materials and layout will allow habitat development. For instance, reef balls can be designed as breakwater while providing shelter for juvenile fish.

Additionally, the life span of a coastal structure could increase with integration of green infrastructure approaches.

A coastal structure project may have to undergo analysis of why living shorelines are not applicable to this site as suggested in DCRM Rules and Regulations NMIAC §15-10-101 (c). A project subjected to the Coastal Hazards APC faces more scrutiny.

Technique	Description	Benefits	Issues
	Breakwater integrates an offshore structure to break waves, reduce the force of wave action, and encourages sediment accretion. Can be floating or fixed to the ocean floor, attached to shore or not, and continuous or segmented. Suitable for: Most areas except high wave energy environments often in conjunction with marinas Material Options: reef balls, Grout-filled fabric bags, armorstone, wood, rock, or pre-cast concrete blocks	• Reduces wave force and height • Stabilizes wetland areas • Can function like a reef • Economical in shallow areas • Limited storm surge • Limited storm surge flood level reduction	• High construction cost in deep water • Can reduce water circulation (floating breakwater has less effect) • Potential navigational hazard • Require more land area • Uncertainty of successful vegetation growth and competition with invasive • No high water protection

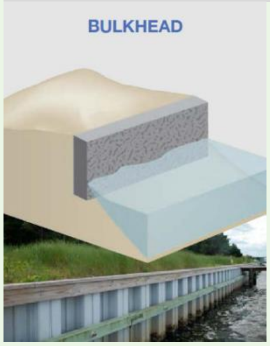
Average cost: $457-$966 per linear foot [b]
High initial construction cost Maintenance cost: $100 to over $500 per linear foot annually

Technique	Description	Benefits	Issues
	Groin integrates a structure perpendicular from the shoreline to the water. Intercept water flow and sand moving parallel to the shoreline to prevent beach erosion and break waves. Retains sand placed on the beach. Suitable for: Coordination with beach nourishment Material Options: Concrete/stone rubble (needs appropriate sizing for the site specific wave energy), timber, metal sheet piles	• Protection from wave forces • Methods and materials are adaptable • Can be combined with beach nourishment projects to extend their life	• Erosion of adjacent sites • Can be detrimental to shoreline ecosystem (e.g. replaces native substrate with rock and reduces natural habitat availability) • No high water protection

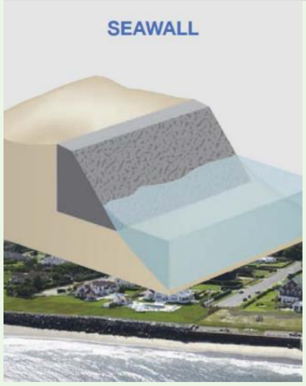
Average cost: $2,500 per linear foot [2b]
Maintenance cost: 10% of total cost per year [2b]

Technique	Description	Benefits	Issues
	Revetment integrates hard material on the slope of a shoreline for increased protection from erosion and waves. Suitable for: Sites with pre- existing hardened shoreline structures Material Options: Stone rubble, concrete blocks, cast concrete slabs, sand/concrete filled bags, rock-filled gabion basket	• Mitigates wave action • Little maintenance • Indefinite lifespan • Minimizes adjacent site impacts	• No major flood protection • Require more land area • Loss of intertidal habitat • Erosion of adjacent unreinforced sites • Require more land area • No high water protection Prevents upland from being a sediment source to the system

Average cost: $2,500 per linear foot [2b]
Maintenance cost: less than $2,500 per linear foot annually [b]

Technique	Description	Benefits	Issues
	Bulkhead integrates hard material to form a vertical retaining wall parallel to the shoreline for stabilization Suitable for: High energy settings and sites with pre-existing hardened shoreline structures. Helpful for docks Material Options: Steel sheet piles. Timber, concrete, composite carbon fibers, gabions	• Moderates wave action • Manages tidal level fluctuation • Long lifespan • Simple repair	• No major flood protection • Erosion of seaward seabed • Erosion of adjacent unreinforced sites • Loss of intertidal habitat • May be damaged from overtopping oceanfront storm waves • Prevents upland from being a sediment source to the system • Induces wave reflection

Average cost: $68-$113 per linear foot [b]
Maintenance cost: less than $100 per linear foot annually [b]

Technique	Description	Benefits	Issues
	Sea wall integrates a vertical or sloped wall parallel to the shoreline. Soil on one side of the wall is the same elevation as water on the other. Absorbs and limits impacts of large waves and directs flow away from land Suitable for: Areas highly vulnerable to storm surge and wave forces Material Options: Stone, rock, concrete, steel/vinyl sheets, steel sheet piles	• Prevents storm surge flooding • Resists strong wave forces • Shoreline stabilization behind structure • Low maintenance costs • Less space intensive horizontally than other techniques (e.g. vegetation only)	• Erosion of seaward seabed • Disrupt sediment transport leading to beach erosion • Higher up-front costs • Obstructs view • Loss of intertidal zone • Prevents upland from being a sediment source to the system • May be damaged from overtopping oceanfront storm waves

Average cost: $125 per linear foot for vinyl bulkhead [b] to $1,500 per linear foot for a seawall [2b] Maintenance cost: $100 to over $500 per linear foot [b]

PROJECT CONSIDERATIONS

Addressing your site-specific erosion comes down to selection of the most appropriate stabilization method that fits your site environment, needs, and budget.

Use the following considerations help in selecting a suitable stabilization method: Benefits, Design Considerations, Maintenance, Costs, and Resources Required. You can write your answers in a separate piece of paper.

