Chapter 6
Foredune Restoration Before and After Hurricanes: Inevitable Destruction, Certain Reconstruction

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6.1 Introduction

On Gulf of Mexico coastlines, hurricanes and tropical storms disturb beach and foredune development quite frequently. For example in Texas, a good "rule of thumb" is that a tropical system makes landfall within 100 km of a given point, once in every 5 years (Morton et al. 1983). In natural areas where the sediments can move dynamically, dunes simply re-form over time, although in new spatial locations.

However, in urban or developed areas, housing and infrastructure often impede dune migration, leaving no space for dune-building processes to occur (Nordstrom 2008; Psuty 2004). In this urban context, for example on Galveston Island, Texas, there are only a few meters available for a dune in the cross-shore direction.

At many locations around the world, people often restore foredunes for ecological purposes, for example, to enhance habitat for plants or animals. However, on Galveston Island, with cross-shore erosion rates that threaten to eliminate any available width within a few years, restoration provides minimal habitat value and only briefly establishes a human-managed ecosystem. Still, dunes are consistently restored in this context on Galveston (typically, they are not restored in natural areas in Texas as there is no financial incentive in these isolated, rural areas).

Why do both private individuals and government agencies restore foredunes in locations with minimal habitat value, and in an environment where there is a certainty of loss within a few years? In such a context, dunes are restored because:

1. They effectively demarcate the public beach from private property, protecting homeowners from wandering tourists.

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2. They are aesthetically-pleasing, providing a sense of nature and wildness to homeowners and tourists.
3. They protect housing and infrastructure from the impacts of future storms. People on the Texas Coast routinely invest in expensive foredune restoration projects, while understanding that they are likely to be destroyed in less than a decade.

In this chapter, the incentives behind three dune restoration projects on Galveston Island, and the storms that created and/or destroyed them, are examined. Additionally, an example is presented where Light Detection and Ranging (LIDAR) laser altimetry, Global Positioning System (GPS), and Geographic Information System (GIS) were used to develop a novel technique for dune restoration.

6.2 Delineation of Public–Private Property Boundary: Pirates' Beach Project

Tropical Storm Frances (1998) destroyed foredunes in the Pirates' Beach area on Galveston Island, Texas, leaving a flat profile with a low slope. No vegetation remained between the ocean and the residential community of Pirates' Beach that was located approximately 75 m further landward.

Under Texas law, the Texas Open Beaches Act (§61.011), demarcates private from public property using the vegetation line. Thus, after Frances, the residents of Pirates' Beach were concerned that the State of Texas might appropriate their land through this Act, since the vegetation line had receded to a location landward of their houses. In the past, the State had subjectively applied the act, often allowing homeowners to remain, regardless of whether the line of 100 % vegetation coverage was landward or seaward of the housing structure. Although the State would often declare all land seaward of these structures as publicly owned, they largely avoided condemning the structures by declaring eminent domain over them, because of the expense of fighting lawsuits that were often filed by the homeowners. Typically, the State waited until the erosion had become so severe that the housing structures physically collapsed into the ocean. Most of the homeowners in Pirates' Beach were not in jeopardy of losing their homes to the State after Frances; however, they had little to no land seaward of their homes.

Residents of the Pirates' Beach community were concerned that the public easement was encroaching upon their private lands, and they could foresee that the most seaward structures would be lost in a few years. Moreover, residents expressed concern that the public was accessing the beach through their property, walking through their manicured lawns, creating the potential for crime, and resulting in a loss of privacy for their high-income community.

The community of Pirates' Beach pointed out that erosion at their location had been hastened by the existence of shoreline armoring that had been in place for decades prior (the Galveston Seawall and jetties), located upstream in the littoral current to the east. Pirates' Beach residents argued that their downstream loss of

Fig. 6.1 Foredune restoration project at the Pirates' Beach. *Left image* shows the geotube covered with sand, prior to planting vegetation. *Right image* shows the geotube after Hurricane Lilly removed the sand and vegetation in 2002. By 2003, the geotube was partially torn apart by Hurricane Claudette. Photos by Rusty Feagin

private land was partially due to the State's intervention in the natural sedimentary dynamics of the region, and that the State should extend the armoring further westward to protect their properties as well. By 1998, however, "hard" shoreline armoring was no longer allowed or approved by the State, in general. As an alternative solution, geo-textile tubes were proposed for Pirates' Beach. Geo-textile tubes, or geotubes, are essentially large textile socks filled with sand. They can be cut open and removed relatively quickly if desired.

