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March 28th, 2022

Shoreline Director
City of South Padre Island
4601 Padre Boulevard
South Padre Island, TX 78597

Subject: **Draft Dune Maintenance and Management Plan**

Dear Ms. Boburka,

The following document is a draft of the Dune Maintenance and Management Plan that was completed by a subcontractor to Integral Consulting, BIO-WEST. The final version of the report will be included as an Appendix to the final Beach and Dune Assessment Report currently being prepared by Integral. Please review as is convenient and we welcome any comment or feedback.

Warm Regards,

Cheryl Hapke, Ph.D.
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Assessment and Investigation of the Beach and Dune Conditions at SPI

Dune Maintenance and Management Plan at SPI

Prepared for

City of SPI
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March 23, 2022

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ACRONYMS AND ABBREVIATIONS

ADA	Americans with Disabilities Act
ADAPT	Adaptation Decision and Planning Tool
BLS	Building Setback Line
CCC	Texas Coastal Coordination Council
CEPRA	Coastal Erosion Planning and Response Act
CFR	Code of Federal Regulations
CMP	Texas Coastal Management Program
CWA	Clean Water Act
FEMA	Federal Emergency Management Agency
GLO	Texas General Land Office
Integral	Integral Consulting Inc.
LF	linear feet
LOV	line of vegetation
CMP	Texas Coastal Management Program
MHT	mean high tide
MLW	mean low water
MOCZM	Massachusetts Office of Coastal Zone Management
NOAA	National Oceanic and Atmospheric Administration
NRC	Texas Natural Resources Code
NRCS	U.S. Department of Agriculture - Natural Resources Conservation Service
PVC	polyvinyl chloride
PWC	Parks and Wildlife Code
RGL	Regulatory Guidance Letter
RHA	Rivers and Harbors Act
SLR	sea level rise
SPI	SPI
the City	the City of SPI
the Plan	Dune Maintenance and Management Plan
U.S.C.	United States Code
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

1. EXECUTIVE SUMMARY

South Padre Island (SPI) is a narrow, low-lying, naturally occurring barrier island along the south Texas coastline that is frequently impacted by erosive winter storm events and infrequent but extremely damaging major hurricanes. As a resilient natural barrier to the destructive forces of wind and waves, the coastal sand dune and swales ecosystems of SPI are a valuable and effective defense against storm-surge flooding and beach erosion. Dunes absorb the impact of storm surge and high waves, preventing or delaying intrusion of waters into inland areas well as retaining sand that replaces eroded beaches after storms in a dynamic cycle. This positive feedback loop can be strengthened by increasing the height and stability of existing dunes, repairing washouts and erosional areas, and reestablishing native vegetation. Beach and dune restoration and protection is important along the Texas Gulf Coast, particularly in areas experiencing shoreline erosion and concentrated urban development.

Integral Consulting Inc. (Integral) was awarded a contract with the City of SPI (the City) in 2020 to assess and investigate the beach and dune conditions along the SPI shoreline. The project is being undertaken in four phases following an Integral-developed and managed framework called Coastal ADAPT (Adaptation Decision and Planning Tool) that uses a variety of modeling approaches to examine adaptation options for increasing resiliency to coastal hazards and sea level rise (SLR)-related climate change risks. Under this contract, Integral contracted with BIO-WEST, Inc. (BIO-WEST) to draft a Dune Maintenance and Management Plan (the Plan) that analyzes the current beach-dune ecosystem, morphology, and trends with respect to storm events and human activities; compares these datasets with potential modeling outcomes of future response to SLR, winter storm events and major hurricanes; and produces a framework for use by the City and local stakeholders.

The primary purpose of this Plan is to develop a set of guidelines and rules that will assist the SPI community in developing and maintaining a stable, ecologically functional dune system appropriate for the south Texas coast that reduces maintenance costs, alleviates public safety concerns, and benefits the aesthetic and culture of SPI. Additionally, this Plan is designed to provide background information on the unique coastal ecosystems of the south Texas coast, their functions and services, and how they can mitigate the impacts of coastal storms, as well as to enable users to make informed decisions on coastal resilience by incorporating beach and dune dynamics with suitable plantings, proper structures, and define processes.