Benefits	Environmental benefits: Societal co-benefits: Economic co-benefits:
Design Considerations	Size and dimensions: Circle the desired outcome(s): wave attenuation, sediment transport, stormwater retention, coastal buffering, stormwater infiltration, improved wildlife habitat Construction materials needed:
Maintenance	Type of maintenance needed: Frequency: Responsibilities (who and what):
Costs	Design or construction costs: Maintenance costs: Other cost considerations (permits, consulting, etc):
Resources Required	Technical expertise: Partner resources: Funding/budget:

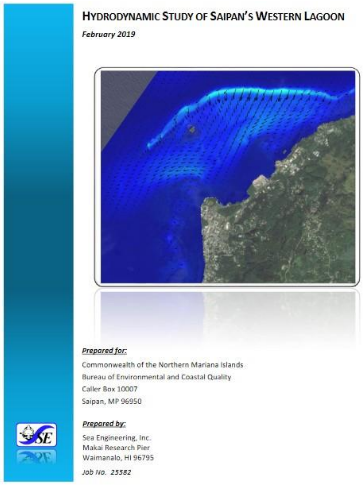
TOOLS AND RESOURCES

In addition to physical observations, these tools and information resources can supplement the preliminary self-assessment of your shoreline situation. Contact DCRM if you need assistance in obtaining the following resources. More resources and tools will develop overtime. Nonetheless, you should consult an engineer to develop a functional design that will address your needs.

Hydrodynamic Study of Saipan's Western Lagoon (2019)

DCRM relies on the 2019 hydrodynamic study conducted by Sea Engineering to predict sediment transport based on wave flow from different trade wind conditions. Smaller scaled nearshore dynamics modeling would improve knowledge of localized sediment transport.

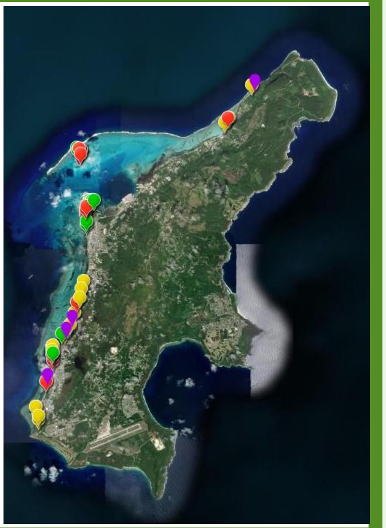
Link: https://dcrm.gov.mp/wp-content/uploads/crm/25582_Hydrodynamic-Study-of-Saipans-Western-Lagoon-02-25-19.pdf



Shoreline Monitoring Data Report and Map

DCRM's Shoreline Monitoring Program routinely records elevation difference measurements of the transects along the sandy coastline of Saipan, Mañagaha, Tinian, and Rota to understand coastal processes and the state of the shoreline. The Shoreline Monitoring map provides information and beach profiles, or cross-sectional graphs of a surveyed piece of shoreline.

Link: https://dcrm.gov.mp/our-programs/coastal-resources-planning/shoreline-monitoring/



Living Shoreline Applicability Index

The Nature Conservancy's Living Shoreline Applicability Index is a user-friendly Excel model that states the applicability of each living shoreline type based on site specific characteristics. Below are the definitions for scoring categories for the index. In providing this information, you may want to think about your site conditions during a storm. This tool is helpful to determining what living shoreline project will be appropriate (see next page).

Link:http://www.conservationgateway.org/ConservationPractices/Marine/crr/Documents/FINAL_Applicability_Index_7_12_2017_LOCKED.xlsx?Web=1

TOOLS AND RESOURCES

Figure 28: Living Shoreline Applicability Index is an informal planning and assessment tool mentioned in page 29.

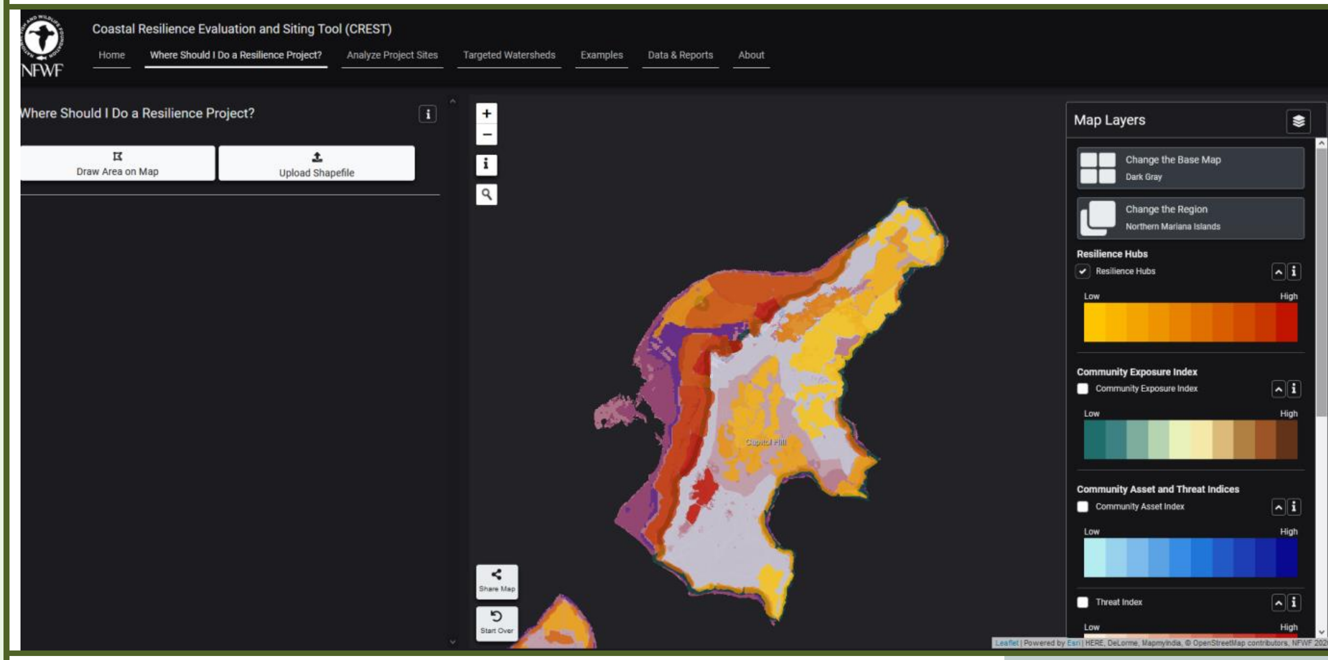
Energy State	Definitions
High	Project site has waves >5 feet, strong currents, high storm surge
Moderate	Project site has 2 – 5 foot waves, moderate currents, moderate storm surge
Low	Project site has waves < 2 feet in height, low current, low storm surge
Existing Resources	**Definitions**
Coastal Bank	Project will occur where there is an existing coastal bank
Coastal Dune	Project will occur where there is an existing coastal dune
Coastal Beach	Project will occur where there is an existing coastal beach
Salt Marsh	Project will occur where there is an existing coastal marsh
Mudflat	Project will occur where there is an existing salt marsh
Subtidal	Project will occur where there is an existing mudflat
Vegetated Upland	Project will occur in an existing subtidal area
Nearby Sensitive Resources	**Definitions**
Endangered/Threatened Species	Project site is near or in habitat or endangered or sensitive resources
Submerged Aquatic Vegetation (seagrass or algae)	Project site is near or in an area that contains submerged aquatic vegetation (SAV)
Shellfish	Project site near or in an area that contains significant shellfish populations
Cobble/Rocky Bottom	Project site is near or an area with cobble or rocky substrate
Tidal Range	**Definitions**
Low	Tide range at project site is less than 3 feet
Medium	Tide range at project site is between 3 and 9 feet
High	Tide range at project site is more than 9 feet
Elevation	**Definitions**
>Mean High Water	Location where project is to be built is above MHW
Mean High Water – Mean Low Water	Location where project is to be built between MHW and MLW
<Mean Low Water	Location where project is to be built is below MLW
Intertidal Slope	**Definitions**
Steep	Slopes 3:1 (base:height) and steeper
Moderate	Slopes between 3:1 and 5:1 (base:height)
Flat	Slopes 5:1 (base:height) and flatter
Nearshore Bathymetric Slope	**Definitions**
Steep	Slopes 3:1 (base:height) and steeper
Moderate	Slopes between 3:1 and 5:1 (base:height)
Flat	Slopes 5:1 (base:height) and flatter
Erosion	**Definitions**
High	Erosion at project site is high (>3feet/year)
Moderate	Erosion at project site is moderate (1-3 feet/year)
Low	Erosion at project site is low (<1 foot/year)

