UNEP

**Caribbean Environment Programme**

**United Nations Environment Programme**

# MANUAL FOR SAND DUNE MANAGEMENT IN THE WIDER CARIBBEAN

**WITH THE SUPPORT OF:** **November 1998**

USAID

**Note:**

This document was commissioned by the Natural Resource Management Unit of the Organization of the Eastern Caribbean States (OECS) from Gillian Cambers of the University of Puerto Rico, through the United Nations Environment Programme (UNEP) - Caribbean Environment Programme (CEP), under the USAID / UNEP Caribbean Environmental Network (CEN) Project (CR / FP / 0401-94-15[CP / 0401-94-47]).

## FOREWORD

The Anguilla Sand Dune Project was undertaken through a Memorandum of Understanding between the Natural Resources Management Unit of the Organization of Eastern Caribbean States (OECS-NRMU) and the Regional Coordinating Unit of the Caribbean Environment Programme of the United Nations Environment Programme (UNEP-CAR/RCU). The memorandum is related to UNEP-CAR/RCU's sub-programme "Conservation and Sustainable Use of Major Ecosystems in the Wider Caribbean" of the Regional Programme on Specially Protected Areas and Wildlife (SPAW) and established in the project CR/FP/CP/0401-94-15: "Regional Programme on Specially Protected Areas and Wildlife (SPAW)"

In keeping with the objective and spirit of the SPAW Programme, the Caribbean Environment Programme (CEP) has embarked on a new but integral component of the Programme - the Caribbean Environment Network (CEN) Project - aiming at improving environmental quality and the conservation of natural resources of the coastal and marine environment. The CEN Project focuses on reducing environmental impacts by tourism, given the importance and scope of the industry in the Wider Caribbean and its close linkages with various marine and coastal habitats in the region.

This activity is part of the USAID's Caribbean Environmental Network project in support of the Caribbean Environment Programme. This project was undertaken in response to the Cartagena Convention and its Protocols and also responds directly to the recommendations of Chapter 17 in Agenda 21, adopted at the Earth Summit in 1992, the Programme of Action of *SIDS* and to the Regional Agenda for Action of the International Coral Reef Initiative (ICRI), developed in Jamaica in July 1995.

The Natural Resources Management Unit (NRMU) of the Organization of Eastern Caribbean States (OECS) has been fostering effective collaboration, cooperation and coordination among OECS countries in the utilization and management of the use of natural resources for sustainable development in the region. The OECS-NRMU has also been coordinating and implementing programmes of multilateral and international donor agencies in the areas of coastal and marine resources management, human settlements, forestry, waste management, watershed management, environmental education and public awareness. It has, and continues to assist, governments with policy formulation, training, natural resource assessment and monitoring and development of plans and manuals, among others in the above-mentioned areas.

The emphasis on sand dunes in Anguilla and within the OECS generally is predicated on the emerging paradigm of Island Systems Management (ISM), which recognizes the intricate linkages between all systems on an island and the need for a special management regime. The island itself is seen as an assemblage of systems all interacting with each other. Intervention in any system will impact other linked systems. Therefore, any management framework must consider the interactions and linkages between systems on islands and must be multi-disciplinary and multi-sectoral. ISM is therefore seen as an adaptive management strategy which addresses issues of resource use conflicts, and which provides the necessary policy orientation to control the impacts of human intervention on the environment.

It is within this framework that the OECS-NRMU undertook to implement the pilot demonstration activity in Anguilla to assess the status of sand dunes, improve the methodology for their rehabilitation and improve current practices in Island Systems Management pertinent to the management of the use of sand dunes.

The focus on sand dunes in this project is the result of the extreme degradation caused to these systems through unsound exploitation practices such as extraction for construction aggregate or the construction of infrastructure on these systems. The importance of sand dunes to the protection of shore areas from erosion by the sea, has been lost in the drive to secure economic benefits, and it is the purpose of this project to help to educate and to establish policies throughout the Wider Caribbean, which would ensure the sustainable use of these vital shore systems.

This manual is one of the products of a one year project entitled 'Sand Dune Rehabilitation and Awareness Project', conducted in Anguilla during 1997-1998, following the extensive damage to infrastructure and environmental resources caused by Hurricane Luis in 1995. This project had two main components: sand dune rehabilitation at two sites and the design and implementation of an awareness campaign on coastal resources. This manual draws upon the experiences gained in Anguilla and combines them with other case studies and activities in the region and beyond, to produce a practical series of guidelines for the management of the use of sand dunes in the Wider Caribbean.

A number of other regional and international organizations have embarked on programmes to improve environmental practices towards achieving sustainable tourism in the region. It is the goal of all the agencies (USAID/UNEP CEN, OECS-NRMU) involved in this project to contribute to these efforts in support of the sustainable use of natural resources of the Wider Caribbean region.

**ACKNOWLEDGEMENTS**

Many persons have shared experiences, ideas and information which have contributed to this report. In particular, appreciation is expressed to:

**Anguilla National Trust**: Gina Brooks, Ijanhya Christian, Elizabeth Subin;

**Cap Juluca, Anguilla**: Kerry Knotts, Bonnie Warner Fleming;

**Department of Fisheries and Marine Resources, Anguilla**: Roland Hodge, Othlyn Vanterpool;

**Physical Planning Department, Anguilla**: Orris Proctor, Sharon Roberts-Joseph;

**Coastal Zone Management Unit, Barbados**: Leonard Nurse, Yuri Chakalall;

**Department of the Environment, Belize**: Evaristo Avella;

**Department of Fisheries and Conservation, British Virgin Islands**: Halstead Lima;

**Smith Warner International Ltd., Jamaica**: David Smith;

**United Nations Environment Programme, Jamaica**: Monica Borobia;

**Department of Natural and Environmental Resources, Puerto Rico**: Andrea Handler;

**Department of Environment, St. Kitts and Nevis**: June Hughes;

**Organization of Eastern Caribbean States Natural Resources Management Unit, St. Lucia**: Keith Nichols;

**Seismic Unit, Ministry of Agriculture, St. Vincent and the Grenadines**: Chalis Porter.

## *EXECUTIVE SUMMARY*

*The physical, ecological and aesthetic functions of sand dunes in the Wider Caribbean have received little attention, even though their economic value has been widely recognized and utilized as dunes have been exploited for construction sand and have become prime sites for coastal real estate.*

*This manual attempts to provide guidelines for the assessment, management and rehabilitation of sand dunes in the Wider Caribbean Region. It has been designed for government officials, community groups and environmental organizations. Information for the manual has been drawn from a literature search, consultations with experts in the field, and the results of case studies in the region and beyond, in particular a recent dune rehabilitation project in Anguilla.*

*After a generalized section on the form and processes shaping sand dunes, dune rehabilitation methods are described and discussed. Steps involved in selecting, screening and assessing suitable sites are outlined. These include a detailed checklist for site assessment. Three methods for dune rehabilitation are described in detail: sand trapping fences, mechanical dune building and revegetation. Finally, the stages involved in implementing a dune rehabilitation project are outlined, these include management, planning, execution and post-project activities such as monitoring and evaluation.*

*Several best management practices for sand dunes are discussed in detail. These include the planning of shoreline development, construction guidelines, sea defense planning, control of sand mining, construction of dune accesses, post-hurricane dune rehabilitation, and education and awareness activities. Several different types of projects which involve people and groups in beach and dune related activities are described. Involvement in such activities is seen as key to education and enhanced awareness on the role of sand dunes in the overall coastal system.*

# 1. INTRODUCTION

Beaches and sand dunes represent flexible barriers which absorb wave energy during storms by moving and adjusting their shape and position. Dunes are essentially sand reserves where sand accumulates during 'normal' conditions and is then released to the beach and offshore zone during storms and hurricanes. Under 'normal' conditions beaches will rebuild naturally after the storm event and the process of dune accretion will recommence. However, such changes result in considerable variations in the **position** of beaches and dunes, which inevitably conflicts with immovable coastal property.

Little research has been undertaken on sand dunes in the Wider Caribbean Region. However, their economic value has been recognized. In many countries/territories, sand dunes have been exploited, and in some cases totally destroyed in order to supply construction sand. Their proximity to the ocean has made them desirable sites for coastal real estate. However, such uses have led to the degradation and destruction of sand dunes. It is the purpose of this manual to provide guidelines for the assessment, management and rehabilitation of sand dunes to ensure the sustainable use of these systems.

Sand dunes, however, cannot be viewed in isolation from other components of the coastal system. It is recognized that sand dunes and beaches are so interdependent that they have to be managed together. Sand dune management, furthermore, should be viewed within the overall context of integrated coastal area management (ICAM) through linkages within the physical, economic and social components of coastal systems.

## 1.1 Background

This manual has been developed within the framework of the Caribbean Environment Network (CEN) Project, a joint venture between the Caribbean Environment Programme of the United Nations Environment Programme (UNEP-CAR/RCU) and the United States Agency for International Development (USAID). The CEN Project focuses on reducing the environmental impacts generated by the tourism industry.

Within the context of the CEN Project, a one year project entitled 'Sand Dune Rehabilitation and Awareness Project' commenced in Anguilla in October, 1997. This project has two main components: sand dune rehabilitation at two sites; and design and implementation of an awareness campaign on coastal resources, to include, but not be limited to sand dunes.

The Anguilla sand dune project had its origins in a natural disaster. Between 4th and 6th September, 1995, Hurricane Luis, a category 4 hurricane, passed over Anguilla causing extensive damage to the island's infrastructure and environmental resources. The environmental damage was quantitatively assessed (Bythell *et al*, 1996):

- **Coral reefs**: 61% of intact live reefs were degraded to rubble or bare rock;
- **Seagrass beds**: seagrass cover was reduced by 45%;
- **Beaches**: beach volume decreased by 40% and beach width by 9 m on average;
- **Sand dunes**: the dune base retreated an average 9 m inland;
- **Mangroves**: mortality rates varied between 68 and 99%.

Beaches recovered quickly after the hurricane and had reached 75% of their pre-hurricane volume four months afterwards (Cambers, 1996a). While it was recognized that seagrass beds and coral reefs would slowly recover on their own, it was recommended that rehabilitation of the sand dunes be undertaken.

An assessment of Anguilla's sand dunes was conducted and two sites were selected for rehabilitation: Shoal Bay and Savannah Bay. Sand fences were constructed at these two sites in November, 1997 and subsequently monitored. The results of this project and other sand dune rehabilitation projects in the region and beyond, combined with a literature search and regional consultation, have provided the information for this manual.

### 1.2 Purpose and Limitations of this Manual

The purpose of this manual is to provide government officials, community groups, environmental organizations and others with the basic information on how to manage sand dunes. Not every item in the manual will necessarily refer to a specific case.

The major focus of the manual is on sand dunes, however, it is often impossible to discuss sand dunes without including the adjoining beach system. The manual discusses beaches through their interaction with sand dunes. However, the sections dealing with beaches and their processes are not comprehensive.

The manual is generally applicable to the Wider Caribbean Region and has been designed as a practical tool for the busy community group or coastal manager. It is not a research document, but has attempted to clearly summarize the consensus results from many research projects conducted around the world. Manuals developed for sand dune management in regions other than the Caribbean have also been consulted.

Sand dunes, unlike beaches, wetlands, coral reefs and seagrass beds, have received remarkably little attention in the Wider Caribbean Region. While they do not exist in every country/territory, they remain an important part of the coastal landscape in the Caribbean region.

### 1.3 How to Use this Manual

In order to manage, and possibly rehabilitate sand dune systems, an understanding of the natural processes that build and destroy sand dunes is necessary. **Section 2** describes these natural processes.

**Section 3** deals with dune rehabilitation. The steps involved in site assessment and site selection are described in detail and a site assessment checklist is provided. Various methods for dune rehabilitation are described, including sand trapping fences and revegetation. The steps involved in project implementation are discussed, and include management, preparation, execution and post-project activities such as monitoring and evaluation.

**Section 4** discusses several best management practices for sand dune management. These include activities that can be undertaken by community groups as well as regulatory and planning measures that can be implemented by government agencies.

**Appendix I** contains details regarding the sand dune rehabilitation project in Anguilla in 1997-8.

## 2. SAND DUNES: FORM AND PROCESS

Sand dunes are mounds of sand lying behind the active part of a beach. In the Wider Caribbean they range from very low formations 0.3-0.6 m (1 - 2 ft) high to large hills of sand up to 6 m (20 ft) high, see **Photograph 1**. There may be several parallel rows of dunes which are usually named primary, secondary, etc., starting from the most seaward line. Not all beaches, however, have sand dunes. Some beaches may be backed by cliffs or steep slopes, while others may be backed by low sandy platforms or wetlands. The dominant process forming sand dunes is that of wind action blowing over the dry part of the beach and transporting sand inland where vegetation plays an important role in trapping the sand.

A beach may be defined as a zone of loose material extending from the low water mark to a point landward where either the topography abruptly changes or permanent vegetation first appears, see **Figure 1**. Although beaches are often made up of sand particles (0.08-4.6 mm), they may also consist of clay, silt, gravel, cobbles or boulders. By contrast, sand dune formation will only take place adjacent to a beach which is predominantly composed of sand particles. There are two main sources of beach material: land based and offshore sources. Rivers and streams drain the land and carry sediment particles towards the sea. The size of these particles depends on the composition of the parent rock and the fluvial erosion that occurs during transport. Sediment may also be eroded from cliffs by wave action. Offshore sources of sand consist of coral reefs, seagrass beds and marine organisms; here biological, chemical and mechanical processes produce sand particles which are then transported shorewards by waves and currents.

Beaches are formed by waves, currents and tidal action, with waves generally being the predominant force. Within the surf zone, deep water waves begin to interact with the seabed. This results in changes in the direction and height of the incoming waves, which tend to align themselves in a direction parallel to the shoreline. Depending on the actual direction from which these waves approach, sand or other material may be transported along the shore or in an onshore / offshore direction, or a combination of both.

Dunes form when sand is carried by the wind from the beach towards the land. The wind transports the sand in three ways: in suspension, by lifting the smaller, lighter fractions into the airstream and carrying them for long distances; by saltation, as heavier grains are moved in a series of 'hops' and 'jumps' along the beach surface; and as surface creep, in which sand particles are rolled along the surface as a result of wind forces or the impact of descending saltating particles. Although most sand particles are moved by saltation, surface creep may account for 20-25% of the moved sand (Bagnold, 1954). Most of the sand is carried within 0.15 m (6 inches) of the ground surface.


**Photograph 1. Sand dunes at Sand Bank Bay, St. Kitts. May, 1996.**
Erosion has left the seaward face of these dunes steep and bare of vegetation.