A large foredune was thus reconstructed along a 2-km stretch of Pirates' Beach in the spring of 2000, using a geotube at its core (Fig. 6.1, see also Feagin 2005, for a full description of the project). Sand was placed on top of and around the geotube, making it look like it was natural. In June through July 2000, vegetation was planted on the reconstructed dune at 1-m spacings. *Sporobolus virginicus* was planted at its seaward base, *P. amarum* over the entirety of the dune, and *Spartina patens* at its landward base. A drought ensued, and temperatures were at all-time highs in the Galveston region for much of the late summer. By winter, it was anticipated that the majority of the plants were dead; however, by the following spring it became apparent that the survival of *P. amarum* was over 90 %.

Residents were quite happy with the reconstructed dune, and felt that it looked natural. It was aesthetically pleasing and kept the public at a distance from their homes. Their private property was relatively secure, since the vegetation line had been re-established tens of meters seaward of where it had been post-Frances. In an ironic twist, the residents' private property was thus extended seaward by the State itself, funding portions of the reconstruction project with grants.

In 2001, 2002, and 2003, a series of tropical storms and hurricanes removed all of the sand and vegetation that covered the geotube (Feagin 2005). The storms also destroyed the walkovers and bridges that stretched across the geotube, reducing public access to the beach. In some locations, the geotube had ripped open.

Residents of Pirates' Beach felt that the reconstructed dune had protected their homes from the waves and surges of these storms, and they were quite happy with its performance. However, public citizens were angry that the geotube was now uncovered, unnatural, and ugly. Several public interest groups challenged the subsequent use of geotubes at other locations, arguing that they blocked access to the public resource and violated the Texas Open Beaches Act. Over the following years, sand and vegetation were never replaced on the geotubes at Pirates' Beach, and the geotubes were not well-maintained. On 13 September 2008, Hurricane Ike completely destroyed what remained of the geotube at Pirates' Beach. The surge during this storm was approximately 4 m at this location with waves several meters high (Williams et al. 2009), and the entire community was flooded the day before Ike actually made landfall. The remnant portions of the geotube were removed by 2010. Still, the example of the dune reconstruction at Pirates' Beach elucidates the strong incentive for private landowners to build dunes, and maintain the vegetation line, for the purpose of delineating private versus public land.

6.3 Aesthetics and Natural Habitats: Galveston Island State Park Project

The image of sea oats (*Uniola paniculata*), with tall stems and majestic seed-heads, is a classic icon that graces Texas coastal literature, photos, and paintings. Coastal management literature often features images of *U. paniculata*. Sea oats seem to be synonymous with the beach and dune ecosystem in Texas.

However, there are no *U. paniculata* plants of the native Caminada variety left on Galveston Island, except in paintings and pictures on the walls of hotel rooms. This genetic variety is apparently limited to the Western Gulf (Subudhi et al. 2005) and its seeds are essentially unviable (NRCS 2005). Restoration has been done previously using this variety (NRCS 2008) and specific recommendations have been made regarding its planting, although not on Galveston Island. This variety of the species spreads primarily through rhizomatous runners and forms large clumps on the tops of the dune. These traits are not favorable on an island where a high hurricane frequency, a history of overgrazing, and modern development have wiped out any local source from which the species could spread (Feagin et al. 2005). The few Caminada variety plants that were propagated on Galveston were grown in the nursery, did poorly, and were never transplanted to natural dunes.

During one project, a primary objective of restoration was to re-introduce sea oats, *U. paniculata*, to Galveston Island (see Feagin et al. 2008 for full project description). Several sites were chosen for the re-introduction of the species to Galveston Island. Sites were chosen because they were located on public property owned by the State of Texas, and they were appropriately located to maximize the potential spread of *U. paniculata* across the island. A workshop was conducted on sand dune restoration at Galveston Island State Park, and local residents were recruited to assist with the re-introduction of *U. paniculata*.