TOOLS AND RESOURCES

Coastal Resilience Evaluation and Siting Tool

The National Fish and Wildlife Fund's Coastal Resilience Evaluation and Siting Tool (CREST) is an interactive map that aids in informing where and how resilience could be built on our islands. Learn about your project site by capturing the area into the map to see its rating on the Resilience Hubs, Community Exposure, Community Asset, Threat, and Fish and Wildlife index. A justified project could be eligible for the National Coastal Resilience Fund.

Link to report: https://www.nfwf.org/sites/default/files/2020-08/northern-mariana-islands-coastal- resilience-assessment.pdf
Link to tool: https://resilientcoasts.org/



CNMI Smart Safe Growth (SSG) Guidance

The Office of Planning and Development, in collaboration with other resource agencies, published the SSG Guidance to support community resilience and alignment with long-term sustainability goals and objective.

Link: https://opd.gov.mp/assets/cnmi-ssg-guidance-manual-final-2018-11-14.pdf

FUNDING OPPORTUNITIES

This section presents federal funding opportunities for green infrastructure and nature- based solutions. This is primarily for government agencies, but residents are also welcomed to reach out to DCRM regarding their interest. For more information, reach out to shorelines@dcrm.gov.mp.

US Environmental Protection Agency

- **Clean Water State Revolving Fund (CWSRF) Water Infrastructure Finance and Innovation Act**
- **Environmental Justice Grants**
- **Great Lakes Restoration Initiative (GLRI) Overflow and Stormwater Grants Section 319 Non-Point Source Grants**

US Department of Agriculture

- **Watershed and Flood Prevention Operations Program**
- **Watershed Rehabilitation Program**

US Department of Housing and Urban Development

- **Community Development Block Grant (CDBG)**
- **Community Development Block Grant (CDBG) - Section 108**

Federal Emergency Management Agency

- **Building Resilient Infrastructure & Communities (BRIC)**

National Oceanic and Atmospheric Administration

- **Coastal and Marine Habitat Restoration Grants (NMFS OHC)**
- **Coastal and Estuarine Land Conservation Program (CELCP)**

National Fish and Wildlife Foundation

- **National Coastal Resilience Fund**

US Army Corps of Engineers

- **Floodplain Management Services Program (FPMS) Technical Assistance**
- **Planning Assistance to States (PAS)**
- **Continuing Authorities Program (CAP) Sec 205 – Small Flood Risk Management Projects**
- **Continuing Authorities Program (CAP) Sec 204 – Beneficial Use for Dredged Material**
- **Continuing Authorities Program (CAP) Sec 1135 – Modification of Projects for the Environment**
- **Individually Authorized Feasibility Studies and Projects**
- **Watershed Studies**

PLANNING AND PERMITTING STEPS

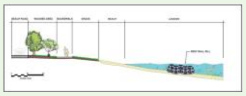
Step 1: Consult with DCRM

Communicate with DCRM on the need for stabilization. Before you submit any permit applications, schedule a pre-application meeting to identify all required permits and approvals indicated in Step 6.

Step 2: Conduct a Site Analysis

Consult with an engineering firm to thoroughly assess the site conditions before and during storm conditions. You can use the resources in page 29 to guide your analysis. This assessment could help you and the consultant with the next step.

Step 3: Prepare a Project Design



Create map and sketches of the project design with specifications of the select stabilization measure(s). Once this is completed, you can schedule a pre-application meeting to present the designs to DCRM and identify all required permits and approvals.

Step 4: Present your Project Proposal

Fill out the Division of Environmental Quality (DEQ) One Start permit application. The following questions on the next page are intended to gather as much relevant information about your project to allow DCRM to properly assess the potential impacts of your activities and if needed, provide additional guidance.

NOTES

PLANNING AND PERMITTING

Please answer the following questions. You can consult DCRM or an environmental firm in filling in any questions that might require expert knowledge.

What types of natural habitat are present at the site and along adjacent shorelines?

What is the extent, rate, and cause of the current erosion problem?

What are the site's slope, orientation, bathymetry, direction of seasonal currents, and level of wave energy?

Are other hard stabilization structures nearby?

Does land loss occur mostly during large storms, or year-round?

What are the current land and water uses in the area and who owns or manages them?