The rate of sand movement depends on the wind speed, sand grain size and moisture content of the sand:

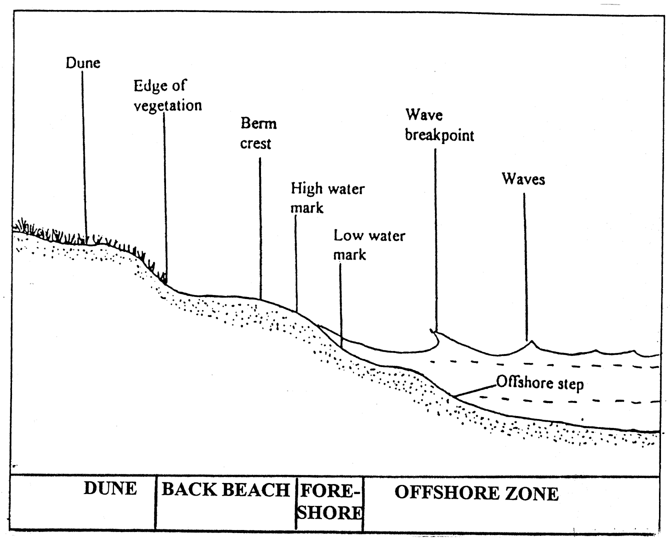



**Figure 1. Cross section of a typical beach and dune.**

**Wind speed**: Based on fundamental research on desert dunes (Bagnold, 1954), significant sand movement will take place when the wind speed measured at a height of 1 m (3 ft) above ground level exceeds 12 knots (6 m per sec), see **Figure 2**. In the Wider Caribbean, with its dominant Northeast Trade Wind regime, average wind speeds equal or exceed this value especially in the months of June to July and December to March.

**Sand grain size**: Onshore winds will dry the sand and selectively pick up the smaller grains of sand (0.08 - 0.5 mm) and move them towards the land. Sand grain sizes in dunes are therefore finer than that on beaches. This is important because fine sand deposits have greater water retention capacity than coarse sands and are therefore more suitable for vegetation growth.

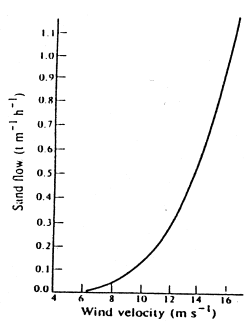
**Moisture**: Moist sand is moved less easily by the wind than dry sand since moisture promotes surface adhesion. The threshold shear velocity (the wind strength needed to initiate movement) is higher for moist sand (King, 1972).

When the wind encounters an obstacle such as a clump of vegetation, the wind speed is reduced and the sand grains fall out under gravity, resulting in sand deposition. As the sand accumulation continues, a dune is formed. Dunes form when there is an adequate sand supply and onshore winds of sufficient velocity to move the sand. As the dune builds, it becomes a major obstacle to the landward movement of windblown sand. Thus, the dune serves to conserve sand in close proximity to the beach system.

Dunes are highly dynamic topographic features, and especially when not anchored by vegetation, may undergo rapid changes over short time periods. They may move inland as a result of onshore winds and may be eroded by wave action and high water levels associated with severe storms. Furthermore, loss of vegetation as a result of drought, disease or animal-grazing may result in localized 'blowouts.'

**Sand dunes are not permanent landforms. They are temporary features which may disappear overnight.**

Dunes function as a protective barrier, preventing storm waves from reaching the land behind the dunes. They also function as a sand reserve nourishing beaches during storms. **Figure 3** shows a schematic drawing of storm wave attack on a beach and dune. During a storm or hurricane, the beach is eroded and the waves reach the dunes. This results in the erosion of the dunes and sand is carried into the water and possibly to a deposit offshore. (Some sand may also be moved inland behind the dune line). This offshore sand deposit can serve to absorb some of the destructive wave energy that would otherwise be focused on the beach and dunes. Following the storm, sand is moved back onto the beach and/or along the beach. As the beach accretes, the process of sand dune formation starts over again.




Relationship between sand flow rate and wind velocity measured at a height of 1 m above ground level, for 'average' dune sand (Bagnold 1954). This has a diameter of 0.25 mm and is normally graded. The quantity $\rho/g$ for 'average' sand has a value of $1.25 \times 10^{-6}$.

**Figure 2. Relationship between sand flow rate and wind velocity.**
Measured at a height of 1 m above ground level for 'average' dune sand, diameter of 0.25 mm and normally graded (adapted from Gardiner and Dackombe, 1983).

**Sand dunes and beaches must be managed as one system. Dunes depend on beach sand for their formation and beaches need the sand reserve held in the dunes during storms.**

These processes were seen at many sites in the Leeward Islands during Hurricane Luis in 1995. Beaches and dunes were severely eroded, sand was moved inland covering roads and buildings as well as being moved offshore and deposited in offshore sand bars. These offshore sand bars migrated onto the beach in the weeks and months following the hurricane.

Sand dune formation is a slow process when compared to beach changes. Four months after Hurricane Luis which occurred in September 1995, measurements in Anguilla showed that beaches had recovered to 75% of their pre-hurricane levels (Cambers, 1996a). However, the sand dunes, which showed an average retreat of 9 m due to Hurricane Luis will take decades to recover to pre-hurricane volumes. Against a background of rising sea levels and shoreline retreat, complete recovery of the dunes may never take place.

**Sand dune formation is a slow process. It may take decades.**

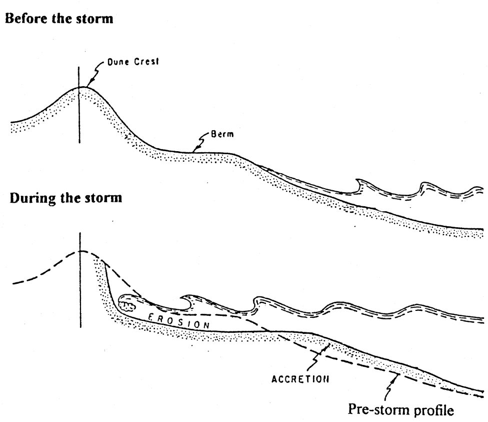



**Figure 3. Storm wave attack on a beach and dune.**
During the storm the beach is eroded and the waves begin to attack the dune, resulting in a vertical dune face. The dune sand is deposited offshore, this will eventually return to the beach (adapted from Coastal Engineering Research Center, 1984).

Dune vegetation promotes the large scale trapping of sand. The stems of dune grasses reduce the wind velocity near the surface, causing the deposition of sand. Plant roots also serve to bind and consolidate the sand. Dune grasses thrive on incoming sand and accelerate their growth to keep up with the increasing height of the dune (Broome *et al*, 1982). The vegetation cover represents the difference between a mobile pile of sand and a stabilized dune (Salmon *et al*, 1982). Dune plants have to adapt to harsh conditions which include high temperatures, dryness, occasional inundation by saltwater and the accumulation of sand. Generally, native beach grasses, trailing vines and small perennials are the most hardy species and are found on the seaward face of the dunes. Shrubs and trees are more abundant in the back-dune zone. **Table 1** lists some of the more common flora found on Caribbean sand dunes. **Figure 4** shows a cross section through a typical Caribbean beach / dune / coastal woodland zone.

Unfortunately, sand dunes are often seen as prime sites for sand mining activities. Like wetlands, sand dunes have been perceived as 'useless' areas and their many functions such as sand reserves for the beach and protection for land areas from harmful salt laden winds have been little understood. Many dunes in the Caribbean region have disappeared altogether as a result of mining activities, e.g. at Josiah's Bay in Tortola, British Virgin Islands and Diamond Bay in St. Vincent and the Grenadines. At the latter site, dunes more than 6 m (20 ft) high consisting entirely of black sand have been completely mined out leaving the sea to cut into the low land that was once behind the dunes.

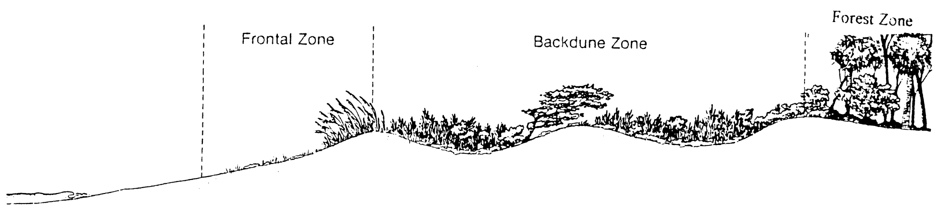



**Figure 4. Cross section showing typical vegetation zones in a coastal dune area.** The frontal zone, which includes the back beach and the seaward face of the primary dune, is usually covered with grasses and vines. In the back dune zone there are more shrubs and herbaceous plants. This eventually gives way to the coastal forest zone (adapted from Craig, 1984).

**Table 1. Some common herbaceous plants and shrubs found on Caribbean sand dunes.**

| |
|---|
| **Grasses** |
| Seashore dropseed (*Sporobolus virginicus*) |
| Panicgrass (*Panicum amarum v. amarulum*) |
| Seaoats (*Uniola paniculata*) |
| Sandbur (*Cenchrus spp. L.*) |
| **Other herbaceous plants** |
| Beach morning-glory (*Ipomoea pes-caprae*) |
| Beach bean (*Canavalia maritima*) |
| Sea purslane (*Sesuvium portulacastrum*) |
| **Shrubs and trees** |
| Cocoplum (*Chrysobalanus icaco L.*) |

Sea lavender (*Tournefortia gnaphalodes*)
Sea grape (*Coccoloba uvifera*)

On the east coast of St. Kitts, mining activities have stripped the vegetation and lowered the height of the primary dune in several places, see **Photograph 2**. Erosion during high wave events may result in breaching the dune line and flooding the land behind the dune. Sometimes storm waves carry beach sand through the breached dunes filling sand mining pits with fresh sand. While this may benefit the sand miner in the short term, the beach experiences a deficit in the sediment budget and more erosion results in the long term.

**Photograph 2. Dune mining at Halfmoon Pond, St. Kitts, April, 1983.**
In this case the mining has almost cut through the primary dune.

Dunes are the result of decades of slow accretion. As dunes grow naturally, each new layer of sand compacts the layers below, so that a firm structure forms. There are ways to speed up the process of dune formation such as building sand fences and replanting vegetation. These and other methods will be discussed in Section 3.2.

Obviously dunes will not form at every beach. One of the most important criteria is that there must be a large area of dry-sand beach over which the wind can blow and pick up the sand grains. Unless this is present, then dune formation is unlikely to take place.

**There must be a large area of dry-sand beach over which the wind can blow in order for dunes to form.**

Dunes are fragile systems and trampling by beach goers destroys the vegetation and results in deterioration of the dune. Vehicular traffic on the dunes has an even more disastrous effect.

**Dune vegetation has to survive harsh natural conditions. It cannot withstand heavy trampling by beach goers or the impact of vehicles.**

Sand dunes, especially primary dunes, are not permanent features of the landscape, nevertheless, they play a very important role in shoreline stability and should be managed accordingly.

## 3. DUNE REHABILITATION

There are several situations in which a government agency, a community group or a private property owner may find themselves wishing to rehabilitate an area of eroded sand dunes. These may include:

- dunes which have been eroded by a winter swell event;
- dunes which may have completely disappeared as a result of a major hurricane;
- a mining activity may have removed large portions of a dune system;
- a heavily used beach access path may have resulted in a breach in the dune line;
- vehicles driven along the beach may have destroyed the dune vegetation.

Dune rehabilitation is usually a relatively low cost activity, and is therefore often popular as a project. However, it involves considerable time and manpower. Furthermore, building sand dunes cannot prevent gradual shoreline erosion. Sand dunes offer significant protection during severe, infrequent storms such as hurricanes, by providing a reserve of sand for the beach. However, **dunes do not provide substantial protection against long term shoreline retreat.** So, if for the past few decades, a shoreline has been retreating inland, there is no point in trying to build a dune seaward of the gradually eroding dune scarp because the project will fail.

**Sand dunes offer significant coastal protection during storms and hurricanes by providing a supply of sediment to be impacted by the waves, but they cannot prevent long-term shoreline retreat.**

Therefore, it is especially important to carefully establish goals for a particular project and to obtain as much information as possible about the proposed rehabilitation site. There are three main stages in a dune rehabilitation project:

- Site selection;
- Design of rehabilitation measures;
- Project implementation.

### 3.1 Site Selection

Site selection is possibly the most important stage in a dune rehabilitation project since it will determine the success or failure of the project. There are four steps in the site selection process:

- Determination of the number of sites requiring rehabilitation in the geographic area;
- Site screening;
- Site assessment;
- Final site selection.

#### 3.1.1 Determination of the Number of Sites Requiring Rehabilitation in the Geographic Area

The number of sites selected for rehabilitation will depend largely on the available funding and manpower. Whether the geographic area is an entire island, one particular shore, or a municipality, all the sites requiring dune rehabilitation should be listed.

#### 3.1.2 Site Screening

Dunes will only form under very specific conditions. So, it is essential to determine whether a particular site is suitable. Once all the sites requiring dune rehabilitation in the geographic area have been listed (Section 3.1.1), they should then be screened for suitability. In order to pass this initial screening process, a site should fulfill all the criteria listed in **Table 2**.

**Table 2. Criteria for selection of sites for dune rehabilitation**.

| |
|---|
| **Sand dunes exist now or have existed at the beach site within the previous two decades:** It is unlikely that dune rehabilitation efforts will be successful if there is no history of sand dunes existing naturally at a particular site. So, sites should be selected where dunes exist or have existed in the past 20 years. |
| **The rehabilitated sand dunes will protect existing or planned developments**: At sites where there is no development behind the beach, it is best to let natural processes continue. There is no real justification for rehabilitating sand dunes here. Sites for dune rehabilitation therefore should be selected at beaches where the adjoining land is developed or where development is planned. |
| **The prevailing winds blow from the sea towards the dunes**: Dunes are formed by wind action. Beaches exposed to the prevailing winds, which in the Caribbean blow from directions between northeast and southeast, are the most likely sites for dune formation. Thus, in the Lesser Antilles dune rehabilitation efforts are more likely to be successful on east, north and south coasts than on west coasts. |

Those sites which fulfill these three criteria should then be listed. These sites will then be subjected to a more detailed assessment, see Section 3.1.3.

### 3.1.3 Site Assessment

In order to conduct a site assessment, several environmental characteristics must be measured and analyzed. The nature of the measurement and the depth of the analysis depend on the time and skills available. The characteristics described in this section represent the **minimum** necessary for an assessment. These characteristics are shown in a checklist in **Table 3**. (A completed checklist for a site in Anguilla has been included in **Table 12** in **Appendix I**). In order to complete a dune assessment, it is necessary to examine topographic maps, recent and historical aerial photographs and to make observations on the ground. Maps are usually available for sale at the government offices dealing with land survey. Aerial photographs are most often stored at the same government agency, and can usually be viewed there if prior arrangements are made.

The specific characteristics as they appear in the checklist are described in the following paragraphs.

***Site Name, Location and Orientation***

Locate the beach or bay on the map and note the **name** on the checklist.

**Table 3. Dune assessment checklist**

| | |
|---|---|
| **Site Name** | |
| **Date of Assessment** | |
| **Site Location and Orientation**<br>Beach length:<br><br>Beach orientation:<br>Vehicular access: | |
| **Dune Physical Characteristics**<br>Length:<br>Width:<br>Height:<br>Presence of parallel dune systems:<br>Presence of new dunes:<br>Presence of low points in dune line:<br><br>Condition of seaward dune slope: | |
| **Dune Vegetation**<br>Types of vegetation, main species:<br>Vegetation coverage: | |
| **Turtle Nesting** | |
| **Beach Characteristics**<br>Width of dry-sand beach:<br>Minimum width of dry-sand beach:<br><br>Beach composition: | |
| **Wind Pattern**<br>Wind speed:<br>Wind direction: | |
| **Site History**<br>History of beach / dune area: | |
| **Site Ownership** | |

| **Overall Assessment**: | |
|---|---|

Determine the **beach length** using the map. This can be simply done by laying a length of string along the beach length and measuring the distance against the map scale.