The Caminada variety of *U. paniculata*, the variety that is native to the Western Gulf, was initially sought. The UDSA, NRCS Plant Materials Program offices in Kingsville, Texas and Galliano, Louisiana were contacted for plant material. The Kingsville office could not provide plants. The Louisiana office provided a list of growers; however, only one grower claimed to have *U. paniculata* and was requesting a very high price per plant. After consulting with this grower, who refused to discuss where the sediment for the plants came from, it was inconclusive as to whether sediment in the plant pots may already be mycorrhizal. Moreover, there was a good chance that these *U. paniculata* plants were of the Eastern Gulf variety.

For these reasons, *U. paniculata* was purchased from growers in Florida. This plant material was almost certainly the Eastern Gulf variety, as the seeds were viable. Although the Caminada variety was preferred, the Eastern Gulf variety would also allow the plants to potentially spread in the future.

On 5–6 May 2008, approximately 1,000 Eastern Gulf variety plants were planted at three restoration sites. At Galveston Island State Park, the plants were placed where the back beach graded into the dunes, in an area with low embryonic dunes that were already vegetated. This less-than-ideal location along the beach–dune gradient was chosen because the area immediately seaward was covered with beach wrack, denoting an elevation and location that was often inundated during high tides, and the area immediately inland was already covered with 100 % plant cover, which would have likely resulted in high competition for the re-introduced plants.

Individual plants were spaced at 0.5-m intervals in the long-shore direction, and 1-m intervals in the cross-shore direction (between rows). Rows were offset from each other by 0.5 m, and plot locations were offset from each other by 1.5 m.

For planting, a small hole was dug to 10 in. in depth; mycorrhizae were added and mixed with sand at the bottom of the hole. A single plant was then placed into the hole, and the hole was refilled with the original sand. Plants were not watered and no additional fertilizer was added, although the sand was damp to two inches below the surface because of recent rains.

After the restoration, a minor drought occurred and no rainfall fell for approximately 1.5 months. All plants were monitored in late July for their survival, number of stems, length of each stem, and total vegetative length (sum of all stem lengths). Owing to the minor drought that immediately followed the restoration plantings, survival was relatively low. The survival rate for all plants at Galveston Island State Park site was 22.91 %. Although such a value is typical of many inland restoration projects, it is quite low for coastal sand dune projects in Texas. Still, those plants that did survive were growing well. For those that survived only, the average number of stems per plant was 3.4, the average length of a stem was 24.8 cm, and the average total vegetative length was 84.58 cm.

On 13 September 2008, Hurricane Ike destroyed all of the three restoration sites that had been planted. At the Galveston Island State Park site, the location that had

Fig. 6.2 Hurricane Ike destroyed the Galveston Island State Park restoration site. *Left images* are before Ike, *right* are after Ike. *Top images* show the general area, *bottom images* are zoomed in. Restoration plantings were placed even with the black line in the bottom picture, which sits at the exact same location in both pictures. Imagery courtesy of the Texas Natural Resource Information System (TNRIS)

been restored sat at the waterline shortly after the storm (Fig. 6.2). At the other two sites, the dunes were completely leveled and the plants were washed away. Thus, after approximately 6 months, there was 0 % survival for all three sites.

Hurricane Ike ultimately destroyed all of the restoration sites, leaving no plants. Still, several valuable lessons were learned that can be passed on to future attempts at re-introducing *U. paniculata* (sea oats) to Galveston Island.

First, there is no seed stock available for the genetic Caminada or Western Gulf variety of this plant, nor is there any readily available plant stock, regardless of the fact that the USDA had worked to build such a stock in the past. The Western Gulf variety has sterile seeds with effectively zero viability. All of the *U. paniculata* that is currently available is actually a genetic variety from the Eastern Gulf. Although it would be ideal to obtain the Western Gulf variety for the restoration projects west of the Mississippi River, it is not feasible. The only other possibility is to take cuttings from already established Western Gulf plants growing in the field, but this is both destructive to the few plants that remain on the Upper Texas Coast and has never been proven to work. Thus, this explains why all restoration projects use the Eastern Gulf variety. Since the Eastern Gulf variety has viable seeds, the long-term outcome of this restoration practice is that *U. paniculata* will likely become a more resilient species on the Upper Texas Coast, but genetic diversity may be lost (Franks et al. 2004).