How much boat traffic occurs along the shoreline?

Is the site suitable for planting vegetation as part of a living shoreline project?

What would be the result if nothing was done to the site (aka: no action alternative)?

What ecologically valuable aquatic habitats (seagrass, coral reef, native-dominated tidal wetland, federally threatened or endangered species habitat) or animals are living along the shoreline at the site? What would be the impact to these habitats?

PLANNING AND PERMITTING

Step 5: Develop a maintenance plan

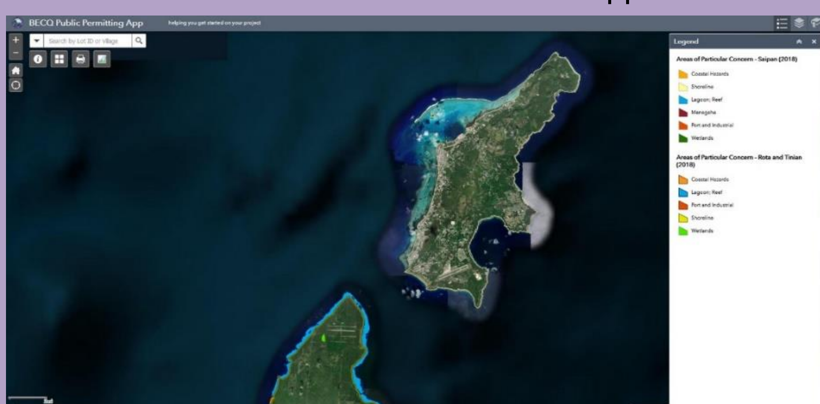
Develop a maintenance plan that covers: goals and objectives, team member(s) responsible, time/frequency of maintenance activities, identified sources of selected plant species, repair/replanting protocol for before and after a major storm, and documentation to adjust management actions.

Step 6: Submit One Start Permit and follow through with permits needed to achieve environmental compliance and reduce adverse effects.

All shoreline projects must comply with federal, state, and local laws and regulations. Permits must be received before construction. The following agencies are highlighted but may not be the least involved.

DCRM will determine which of the following will apply:

Shoreline Area of Particular Concern - area between high tide line and 150 feet inland
Lagoon and Reef – area consisting of partially enclosed body of water formed by sand spits, bay mouth bars, barrier reefs, or coral reefs within the Commonwealth
Major Siting - required for all major developments, uses, or activities that have potential to cause significant adverse impacts to coastal resources
Federal Consistency - required by Section 307 in the Coastal Zone Management Act that certain federal actions be consistent with approved state coastal management actions



The BECQ Public Permitting App can be used to see what APCs your project falls under.

PLANNING AND PERMITTING

DCRM Rules and Regulations NMIAC §15-10-101 (c): "Soft measures" such as living shorelines, planting native beach vegetation, maintaining or establishing vegetative buffers, or building green swales for water collection and the like must be considered as alternatives to hard structures, such as sea walls, to limit coastal erosion. If "hard structures" are proposed, application must explain what "soft measures" were considered and why they were determined to be inappropriate.

Need to understand the major siting permit requirements? DCRM Major Siting Permit guidance book is available online: https://dcrm.gov.mp/wp-content/uploads/crm/Final-Guide_finalv2.pdf

HPO will determine if project is proposed in sensitive areas on or near known archaeological or historical sites.

If so, additional consultation may be needed.

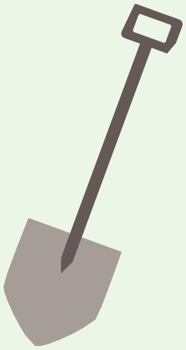
DFW needs to know if the proposed project may impact an endangered or threatened species and/or their critical habitat.

Biological consultation may be required.

USACE Nation Wide Permit #54

Contact the appropriate Corps district office to determine if regional conditions have been imposed on a Nation Wide Permit and if your project requires a permit from Army Corps. Important note: The Living Shoreline permit doesn't authorize beach nourishment or land reclamation activities.

The district engineer may waive the criterion by issuing a written determination that concludes that the proposed activity(s) will not have any result more than minimal adverse environmental effects.



Step 7: Site preparation and construction sequencing

After the permits have been approved, your construction team can commence preparing the sites.

Step 8: Installation

Ensure that the project is properly installed accordingly to plan and follows permit conditions. During this time, modification is expected to existing shorelines, emplacement of any structural elements, with post construction grading or site modifications.

Step 9: Post-construction maintenance

Implement the maintenance plan developed in Step 5. This is required until the area is stabilized and self-sustaining. Debris removal, replanting vegetation, and ensuring organic and structural materials shall be executed after high energy storms as outlined. Documenting the progress of the project can contribute to local research on the efficacy of local nature-based solution implementation.

LANDSCAPING AND SUITABLE PLANTS

Worldwide, salt-tolerant seaside plants stabilize sandy ground while benefiting humans and wildlife. The "Vegetation Only" stabilization method is the most affordable option and can be done by the landowner. However, native species in the CNMI can function and thrive when they are strategically planted where they are known to do well. In landscaping and plant selection, you should think about selecting plant species that have high tolerance to salinity and wind, and where your landscaping project area falls within the general layout of your shoreline as portrayed in Figure 29 and 30. This section provides a list of native species plants suited for stabilization and their preferred location along a shoreline area.

Nearshore and intertidal areas are challenging areas to plant due to wave damage, but it is worthwhile to stabilize the backshore areas with many plants for stormwater retention and infiltration.