The **beach orientation** should also be measured in order to determine which direction it faces. If the beach is curved, as is often the case, the orientation will have to be measured in several places. This can be done on the map using the north reference or the compass grid, or it can be done in the field using a hand held compass. Reference to **Figure 5**, which shows a sample beach at Shoal Bay, shows that one section of the beach is *orientated* such that is faces northeast, while west of the promontory, the beach faces northwest. In view of the fact that the prevailing wind at this site is from the northeast to east, the section of beach facing the northeast is likely to be the most appropriate for a dune rehabilitation project. Note the results on the checklist, it is recommended to draw a small sketch map which will show the beach plan form (see **Figure 5**).

**Vehicular access** to the beach should be noted while in the field, this is important information for planning project details such as transporting materials to the site.

***Dune Physical Characteristics***

Topographic survey maps and aerial photographs may be used to provide a first approximation of **dune length and width.** However, topographic survey maps may not be sufficiently detailed to show specific dune features.

Both topographic maps and aerial photographs show historical conditions. A recent hurricane or sand mining activities, may have drastically changed the shape of the dunes. So, it is always recommended to measure the dune length in the field using a tape measure. Dune width can also be measured in the field at 50 m intervals along the beach.

**Dune height** should be measured in the field. If the dune is very low, the vertical height can be measured very simply with a tape measure. If the dune is higher than 1 m (3 ft), it can be measured with a simple hand-held instrument such as a clinometer or an Abney level and tape measure.

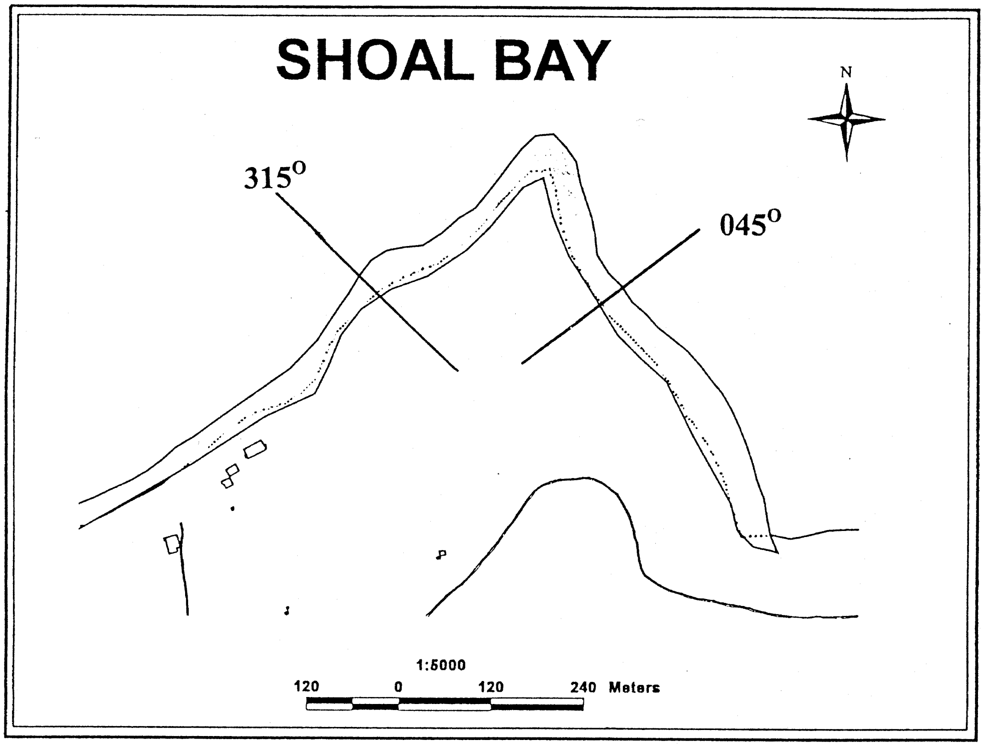



**Figure 5. Map showing coastline orientation at Shoal Bay, Anguilla.**

(Clinometers are standard equipment at most government agencies dealing with forestry, while more sophisticated surveying equipment such as engineers' levels and theodolites are available at agencies dealing with land surveys).

Aerial photographs can be used to determine whether **parallel dune systems** comprising several lines of dunes (primary, secondary etc.) exist. This will require field checks.

During the field survey, it is important to note whether there are any **new dunes** forming on the beach - these might be small mounds of sand with or without a clump of vegetation on top. Such features indicate that conditions exist for present day dune growth.

Any **low points** in the dune line should be identified in the field, these indicate vulnerable points where high waves have the potential to break through the dunes. These may be areas particularly in need of rehabilitation.

Another important characteristic is the **condition of the dune slope** on the seaward side. Features such as steep, bare slopes, undercutting, slumping of material, absence of vegetation indicate that the dunes may be experiencing direct wave action.

***Dune Vegetation***

The main types and species of **vegetation** on the dune, as well as the **vegetation coverage** (%) should be recorded at 50 m intervals along the beach.

***Turtle Nesting***

Many beaches in the Wider Caribbean are **turtle nesting sites**. Activities associated with dune rehabilitation may disturb existing nests. If a particular beach is a nesting site, the dune rehabilitation activities should be scheduled outside the nesting season to avoid disturbing the nesting sites. Some sea turtles, such as Hawksbill turtles (*Eretmochelys imbricata*) nest in the vegetation behind the beach. Dune rehabilitation measures such as dune fences should not be used at these sites.

***Beach Characteristics***

The **width of the dry-sand beach** is an important characteristic. This is the distance from the high water mark to the base of the dune, and should be measured with a tape measure at 50 m intervals along the beach. However, this will only show conditions on one particular day. If time permits, these measurements should be repeated at monthly intervals over a period of 12 months, since seasonal changes in the position of high water mark can be very significant. These data can then be used to determine the **minimum width of the dry-sand beach**. However, if time is not available for such measurements, then indicators such as lines of debris further inland and close to the dune base show the landward limits of previous storms and may be used to estimate the minimum width of the dry-sand beach.

More accurate information on beach changes can be obtained from the beach change databases which have been established in some Caribbean countries/territories. In the Lesser Antilles, such programmes established under the umbrella of the regional Coast and Beach Stability in the Caribbean (COSALC) Project measure beach profiles at three monthly intervals and the databases are stored at government agencies responsible for fisheries or the environment. The width of dry-sand beach at different times of the year and over several years can be determined from the beach profile graphs. If the particular beach is not included in this database, then data from an adjacent beach may give an indication of the likely variation in dry-sand beach width.

**Beach composition** is another important characteristic. The type of material should be noted, whether sand or a mixture of sand and other material such as stones or coral pieces. The origin of the sand, whether marine based or terrestrial, should be determined. Finally, if the beach consists of sand, it should be determined if it is coarse, medium or fine sand.

***Wind Pattern***

The **wind speed and direction** are critical parameters for a dune rehabilitation project. Local meteorological offices have information on wind speed and direction, although often this information is based on airport observations only. However, if information on other sites exist, data from the site closest to the pre-selected beaches should be used. Statistics for Anguilla, showed that the average monthly wind speed exceeded 6 m/sec for each month and the wind direction varied between east-northeast and southeast. The wind direction will provide information on whether the site is a suitable one for dune growth, e.g. beaches facing the prevailing wind direction are likely sites for dune growth. The wind speed information will show in which months sand movement and dune accretion is most likely to take place.

***Site History***

Consult with local land owners and other knowledgeable persons about the **history of the site**. Factors such as past mining activities, changes caused by recent storms and hurricanes will provide valuable information as to the suitability of the site for a dune rehabilitation project.

***Site Ownership***

Obtain **land ownership** information from the land registry office. If the dune lands are privately owned, then it will be necessary to obtain permission from local land owners for any dune rehabilitation work. It is important to involve local landowners in all aspects of any dune rehabilitation project. This will lay the groundwork for community acceptance and eventual adoption of the project.

After completing the checklist, an overall assessment of the suitability of the site for dune rehabilitation is made. In particular, any constraints that may represent a significant problem should be listed.

### 3.1.4 Final Site Selection

Using the site assessment checklists, the pre-selected sites may be ranked. Sometimes there will be one over-riding factor which means deleting a pre-selected site e.g. the land is privately owned and the owners do not want any work done on the dunes, or winter swells reach a site on a frequent basis. If such major constraints exist, these sites should be deleted.

Once the ranking is completed, the site ranked first becomes the site selected for the dune rehabilitation project. If this is a 'first-time' project for a group or country, then it is recommended that the project goal should be to rehabilitate the dunes at one beach in the first instance.

### 3.2 Design of Rehabilitation Measures

Having selected the beach for a dune rehabilitation project, and having decided to go ahead with the project, it is first necessary to obtain permission from the relevant government agencies. The actual agency and their requirements will vary amongst countries/territories, but it will usually be either a physical planning and/or environmental agency.

**It is advisable to involve the relevant government agencies in the project at an early stage.**

There are three main methods to rehabilitate eroded dunes:

- construction of sand trapping fences;
- mechanical dune building;
- revegetation projects.

Each method may be undertaken individually or in combination, e.g. sand trapping fences may be constructed and once they have trapped sufficient sand the newly created dune is revegetated. (This was the combination of methods selected for the Anguilla project). Revegetation projects may also be undertaken alone - if there is enough sand movement on the beach, a good stand of plants will begin the dune building process. However, revegetation projects by themselves may take longer to rehabilitate eroded dunes, since it will be necessary to wait for the plants to become established and to develop a sand trapping capacity.

Information about these methods is detailed in the following sections (3.2.1 to 3.2.3). The method selected will depend on the characteristics of a particular site and the project goals.

### 3.2.1 Construction of Sand Trapping Fences

Sand trapping fences are porous barriers that reduce the wind velocity sufficiently so that sand drops out of the wind stream and accumulates on both sides of the barrier. The function of sand fencing is to speed accumulation of sand in the location chosen for dune rehabilitation. Almost any kind of fence can be used provided the structure slows but does not completely block the wind. So neither a completely solid fence such as plastic sheeting or open fencing such as chicken wire will work as a sand fence. Typical sand fences consist of vertical wooden slats joined with chicken wire, see **Photograph 3**, or wooden pallets wired together and supported with fence posts see **Figure 6**. **Photographs 4 and 5** show a successful sand trapping fence made of wooden pallets near Barceloneta in Puerto Rico.

**Photograph 3. Sand trapping fence, Kealie Beach, Maui, Hawai'i, 1998.**
The fence is made of wooden slats joined with wire.

Other materials have been used to trap sand, such as branches or young trees placed flat on the ground. In some States in the U.S.A. discarded Christmas trees have been used as sand trapping fences and have had some success, especially where they were used to repair the damage caused by vehicles driving over dunes. Live fir trees are imported from North America into many Caribbean countries/territories each Christmas season. Use of the discarded trees or other brush material for sand trapping fences may provide a means of involving the public in such projects (Barnett *et al*, 1989). If constructing a brush fence, trees should be loosely piled in rows and pegged down with light rope or twine, or they may be held between posts, see **Figure 7**. The trees should be placed end to end, one or two trees wide, in a long row. If using more than one row, the rows should be about 4.5 m (15 ft) apart, (Salmon *et al*, 1982).

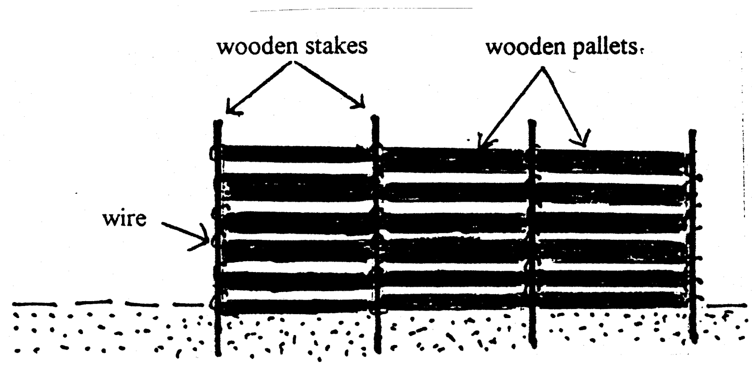



**Figure 6. Sand trapping fence using wooden pallets.**

**Photograph 4. Sand fence at Barceloneta, Puerto Rico, May 1996.**

**Photograph 5. Sand fence at Barceloneta, Puerto Rico, October, 1997.**
Note the fence has trapped sand so that the pallets are almost covered.

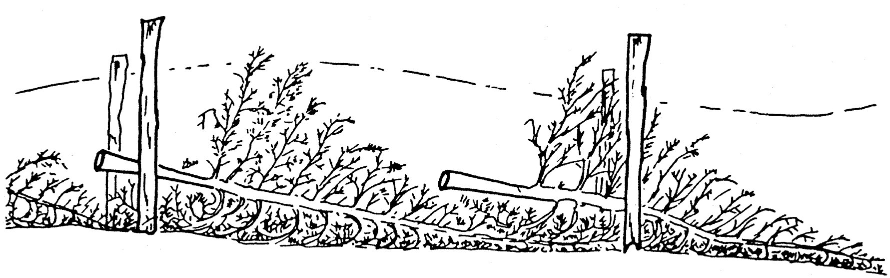


**Figure 7. Brush fences using discarded Christmas trees (adapted from Salmon *et al*, 1982).**

**Table 4** shows some general guidelines for sand fences based on various field tests and projects conducted in the U.S.A. and the Caribbean.

In the Anguilla project, wooden pallets were used because of their ready availability. **Table 13**, Appendix I lists the design details and costs of the pallet fences. It was found that an experienced crew of 6-8 persons could construct a fence at a rate of 10 m per hour. Materials cost US$ 5.5 / metre length of fence. **Photograph 6** shows the fence under construction, while **Photograph 7** shows the fence eleven months after installation.

**Table 4. Guidelines for sand fences. (Clark, 1996, Craig, 1984 and others).**

| |
|---|
| Fences should have a **porosity** of about 50%. The porosity is the area of open space to the total projected area. |
| Fences should be **placed well landward of the high water mark**. If waves reach the fence on a regular basis, or even a few times during the winter swell period, any accumulated sand will be quickly eroded. Fences are most successful when they coincide with the natural vegetation line or dune line. Thus the width of dry-sand beach and the minimum width of dry-sand beach, (see checklist in Table 3), are very important parameters to consider when designing and positioning sand fences. |
| Fences should be **aligned parallel to the shoreline** rather than along zig zag alignments. |
| The fence does **not need to be perpendicular** to the prevailing wind direction, it should, however, parallel the shoreline. |
| A 1.2 m (4 ft) high fence with 50% porosity will usually **fill to capacity within 1-2 years**. The dune will be about as high as the fence. |
| As the fence fills, the **dune height can be raised** by installing another fence on top of the newly formed dune. Succeeding lifts should be parallel to and about four times the fence height from the original fence. |
| **Fence-built dunes must be stabilized with vegetation** or the fence will deteriorate and release the sand. The construction of dunes with fences alone is only the first step in a two-phase process. |

**Photograph 6. Sand fence under construction, Shoal Bay, Anguilla, November, 1997.**

**Photograph 7. Sand fence, Shoal Bay, Anguilla, October, 1998, eleven months after installation.** Note sand is beginning to accrete in front of the fence.