In terms of planting survival, *P. amarum* is likely to be a much better choice than *U. paniculata* for Galveston Island dunes. *U. paniculata*, if planted, needs to be consistently watered for at least the first 3 months. In previous experience, *P. amarum* has been seen to withstand much longer periods of drought than the *U. paniculata* plants withstood in this project, with little to no adverse effects on their long-term growth (Pirates' Beach project, see Feagin 2005). Thus, if *U. paniculata* re-introduction is not a priority, *P. amarum* should be used for restoration in the Galveston area. Another potential strategy is to plant a mixture of the two plants, with the majority being *P. amarum*, as recommended by the NRCS (2008).

Finally, hurricanes are a fact of life on Galveston Island, and when coupled with the low seed viability of the native Western Gulf variety of *U. paniculata* and historical usage of Galveston for cattle grazing and modern development of the landscape immediately behind most foredunes on the island, may explain their absence from Galveston Island. The plants cannot simply re-establish, and for this reason it may be good practice to introduce the Eastern Gulf variety and allow the two varieties to interbreed. Future work could attempt to breed these two varieties in a planned manner, so as to preserve as much genetic diversity as possible while also re-introducing the species to Galveston Island.

6.4 Protection of Infrastructure and Housing: Sandhill Shores Project

Hurricane Ike flattened nearly all of the dunes on Galveston Island, Texas on 13 September 2008 (Williams et al. 2009). When Ike hit the Galveston Island community known as Sandhill Shores, the surge was approximately 4 m, with waves of several m in height (Williams et al. 2009). The dune sands were pushed

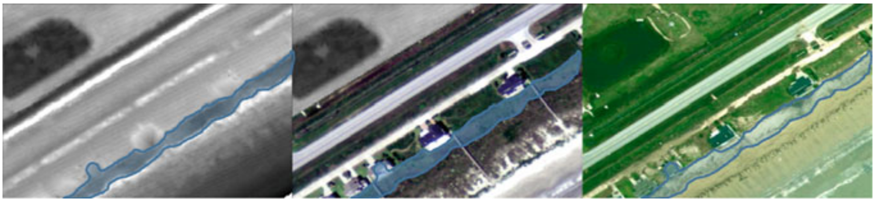

Fig. 6.3 Using a GIS–LIDAR–GPS survey approach to restoration. Hurricane Ike altered the dune and swale topography at the Sandhill Shores site. *Left image* shows pre-storm LIDAR elevation data, clearly indicating the swale and dune locations (*black* is low elevation, *white* is high). *Center image* is pre-storm aerial imagery, *right image* is the post-storm image. In all three geo-referenced images, the outlined *blue* area denotes the same swale location, for comparison. Imagery courtesy of the TNRIS

landward and deposited into swales that were formerly behind them, filling them. A small amount of remaining sand was washed under and around the houses (many houses were on stilts), and further landward onto the streets. Much of the beach sands seaward of the dunes were eroded and deposited in the nearshore.

Residents of the Sandhill Shores residential community clearly stated that the dune and swale structure protected their houses and investments from Ike's wrath. The 3-m dunes at Sandhill Shores were considerably taller than dunes on most of Galveston Island, but the residents were especially vocal that the 3-m deep swale provided the majority of the protection. According to eyewitness reports, the breached dunes were swept into the swales, and the majority of the wave energy continued to break upon and rework these areas. Although the surging waters did sweep further landward and under the houses, there was no erosion in these areas, but rather accretion via overwash deposits. The residents strongly stated that they wanted the dune–swale structure restored after Ike.

A primary objective of the Sandhill Shores project was to restore the dune–swale structure, as closely to its pre-Hurricane Ike state as possible. Residents wanted both the restored dune and swale volumes to match pre-Ike volumes, along the entirety of the community's 1-km-long shoreline. The challenge was finding a historical reference to help rebuild the dune and swale to the exact former dimensions, as the residents desired. A novel technique was developed using LIDAR, GIS, GPS, and surveying to address this challenge (Fig. 6.3).