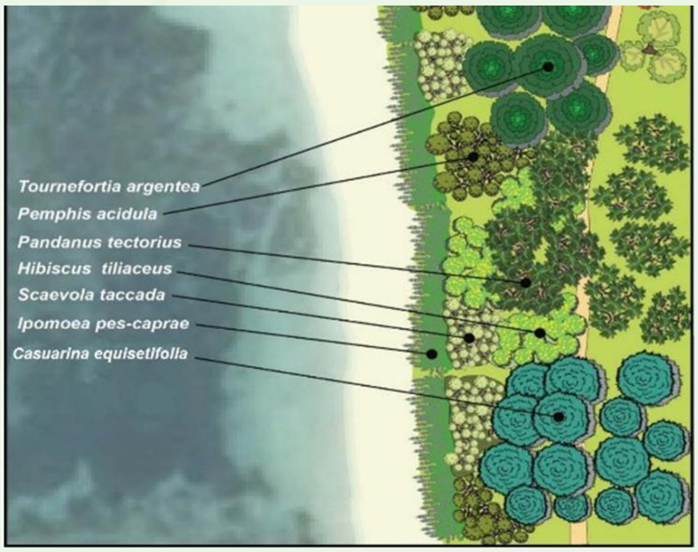


Figure 29 - Example landscaping plan of a portion of Beach Road indicating where native species are preferred along the shoreline at aerial view. Retrieved from the Garapan Area Shoreline Assessment Study.

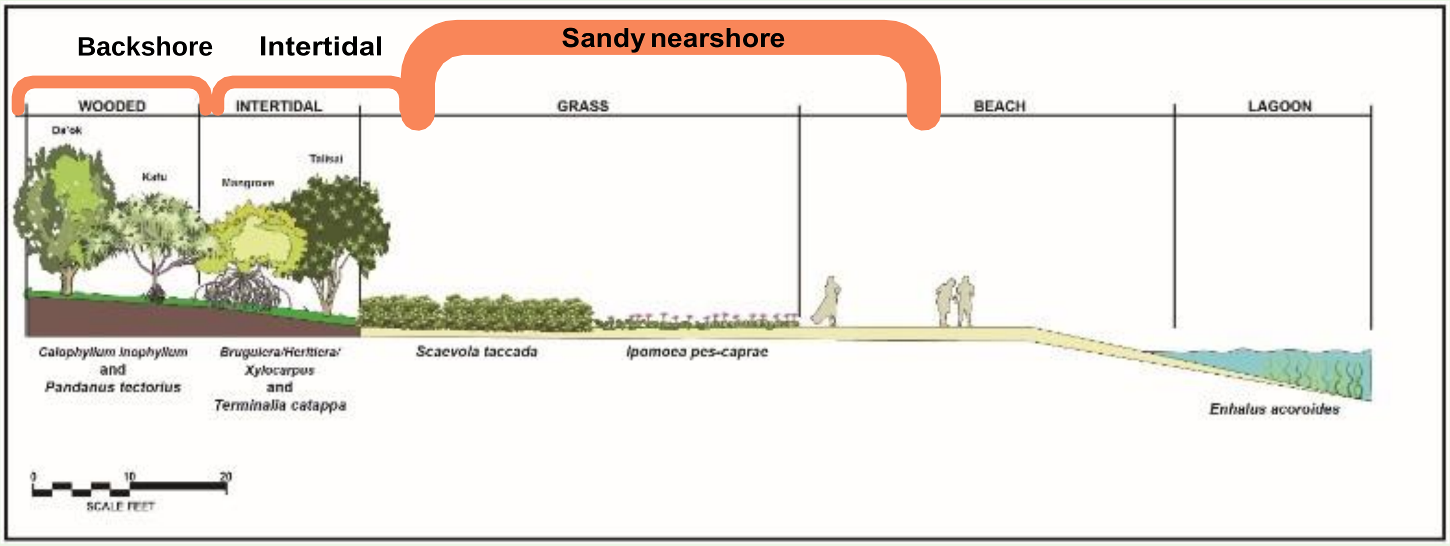


Figure 30 - The general layout of a shoreline on the western side of Saipan consists of wooded, intertidal, grass, beach, and lagoon area (from left to right). Consider the location of your project.

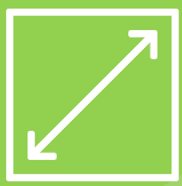
Planting Tips

Listed plants marked with this CNMI Forestry-verified symbol are recommended and more likely to be found in their plant nursery.

Ensure that the plant has a 4 foot diameter buffer from other plants

Ensure that bushcutting activities will not destroy the plant by placing a barrier or communicating with the maintenance worker

Consider the size of the plant species to determine how much space and distance it needs from other plants



Consider the costs of maintenance (such as water, soil, fertilizer, etc) into the budget

NUSERIES

CNMI Forestry

Location: Department of Agriculture, Kagman
Point of Contact: Pedro Tudela
Phone: 1 (670) 256-3320 (24 hour hotline)
Email: ptudelacnmiforestry@gmail.com
Notes: Free plants are available based on inventory and early consultation

Shop your local plant nurseries for native and ornamental plants.

Ornamental non-native species that are hardy and have extensive roots can also be planted in the backshore areas.

This list emphasizes native plants because they are essential for native ecosystems and typically require have less maintenance.

SANDY NEARSHORE (where waves break)

***Ipomea pes caprae*/ Beach Morning Glory/Alalai-Tasi**

Type: Groundcover vine Requirements: Sunny area Propagation preference: Cuttings

Benefits: Great sand stabilizer, medicinal value
Resources: http://tropical.theferns.info/viewtropical.phpid=Sporobolus+virginicus

Lepturus repens

Type: Perennial grass Requirements: Sunny area and sandy and muddy soil Propagation preference: Cuttings and seeds
Benefits: Great soil stabilizer for shorelines and stream banks, medicinal value

Resources: Carr, C. 2010. Plant Fact Sheet for Knotgrass (Paspalum distichum). USDA-Natural Resources Conservation Service, James E. "Bud" Smith Plant Materials Center. Knox City, TX 79529 https://plants.usda.gov/factsheet/pdf/fs_padi6.pdf

***Canavalia maritima*/ Coastal Jack Bean**

Type: Groundcover vine Requirements: Sunny area and sandy soil
Propagation preference: Seeds
Benefits: Great sand stabilizer, attractive flowers and leaves

Resources:
http://www.wildsingapore.com/wildfacts/plants/coastal/canavalia/maritima.htm

***Vigna marina*/ Yellow Beach Bean**

Type: Groundcover vine
Requirements: Sunny area Propagation preference: Seeds
Benefits: Great sand stabilizer, attractive flowers and leaves, medicinal value

Notes: Symbiotic relationship with certain soil bacteria that form on the nodules of roots and fix atmospheric nitrogen