### 3.2.2 Mechanical Dune Building

There are situations when it may be decided to build dunes by mechanical means, such as after a severe storm or hurricane when coastal infrastructure is endangered. Usually, sand has to be imported from other beaches or inland areas, or alternatively it may be dredged from offshore. Heavy equipment such as backhoes are then used to push the sand up into dunes. The use of tools such as environmental impact assessments should be used to ensure that the removal of sand from the borrow area has minimum negative impacts.

Such projects require special permission and are relatively expensive. These 'instant' dunes do not have the same compaction as dunes formed by wind processes. As dunes form naturally, each new layer of sand compacts the layers below so that a firm structure is formed. 'Instant' dunes, however, do not have this compaction, and are therefore very vulnerable to erosion when wave action is directly experienced.

A case study from Maunday's Bay, Anguilla, illustrates this point. Following Hurricane Luis in 1995, dunes were reconstructed mechanically using dredged sand and the newly created dunes were then replanted. These reconstructed dunes were eroded by wave action during a minor weather event eighteen months later. This case study illustrated two main features: firstly, that 'instant' dunes offer little resistance to wave action, and secondly, that dunes, whether formed by natural or mechanical processes, do not protect a shoreline against long-term shoreline retreat. In other words, if a shoreline has been retreating inland over a period of several years, newly created dunes will not stop that process.

### 3.2.3 Revegetation Projects

Planting should be designed as part of a comprehensive plan for protecting the coastal dune area. It is necessary to consider the surrounding area, not just the specific site for rehabilitation. Selection of plant species is most important. It is always recommended that the advice of local horticulturists be sought. These experts are experienced about conditions in specific countries / territories.

**Always consult local horticulturists before starting any dune planting project.**

Dune revegetation rarely works well if beginning with seeds (Salmon *et al*, 1982). Some seeds may not germinate or may be slow to germinate, and seedlings may grow slowly. Transplantation is the recommended method for revegetation of dunes. Plants may be obtained from a nearby dune or a nursery, or a nursery may be established specifically for the project. Alternatively, cuttings can also be used to propagate new plants. Cuttings should be taken from the young, but woody, branches of the plant, most of the leaves should be removed to reduce water consumption, and the base of the cutting should be kept moist until planted (Nellis, 1994).

If transplanting from neighbouring dune areas, lower, younger dunes should be chosen. It is necessary to dig carefully round the plant base so as to remove as much of the plant root as possible. The roots should be immersed in fresh water for brief storage (2-3 days) and the tops trimmed to 12-24 cm (5-10 ins), (Salmon *et al*, 1982).

There are only a few species that are tolerant of the stresses of the beach environment. Plants must be able to survive sand blasting, burial by sand, salt spray, saltwater flooding, drought, heat and low nutrient supply. The primary stabilizers of the most seaward dunes are perennial grasses, some of these together with other herbaceous plants and shrubs have been listed in **Table 1**. A more complete plant list is contained in **Appendix II**. Nearby sites should be examined to determine which species are best adapted to local conditions. Specific planting guidelines for most species are contained in the literature e.g. Craig, 1984, and local horticulturists will also be able to provide specific information. **Table 5** provides some planting guidelines for establishing shoreline plants.

**Table 5. Guidelines for establishing new shoreline plantings (Nellis, 1994).**

| |
|---|
| Examine adjacent and nearby similar shorelines and record the species present. |
| Draw the planting site and mark the ecological area suitable for each species. |
| Select a mixed-species planting, this is more likely to survive and adapt to a specific site. |
| Distribute the plants randomly within their ecological zone, this gives a natural looking community. |
| Arrange plantings close enough to offer some mutual support against wind erosion, wind buffeting and foot traffic. |
| Obtain a sufficient number of plants to firmly establish the community structure being planned. |
| Dig a hole in proportion to the expected future root zone of the new plants.<br>-On beaches with quartz sand, add some ground limestone and about 1/3 compost or aged manure.<br>-On clay soil, add about 1/4 carbonate sand and 1/3 compost or aged manure.<br>-On carbonate sand sites, add half the volume of compost or aged manure. |
| Choose a planting time more likely to offer cool, moist weather. |
| If needed, provide support for woody species until the plants are established. (Continued use of these aids is an indication of a mistake in plant selection for the habitat). |

Some plants, known as 'hostile plants,' growing in dry environments secrete chemical inhibitors which reduce the growth of potential competitors. When evenly spaced plants are found growing naturally with bare ground around them, then planting next to them may be unsuccessful.

In general, vigorous mature plants should be planted in rows 0.3 - 0.6 m (1-2 ft) apart. The area should be planted uniformly. Tall beach grasses should be placed about 20 cm (8 inches) deep, this may mean that some of the leaf surface is buried. The soil should be packed firmly around the plant and the roots kept moist during the planting operation.

Dune sand is generally deficient in plant nutrients especially nitrogen, so it may be necessary to use fertilizer. Again, a local horticulturist will be able to provide information on the type of fertilizer to use. Generally, fertilizer should be applied at planting time as well as in the weeks following planting. Frequent applications are more effective than a single large application because nutrients are readily leached from dune soils. However, the fertilizer residues will eventually be leached into the marine environment, so it is especially important to obtain the advice of local horticulturists regarding the use of fertilizers, and to carefully follow the manufacturer's specifications.

**Cautious use of fertilizers during and after planting is recommended.**

**Photograph 8. Seaoats growing on a low dune at Grace Bay, Providenciales, Turks and Caicos Islands, July, 1995.**

A surface mulch should be spread around the plants. This may consist of a layer of dead leaves or seagrass. The mulch will reduce wind and water erosion and will promote moisture retention. When the sand surface is very unstable, it may be necessary to use netting, either jute or synthetic, to assist in stabilizing the sand surface such that the vegetation can become established, (see **Photograph 9**). Such netting must be properly installed.

| A surface mulch of leaves or straw will increase moisture retention. |
|---|

**Photograph 9. Surface netting protecting the surface of a newly created sand dune at Maunday's Bay, Anguilla, January, 1996.**

In the Wider Caribbean, planting should coincide with the wet season, usually June through November. During this period, there will be less moisture stress and usually wind speeds are lower. However, even if planting in the wet season, watering will be necessary until the plants become established.

**Plant just before or during the wet season.**

The follow-up care, which includes watering and the addition of fertilizer is essential for a successful revegetation project. Unfortunately, this aspect of a project is all too often neglected. Newly planted areas should be maintained by reestablishing plants that do not survive. It is important to keep people and grazing animals away from newly planted areas, so fences and / or notices may be necessary.

**Follow-up care, which includes watering and the addition of fertilizer is essential for a successful revegetation project.**

### 3.3 Project Implementation

There are several stages in project implementation: management, planning, execution and post project activities.

#### 3.3.1 Project Management

With any dune rehabilitation project, it is recommended that a committee of persons with different skills be established to manage the project. Ideally, such a committee should include persons from the local community, government, as well as persons skilled in horticulture, management and communication. A committee of about six persons should combine the necessary skills without being too large.

**Establish a committee of persons with different skills to manage the project**.

Once the dune rehabilitation method for the particular site has been selected, it may be necessary to return to the permitting authorities to obtain final approval for the project activities.

**Obtain the necessary permits from government agencies.**

Involve the community in the project by holding one or more informal community meetings where presentations can be made about the proposed rehabilitation project and discussion encouraged. These were successful for the most part in the Anguilla project where people were able to voice their questions and concerns and to provide useful information on historic beach trends in the area. Furthermore, such meetings lay the groundwork for monitoring and maintenance of sand trapping fences and planting projects. Such public involvement should be maintained during and after the execution phases. Members of the public may help with follow-up actions such as reporting the start of trails through the project area, or vehicles driving on the dunes. For, with the exception of major storms and hurricanes, it is human activity which is the greatest threat to dunes (Salmon *et al*, 1982).

It is also recommended that the media should be involved in the project from an early stage so as to obtain maximum publicity and create awareness in people outside of the immediate project group.

### 3.3.2 Project Preparation

Having already selected the method to be used for dune rehabilitation at the specific site, an implementation plan should be prepared. This should include time scheduling, purchase and assembling the necessary materials on site, recruiting volunteers or paid labour, meeting with nearby landowners particularly if access is required across their land to get to the site, publicity and awareness about the project, preparation of information signs, arrangements for follow-up care and monitoring. (One of the tasks in site assessment, (see Section 3.1.3), included obtaining permission from local landowners if the site for the proposed dune rehabilitation work was privately owned).

**Prepare an implementation plan detailing the specific tasks and individual responsibilities.**

The next step is to make a site plan. This can be a simple sketch plan showing the site details, the proposed location, length and orientation of the sand fence, or in the case of a revegetation project, the planting plan. Figure 8 shows a sample site plan.

**Prepare a simple site plan.**

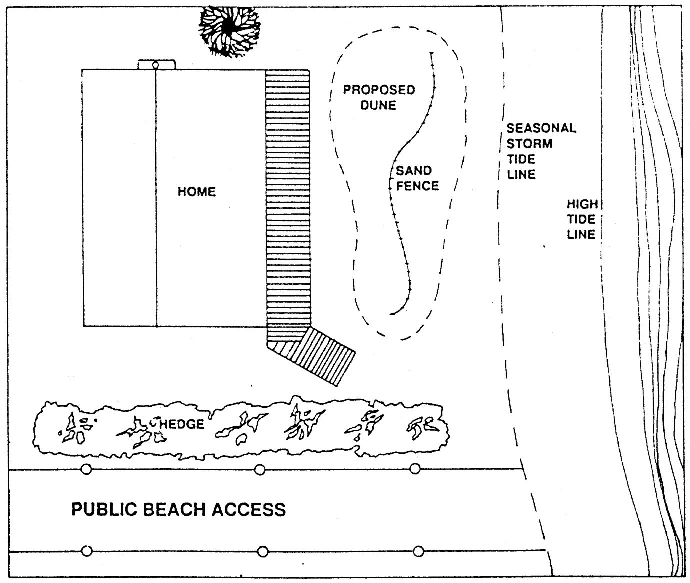



**Figure 8. Sample site plan for a dune rehabilitation project (adapted from South Carolina Coastal Council, 1982).**

Determine the quantity of materials and their cost. For example, in Anguilla, a wooden pallet fence cost US$5.5 per metre length (see **Table 13**, **Appendix I**), not including any costs for the pallets or for labour. Funding for the project and follow-up monitoring may be considered necessary.

**Prepare a list of materials and costs. Include funds for signs, awareness activities as well as after-project care and monitoring.**

Dune rehabilitation projects are fairly inexpensive, particularly when compared with the costs of shoreline armouring such as seawalls. The use of volunteers may reduce the costs of dune rehabilitation. However, the use of paid labour may be considered as an alternative.

With revegetation projects, it is essential to allow enough lead-time to obtain the plants and fertilizer (if used) and to prepare the dune for planting. It may also be useful to hold a demonstration session to show 'how to plant' (Salmon *et al,* 1982).

As soon as the fence has been constructed, or the dune planted, appropriate signs should be prepared and erected to inform the public and visitors to the site about the project. **Table 6** shows some general guidelines for the preparation and positioning of signs.

**Table 6. Guidelines for the preparation of signs at project sites.**

| | |
|---|---|
| **Size:** | Signs should be large enough so that the information can be easily read, but not obtrusive. In the case of dune rehabilitation projects, it is important that signs can be read from a distance so that persons do not have to walk on the newly accreting dune to read the sign. These signs should also provide sufficient information on the project.<br><br>Print should be bold, black lettering on a white background or two contrasting colours. |
| **Content:** | Messages should be kept simple with minimum words, schematics may also be useful. |
| **Positioning:** | Signs should be placed on the landward side of the project, and at nearby major beach access points. |
| **Endurance:** | Signs on Caribbean beaches are subjected to intense light and 'sea blast' so it may be necessary to "touch-up" signs as necessary. |

### 3.3.3 Post-Project Activities

Follow-up maintenance and monitoring are very important phases of the project and must be rigidly executed.

Sand accretion is measured along the beach profile from a point landward of the fence / revegetation area out into the sea, at least as far as the offshore step (**Figure 1** shows a typical beach profile). The starting point for measurement should be a monument (e.g. a buried concrete block) behind the dune which has been tied into datum so that the vertical height is known. The beach profile can then be measured using simple surveying equipment, e.g. an Abney level and tape measure, or more accurate surveying equipment, e.g. a theodolite. Profiles should be measured just prior to the dune rehabilitation activities and then at three month intervals. Care should be taken during the monitoring not to disturb any newly accreted sand. If time and expertise are available, simple monitoring of wave characteristics on a regular basis (daily if possible) would provide information which would help to explain beach profile changes at the project site. These measurements would include wave height, wave period and wave direction.

**Monitor the rate of sand accretion at the dune rehabilitation site.**

A simpler, though less accurate method for monitoring sand fences only, is to measure the vertical accretion along the fence line. (This method can sometimes produce misleading results since there is often some wind scour in the immediate vicinity of the fence, thus, the measurements may not reflect the true build-up in front of and behind the fence). Marks can be made with spray paint at the top of the fence at intervals of 20 m. At each mark the height from the top of the fence to the sand level is measured with a tape measure. These monitoring sites should be set up immediately after the fence is constructed, and then measured at three monthly intervals. Care should be taken not to disturb any newly accumulated sand during the monitoring activities. Monitoring will provide information of the rate of sand accretion and the time of year when it takes place. **Table 7** shows a simple monitoring form.

**Table 7. Monitoring form for accretion at a sand trapping fence.**

| Date | Distance from top of fence to sand at Site 1 (m) | Distance from top of fence to sand at Site 2 (m) | Distance from top of fence to sand at Site 3 (m) | Distance from top of fence to sand at Site 4 (m) | Distance from top of fence to sand at Site 5 (m) |
|---|---|---|---|---|---|
| 17.11.97 | 1.01 | 1.2 | 1.01 | 1.17 | 1.05 |
| 14.02.98 | 1.0 | 1.2 | 1.01 | 1.16 | 1.04 |
| 20.05.98 | 0.9 | 0.99 | 0.9 | 1.15 | 1.05 |
| 23.08.98 | 0.81 | 0.65 | 0.78 | 1.15 | 0.96 |

Before and after photographs, taken from the same point and showing the same angle, are very useful means of monitoring the site qualitatively. It is recommended that they always be used to supplement other monitoring methods.

If the dune rehabilitation project involved revegetation, then the rate at which the vegetation grows and covers the sand surface should also be monitored. Vegetation monitoring should be conducted before the planting project and at six monthly intervals after the project. It is recommended that 1 x 1 m square quadrats be used to record the species present and their percentage cover, the area of bare sand should also be measured. The quadrats can be either random or fixed and control measurements should also be made adjacent to the planted area.

If the initial project involves only the construction of a sand trapping fence, then as the sand accumulates, it will be necessary to consider whether to raise the height of the dune still further with an additional fence, see **Table 4**, or to plant the new dune.

If the project involves revegetation, then it will be necessary to prepare a post-planting plan even before the initial planting takes place. This should include a list of specific tasks, their frequency and the persons responsible. The tasks will include watering, addition of fertilizers, re-establishing plants that do not survive, addition of further surface mulch. Keeping careful records can prove beneficial to future projects.