Within a GIS, virtual cross-shore transects were created that started at the back-beach and stretched landward across the dunes, beyond the swales up to the base of the houses. These transects were distributed every 50 m alongshore direction. Several points were then placed on these transects, with particular care taken to mark the tops of the dune and its base, the depths of the swale and its interior sides.

Once the points along each transect were selected, their horizontal location was noted in latitude and longitude coordinates. Pre- and post-Ike aerial photography was utilized, to confirm locations and assist in the process of adding additional points. In the field, a GPS was used to find these points, and flags were used to mark the pre-Ike horizontal locations of the dune and swale.

Fig. 6.4 Digging out the swale and reconstructing the foredunes, Sandhill Shores project. The reconstructed locations of the dune, swale, and their heights/depths were marked on flags for the bulldozer operator to follow. The dune was reconstructed after the storm with the aid of a GIS, GPS, and survey equipment, but the dimensions and volume were defined to match pre-storm topography, as based upon a LIDAR elevation dataset and aerial photography taken before the storm. Photo by Paul White

To virtually reconstruct the vertical elevations, the pre-Ike absolute elevation of each point was found, using a 2008 pre-Ike LIDAR dataset that was acquired from the Texas Natural Resource Information System (TNRIS). The resolution of this dataset was 1 m horizontally, 0.01 m vertically. This dataset allowed the topography and structure of the dune–swale structure to be viewed, prior to Ike's rearrangement of the sands.

However, after Ike hit, the absolute elevation had completely changed in the area (the entire beach profile was approximately 0.75 m lower). A changing profile would modify the base structure upon which the dune and swale vertical locations were fixed. Thus, when using the LIDAR dataset, the absolute elevation of each of the points was adjusted relative to a nearby fixed point at the base of each house (its concrete driveway, or similar feature that presumably did not change in elevation pre- to post-storm). In the field, survey equipment was then utilized to assess the vertical difference between the same nearby fixed point and the surveyed points, so that the vertical distance could be defined that the surface would have to change to approximate the pre-Ike absolute elevation. The flags were then marked to denote this information. To double-check the calculations of depth and height, several holes were also dug at the location of the swale until the original surface had been hit. The vertical and horizontal match was quite strong, with calculated depths less than 0.05 m off from actual field depths.

Once vertical and horizontal locations were marked in the field, backhoes and tractors were used to reconstruct the pre-Ike topography. *Sporobolus virginicus* was then planted at the base of the dunes, with *P. amarum* covering the rest of the dunes. *Spartina patens* was planted in the swales. Over the next year, the beach profile also partially recovered as much sand returned from the nearshore. Accretion visibly occurred at the base of the reconstructed dunes, although it was not quantified.

The residents of the Sandhill Shores community were quite happy with the reconstructed dune–swale ecosystem (Fig. 6.4). They spent less than $100,000 (in 2009) on the restoration along the 1-km stretch of beach, and felt that the original dune and swale structure had protected their homes from a much greater expense during Hurricane Ike. Moreover, residents expressed that the reconstructed dunes enhanced the aesthetic value of their property and buffered them from public intrusions onto their property.

6.5 Conclusion

As these three projects show, several incentives exist to restore coastal sand dunes, even if hurricanes or other storm events destroy them every few years. They are continually rebuilt because:

1. They effectively demarcate the public beach from private property, which is a significant legal feature in many parts of the world.
2. They are aesthetically pleasing, providing a sense of nature and wildness.
3. They protect housing and infrastructure from the impacts of future storms.

It is gratifying when governments or individuals contribute money toward conserving or restoring natural dune ecosystems. Often, foredune restoration projects are initiated because people realize the value of a functioning dune ecosystem. However, in the context of repeated destruction of these projects, and in a world of fiscal constraints and competing interests, there must be other incentives that drive their construction. The financial benefit must outweigh the cost of such projects.

This is a powerful story that is not to be viewed cynically—dune restoration projects can find support even when there is no ecological reason to do so, and where there is no support from an environmental lobby or concerned citizens. Small pockets of the natural world can exist located within a largely urban matrix, simply because it is in people's financial interest to maintain them. In Galveston, Texas, this interest is strong enough to ensure that these small, semi-natural dune areas are diligently restored after every storm.

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