ELBOW CAY BEACH EROSION DAMAGE FROM HURRICANE FLOYD

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The following report regarding storm impacts from Hurricane Floyd to the beach along the windward coastline of Elbow Cay, based on an October 6, 1999 site visit, is reproduced here by kind permission of the author and Messrs Mike Alexiou and Keith Bishop. The area in question is known as White Sound.

DUNE BREACH NEAR ABACO BY THE SEA.

Of obvious principal importance is the reconstruction of the sand dune that was breached between Abaco-by-the-Sea and Sea Spray Resort. By rule-of-thumb, the dune volume should be about 27 cubic yards of sand per ft alongshore (cy/ft), measured above the beach elevation that presently exists. This volume is theoretically sufficient to withstand a storm similar to Hurricane Floyd. For typical, steep dune side slopes of 1 (vertical): 2.5 (horizontal), this volume would require a 100-ft wide base, more or less. Its crest would be about 50-ft wide. This may be impractically wide given the site's requirements for a road, houses, etc.

If the dune is downscaled in size, then it should probably be not less than, say, 2 to 2/3rds of the rule-of-thumb value -- or, 14 to 18 cy/ft. This reduces the base to 75 to 85 feet, with crest of about 25 to 35 feet width.

Figure 1. General view south from Abaco Inn after restoration. (Photo: Sealey)

The seaward toe of the reconstructed dune should be no further seaward than the pre-storm location. A prudent set-back of the dune toe would be about 90 feet landward of the low, exposed rock shelf that outcrops at about the mean low water line. This location is probably about 10 to 15 ft further landward than the pre-storm location of the dune toe, based upon our field measurements.

As was observed in the field, the sand that overwashed toward White Sound should be used to reconstruct the dune. In the meantime the backshore area, from the beach to the Sound, should be trenched to reveal the thickness of the sand deposit. From these measurements the approximate volume of sand available for dune construction can be estimated.

Any structure -- rock boulders, rip-rap, sand-filled geotextile tubes,

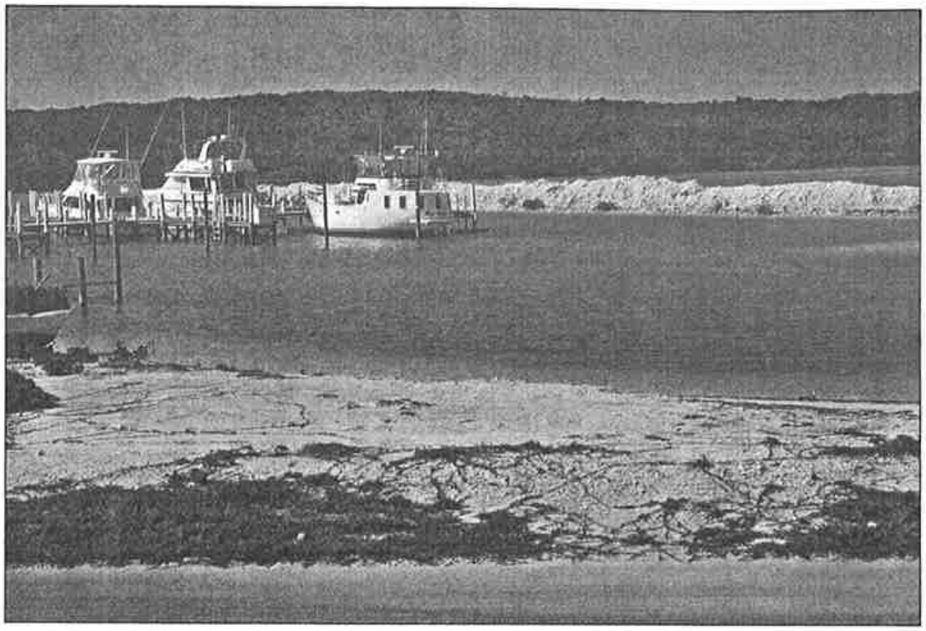

Figure 2. White Sound showing remaining mounds of sand washed into bay after hurricane. (Photo: Sealey)

et cetera -- within the reconstructed dune will not increase the dune's longevity or resistance to erosion, unless placed along the seaward face of the dune. Adding structures to the seaward face of the dunes, however, would represent beach armoring -- viz., unsightly structures that protect the upland at the expense of the recreational sand beach. I do not recommend such structures along this coastline.

Any structure buried inside the dune will serve only as a 'dike' in the event that the overlying dune is eroded and the interior structure becomes exposed to waves. So long as such buried structures are exposed only rarely (during severe storms), they do no harm. If they are built too close to the sea, such that they are routinely exposed by waves or frequent storms, then they negatively impact the beach. Their benefit is marginal at this site -- especially relative to their cost -- as it may not be critical to completely prevent dune washout in a severe storm event (so long as homes are elevated on piles above the dune, as described below).