**Prepare and implement a plant care plan. Keep careful records**.

If after two to three years there has been no sand accretion, then the project should be re-evaluated to consider what, if anything, went wrong. For instance, if no sand accumulated in front of a sand fence, then the wind records should be examined. Published data on wind speed and direction are based on long-term averages, the actual data for one or two years may differ significantly from the average. Similarly, records indicate that periods of severe winter swells run in cycles (Deane *et al*, 1973). Thus, waves may have reached the fence, or the newly planted grasses, on several occasions during the project period. A community meeting would be a good place to review the project and to obtain local input. If a sand fence has not shown any significant accretion after three years, and provided there has been no extreme climatic event then based on the project evaluation, a decision should be taken on whether to leave the fence in place or to remove it. Factors such as fence-deterioration and aesthetic aspects will also have to be considered.

## 4. BEST MANAGEMENT PRACTICES FOR SAND DUNES

As has been emphasized in this manual, sand dunes cannot be viewed in isolation, they represent but one physical component of the overall coastal system. The coastal system, essentially the area where the land meets the sea, consists of several natural and socio-economic systems. Various planning and management approaches for coastal systems have evolved over the past two decades.

The approach which is most relevant to the Wider Caribbean has been termed "integrated coastal area management" (ICAM). Although there are several definitions, the UNEP-CEP, 1996 recognizes the following:

> (ICAM is a) dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve the conservation and sustainable multiple use of the coastal zone (CAMPNET, 1989).

ICAM involves the continuous planning and management of the use of coastal lands, waters and their resources within a defined area, the boundaries of which are usually politically determined. Within the smaller islands of the eastern Caribbean belonging to the Organization of Eastern Caribbean States (OECS), an island systems management (ISM) approach is being developed such that the entire island and its surrounding waters are considered a management entity.

Within the scope of best management practices for sand dunes, linkages between natural, social, cultural and economic components of coastal systems must also be considered.

**4.1 Planning of Shoreline Development**

By their very nature, sand dunes are temporary features. Although they may look permanent and their vegetation established, sand dunes, particularly the most seaward (primary) dune, may disappear completely during a storm or high wave energy conditions. This was the case in Anguilla in October, 1997, when an area of disturbed weather generated waves which eroded the dunes, shown in **Photograph 10**, several metres, leaving steps detached from expensive villas and the villas themselves perched on the edge of the dunes.

Against this background, a fundamental guideline intrinsic to sound coastal planning is to leave the primary dune intact and to position new development behind (landward of) the primary dune, see **Figure 9**.

**A general guideline is that building should not be permitted on the seaward (primary) dune.**

**Photograph 10. Eroded dunes at Maunday's Bay, Anguilla, October, 1997.**
Note the concrete steps are detached from the villas, and the villas are perched on the edge of an unstable 'cliff' of sand.

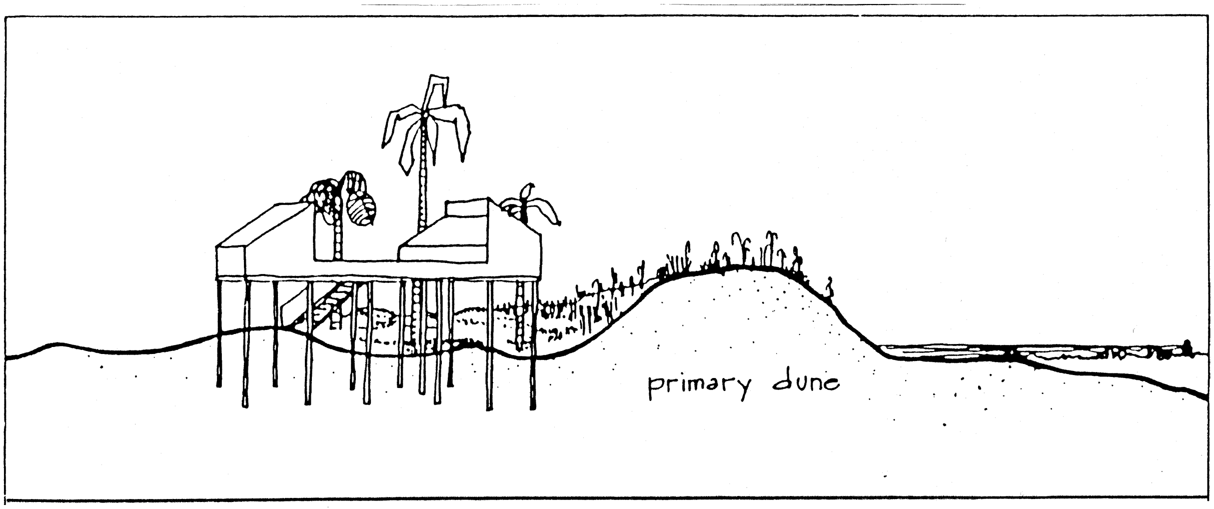



**Figure 9. Recommended construction on a dune.**
Here the primary dune has been left intact. The building has been built on piles so as to allow for the uninterrupted flow of floodwater and has been positioned behind the primary dune (adapted from the U.S. Department of Housing and Urban Development, 1981).

There may, however, be certain conditions where a country/territory wishes to consider exceptions to this general guideline. For instance, problems sometimes arise with the siting of beachfront restaurants, which some argue should be adjacent to the beach. Provisional coastal planning guidelines recently developed in Antigua and Barbuda and Nevis have proposed that a special provision be made for small individual buildings, made of wood and with no concrete foundations, to be used exclusively for the purpose of beach restaurants/bars, on the grounds that their economic viability depends on their proximity to the beach. The specific provision is that these structures should be set back 8 m (25 ft) landward of the line of permanent vegetation (Cambers, 1998a, b). In some cases, this would mean positioning such structures on the primary dune.

Other controls that a country/territory may wish to consider include the attachment of certain conditions to a planning permit. These could include controls on re-building a structure after a hurricane or storm has destroyed the dune and/or building.

Other problems may arise with the implementation of this general guideline concerning the restriction of building on primary dunes. For instance, if there is only a single sand dune between a beach and a wetland/saltpond area, then if the dune land is in private ownership, a planning authority would not be able to restrict the owner from development on the primary dune without compensation. In such circumstances, where development on a primary dune is permitted, an environmental impact assessment should be a requirement. Alternatively, a recommendation might be made to the government to acquire the land for public use.

Declaration of coastal marine parks, reserves and other protected areas may also provide a mechanism to protect some sand dune resources in a particular country/territory. Such areas provide a focused natural area conservation approach to ICAM, which can be an integral part of a country/territory's overall ICAM programme. This and other mechanisms for the implementation of ICAM are discussed in more detail in *Guidelines for Integrated Planning and Management of Coastal and Marine Areas in the Wider Caribbean Region* (UNEP-CEP, 1996).

Another mechanism through which coastal development can be controlled is through the application of coastal development setbacks.

**A coastal development setback may be defined as a prescribed distance landward of a coastal feature, such as the high water mark or the line of permanent vegetation, within which all or certain types of development are prohibited.**

In many of the countries/territories of the Wider Caribbean, coastal development setbacks have been used with varying degrees of success to control coastal development. Actual setback distances vary from 15 m (50 ft) to more than 60 m (197 ft). Implementation of such setback distances has been fraught with difficulty, not only because high water mark is a moveable baseline for measurement but also because many people do not understand the rationale behind leaving valuable beachfront land undeveloped (Robinson, 1997). The inadequacy of existing setbacks was illustrated in the northern Leeward Islands during the recent hurricanes in 1989 and 1995, where erosion during the hurricanes resulted in the loss of valuable beachfront land and, in some cases, the destruction of properties located on that land.

There are various methods for calculating coastal development setbacks. Some States in the U.S.A. utilize the concept of variable setbacks which make allowances for natural variations in shoreline trends from one beach to another. For instance, in South Carolina, the width of the setback is prescribed as a distance 40 times the annual erosion rate measured from the most seaward dune (National Research Council, 1990). This mechanism provides for the conservation of the seaward dune and the actual setback distance will vary depending whether a beach is eroding or accreting.

Another method which can be used for determining setback distances, is to determine the height which waves from a particular storm e.g. a 1 in 50 year event, will reach the shore and to use this as the setback distance. There are several models available for storm surge modeling. These require detailed offshore bathymetry and deepwater wave climate data.

A method which has been recently adopted in some of the smaller Caribbean islands utilizes the concept of variable setbacks which are determined on an individual basis for each beach. The baseline for the setback measurement is the line of 'permanent' vegetation, or the tree line. Setback distances are determined for each beach, based on shoreline changes over the past 30 years, shoreline erosion resulting from recent hurricanes, and predicted sea level rise. The actual setback distance may then be modified according to ecological, geographical and planning considerations relating to the particular beach (Cambers, 1997). **Table 8** shows a summary of this methodology.

## 4.2 Construction Guidelines

While it has been recommended that the primary dune should be left intact, it has also been recognized that a country/territory may wish to consider certain exceptions to this guideline. Furthermore, development on dunes landward of the primary dune will require specific controls.

**Table 8. Coastal development setback guidelines (Cambers, 1997).**

Coastal development setbacks are especially important in the tourism-orientated islands and countries. They:

- provide buffer zones so that beaches may move naturally without anthropogenic interference;
- serve to reduce damage to beachfront property during high wave events e.g. hurricanes;
- provide improved vistas and access along the beach;
- provide privacy for the occupants of coastal property and for people enjoying the beach.

The use of a fixed setback for all beaches in an island has proved difficult to implement. Beaches behave differently. Some erode, remain stable while others accrete. The nature of the change may also vary over the short and long term. In response to these variations, these guidelines develop specific setbacks for individual beaches based on a combination of different parameters:

- historical changes over the last 30 years (determined from aerial photograph comparison);
- recent changes over the last 5-10 years (determined from beach monitoring data);
- changes in the position of the shoreline (dune) line likely to result from a category IV hurricane (based on measured changes during hurricanes in 1989 and 1995);
- coastal retreat likely to occur as a result of projected sea level rise over the next 30 years;
- the existence or absence of offshore features such as coral reefs or beachrock ledges. These provide protection during high wave events;
- anthropogenic factors such as beach and dune mining;
- planning considerations such as lot size, marine park designations, special types of development such as beach bars.

The actual setback for a specific beach was determined as follows:

setback = (a + b + c) times a factor 'd'

where **a** is the projected change in shoreline position over the next 30 years (based on historical and recent changes);
**b** is the change in position of the dune line / shoreline likely to result from a major hurricane (it is anticipated that the coastlines of most of the countries / territories of the Wider Caribbean will be impacted by a major hurricane at least once in the next 30 years);
**c** is the change in position of the shoreline likely to result from predicted sea level rise over the next 30 years;
**d** represents other factors such as ecological, planning and social conditions.

Using this methodology, specific setbacks can be determined for each beach. While factors **a**, **b**, and **c** are quantitative parameters which can be determined scientifically, **d** is a qualitative parameter based on judgement, nevertheless, it is considered too important to neglect.

In all cases, setbacks should be measured from the line of permanent vegetation. In Anguilla, where setbacks using these guidelines are being implemented, the setback values for individual beaches ranged from 18 m (60 ft) to 92 m (300 ft). Aside from the beaches, blanket setbacks can be determined for other coastal types, such as cliffs and low rocky shores. However, it is recommended that setbacks for mangrove shorelines should also be determined on an individual basis and should be based on the ecological characteristics of the particular wetland.

Setback guidelines can only be successfully implemented if people fully appreciate the need for them. Guidelines must be combined with environmental awareness and education programmes.

Planning and infrastructure standards developed for the Caribbean countries/territories do not identify specific standards for building on dunes, instead the sensitivity of coastal zones is emphasized together with the need for detailed studies prior to development (Wason & Nurse, 1994). In the absence of specific guidelines for building on dunes in the Caribbean region, guidelines from the U.S. Department of Housing and Urban Design, 1981, and other parts of the world have been listed below:

- Building on piles is recommended. This allows for some sand movement without building collapse. Furthermore, the space below the floor level should be left open for the uninterrupted flow of flood water and debris.

- Alternative building materials should be considered.

- The first floor elevation should be above the 100 year flood level and calculated to include estimated sea level rise.

- All wood piles should be treated to minimize decay and damage from fungus and marine borers.

- Piles must be designed to resist downward loads from the weight of the structure, upward loads due to wind uplift and lateral forces due to wind and water.

- Piles must be embedded well below the depth of potential scour.

- Careful consideration should be given to the method of inserting the pile in the ground, use of a pile driver is preferable to water jetting which loosens the soil around and below the pile.

### 4.3 Planning of Sea Defense Measures

When beach and/or dune erosion endangers coastal infrastructure there are several sea defense options that can be evaluated. An in-depth evaluation of the sea defense options is beyond the scope of this manual, however, there are several excellent texts which discuss these options for the technical and non-technical reader, some of which are listed in the bibliography.

**Table 9** lists the main sea defense measures being utilized in the Wider Caribbean Region. The list is not totally comprehensive, for instance, lesser used techniques such as beachface dewatering and artificial seaweed have not been included. The table summarizes, in a very generalized manner, the main design functions, time frame and limitations for each type of measure.

**Table 9. Summary of sea defense measures**.

| **Sea Defense Measure** | **Design Function** | **Timeframe** | **Limitations (generalized - these may not occur in every situation)** |
|---|---|---|---|
| Seawalls, bulkheads and rock revetments. | Protection of land and/or property behind the structure from wave action. | Can be installed fairly quickly under emergency conditions. | Continued erosion of beach in front of, and adjacent to the structure. |
| Groynes | Beach accretion by trapping sand moving along the coast by longshore transport. | Depending on natural conditions, groynes may take several months/years to result in significant sand accretion. | 1. Groynes will only work with certain wave and sediment conditions. They do not work on all coasts. 2. Sand accretes on one side of the groyne, but there is usually erosion on the downdrift side of the groyne. |
| Offshore breakwaters | Beach accretion by protecting the coast from wave action and reducing the rate of longshore transport. | Depending on natural conditions, offshore breakwaters may take several months/years to result in significant accretion. | 1. There may be erosion downdrift of the newly accreted beach. 2. Offshore breakwaters are costly and require very careful design. |
| Beach nourishment | Creation of a wider beach by adding sand from an inland or offshore source. | If offshore sand is the sand source, beach nourishment may take several months to implement. | 1. Newly created beach may be completely eroded during next storm. 2. Suitable sand sources may be a limitation in some Caribbean countries and territories. |
| Dune rehabilitation (sand fences) | Creation of new or higher dunes by encouraging the deposition of wind-blown sand. | May take 1-2 years to see significant accretion. | 1. Only work under certain natural conditions - they are not an option at every beach. 2. New dune may be eroded during next hurricane/storm. |
| Revegetation of dunes | Creation of new or higher dunes by encouraging the deposition of wind-blown sand. | May take several years to see significant accretion. | 1. Will only work where natural conditions exist for dune accretion - this is not an option for every beach. 2. New dune may be eroded during next hurricane/storm. |
| Replanting of | Stabilization of beach | May take several years | Trees will not stop beach |

| | | | |
|---|---|---|---|
| beaches. | sand, creation of shade, aesthetics. | for significant tree growth. | erosion or even withstand direct attack by hurricane waves. (Trees may slow down beach erosion during more frequent wave events). |

While it is very difficult to generalize about sea defense measures, there are three considerations that are universal to every situation: scheduling, site individuality and expert advice.