Resources:
http://tropical.theferns.info/viewtropical.php?id=Lepturus+repens

SANDY NEARSHORE (where waves break)

***Sporobolus virginicus*/ Seashore Dropseed**

Type: Perennial grass Requirements: Sunny area Propagation preference: Cuttings (vegetative rhizomatous slips)

Benefits: Great sand stabilizer, medicinal value

Resources: http://tropical.theferns.info/viewtropical.php?id=Sporobolus+virginicus

***Paspalum distichum*/ Knotgrass**

Type: Perennial grass Requirements: Sunny area and sandy and muddy soil Propagation preference: Cuttings (sprigs or sod), seeds (break from dormancy at 20-30 degrees celsius)

Benefits: Great soil stabilizer for shorelines and stream banks, medicinal value

Resources: Carr, C. 2010. Plant Fact Sheet for Knotgrass (Paspalum distichum). USDA-Natural Resources Conservation Service, James E. "Bud" Smith Plant Materials Center. Knox City, TX 79529.https://plants.usda.gov/factsheet/pdf/fs_padi6.pdf

Cyperus javanicus

Type: Perennial grass Requirements: Sandy and muddy soil; freshwater input Propagation preference: N/A

Benefits: Great soil stabilizer for shorelines and stream banks, medicinal value

Notes: Native grass suitable for coastal marshes and mangrove edges. Grows up to 40-100 cm (1.5 - 3 feet) tall. May be suitable for drainage areas

Resources: http://nativeplants.hawaii.edu/plant/view/Cyperus_javanicus

***Cyperus odoratus*/ fragrant flatsedge**

Type: Perennial grass Requirements: Sandy and muddy soil; freshwater input

Propagation preference: N/A

Benefits: Great soil stabilizer for shorelines and stream banks, medicinal value

Notes: Native grass suitable for coastal marshes and mangrove edges. Grows up to 30-100 cm (1 - 3 feet) tall. May be suitable for drainage areas

Resources: https://www.wildflower.org/plants/result.php?id_plant=CYOD

SANDY NEARSHORE (where waves break)

***Cyperus polystachyos*/many spike flatsedge**
Type: Perennial grass Requirements: Sandy and muddy soil; freshwater input
Propagation preference: N/A

Benefits:
Notes: Native grass suitable for ditches, roadsides, and cultivated areas. Grows up to 10-60 cm (0.5 - 2 feet) tall, with triangular steams. May be suitable for drainage areas
Resources:

***Scaevola sericea*/beach naupaka/nanasu**
Type: Perennial grass Requirements: Sandy and muddy soil; freshwater input Propagation preference: N/A

Benefits: Buffers strong winds and waves, attractive flowers and leaves, can be shaped into hedges, drought tolerant, medicinal value, cultural value
Notes: Spreads alone the wracklines of the coast, canal banks, mangroves and inland shorelines

Resources:
http://www2.hawaii.edu/~eherring/hawnprop/sca-seri.html

INTERTIDAL (where water hits during high tide)


***Barringtonia asiatica*/fish poison tree/puteng**

Type: Large tree Requirements: Fertile, humid, well-drained soil; sunny or light shady areas; brackish water Propagation preference: Cuttings and seeds

Benefits: Buffers strong winds and waves, attractive flowers and leaves, medicinal value

Notes: Oily seed is toxic. Not tolerant of fire. Grated seed has stupefying effect on fish

Resources: http://tropical.theferns.info/viewtropical.php?id=Barringtonia+asiatica

***Bruguiera gymnorhiza*/oriental mangrove/mangle manchu**

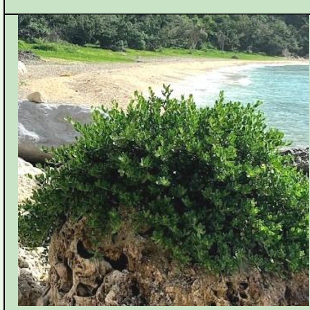
Type: Small to medium tree Requirements: Brackish water- logged soils, partial to full sunny areas

Propagation preference: Seeds

Benefits: Buffers strong winds and waves, wildlife shelter and food source

Notes: N/A

Resources:https://www.researchgate.net/profile/Norman-Duke/publication/240618767_Bruguiera_gymnorrhiza_large-leafed_mangrove/links/0c960528ad92651d5c000000/Bruguiera-gymnorrhiza-largeV-loelakfeadm-merainagirnoeverm.pdisf/seaside clerodendrum/lodugao



***Pemphis acidula/*nigas**

Type: Shrub or small tree

Requirements:

Propagation preference: Seeds

Benefits: Buffers strong winds and stabilizes rock, attractive flowers and leaves, medicinal value, cultural value, and food value

Notes: Locally protected from harvesting.

Resources: http://tropical.theferns.info/viewtropical.php?id=Pemphis+acidula

***Volkameria inermis*/seaside clerodendrum/lodugao**

Type: Sprawling shrub Requirements: Sunny and sandy soils

Propagation preference:

Cuttings and seeds

Benefits: Buffers strong winds and waves, attractive flowers and leaves

Resources:
https://toptropicals.com/catalog/uid/Clerodendrum_inerme.html

BACKSHORE (more inland areas)

***Guilandina bonduc*/beach nicker/pakao**

Type: Vine
Requirements: Salty and waterlogged soils; partial to full sunny areas
Propagation preference: Seed

Resources: http://tropical.theferns.info/viewtropical.php?id=Guilandina+bonduc&redir=Caesalpinia+bonduc

***Calophyllum inophyllum*/da'ok**

Type: Medium, wide tree
Requirements: Variety of soils Propagation preference: Seed

Benefits: Shade tree, windbreak, wildlife shelter, attractive sweet-smelling flowers, medicinal use

Resources: http://tropical.theferns.info/viewtropical.php?id=Calophyllum+inophyllum

***Casuarina equisetifolia*/ironwood/gago**

Type: Tall, wide tree
Requirements: Sunny areas and sandy (or other coarse-textured) soils
Propagation preference: Seed
Benefits: Tolerant to salt spray and moderate typhoon damage, wildlife shelter
Notes: The leaf litter releases chemicals that inhibit growth of understory species. Shallow root system suggests it may be uprooted and fell by powerful wind storm events. Best to avoid planting on or too close to water lines and sewer lines.