Per our site discussions, one method to supplement the quantity of material available to reconstruct the dune is to bury non-beach-quality sand below the beach grade under the dune's crest. In this way, the beach would be trenched along the dune's centerline (approx.). The beach sand excavated from the trench is temporarily stockpiled. Silty sand or other non-beach sand derived from the White Sound area is then replaced in the trench, and then buried with beach sand to form the dune. This method 'stretches' the quantity of beach sand available from the overwash deposit -- and can also help to eliminate some of the offending shoals and deposits in White Sound. Debris from the storm could also be eliminated using this trench approach. However, the debris must be broken up and exposed steel removed, etc. This may entail more difficulty than it saves. Also as we discussed, broken-up structural concrete (such as cistern walls, etc.) rarely make good shore protection material because it is flat (i.e., tabular).

HOUSE RECONSTRUCTION IN DUNE BREACH

Houses and other structures can be rebuilt in the dune wash-out area so long as they are on properly engineered, pile foundations and their lowest-floor structural members are near or above the elevation of the dune's crest. The buildings should be located over or behind the landward slope of the dune. The dune should not be excavated or otherwise compromised to facilitate the houses' construction; that is, the houses and cisterns should be totally free and clear of the dune and should not interfere with dune movement (excepting the presence of the piles).

Pile-foundations for these houses -- either timber, cast, or pre-stressed concrete -- are by no means an atypical requirement for

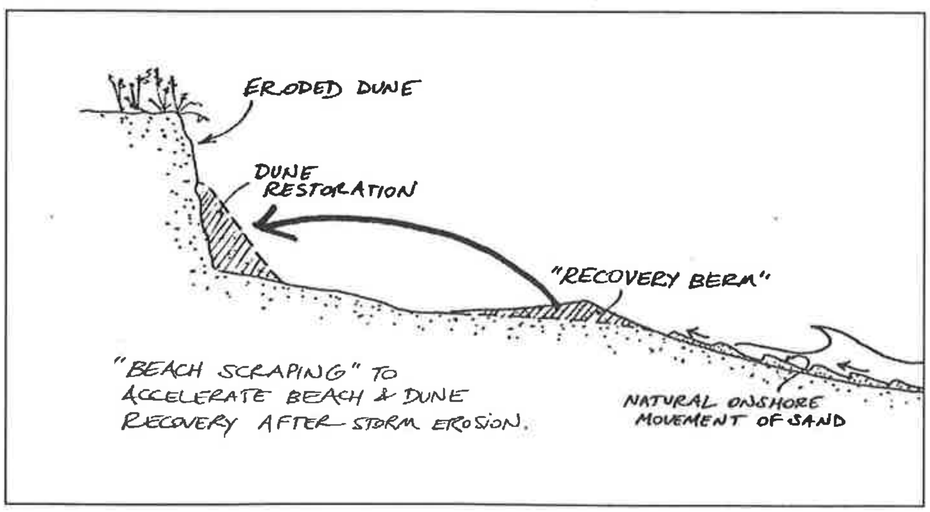

Figure 3. Limited, judicious transfer of sand from the natural recovery berm to the dune toe can accelerate both beach and dune recovery.

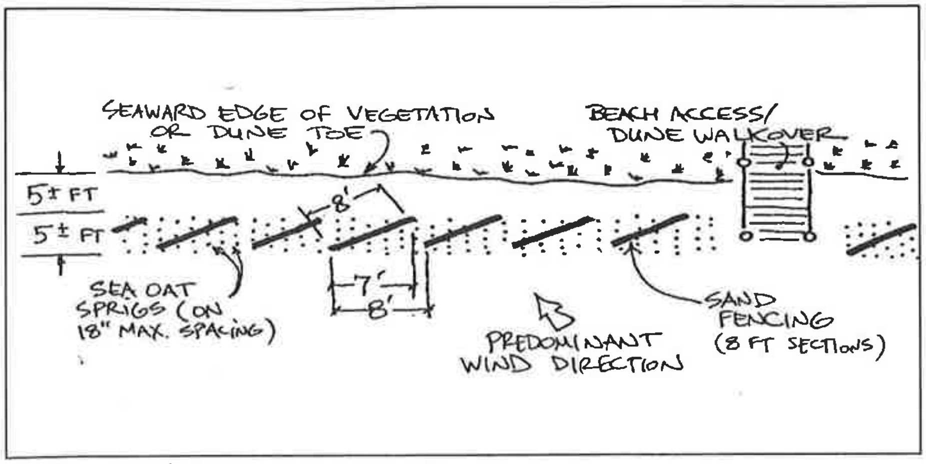

Figure 4. Typical dune fence and vegetation plan.

erosion-susceptible areas such as this site. The cost is not prohibitive, and there are several Bahamian and many U.S. contractors that can auger-cast or drive the piles. The piles and foundation must be designed by a qualified structural engineer. Pre-stressed concrete piles or timber piles can be driven into place (usually requiring a crane and hammer), or steel-reinforced concrete pilings can be cast in-place so long as proper penetration into the seabed can be made (usually requiring an auger).