**Scheduling**: The time to act is **before** the erosion constitutes a problem. Once waves are undercutting a dune or coastal structure, then options become limited and costs increase. The potential for erosion should be considered while planning a coastal development and measures such as coastal development setbacks implemented to reduce the risk, see Section 4.1 and Table 8. Continuous monitoring of beaches can also assist in early identification of potential erosion problems, when it is still feasible to evaluate several different options.

**Site individuality**: Each site is different and each erosion problem has its particular characteristics. For this reason, it is impossible to recommend one type of sea defense measure over the others. Each measure has its advantages and limitations and none is universally appropriate for all sites.

**Expert advice**: When beach/dune erosion problems arise, it is always recommended to seek the advice of experts in the field who are also familiar with conditions in the particular country/territory.

## 4.4 Control of Sand Mining.

Sand mining, whether from beaches, dunes or coastal ponds, is a common practice in many Caribbean countries/territories. Most of the countries/territories have legislation regulating sand mining, such that sand can only be removed under permit. Usually, sand removal is not permitted from the foreshore (area between low water mark and high water mark), nor is it permitted if it results in the removal of a barrier to the sea. However, the full implementation and enforcement of the laws have been sadly lacking in past decades. As a result, beaches and dunes have been mined largely indiscriminately.

Against a background of an increased demand for sand, widespread coastal erosion and predictions for increased hurricane activity in the next two decades (Vermeiren and Watson, 1994), countries/territories may wish to review and perhaps revise their beach sand mining legislation. This may involve revising specific laws for beach sand mining or incorporating new controls into more comprehensive Planning legislation.

**Beach sand mining legislation may need review and revision in some countries/territories.**

Furthermore, the countries/territories may wish to consider the use and promotion of other building materials as well as alternative sand supplies such as:

- the substitution of local quarry products for beach sand;
- offshore dredging for sand;
- importation of sand from countries with vast inland supplies. e.g. Guyana.

However, implementation of any one of these alternatives will have economic implications for local construction costs. When considering alternatives such as importation, the possible introduction of plant pests and other diseases must also be considered.

Only in recent years, as a result of extensive education and awareness efforts, have some countries/territories taken steps to begin to control the removal of sand from the beaches and dunes. As a general guideline, the removal of sand from the beach or primary dune should be prohibited. This will include removal by hand, e.g. shovels, and mechanical means, e.g. backhoes, drag-lines. This should be a total ban with no exceptions permitted.

**As a general guideline, any removal of sand from the beach or primary dune should be prohibited.**

Some countries/territories may wish to consider the extraction of sand from secondary dunes and those further landwards. Any such extraction should be carefully regulated such that there is no infringement onto the primary dune. In addition, the development of plans for site restoration after removal of aggregate should also be a prerequisite for approval. Planning tools such as environmental impact assessments may also be a requirement for such activities.

**If sand extraction from secondary and more landward dunes is permitted, it should be carefully regulated and sites should be restored after mining is completed.**

Cases may arise where there is no clear primary/secondary/tertiary dune system. Instead, a single dune system may extend several hundred metres inland. In such cases, should countries/territories wish to permit mining, then an environmental impact assessment is recommended prior to any extraction. And, while there is no magic number that can be called 'safe', it is recommended as a general guideline that no extraction should be permitted in the zone 150 m (522 ft) landward of the crest of the primary dune.

When sand mining is permitted, a mining plan, which includes details of the mining operation, plans for rehabilitation of the mined area, and provisions for compliance monitoring, should be prepared. **Table 10** shows some guidelines for the preparation of a mining plan. While rehabilitation plans are sometimes prepared for mining operations in the Wider Caribbean, unfortunately, they are rarely implemented. The imposition of a refundable 'environmental deposit' can be effective in ensuring compliance with the conditions of approval. Should the developer not comply, or should the rehabilitation not be undertaken after the mining operation is complete, then the environmental deposit is forfeited and can be used for the restoration of the site. The amount of the environmental deposit will vary according to the scale of the project.

**Table 10. Guidelines for the preparation of a mining plan.**

A mining plan should include:

**Details regarding the actual mining operation**:

- location map;
- scaled topographic map showing the size of the area to mined, and cross sections showing the depth of the proposed cuts;
- volumes of material to be removed;
- selling price of material;
- geotechnical analysis of material to be mined;
- schedule of daily activities, including times when material will be moved off the site;
- time frame and phasing for the entire mining operation;
- mining method and equipment to be used;

**Rehabilitation plan:**

- methods for restoration of the mined area;
- equipment to be used;
- time frame for restoration;
- estimated cost of restoration.

**Compliance monitoring**, both during the mining operation and the rehabilitation phase, to include:

- type of monitoring to be conducted;
- who will undertake the monitoring;

estimated cost of monitoring;
responsibility for payment of monitoring activities;
frequency of the monitoring and the schedule for reporting.

Sand mining is a major issue in the Caribbean region and many beach and dune areas have been, and still are being destroyed as a result of mining activities. While other sources of sand exist, e.g. inland and offshore sources, they have been little exploited to date mainly because of cost factors. As tourism and residential development concerns are competing for prime coastal sites, suitable sites for mining are becoming scarce. To date, little attention has been given to post-mining site rehabilitation. Such costs can be very high and should be included in project planning. (Appendix III provides an example of costing for a proposed post-mining rehabilitation project in Anguilla). Only if site rehabilitation costs are included, can the various sand sources be fully evaluated in environmental, social and economic terms.

### 4.5 Control of Access Across Dunes

As has already been discussed, with the exception of major storms and hurricanes, human activity is the greatest threat to dunes (Salmon *et al*, 1982).

Concentrated foot or vehicular traffic, and grazing animals will destroy coastal vegetation. This leaves the dune vulnerable to wind erosion and low spots and blowouts develop. It is recommended that the countries/territories of the Wider Caribbean incorporate mechanisms to control human activity on sand dunes into their legal framework. Mechanisms such as the control of vehicles on beaches, access to beaches should be incorporated into existing or planned regulations under the appropriate authority, with provisions for enforcement.

Access walkways can prevent dune erosion caused by people walking to the beach. Such walkways are usually made of wood and are about 2 m (6 ft) wide. They act as bridges around or over the dune. They should be conveniently placed so that people will use them, but the dune itself should not be modified or should be disturbed as little as possible, see Figure 10. Photograph 11 shows a typical access. Generally, people will use such accesses provided they are conveniently placed since it is easier to walk on wooden boardwalks than on sand or vegetation. They can also be designed to accommodate persons with physical disabilities.

The problem of vehicles driving over the dunes and the beach itself, particularly at deserted sites is a difficult one to control, especially as the number of recreation and off-the-road vehicles is increasing. Boulders and fences at beach access points prevent most vehicles from driving on the dunes, but not off road drive vehicles. Besides damaging the dunes and the vegetation, vehicles may also damage sea turtle eggs buried under the sand. Widespread and continual education and awareness is the only solution to this problem since it is impossible to patrol all the beaches. Developing a sense of environmental responsibility for the adjacent beach and dune areas within members of the public and coastal communities is one way to begin to control this problem.

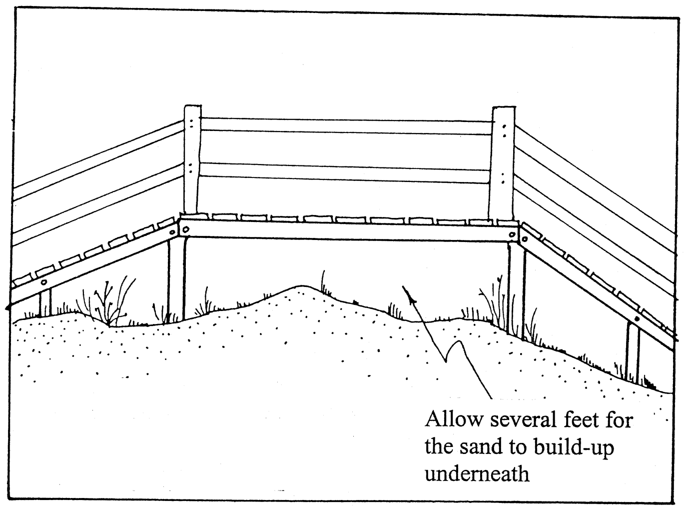



**Figure 10. Dune walkway (adapted from Salmon *et al*, 1982).**

**Photograph 11. Wooden walkway over the dune at Long Bay Belmont, Tortola, British Virgin Islands, April, 1990.**
Such accesses provide an easy path to the beach and protect the dunes and their vegetation.

## 4.6 Post-Hurricane Dune Rehabilitation

After a major hurricane, such as Hurricane Hugo in 1989 or Hurricane Luis in 1995, dunes may be severely eroded and left with their seaward faces standing at near vertical angles, and devoid of vegetation, see **Photograph 12**.

**Photograph 12. Dune erosion at Rendezvous Bay, Anguilla after Hurricane Luis, October, 1995.**

During the months and years after the hurricane, the sand will slump down the dune face and eventually a stable angle will be achieved, see **Figure 11**. However, in such cases, it may be worthwhile to speed up the recovery process by regarding the seaward slope to a stable angle and conducting a replanting project, see Section 3.2.3. However, any dune rehabilitation works should only be implemented on the advice and permission of the relevant authorities.

Within shore systems, it is often best to let natural processes take care of the recovery after a major hurricane. For instance, with eroded beaches, the best management practice is to let the waves move the sand back onto the beaches in the months after the hurricane. Measurements after Hurricane Hugo in 1989 and Hurricane Luis in 1995 showed that most beaches will recover to at least 80% of their pre-hurricane volume within 6-12 months of the hurricane, (Cambers, 1996b). This 'wait and see' policy is often hard to implement especially when property owners view the devastation after a hurricane, but it is undoubtedly the best practice.

However, notwithstanding the above, some simple slope regrading and planting of dune slopes after a hurricane will help to establish new vegetation which can then begin the process of trapping sand and dune building.

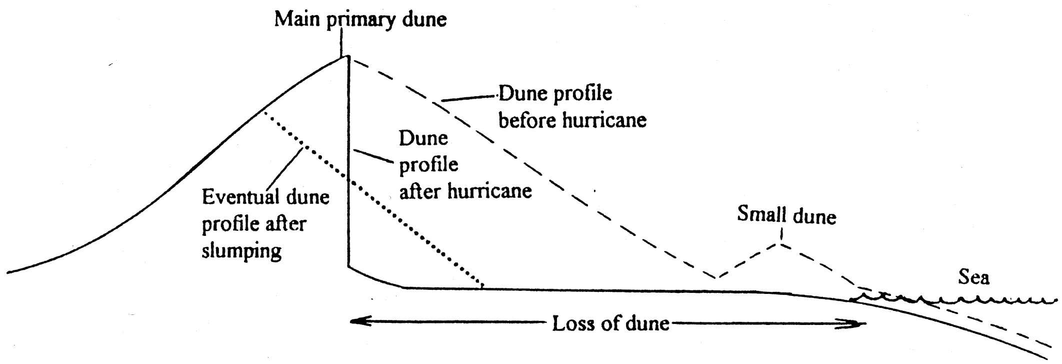



**Figure 11. Dune retreat after a hurricane (adapted from Cambers, 1995).**
The dune face has been eroded back leaving a near vertical slope. In the months/years following the hurricane, the sand will slump to form a more stable slope.

## 4.7 Education and Awareness Activities

Information about dune systems - their characteristics, functions and changes - should be incorporated into ongoing awareness and education projects and programmes particularly within the framework of integrated development planning. A basic understanding of the temporary nature of dune systems and their role as a sand reserve for the beach, while intrinsic to dune management and conservation, is rarely understood by the public at large. A variety of media approaches can be used to convey such themes, e.g. brochures, fact sheets, newspapers, magazines, radio, television, videos, talks/presentations, children's drama, school programmes, etc. Church groups, environmental and women's organizations can also be involved in the awareness activities so as to reach as wide an audience as possible. Table 11 shows some suggested education and awareness activities, and Table 14 in Appendix I includes, as an example, some of the activities that were undertaken during the Anguilla pilot project, 1997-1998.

**Table 11. Suggested education and awareness activities.**

| | |
|---|---|
| Activity: | **Training workshops on conservation for teachers.** |
| Objective: | To provide teachers with information on conservation which can then be used in the classroom through the infusion technique whereby environmental issues are incorporated into all subjects contained in the school curriculum. |
| Audience: | Teachers for all grades. |

| | |
|---|---|
| Activity: | **Training courses for law enforcement officers.** |
| Objectives: | To provide officials with information about environmental issues and how to implement the relevant laws in a particular country / territory relating to these issues. To explore mechanisms and develop procedures whereby law enforcement officers from different agencies can co-operate. |
| Audience: | Law enforcement officials from agencies responsible for police, customs, planning, environment, immigration, health and others. |
| Activity: | **Sensitization of senior administrators and politicians regarding environmental issues through meetings, presentations, field visits, workshops, conferences and other means as appropriate.** |
| Objective: | To ensure that these officials are fully aware of all aspects of environmental issues and to facilitate sound informed decision making and the establishment of policies. |
| Audience: | Senior civil servants, heads of government agencies, elected officials. |
| Activity: | **Public awareness campaign using mechanisms such as video documentaries, video clips, radio interviews, talk shows, drama, published articles, carnival and festival activities, exhibitions etc.** |
| Objective: | To enhance public awareness about coastal resources, especially sand dunes. |
| Audience: | General public. |
| Activity: | **Community involvement in sand dune projects.** |
| Objective: | To create a sense of environmental stewardship in communities and engender support. |
| Audience: | Members of coastal communities, church groups etc. |
| Activity: | **National consultations on coastal resources management**. |
| Objective: | To derive consensus on actions to be taken. Such consultations can be directed towards specific issues e.g. harassment of tourists on beaches, rehabilitation of a mined dune. |
| Audience: | Invited guests, consultations may also be open to the general public. |

Involvement in specific activities and projects is another recommended approach. Some suggested activities are:

- Adopt-a-beach projects;
- Beach clean-up projects;
- Participation in the International Beach Clean-up;
- Revegetation projects;
- Sea turtle nesting monitoring projects;
- Beach change monitoring projects;

- Field trips and conservation projects for schoolchildren;
- Coastal walks and hiking trips.

### 4.7.1 Adopt-a-Beach Projects

A group such as a local community, a school or a service group adopts one particular beach and undertakes various activities to maintain its environmental integrity and ensure sustainable use. The activities can be tailored to the particular beach, a few examples are:

- provision of litter bins,
- installation of warning notices for manchineel trees,
- installation of wooden walkways along public accesses,
- demarcation of swimming-only areas with buoys

### 4.7.2 Beach Clean-up Projects

These are often popular activities, since the results are immediately apparent. They can be held to coincide with particular events, e.g. Fisherman's Day (29th June), World Environment Day (5th June), with other local events or with the International Beach Clean-up Day. However, subsequent littering can be discouraging to the volunteers, particularly children. Combining beach clean-ups with other activities such as education efforts and the provision of litter bins is a way of reaching a sustainable solution.