Resources: https://cnas-re.uog.edu/wp-content/uploads/2019/07/WSARE-Updated-ironwood-manual-06082019.pdf

***Cocos nucifera*/coconut tree/niyok**

Type: Tall tree
Requirements: Variety of soils
Propagation preference: Seed
Benefits: Food source, high cultural use, tolerant to typhoon wind damage
Notes: May be hazardous due to falling heavy fruit. Although highly tolerant to salt water, it is not encouraged to plant right on highly erosive sandy grounds.

Resources: https://www.thespruce.com/grow- coconut-palms-inside-1902595

BACKSHORE (more inland areas)

***Cordia subcordata*/marer/niyoron**

Type: Tall tree
Requirements: Variety of soils
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, shade tree, cultural value
Notes: Do not overwater seedlings since pathogenic fungi can injure roots during outplanting.

Resources: https://www.uog.edu/_resources/files/extension/Niyoron.pdf

***Dendrolobium umbellatum*/palaga hilitai**

Type: Bushy shrub
Requirements: Salty and rock soils; partial to fully sunny areas
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, construction and fuel value, medicinal value, food (young leaves)

Resources:
https://www.nparks.gov.sg/florafaunaweb/flora/6/6/6673
http://tropical.theferns.info/viewtropical.php?id=Dendrolobium+umbellatum

***Guettarda speciosa*/zebrawood/panao**

Type: Evergreen small or large shrub
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, shade tree, wildlife food source, cultural value, fast growing
Notes: Can be pruned to achieve desired shape and size

Resources:
http://tropical.theferns.info/viewtropical.php?id=Guettarda+speciosa
https://www.guamnativeherbology.com/guettarda-speciosa.html

***Eugenia reinwardtiana*/beach cherry/a'abang**

Type: Large shrub to small tree Requirements: Well-drained, fertile limestone soils; partial to full sunny areas
Propagation preference: Seeds and cuttings
Benefits: Attractive flowers and leaves, coastal protection, windbreak, construction and cultural value, wildlife food source, food value
Notes: Can be potted and used as a hedge

Resources: https://cnas-re.uog.edu/wp-content/uploads/2017/03/Aabang.pdf

BACKSHORE (more inland areas)

Hernandia nymphaeifolia/lantern tree/nonak
Type: Large tree
Requirements: Sandy soil
Propagation preference: Seeds and cuttings of mature wood
Benefits: Attractive, shade tree; wildlife shelter and food source; medicinal value; fast-growing tree
Notes: Seeds are flammable and culturally used as candles

Resources: https://www.uog.edu/_resources/files/extension/Nonak.pdf

Hibiscus tilliaceus/beach hibiscus/pago
Type: Evergreen small or large shrub
Requirements: Sandy and organic soil and sunny to lightly shady areas
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, shade tree, wildlife food source, cultural value, fast growing
Notes: Can be pruned to achieve desired shape and size

Resources:
https://www.gardeningwithangus.com.au/hibiscus-tiliaceus- sea-hibiscus/

Mammea odorata/chopak

Type: Medium, wide tree
Requirements: Limestone or rocky grounds with part shade

Propagation preference: Seed

Resources: https://cnas-re.uog.edu/wp-content/uploads/2017/03/Chopak.pdf

http://tropical.theferns.info/viewtropical.php?id=Mammea+odorata

Ochrosia oppositifolia/twin apple/fagot
Type: Evergreen small or large tree
Requirements: Sandy and limestone soils and sunny to lightly shady areas
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, shade tree, wildlife food source, cultural value, fast growing
Notes: Can be pruned to achieve desired shape and size

Resources: http://tropical.theferns.info/viewtropical.php?id=Ochrosia+oppositifolia

Pandanus tectorius/screwpine/kafu
Type: Small evergreen tree
Requirements: Sandy soils,
preferred position right next to nearshore
Propagation preference: Seed
and (large) cuttings
Benefits: Cultural use (crafting)

Resources: http://tropical.theferns.info/viewtropical.php?id=Pandanus+tectorius

Premna obtusifolia/aghao/false elder
Type: Small to medium tree Requirements: Damp soils
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, aromatic smell, construction and cultural value, windbreak, shade tree, wildlife food source, medicinal value
Notes: Do not overwater seedlings since pathogenic fungi can injure roots during outplanting

Resources:http://www.comfsm.fm/~dleeling/angio/premna_obtusifolia.html

Suriana maritima/bay cedar/nietkot
Type: Shrub
Requirements: Sandy and limestone rubble soils; fully sunny areas
Propagation preference: Seeds and cuttings of mature wood
Benefits: Attractive flowers and leaves, coastal protection, windbreak, drought tolerant
Notes: Can be used as a hedge and found landward of Avicennia mangrove

Resources: http://tropical.theferns.info/viewtropical.php?id=Suriana+maritima

Terminalia catappa/pacific almond/talisai
Type: Small to medium tree
Requirements: Limestone soils
and shady areas
Propagation preference: Seed
and cutting

Benefits: Coastal protection, windbreak, shade tree, wildlife, food source, cultural value

Resources:
http://apps.worldagroforestry.org/treedb/AFTPDFS/Terminalia_catappa.PDF

 **Thespesia populnea/rosewood/banalo** Type: Medium tree Requirements: Sunny areas and variety of soils Propagation preference: Seeds Benefits: Shade tree, windbreak, wildlife shelter, cultural uses, attractive flowers Notes: Best more inland from mangrove areas and great for wetlands Resources: http://www2.hawaii.edu/~eherring/hawnprop/the-popu.html	 **Tournefortia argentea/hunik** Type: Small evergreen tree Requirements: Partial sunlight first before full sun exposure Propagation preference: Seeds, cutting, air-layering Benefits: Windbreak, medicinal, wildlife shelter, cultural use Resources: https://www.uog.edu/_resources/files/extension/Hunik-1.pdf

BACKSHORE (more inland areas)

Triumfetta procumbens/burbark/masiksi hembra
Type: Groundcover vine
Requirements: Sunny areas
Benefits: Windbreak, topical and cultural value, medicinal value
Notes: Ground cover