It is likely that the road between Abaco-by-the-Sea and Sea Spray Resort will need to be relocated toward White Sound in order to provide sufficient area for house reconstruction landward of the rebuilt dune.

BEACH SCRAPING AND DUNE Reconstruction; General, Island-Wide

As shown in Figure 3, I recommend limited beach 'scraping' to transfer sand from the accreting berm to the base of the dune. This action results in immediately improved dune protection against the next month's storms, and significant increases the vertical elevation and breadth of the dunes that would otherwise take at least 6 to 10 years to create by wind. If undertaken judiciously, this should accelerate the natural shoreward movement of sand back on to the beach, and recovery of the dune. This activity should ideally be undertaken in a uniform fashion along the entire coastline (or contiguous, long portions thereof), preferably through the coordinated use of a limited number of contractors.

Depending upon wave and beach conditions, natural sand migration will re-build the scraped berm within 1 to 10 days after each operation. The scraping process can be thus repeated at this several-day cycle -- often for up to 4 to 6 weeks -- until most of the eroded sand has been naturally moved ashore. Bulldozer (blade) and payloader equipment are recommended, respectively, to control (limit) the amount of sand transfer and to stack the sand high against the dune face. The success of this approach is conditioned upon limited transfer of sand. It is important that only the berm's newly-deposited sand is removed and transferred to the dune on each pass. This usually represents an 8" to 15" vertical thickness of sand, maximum, between the mid-tide line and the wave uprush line (Figure 3). Over-digging, trenching or pits are counter-productive.

Longer-term, natural recovery of the dunes can be accelerated by properly installed sand fencing and vegetation. We normally recommend a single row of wooden-slat fencing – about 40" high – placed in staggered 8-ft long sections. Wooden-slat fencing is available, nade, in 50-ft rolls (approx.); or- : people use plastic fencing with ; that is commonly called "snow :". The wood fencing is usually : aesthetic. Each 8-ft fence sec- should face the predominant . direction. I recommend that ›ractice be employed in a con- ıt fashion along as much of the .ward shoreline as practicable, commenced as soon as possi- The natural accretion process ongest in the weeks following torm, and so the method's net effectiveness is greatest when undertaken immediately. (Figure 4)

Sea oats or other native dune plants can be planted integrally to the fence sections, typically on 18-inch centers across a 4- to 6-ft width. As you know, sea oat plantings are available from landscape nurseries in sizes ranging from sprigs to 1 gallon containers. Sprigs are common, and are provided in bundles with no container. Enough sprigs for 100-ft shore frontage are easily handled; and probably fit in 1 or 2 large table vases. A single dose of 8-8-8 fertilizer (at planting) and 2 to 4 months of irrigation is recommended. A simple irrigation method is to run a flat seepage or sprinkler hose down the middle of the plantings. Excessive or long-term irrigation retards the beneficial, downward growth of the roots into the sand.

SHORELINE ARMORING - General, Island-Wide

As noted above, shoreline armor -- such as boulders, sand-filled geotextile bags or tubes, concrete, etc. -- inside dunes do not increase the dune's longevity. The purpose of such armor is to retard erosion of the upland, or base of the dune, once the overlying dune sand is eroded and the armor becomes exposed. Its benefit is greatest for severe, low-frequency storms -- when the armor provides a last line of defense. Armor can eventually fail as it is overtopped by waves and/or the beach in front of it is eroded. This

Figure 5. Reconstructed dune and rebuilt house. (Photo: Sealey)

is particularly true for sand-filled geotextile tubes -- which tend to deform and roll seaward as the beach sand in front of the bags is scoured away by the reflection of waves off the tube's face. As such, these armor measures basically 'buy some time' in forestalling or slowing erosion during the storm.

The biggest danger in armoring the base of the dune is that:
(1) the armor will become chronically exposed during normal conditions and destroy the beach's beauty, and
(2) it leads to a proliferation of armor along the coastline. The former problem results from armor that is built too far seaward upon the beach; e.g., in an effort to reclaim and protect a pre-storm dune line, or built in an otherwise erosion-stressed location. In these instances the armor is exposed by frequent (annual) storms and retards or negates the beach's natural recovery. It may take months or longer for it to become reburied with sand. The resulting degradation of the beach is obvious.