### 4.7.3 Revegetation Projects

Guidelines for the selection, design, implementation and follow-up monitoring of revegetation projects on dunes have already been described in Section 3. A full list of plant species suitable for beaches and dunes is included in Appendix II.

At some beaches, a particular group may wish to enhance the site by planting shade trees. Some suggested species for this purpose are:

- Sea grape (*Coccoloba uvifera*),
- Seaside mahoe (*Thespesia populnea*),
- West Indian almond (*Terminalia catappa*),
- Coconut palm (*Cocus nucifera*),
- Australian pine (*Casuarina equisetifolia*).

As with dune planting projects, follow-up care is as important as the initial planting.

### 4.7.4 Sea Turtle Nesting Monitoring Projects

Sea turtle stocks are declining throughout most of the Wider Caribbean Region, mainly as a result of over-exploitation. In the Caribbean Sea, five species of sea turtle are recognized as *Endangered* and a sixth, the loggerhead turtle (*Caretta caretta*), as *Vulnerable* by the World Conservation Union (Fuller *et al*, 1992). The five *Endangered* species are: leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*), green turtle (*Chelonia mydas*), Kemp's Ridley turtle (*Lepidochelys kempii*) and the Olive Ridley turtle (*Lepidochelys olivacea*).

These turtles use the Caribbean beaches to nest, usually at night. Some turtles such as the hawksbill turtles make their nests in coastal vegetation. A female may nest several times each season. After a few weeks incubation in the nest, the baby turtles emerge and head to the sea. Because of their *Endangered* status, many countries / territories are seeking to protect turtles by banning both their slaughter and the removal of eggs from the nest.

### 4.7.5 Beach Change Monitoring Projects

Beach changes are measured on a regular basis in some Caribbean countries / territories. This information is intended to be used by Planning agencies and others to reduce the problems caused by coastal erosion and beach sand mining and to conserve and effectively manage the beaches. In the Lesser Antilles, this activity is a major component of the 'Coast and Beach Stability in the Caribbean (COSALC) Project.' Volunteers can assist with the monitoring activities. Besides providing vital information such monitoring activities help to show people how beaches and dunes change over time.

## 5. CONCLUDING REMARKS

This manual has combined sound practices with the results of case studies to produce some guidelines for sand dune management for groups and government agencies in the Wider Caribbean countries / territories. However, as in other aspects of integrated coastal area management, approaches evolve over time as new information becomes available. In order to advance the region's collective knowledge about integrated coastal area management, readers and users of this manual are encouraged to relay their experiences, particularly in sand dune management, to the Regional Co-ordinating Unit of the Caribbean Environment Programme of the United Nations Environment Programme and to the Natural Resources Management Unit of the Organization of Eastern Caribbean States (OECS-NRMU).

## References

Bagnold, R. 1954. *The Physics of Blown Sand and Desert Dunes*. William Morrow & Co., New York, 265 pp.

Barnett, M.R., Rogers, S.M., Halusky, J.G. 1989. *Utilization of Christmas Trees in Dune Restoration.* Proceedings Coastal Zone '89, American Society of Civil Engineers, pp 1051-1063.

Broome, S.W., Seneca, E.D., Woodhouse, W.W. 1982. *Building and Stabilizing Coastal Dunes with Vegetation.* University of North Carolina Sea Grant College Publication UNC-SG-82-05. 18 pp.

Bythell, J.C., Cambers, G., Hendry, M.D. 1996. *Impact of Hurricane Luis on the Coastal and Marine Resources of Anguilla Summary Report.* Report prepared for the Government of Anguilla and the U.K. Dependent Territories Regional Secretariat. 13 pp.

Cambers, G. 1995. Year of the hurricanes. *Sea Grant in the Caribbean,* Puerto Rico, October-December, 1995. pp 1-3.

Cambers, G. 1996a. *The Impact of Hurricane Luis on the Coastal and Marine Resources of Anguilla: Beach Resources Survey*. Report prepared for the U.K. Dependent Territories Regional Secretariat, Barbados. 92 pp.

Cambers, G. 1996b. *Hurricane Impacts on Beaches in the Eastern Caribbean Islands.* COSALC report, 96 pp.

Cambers, G. 1997. *Planning for Coastline Change*: *Guidelines for Construction Setbacks in the Eastern Caribbean Islands.* CSI info 4, UNESCO, Paris, 14 pp.

Cambers, G. 1998a. *Planning for Coastline Change. 1. Coastal Development Setback Guidelines in Antigua and Barbuda*. COSALC report, 63 pp.

Cambers, G. 1998b. *Planning for Coastline Change.* 2a. *Coastal Development Setback Guidelines in Nevis.* COSALC report, 42 pp.

Cambers, G. 1998. *Coping with Beach Erosion, Illustrated by Cases from the Caribbean*. (In press). UNESCO Publishing, 119 pp.

CAMPNET. 1989. *The Status of Integrated Coastal Zone Management: A Global Assessment*. Preliminary Summary Report of a Workshop convened at Charleston, South Carolina, U.S.A. July 409, 1989. 15 pp.

Clark, J. 1996. *Coastal Zone Management Handbook.* Lewis Publishers. 694 pp.

Coastal Engineering Research Center. 1984. *Shore Protection Manual.* U.S. Government Printing Office, Washington, D.C. 2 vols.

Craig, R. 1984. *Plants for Coastal Dunes of the Gulf and South Atlantic Coasts and Puerto Rico.* Agriculture Information Bulletin 460, United States Department of Agriculture. 41 pp.

Deane, D., Thom, M., Edmunds, H. 1973. *Eastern Caribbean Coastal Investigations, 1970-1973.* University of the West Indies, Trinidad, 5 vols.

Fuller, J.E., Eckert, K.L., Richardson, J.I. 1992. *Sea Turtle Recovery Action Plan for Antigua and Barbuda.* CEP Technical Report No. 16. 88 pp.

Gardiner, V., Dackombe, R. 1983. *Geomorphological Field Manual.* George Allen & Unwin (Publishers) Ltd. 254 pp.

Hendry, M.D., Bateson, R.I., Dharmaratne, G., Bascom, R., Tarbotton, M., Hunte, W., Hubbard, D.K., Anderson, J.B. *The Impact of Hurricane Luis on the Coastal and Marine Resources of Anguilla. Feasibility Study for Alternative Sand Resources in Anguilla.* Report prepared for British Development Division in the Caribbean. 72 pp.

King, C.A.M. 1972. *Beaches and Coasts.* St. Martin's Press, New York. 570 pp.

National Research Council. 1990. *Managing Coastal Erosion.* National Academy Press. 182 pp.

Nellis, D.W. 1994. *Shoreline Plants of South Florida and the Caribbean. A Guide to Identification and Propagation of Xeriscape Plants.* Pineapple Press Inc. 160 pp.

Nichols, Keith E. and Vasantha Chase, 1995. Islands Systems Management: A New Concept of Coastal Zone Management for Small Islands. Proceedings of the 48th Gulf and Caribbean Fisheries Institute. 1985.

Robinson, D. 1996. *Baseline Data Spells Relief.* In Cambers, G. (Ed). 1996. Managing Beach Resources in the Smaller Caribbean Islands, papers presented at a UNESCO - University of Puerto Rico Workshop, 21-25 October, 1996, Mayaguez, Puerto Rico. Coastal region and small island papers, No. 1, UPR/SGCP-UNESCO, Mayaguez, pp 13-17..

Salmon, J., Henningsen, D., McAlpin, T. 1982. *Dune Restoration and Revegetation Manual.*

Report No. 48, Florida Sea Grant College Program. 60pp.

Smith Warner International Ltd., Alleyne Planning Associates. 1998. *Conduct of an Assessment of Sand Dune Rehabilitation Efforts in Anguilla with Special Emphasis on the Rehabilitation of Windward Bay*. Report prepared for the Organization of Eastern Caribbean States. 32 pages.

South Carolina Coastal Council. 1988. *How to Build a Dune*. Charleston, South Carolina. 12 pp.

UNEP. 1996. *Guidelines for Integrated Planning and Management of Coastal and Marine Areas in the Wider Caribbean Region*. UNEP Caribbean Environment Programme, Kingston, Jamaica. 141 pp.

U.S. Army Corps of Engineers. 1981. *Low Cost Shore Protection......a Property Owner's Guide.* U.S. Government Printing Office, Washington, DC. 159 pp.

U.S. Department of Housing and Urban Development and Federal Emergency Management Agency. 1981. *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*. FIA-7. 189 pp.

Vermeiren, J.C., Watson, C. 1994. *New Technology for Improved Storm Risk Assessment in the Caribbean*. Disaster Management, Vol 6, No. 4. pp 191-196.

Wason, A.T., Nurse, L. 1994. *Planning and Infrastructure Standards.* Organization of Eastern Caribbean States.

## APPENDIX I

## ANGUILLA DUNE REHABILITATION PILOT PROJECT

The Anguilla Sand Dune Rehabilitation Project commenced in October, 1997 and continued for one year. (Certain aspects of the project such as monitoring and revegetation continued beyond the one year project time frame). The results from this project have been incorporated into this manual. This Appendix serves to briefly summarize the activities and findings of the Anguilla Project. (For ease of reference, the headings and their numbering system are the same as those used in the manual).

### 3.1 Site Selection

#### 3.1.1 Determination of the Number of Sites Requiring Rehabilitation in the Geographic Area.

Sites along the north, east and southeast coasts were listed. These included: Barnes Bay, Meads Bay, Crocus Bay, Shoal Bay East, Island Harbour, Captain's Bay, Windward Point Bay, Savannah Bay, Sile Bay, Mimi Bay.

#### 3.1.2 Site Screening

The criteria listed in Table 2 were used to initially screen the sites. The criteria are:

- Sand dunes exist now or have existed at the beach site within the previous two decades;
- The rehabilitated sand dunes will protect existing or planned development;
- The prevailing winds blow from the sea towards the dunes.

The wind data from the Airport for the period 1990-1998 were compiled, see Figure 12, and field visits were conducted to each site. The list was reduced to five potential sites:

Meads Bay,
Shoal Bay East,
Windward Point Bay,
Savannah Bay,
Sile Bay.

#### 3.1.3 Site Assessment

The checklist shown in **Table 3** of the report, was used to assess each site. A completed checklist for Shoal Bay East is shown in **Table 12**.

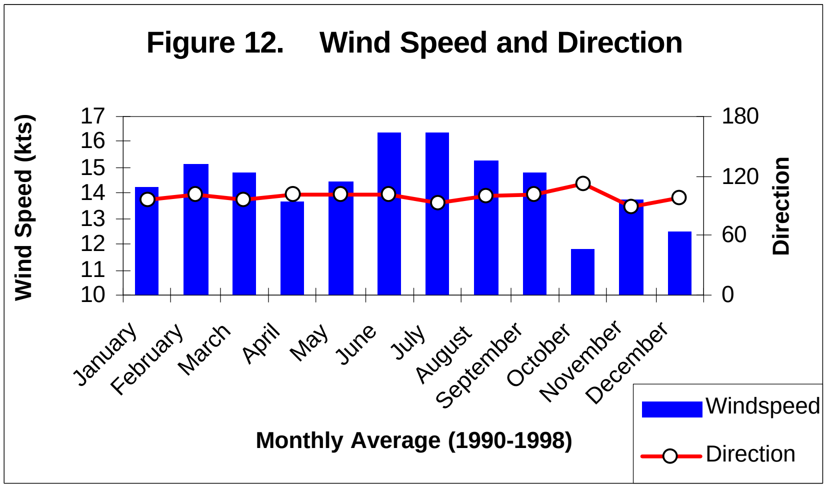



**Figure 12. Monthly wind speed and direction at the Airport, Anguilla, 1990-1998.** (Figure adapted from Smith Warner *et al.*, 1998).

### 3.1.4 Final Site Selection

Using the site assessment checklists, the pre-selected sites were ranked as follows:

1. Shoal Bay East,
1. Savannah Bay,
3. Windward Point Bay,
4. Sile Bay,
5. Meads Bay.

Note that Shoal Bay East and Savannah Bay received joint first ranking. These two sites were chosen as the sites for the dune rehabilitation project.

Key factors used for ranking the sites were the width of the dry sand beach, beach orientation, and past/ongoing mining activities. For instance, at Meads Bay, key factors were the beach orientation - this beach faces north and the prevailing winds are from the east and southeast, in addition, during the winter swell season there was often no dry sand beach. At Sile Bay the existence of a sea defense wall had impeded the development of any beach here, thus, dune fences were unlikely to be successful. While at Windward Point Bay the ongoing mining activities and the designation of this site as a potential sand storage area for a future offshore dredging operation were determining factors.

**Table 12. Dune assessment checklist for Shoal Bay East, Anguilla.**

| | |
|---|---|
| **Site Name** | Shoal Bay |
| **Date of Assessment** | 22.10.97 |
| **Site Location and Orientation**<br>Beach length:<br><br>Beach orientation:<br>Vehicular access: | <br>1,890 m long, divided into two sections east and west of a sandy promontory (point).<br>East of the point, the beach faces northeast.<br>There is a track leading to the beach. |
| **Dune Physical Characteristics**<br>Length:<br>Width:<br>Height:<br>Presence of parallel dune systems:<br>Presence of new dunes:<br>Presence of low points in dune line:<br><br>Condition of seaward dune slope: | <br>East of the point, dune length is 450 m.<br>Dunes extend approx. 100 m inland.<br>1-2 m above the beach level.<br>No dune system distinguished.<br>Low dunes, 1-2 ft high forming at the back of the beach.<br>Some lower areas, but no evidence of sea breaking through the dune line.<br>Some steep, bare areas visible. |
| **Dune Vegetation**<br>Types of vegetation, main species:<br>Vegetation coverage: | <br>Sea bean, sea purslane, sea lavender and several grasses.<br>80%. |
| **Turtle Nesting** | This is not a major turtle nesting beach. |
| **Beach Characteristics**<br>Width of dry-sand beach:<br>Minimum width of dry-sand beach:<br><br>Beach composition: | <br>23 m.<br>0-5 m during very high winter swell events, these conditions are estimated to occur 1-5 times per year.<br>Medium sand. |
| **Wind Pattern**<br>Wind speed:<br>Wind direction: | <br>Mean speed > 6 m / sec.<br>East northeast to southeast. |
| **Site History**<br>History of beach / dune area: | <br>Dunes retreated a maximum distance of 14 m inland during Hurricane Luis in 1995. |
| **Site Ownership** | Dunes in private ownership but the owner is willing to participate in the project. |
| **Overall Assessment**: | This site has potential for dune rehabilitation as long as no attempt is made to try and re-establish the pre-Hurricane Luis coastline. Possible constraints: very high winter swells |

| | |
|---|---|
| | (groundseas), although infrequent may represent a problem. |

### 3.2 Design of Dune Rehabilitation Measures.

Based on experiences in other parts of the Caribbean as well as published literature, it was decided to construct dune fences made of wooden pallets at these two sites, to be followed by revegetation projects once sufficient sand had accumulated in the vicinity of the fences.

### 3.3 Project Implementation

#### 3.3.1 Project Management

A project committee was established with persons from the following agencies:

- Anguilla National Trust (ANT),
- Department of Fisheries and Marine Resources (DFMR),
- Physical Planning Department (PPD).