Resources:
https://irma.nps.gov/DataStore/DownloadFile/486540

Ximenia americana/false sandlewood/piut
Type: Shrub or tree Requirements: Variety of soils; full sunny to lightly shaded areas
Propagation preference: Seeds
Benefits: Attractive flowers and leaves, coastal protection, windbreak, topical and cultural value, wildlife food source, medicinal value, food value
Notes: Can be used as a hedge

Resources: http://tropical.theferns.info/viewtropical.php?id=Ximenia+americana
http://guamology.com/ximenia-elliptica-beach-plum.html

Xylocarpus moluccensis/cannonball tree/lalamyok
Type: Evergreen small or medium shrub Requirements: Salty and waterlogged soils, full sun
Propagation preference: Seed
Benefits: Attractive flowers and leaves, coastal protection, windbreak, shade tree, wildlife food source, cultural value, medicinal value
Notes: Mangrove

Resources:
https://www.nparks.gov.sg/florafaunaweb/flora/3/2/3209

NATURE-BASED SOLUTIONS IN THE CNMI

Nature-based projects to address shoreline erosion are leveraged by local environmental agencies and nongovernmental agencies interested in addressing climate change and disaster mitigation. Innovation and research are important to build knowledge and efficacy of nature-based solutions locally. The following projects are existing cases to help the development of future nature-based projects.

Pacific Coastal Research and Planning and Horsley Witten's Shoreline Stabilization and Enhancement Plan for the Beach Road Pathway

Project highlights:

- Permit ready designs for shoreline stabilization and stormwater enhancement projects along Beach Road
- Community-driven vision and involvement in designs
- Shoreline Master Plan for Beach Road Horsley Witten assessed site's physical and stormwater infrastructure conditions
- Shoreline Conservation assessed site's coastal processes to feed into the shoreline stabilization design
- Funded by National Fish and Wildlife Foundation

Webpage:
https://www.pacificcrp.org/beach-rd-shoreline-study/

Contact Info:
info@pacificcrp.org
670-285-7995

Below are tentative and on-going restoration projects that improve coastal protection led by local environmental agencies and firms:

- Johnston Applied Marine Sciences' Saipan Coral Nursery Pilot Project
- DCRM Coral Nursery
- Coral Reef Initiative Mangrove Restoration
- CNMI Forestry and MINA's "Bring Back our Trees" Campaign
- Green Roof of H.S. Lee Building in Garapan

RECOMMENDATIONS

Despite being prioritized in many planning objectives, nature-based solutions and green infrastructure are challenged with the need for improved cost and benefits data, site-designs, and implementation experience in the CNMI. On-going planning projects revolving around nature-based solutions are important to document and monitor going into the implementation stage, so that future projects can be leveraged through lessons from experience.

Interagency collaboration on the local and federal level must continue in order to plan, fund, enable, and monitor effective projects.

The following presented below are general recommendations that emerged from research on this guidebook along with engagements inside and outside this project:

- Calculate estimated costs accurate to the CNMI
- Build local capacity
- Identify data and develop tools
- Incorporate traditional knowledge into planning and design
- Seeking technical assistance
- Encourage and support the development of native plant nurseries
- Develop and maintain a project tracker tool

SUPPLEMENTARY RESOURCES

From CNMI

2018 DCRM Regulations: https://dcrm.gov.mp/wp-content/uploads/crm/2018_CRMRegs_FINAL.pdf

"Commonwealth of the Northern Mariana Islands Wetland Plants Identification Guide": https://dcrm.gov.mp/wp-content/uploads/crm/CNMI-Wetland-Plants-Identification-Guide-Final_reduced.pdf

"Native Wetland Plants of the Northern Mariana Islands": https://dcrm.gov.mp/our- programs/education-and-outreach/outreach-materials/coral-monitoring-e-learning- course/attachment/native-wetland-plants-of-the-northern-mariana-islands-2/

From Federal Agencies

"Examples of Natural Infrastructure Protection of Coastal Highways": https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/examples.cfm

"Guidance for Considering the Use of Living Shorelines" from NOAA: https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for- Considering-the-Use-of-Living-Shorelines_2015.pdf

"Using Natural Infrastructure to Protect Coastal Roads and Bridges" from the U.S. Federal Highway Administration: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/coastal_roads_and_bridges/coastal.pdf

"Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience" from USACE: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/examples.cfm

FEMA (2020). Building Community Resilience with Nature-Based Solutions. https://www.fema.gov/sites/default/files/2020-08/fema_riskmap_nature-based-solutions-guide_2020.pdf

SAGE, NOAA, and USACE. (2016). Natural and Structural Measures for Shoreline Stabilization. https://coast.noaa.gov/digitalcoast/training/living-shorelines.html

From Other States

"A Community Resource Guide for Planning Living Shorelines Projects New Jersey" from Conservation :https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/Community%20Resource%20Guide%20for%20Planning%20Living%20Shoreline%20Projects.pdf

"Living Shorelines Engineering Guidelines" from the Stevens Institute of Technology: https://www.nj.gov/dep/cmp/docs/living-shorelines-engineering-guidelines-final.pdf

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[5] Krauss, K. W., Doyle, T. W., Doyle, T. J., Swarzenski, C. M., From, A. S., Day, R. H., and Conner, W. H. (2009). "Water level observations in mangrove swamps during two hurricanes in Florida." Wetlands, 29(1), 142–149.

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[8] Nature-Based Resilience and Adaptation to Climate Change in Hawai'i: A Climate Ready Hawai'i Working Paper (2021) Prepared by the Hawai'i Climate Change Mitigation and Adaptation Commission. https://climate.hawaii.gov/wp-content/uploads/2021/04/CRHI-Working-Paper-V5.pdf

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[11] USACE (2017). Garapan Area Shoreline Assessment Study. Prepared for the U.S. Department of the Interior, Office of Insular Affairs and the Commonwealth of the Northern Mariana Islands Bureau of the Environmental and Coastal Quality. https://dcrm.gov.mp/wp-content/uploads/crm/GASAS_LSL_Final-1.pdf

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"Humankind's greatest priority is to reintegrate with the natural world."

- Johnathon Porritt

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