The second problem results from shoreline armor's potential to erode adjacent properties at the expense of the beach. When exposed to waves, armor can accelerate or increase beach and dune erosion on one or both ends. The effect increases with the armor's exposure to the sea.

When erosion cuts behind the ends of shoreline armor, the structure is "flanked" and fails from behind -- often rapidly (see Figure 6) Prudent engineering design calls for "flanking walls," or "return-sections," by which the armor structures' ends turn toward, and cut into, the upland to prevent flanking failure. While this benefits the armored property, it can further increase the potential erosion effect to the neighboring property -- especially if the armor is built too far seaward and is frequently within the waves' uprush. The natural result is that the adjacent property owners perceive a need to protect their upland -- leading to a proliferation of armor along the beach.

Some proponents of sand-filled geotextile bags or tubes claim that the product is less detrimental than conventional armor because it is a 'soft-structure' and easily removed. In fact, to be of benefit, these structures are large and difficult to remove. They cannot be simply 'slit open' and abandoned. Also, their smooth surface reflects wave energy back upon the beach rather than dissipating the energy (as do boulders). Our firm was among the first to re-introduce the use of sand-filled geotextile tubes to the southeastern U.S. in the 1990's and so we have extensive experience in their application.

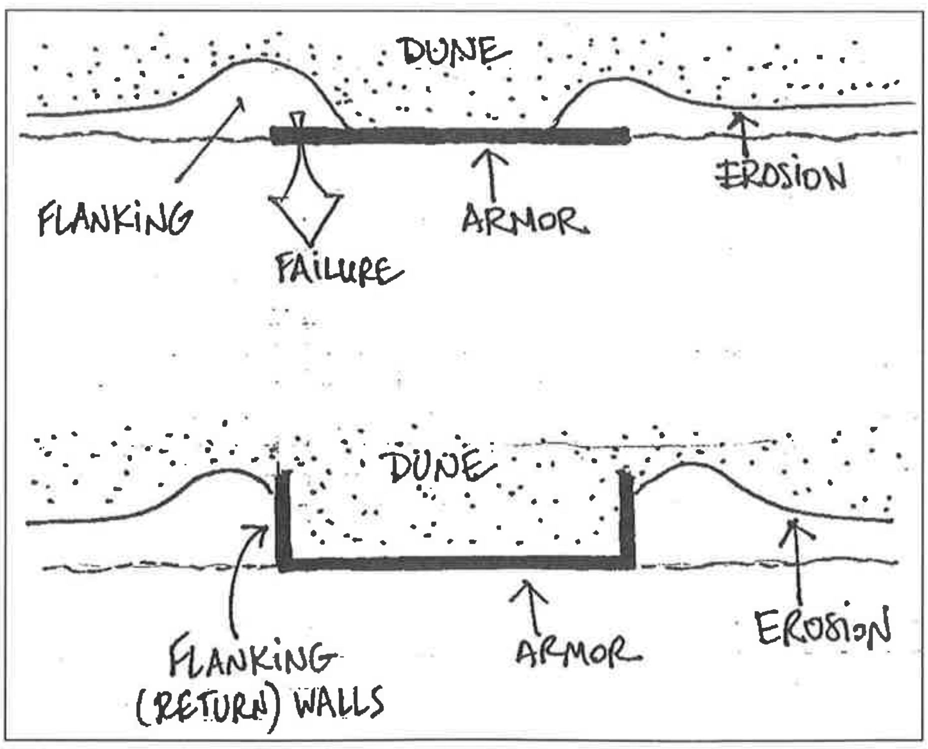

Figure 6. "Flanking" erosion that occurs at ends of seawalls.

If a sand-filled geotextile is used, we highly recommend only those with impermeable inner liners. These fill more uniformly and with greater vertical relief. For example, a "6-ft diameter tube" might fill to only 2.5 to 3.5 ft height if unlined, but can fill to 3.8 to 5.0 ft height with an impermeable liner (and when installed by an experienced contractor). The volume of sand needed to fill such bags is usually small enough to be safely sourced from the beach. The cost of a single sand-filled geotextile tube in Florida (1999 dollars), including materials and labor, is between $150 and $250 per ft alongshore. This is based upon 3 fairly recent projects employing lined tubes of 40" to 70" diameter. The cost of the materials is generally about 35% of the total in-place cost, excluding duties.

Small, conventional sand-bags are generally too small to be of significant value. In a storm, they tend to be scattered, intermittently buried, and ultimately litter the beach.