While all three agencies participated in all aspects of the project, the ANT were responsible for the awareness aspects of the project, the DFMR for the actual construction and monitoring of the fences, and the PPD for overall project coordination and planning aspects.

At the start of the project, arrangements were made to fully involve the media and to make a video of the entire project. Meetings were held with communities living near the two sites: Shoal Bay East and Savannah Bay, some of these meetings were recorded on video.

#### 3.3.2 Project Preparation

The weekend of 15-16th November, 1997, was scheduled for construction of the sand fences, a weekend was selected so as to allow volunteers to participate. A materials list was prepared three weeks before. The wooden pallets were collected from various suppliers and stored at the respective sites. Other materials, such as wooden stakes, wire, paint and tools were also procured. **Table 13** shows details concerning fence construction at Shoal Bay East. Signs were prepared and notices about the activity broadcast on the radio. Meetings were held with the land owners at Shoal Bay East and Savannah Bay and permission obtained for access purposes and to place fences on the dunes. Site plans were prepared showing fences dimensions and positioning at each site.

The fence at Shoal Bay East was constructed on 15th November, 1997. Eleven persons participated in the project, most of these persons were from the agencies comprising the project committee although three persons from two different community groups also participated. On 16th November, 1997, the fences at Savannah Bay were constructed with the help only of the project committee agencies. The work at Savannah Bay proceeded at least twice as fast as on the previous day as a result of the experience gained. Fence construction is very hard manual work and beach conditions are very hot and dry, therefore the provision of ample food and drink is very important. While children can participate in some aspects of the fence construction e.g. painting, most of the work requires adult strength and expertise.

**Table 13. Design details for the construction of a sand trapping fence at Shoal Bay East, Anguilla.**

| | |
|---|---|
| **Length of dune fence**: | 46 m (151 ft). |
| **Position of the fence**: | 5 m (16 ft) landward of the edge of the grass and 3 m (10 ft) shorewards of the existing line of palm trees, approximately 15-20 m (49-60 ft) landward of the high water mark. |
| **Type of construction**: | Wooden pallets, 1.2 x 1 m (4 x 3 ft), positioned with wooden slats horizontal over half the fence length and vertical slats over the other half. Pallets anchored at each end with 2 m (6 ft) long stakes, pointed at one end and made of 2 x 2 pitch pine, pounded into the sand with a 10 lb. sledge hammer. Pallets wired to the stakes at the top and bottom of the pallet with 3.15 mm pliable tying wire. |
| **Number of pallets**: | 41 pallets in total, 27 placed with slats horizontal and 14 placed with slats vertical. |
| **Number of stakes**: | 42 stakes. |
| **Finishing of pallets**: | Pallets were painted ivory because this site was directly in front of a tourist hotel. |
| **Time for fence construction**: | 3-6 hours depending on experience of crew. (This does not include collecting and preparing the materials and assembling them on site which took approximately one week). |
| **Number of persons needed for fence construction**: | 6-8 people (2 people to pound in the stakes with a sledge hammer, 2 people to wire the pallets to the stakes, 2 people to position the pallets and the stakes, 2 people to paint the pallets - note painting is optional depending on the aesthetics of a particular site). |
| **Cost of fence construction**: | US$5.5 / metre length of fence (assuming the fence is painted and the pallets and their transportation are free and labour is voluntary). |

| | |
|---|---|
| **Materials required**: | Wooden pallets, stakes, tying wire, wire cutters, sledge hammer, oil drum (for height when pounding the stakes into the sand), thick gloves, paint, brushes / rollers and paint trays, spray paint for marking the monitoring sites, water and refreshments for work crew. |

Information signs were placed at both sites on 17th November, 1997. Most of the fence construction work was completed during the weekend of 15-16th November, 1997. However, at Shoal Bay East, additional fences were placed north of the hotel site in December 1997 using paid labour.

The limited assistance from the community groups was a little disappointing in the Anguilla pilot project. However, it is always difficult to get people to donate their time, particularly in the busy period leading up to Christmas. Furthermore, dune fences are a relatively new concept in the Caribbean and thus, there is a certain amount of initial scepticism to overcome.

### 3.3.3 Post Project Activities

On 17th November, 1997, a meeting of the project committee was held to review the results, to make plans for completion of the fences at Shoal Bay East and monitoring the sand accumulation at both sites.

The monitoring became the responsibility of the DFMR who already conduct beach profile monitoring. At the sand fence sites at Shoal Bay East and Savannah Bay, beach profiles have been measured regularly since 1992 and 1994, respectively. So, continuation of this beach profile monitoring would also record any sand accumulation in the vicinity of the fences. In addition, marks were sprayed with paint on the fences themselves so as to measure directly the vertical accretion along the fence line. These measurements would be taken every three months, the same interval as the beach profile monitoring. Photographs were taken of the sites prior to, during and post construction.

During the period November, 1997 to October, 1998, sand accumulation started in the vicinity of the fences at Shoal Bay East during the period May to July, 1998, and continued through to October, 1998. At Savannah Bay, some very slight accretion took place during the period May to July, 1998. The maximum sand accumulation over the ten month period was 0.53 cm (1.7 ft) at Shoal Bay East. (This figure is probably an under-estimate because of wind scour in the immediate vicinity of the fence, the sand accumulation was most noticeable about 0.3 m (1 ft) in front of the fence). **Photograph 7** shows accretion at one of the sand fences at Shoal Bay East where natural vegetation, especially sea lavender (*Tournefortia gnaphalodes*) was already colonizing the newly accumulated sand.

On September 20th, 1998, Hurricane Georges, a category 3 hurricane, passed over St. Kitts, 96 km (60 miles) south of Anguilla. In Anguilla, the most severe beach erosion was experienced on the south and east coasts, where dunes were also eroded and retreated inland, e.g. at Rendezvous Bay, Maunday's Bay and Forest Bay. The hurricane generated waves reached the dunes at Savannah Bay and eroded the dunes and some of the seagrape (*Coccoloba uvifera*) bushes. As a result, the fences were destroyed, some of the wooden pallets remain buried in the beach. (The pallets which were scattered over the beach had to be removed together with other debris brought onshore by the hurricane waves). Shoal Bay East, which is on the north coast of Anguilla, was more sheltered from the waves generated by this hurricane.

Nine months is too short a time period to assess the results of the sand fences. Experience in Puerto Rico and other countries has shown that it takes at least 12-24 months to show significant sand accumulation. Some preliminary sand accumulation was apparent at Shoal Bay East. However, no natural dunes or sand fences can withstand the effects of hurricane generated waves - hence the loss of the fences at Savannah Bay. Further time is required to fully assess the results of this pilot project.

The ANT conducted awareness and education activities about coastal resources and, in particular, sand dunes during 1998. Some of the specific activities are shown in **Table 14**. In addition to those activities, a 30 minute video on the entire project was produced.

**Table 14. Education and awareness activities undertaken during the Anguilla Sand Dune Project, 1997-8.**

| | |
|---|---|
| **Activity**: | **Workshop on conservation for teachers.** |
| **Objective**: | To provide teachers with information on conservation to be used in the classroom. |
| **Audience**: | Teachers for primary grades 5 and 6. |
| **Results**: | One group which focused on sand dunes produced a series of mini dramas for use in the classroom which stressed the importance of sand dunes and their vegetation. Some of these mini dramas were also published in the Anguilla Life Magazine. |
| **Activity**: | **Public awareness campaign**. |
| **Objective**: | To increase public awareness about coastal resources, especially sand dunes. |
| **Audience**: | General public. |
| **Results**: | Articles in newspapers and magazines, physical models and photographs |

| | |
|---|---|
| | of the sand dune rehabilitation project at an Open House for the National Trust; TV spots, radio spots to coincide with carnival celebrations and boat racing events. |
| **Activity**: | **Community meetings on the sand dune project.** |
| **Objective**: | To involve the community in the sand dune rehabilitation project. |
| **Audience**: | Members of coastal communities. |
| **Results**: | Difficulty was experienced in getting satisfactory attendance at community based meetings. So an alternative strategy was adopted for outreach, namely, intervention in unrelated community activities so as to attract community attention. |
| **Activity**: | **Preparation of video spots on the sand dune rehabilitation project**. |
| **Objective**: | To increase public awareness about sand dunes. |
| **Audience**: | General public and schools. |
| **Results**: | Several video spots of excellent quality were produced. Unfortunately, a narrator with a non-Anguillan accent was used which meant that the recordings did not have the full Anguillan flavour. |
| **Activity:** | **One day national consultation on coastal resources management**. |
| **Objective**: | Consultation and preparation of a pamphlet on coastal resources management. |
| **Audience**: | Invited guests. |
| **Results**: | A participatory approach was adopted to prepare a pamphlet. Unfortunately, this offended a local hotelier because a photograph of his hotel, damaged after Hurricane Luis, was used and this implied that the hotel had not adhered to setback regulations. However, on the positive side, the process allowed for building a relationship with a property owner who had been hostile to the building of a sand fence in front of his property, but after the consultation there was a significant attitudinal change. |

# APPENDIX II

## PLANTS FOR SHORELINES AND DUNES IN THE WIDER CARIBBEAN

### Grasses

Seashore dropseed, also called Seashore rush grass (*Sporobolus virginicus*)
Panicgrass (*Panicum amarum v. amarulum*)
Seaoats (*Uniola paniculata*)
Sandbur (*Cenchrus* spp. L)
Salt marsh cordgrass (*Spartina patens*)
Seashore saltgrass (*Distichlis spicata*)
Knot grass (*Paspalum vaginatum*)

### Other herbaceous plants

Beach morning-glory (*Ipomoea pes-caprae*)
Beach bean (*Canavalia maritima*)
Sea purslane (*Sesuvium portulacastrum*)
Coastal sedge (*Cyperus planifolius*)
Aloe vera (*Aloe barbadensis*)
Spanish bayonet (*Yucca aloifolia*)
Century plant (*Agave missionum*)
Pinguin (*Bromelia pinguin*)
Samphire, Salt-weed (*Blutaparon vermiculare*)
Sea-blight (*Suaeda linearis*)
Glasswort (*Salicornia bigelovii*)
Common purslane (*Portulaca oleracea*)
Hairy portulaca (*Portulaca pilosa*)
Sea rocket (*Cakile lanceolata*)
Beach pea (*Canavalia rosea*)
Periwinkle (*Catharanthus roseus*)
Beach milk vine (*Matelea maritima*)
Moon vine (*Ipomoea macrantha*)
Seaside heliotrope (*Heliotropium curassavicum*)
Trailing wedelia (*Wedelia trilobata*)
Wild lettuce (*Lactuca intybacea*)
Beach sunflower (*Helianthus debilis*)

**Shrubs and trees**

Cocoplum (*Chrysobalanus icaco* L)
Sea lavender (*Tournefortia gnaphalodes*)
Sea grape (*Coccoloba uvifera*)
Seaside mahoe (*Thespesia populnea*)
West Indian almond (*Terminalia catappa*)
Coconut palm (*Cocus nucifera*)
Manchineel, Poison apple (*Hippomane mancinella*) Note that parts of this tree, including the fruit, are poisonous.
Silver palm (*Coccothrinax antea*)
Shortleaf fig (*Ficus citrifolia*)
Black mampoo (*Guapira fragrans*)
Water mampoo (*Pisonia subcordata*)
Limber caper (*Capparis flexuosa*)
Jamaica caper (*Capparis cynophallophora*)
Nicker bean (*Caesalpinia bonduc*)
Pride of Barbados (*Caesalpinia pulcherrima*)
Tamarind (*Tamarindus indica*)
Coralbean (*Erythrina corallodendrum*)
Lignumvitae (*Guaiacum officinale*)
Limeberry (*Triphasia trifolia*)
Bay cedar (*Suriana maritima*)
Gumbo-limbo (*Bursera simaruba*)
Bushy spurge (*Euphorbia articulata*)
Coast spurge (*Euphorbia mesembrianthemifolia*)
Croton (*Croton discolor*)
Christmas bush (*Comocladia dodonaea*)
Marble tree (*Cassine xylocarpa*)
Poison cherry (*Crossopetalum rhacoma*)
Sida (*Sida rhombifolia*)
Sea hibiscus (*Hibiscus tiliaceus*)
Pitch apple (*Clusia rosea*)
Geiger tree (*Cordia sebestena*)
Wild cinnamon (*Canella winterana*)
Yellow alder (*Turnera ulmifolia*)
Red mangrove (*Rhizophora mangle*)
Buttonwood (*Conocarpus erectus*)
White mangrove (*Laguncularia racemosa*)
Torchwood (*Jacquinia arborea*)
Wild alamanda (*Urechites lutea*)

Bay lavender (*Argusia gnaphalodes*)
Black mangrove (*Avicennia germinans*)
Haggarbush (*Clerodendrum aculeatum*)
Wild sage, Lantana (*Lantana involucrata*)
White-alling (*Bontia daphnoides*)
Golden creeper (*Ernodea littoralis*)
Morinda (*Morinda citrifolia*)
Sandfly bush, wild thyme (*Rhachicallis americana*)
Strumpfia (*Strumpfia maritima*)
Seven year apple (*Casasia clusiifolia*)
Inkberry (*Scaevola plumieri*)

**Cacti**

Wolly nipple cactus (*Mammillaria nivosa*)
Turk's cap cactus (*Melocactus intortus*)
Prickly pear (*Opuntia dillenii*)
Dildo cactus (*Pilosocereus royenii*)

## APPENDIX III

## PROPOSED POST MINING REHABILITATION AT WINDWARD POINT BAY, ANGUILLA

Windward Point Bay lies on the east coast of Anguilla. The bay is 400 m long and is contained by two rock headlands. The beach is exposed to waves from the east and southeast, while Scrub Island provides some protection for waves from the northeast. The beach used to be backed by a series of vegetated dunes extending a maximum of 150 m inland. Historical aerial photographs show that mining of the dunes began at this site after 1984. The aerial photographs taken in 1991 showed that approximately one third of the dune area had been mined, although the primary dune had been left intact and had a width of approximately 30 m. In 1991, this bay was designated as the only sand mining site in Anguilla. The mining continued throughout the 1990's, and by 1995 most of the available sand had been removed. A small ‘remnant’ primary dune, 2 m wide and 3 m high was left at the back of the active beach zone, this was breached by Hurricane Luis in 1995 (Cambers, 1996a). At the end of 1995, a survey indicated approximately 20,000 $m^3$ of sand remained in the former dune area, this represented one year’s supply for Anguilla (Hendry *et al*, 1996). By 1997, almost all the dune sand had been extracted and the quarry operations were beginning to cut into the limestone deposits behind the bay.

A report by Smith Warner *et al* 1998, proposed that this site be rehabilitated by dredging 75,000 $m^3$ from the offshore area and placing the sand at the back of the existing beach where the dunes had been mined out. (A previous report by Hendry *et al*, 1996, had identified potential offshore sand sources close to this bay). Once this dredged sand was in place, the proposal recommended that sand fences be constructed to encourage sand accumulation and dune formation, to be followed by a planting project.

Based on other dredging and beach / dune restoration projects recently completed in Anguilla, it is estimated that the cost of the proposed dredging would be in the region of US$500,000 to US$750,000. Added to this would be the cost of the dune rehabilitation and revegetation efforts.