In general, along this specific coastline, I advise against proposals to armor the beach with structures -- be they rocks, sand-filled geotextile tubes, bulkheads, seawalls, et cetera -- except in those cases when the following criteria are met:

1) a habitable structure is in demonstrably imminent danger of foundation failure, and
2) the structure is less than 50% damaged and/or for which landward relocation is not feasible, and
3) when the beach armor is placed as far landward as possible against the buildings foundation so as to ensure its reliable, long-term burial within a restored sand dune, and
4) when the beach armor is designed (and its installation reviewed) by a qualified engineer.

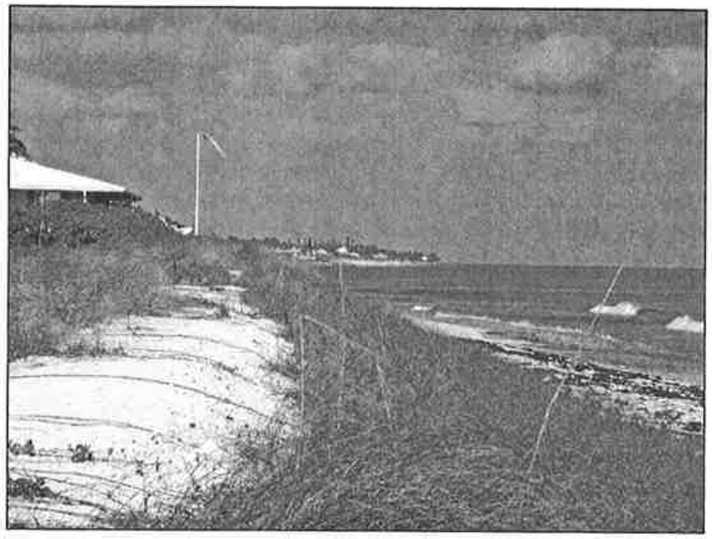

Figure 7. Reconstructed dune showing bare patches and rebuilt house. (Photo: Sealey)

As a guideline, I propose that 'demonstrably imminent' be defined as that instance when the principal structure's foundation is within the static failure plane of the eroded dune face. Typically, this occurs when the foundation's distance from the dune face is about one-half or less of the vertical height of the dune face. (Figures 8 and 9) For example, a foundation that is less than 10 feet from the top of a 20-ft high vertical dune scarp can be considered to be in potential danger of imminent failure. Here, we're referring to foundation(s) for the principal structure; and not those for decks, gazebos, etc. [In contrast to "imminent" danger, a structure is considered "highly susceptible" to danger in the short- or mid-term if its foundation is within three (3) times the eroded dune height; for example, set-back less than 60 feet

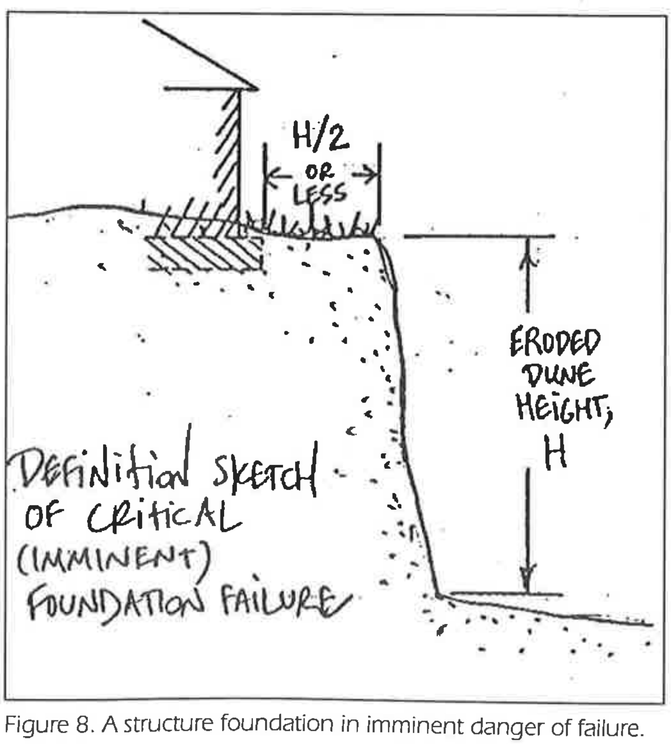

Figure 8. A structure foundation in imminent danger of failure.

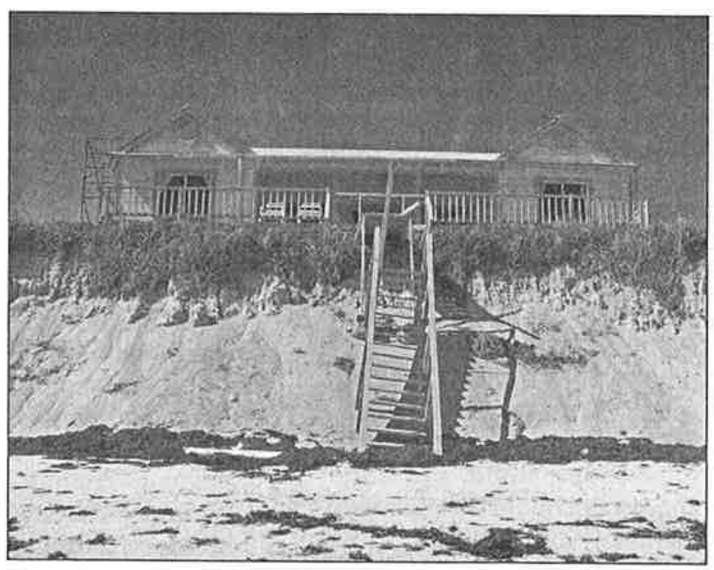

Figure 9. House on nearby Guana Cay in danger of imminent collapse (Photo: Sealey)

from the top of a 20-ft high vertical dune scarp.]

The conventional choice for foundation stabilization is a vertical seawall or bulkhead. This alternative is preferred over a sloping boulder revetment -- along this coastline -- because a vertical wall encroaches minimally upon the beach. (By contrast, a rock revetment should slope at not greater than 1 ft vertical to 1.5 ft or 2.0 ft horizontal. Thus, a 12-ft high revetment occupies about 22 feet of beach width.) Vertical sheet-pile or concrete-panel walls can be installed very close to a building's foundation with a crane and vibratory-hammer. A conventional pile-hammer could excessively vibrate or fracture the upland building.

A proper, steel-reinforced concrete or masonry wall with adequate foundation and tie-backs can be built, to limited height, without use of a crane and hammer. A simple, reinforced concrete or masonry wall -- with sound foundation and screw-anchor tie-backs -- may not provide requisite, complete protection against another Category 3+ storm event such as Hurricane Floyd; however, it may perform adequately enough to retard or reduce critical erosion where foundations are near peril -- and it is notably less expensive than sheetpile seawalls, etc. Construction of such walls, however, requires that the property owner acknowledge that the wall is susceptible to failure, and assumes the risks accordingly.

Regardless of its type, any requisite coastal armor should be buried by sand with subsequent planting of native dune vegetation. The face of this sand (dune) cover is normally placed at a slope not steeper than 1 (vertical) to 2.5 (horizontal). For example, a dune of 15-ft vertical relief would intersect the beach at least 22.5 feet (horizontally) from the eroded dune face or seawall. This intersection point, or "dune toe," should fall no further seaward than the historical, pre-storm location of the dune toe -- and/or not significantly further seaward than the base of the adjacent, rebuilt dunes.

Dune and Beach Nourishment (Dredging and/or Other Imported Sand)

Whether or not armor is constructed, there will probably not be sufficient sand available from beach scraping to re-create the pre-storm dune volume. Beach-compatible sand could be imported and placed to provide the additional volume; however, practical sources are limited. While there are sand shoals on the leeward side of the island, it is probable that the sand grain size is too fine (small) relative to the stable, native beach/dune sand. The utility of near-island (leeward) sand sources may therefore be limited.

Proposals to nourish the beach or dunes using sand from any source - dredged or otherwise - must demonstrate the compatibility of the sand with that of the native beach. Besides color, a fundamental test is the grain size distribution (that is, the percentage of sand grains of various sizes). Individuals proposing beach fill from the sound, shoals, or other sources should provide a description of the proposed borrow source's location, sand thickness, and certified laboratory analysis of the grain size distribution.

Sand from the sound or shoals is frequently much finer than the coarse, native beach sands. Placement of fine sand upon the beach will result in high loss rates and, importantly, offshore movement of the sand onto the nearshore reefs. Usually, and especially when the sand is compatible with the native beach sand, the turbidity and sedimentation that results from hydraulic (dredge) placement of sand upon the beach is not significant enough to warrant concern. The bigger potential impact results from placement of sand that is too fine – both from turbidity and from offshore slumping of the sand upon the reefs. Where sensitive nearshore reefs occur unusually close to shore, then site-specific consideration may be warranted to judge the effect of hydraulic (dredge) placement of the sand.

A minimum requirement for sand placed as beach nourishment material on open-coast beaches in the Bahamas may be typified as something like:

- not more than 2% finer than #200 sieve (0.074 mm)
- not more than 16% finer than #80 sieve (0.18 mm)
- not more than 40% finer than #60 sieve (0.25 mm)
- not more than 70% finer than #40 sieve (0.42 mm)
- not more than 5% coarser than #4 sieve (4.76 mm)

It is not generally advisable -- physically or fiscally -- to dredge sand from the submerged toe of the beach for placement to the dry beach or dune. The 'active' beach extends to the point that the beach profile intersects the stable seabed -- probably -10 ft or deeper along this coastline. (Along non-reef coastlines, such as central east Florida, this depth is -15 to -23 feet.) Waves will naturally transport sand from the toe of the beach toward the waterline. Dredging sand from the active toe, or from the nearshore, can cause the placed sand to simply erode back into the water -- resulting in no net benefit from the operation.

It is possible, though, that the storm transported some sand past the first reef. This sand may be 'stranded' and otherwise unavailable for natural shoreward movement in the near- or mid-term. It would be beneficial for knowledgeable residents to snorkel beyond the first or second reefs within the next few weeks to examine the amount of sand that has been deposited in these areas -- relative to normal, pre-storm conditions. There might be a long-term potential to move this sand onto the beach.

This said, however, the productivity of modest-sized suction dredges in transferring nearshore sand to the beach is usually very limited -- especially along this ener-

Figure 10. Controlled beach access. (Photo: Sealey)

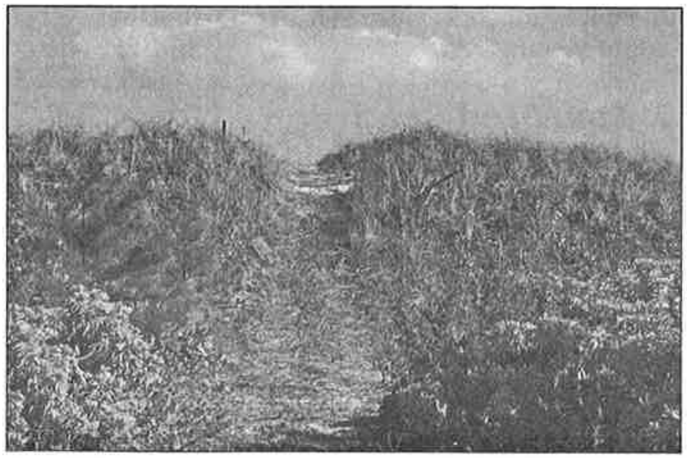
Figure 11. Current beach access over dune. A timber walkway is recommended (Photo: Sealey)

getic, exposed coastline. Alternately, a larger dredge is far more capable and productive; however, the cost to mobilize such a dredge and pipeline is significant (>$250,000+). In either case, the final cost can be high.

In the end, it may be near-equally cost-competitive to import beach quality sand from an off-island source for modest quantities of dune recharge. The typical in-place cost of beach sand in Nassau is about $15/cy; and so the family island cost may be about $20/cy. For a 5 cy/ft (dune) surcharge along a 100-ft shorefront, this amounts to about $10,000 per 100-ft of shore.

The longevity of a beach nourishment project is proportional to the square of its length along the shoreline, theoretically. That is, a 2000-ft long beach fill lasts 4 times as long as a 1000-ft beach fill, all other things being equal, etc. Note that very short projects (1000-ft or less) typically exhibit very short longevity – generally less than 1 year in typical conditions. There is no harm done to the beach from a short project (so long as the sand is beach-compatible). In fact, any beach fill project benefits the overall beach system by adding compatible sand. However, achieving functional utility from a beach nourishment project requires that the fill be continuous along significant lengths of shoreline. This, of course, requires the cooperative effort or participation of many neighboring properties....

GENERAL BEACH MANAGEMENT

Ranges of Alternatives to Consider

In the big picture there are several alternative strategies to consider:

1. No-Action.

The beach can be expected to recover to almost its pre-storm condition, more or less, through natural processes over the course of a year or two. However, the dune will probably not recover -- nor will the eroded upland be restored -- prior to the next major storm event (e.g., a Category 2+ storm). It is probable that the dune might naturally recover to, say, half of its pre-storm condition within 5 to 7 years -- barring a large storm in the interim.

2. Beach Scraping and Sand Fencing.

Limited, mechanical transfer of sand from the beach's recovery berm to the dune face will accelerate beach recovery and can potentially restore the dune to about half of its pre-storm condition immediately. Subsequent natural dune recovery, by wind-blown sand, would be additive to the dune growth; and, it can be accelerated by proper dune fencing and vegetation. Barring storm impacts, fencing and re-vegetation can establish a significant, stable dune within about 2 to 3 years. (See Item C, above.)

3. Dune Nourishment.

Sand can be added to the dune to restore it toward its pre-storm condition -- beyond the beach scraping/sand-fencing work, above. This can be done for individual properties, although the benefits are much greater when multiple, contiguous properties are done together. The completed dune should be planted with appropriate dune vegetation. As the requisite sand quantities are modest, the simplest and most practical sand source might be importation from off-island, landing by barge, and truck-haul to the beach.

4. Beach Nourishment

A large-scale beach nourishment project would require at least 20 cy/ft of sand fill, plus another 5 cy/ft (approx.) for dune restoration. (This is a very small fill; typical projects in Florida, for example, place between 40 and 100 cy/ft.) Beach nourishment must include long, contiguous reaches; it cannot be effectively conducted for individual properties. Along, say, a 10,000-ft long reach of shoreline, fill requirements would be on the order of 200,000 cy (minimum). That easily represents a $1.2M to $2.5M project, and presumes that an appropriate offshore sand source can be located. Without structures (see below), there is no way to retain the sand upon the beach; accordingly, periodic beach re-nourishment would be required.

5. Stabilized Beach Nourishment.

There is no reasonable way to 'hold' the beach sand in place -- excepting proper groin structures (which I do not recommend at this site). That is, a properly designed field of rock, T-head groins, constructed every few hundred feet along the beach, could be constructed to"lock up"the beach sand and simultaneously protect the dune and upland. Because this is a long, continuous beach, the structures would have to be built along its entirety -- lest the unstabilized beach downdrift of the structures would erode. Our firm pioneered the successful use of these structures throughout the southeastern U.S. and the Caribbean, and I have extensive personal experience with their success. That said, I do not recommend their employment at this site, as they are incongruous with the natural splendor of Elbow Cay's beach.

Other structures built along the dune (geotubes, revetments, etc.) will not retain the dune or beach nourishment.Their role is to protect the upland at the expense of the beach, once exposed to the waves. Likewise, I do not recommend segmented offshore breakwaters or the like. To be effective, they must be built to or above the mid-tide water level, close to shore. Like groins, they must encompass long reaches of shoreline; erosion can be induced beyond their end; and they are incongruous with this beach. Submerged offshore breakwaters have either no effect, or detrimental effect, upon the beach.

6. Alternative Technologies

Beach erosion brings"snake-oil salesmen" out of the woodwork. Structures and systems advertised to "attract and retain sand" are countless, and I explicitly state here that these systems are ill-conceived and/or deleterious to the beach. Most consist of structures that ultimately only armor and litter the beach, and may cause one section of the beach to gain sand at the expense of the neighboring section. Unless they produce sand or import compatible sand from a source outside of the littoral (beach) system, they are of little or no long-term net value.

7. Seawalls and Armor

As described earlier I do not recommend the introduction of seawalls or similar dune armor except in those circumstances meeting the four specific criteria detalied above.

8. Relocation.

Whenever possible or practical, severely damaged structures and those in danger of failure should be relocated landward. This is a prudent long-term measure that obviates the need to be critically concerned about frequent, periodic storm impacts to the dune.The near-term cost of re-building a structure at a landward-relocated site is readily offset by the potential long-term cost of attempting to maintain the beach and dune in front of an improperly located structure.

9. Beach Access

Beach access lanes that are low in elevation should be restored to near the natural dune elevation, with a timber walkover built thereupon. At least one or two access points should include a timber-mat ramp over the dune to allow heavy vehicle access to the beach. Low-points in the dune -- typically associated with pedestrian access -- are highly vulnerable to storm inundation. Once storm surge breaches the dune at such a low point, the return flow of water from behind the dune toward the sea will 'blow out' the dune and significantly accelerate its erosion or destruction.

10. Monitoring

file monitoring program be initiated along as much of the shoreline as practicable. This program should consist of beach profile sections surveyed every 1000-ft alongshore, more or less. Each section-survey should be referenced to a fixed station (origin) with measured, recoverable grid coordinates. Each profile survey should commence well landward of the dune (in the upland) and continue across the eroded dune face and the beach into the water, to wading depth.The survey should be repeated in about 6 months, and then again every 2 or 3 years thereafter, or after a storm as required.

The purposes of this monitoring program are multi-fold and important. First, in the near-term, it provides an objective measure as to how well the beach and dune recovery has proceeded. Second, in the mid- and long-term, it provides an objective baseline by which to compare beach health and future storm impacts. Specifically, the profile data establishes a permanent record that can substantiate (or contravene) anecdotal recollections of prior beach and dune conditions.

ACKNOWLEDGMENTS

I appreciate the invitation to these observations and recommendations, and hope that they will be of practical usefulness to the general Hopetown community. I was impressed by the magnitude of oceanfront damage -- but moreso impressed by the fortitude and spirit of the residents and local officials who we met in their effort to quickly rehabilitate the island.

Thanks to Mike Alexiou and Keith Bishop (of Islands by Design) for commissioning this report and agreeing to its publication.

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