This Plan is comprised of four sections. The first section provides a brief regulatory, permitting, and coordination framework to follow, while the second section discusses the basic information associated with dune establishment, repair, and restoration, highlighting erosion repairs activities planting, fencing, and other important considerations related to dune construction. The third section focuses on management techniques and access issues to protect newly restored areas and the fourth section concludes with a brief summary and potential recommendations.

2. REGULATORY REVIEW AND FRAMEWORK

2.1. FEDERAL GUIDELINES

Wetlands and waterbodies are the primary regulatory nexus related to coastal dune ecology. Several major federal laws govern filling and dredging of these areas, including Section 404 of the Clean Water Act (CWA; 33 United States Code [U.S.C.] 1344) and Section 10 of the Rivers and Harbors Act (RHA; 33 U.S.C 403). Between 1987 and the present, multiple federal agencies including the U.S. Army Corps of Engineers (USACE), the U.S. Fish and Wildlife Service (USFWS), the U.S. Environmental Protection Agency (USEPA), and the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) drafted guidance related to discharge of fill material into wetland and waters, including the 1987 USACE Wetlands Delineation Manual, Regional Supplements to the USACE Wetlands Delineation Manual, and Regulatory Guidance Letters (RGLs). Figure 1 below provides an illustrative view of USACE and USEPA jurisdiction.

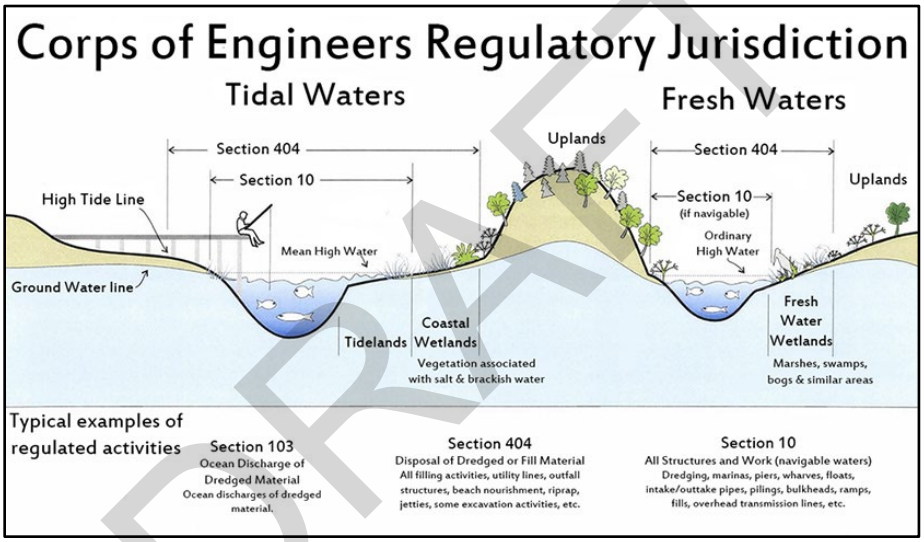

Figure 1: Graphical Depiction of USACE/USEPA Jurisdiction (USACE, 2022)

In almost all cases, the USEPA and USACE are the primary governing agencies that issue federal permits for activities in coastal dune systems. Questions regarding jurisdictional wetlands and waterbodies in Texas and procedures for obtaining proper permits should be directed to the City and/or to the USACE - Galveston District.

In addition to wetlands and waterbodies, the Federal Emergency Management Agency (FEMA) classifies all foredunes and many surrounding areas as coastal high-hazard areas or high-velocity zones (V-zones). A V-zone is defined by FEMA as:

> *Areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.* (44 Code of Federal Regulation [CFR] §64.3)

Figure 2 and Figure 3 below provide a basic understanding of the various hazards and issues associated with coastal development.

Figure 2: FEMA Depiction of Coastal High Hazard Areas

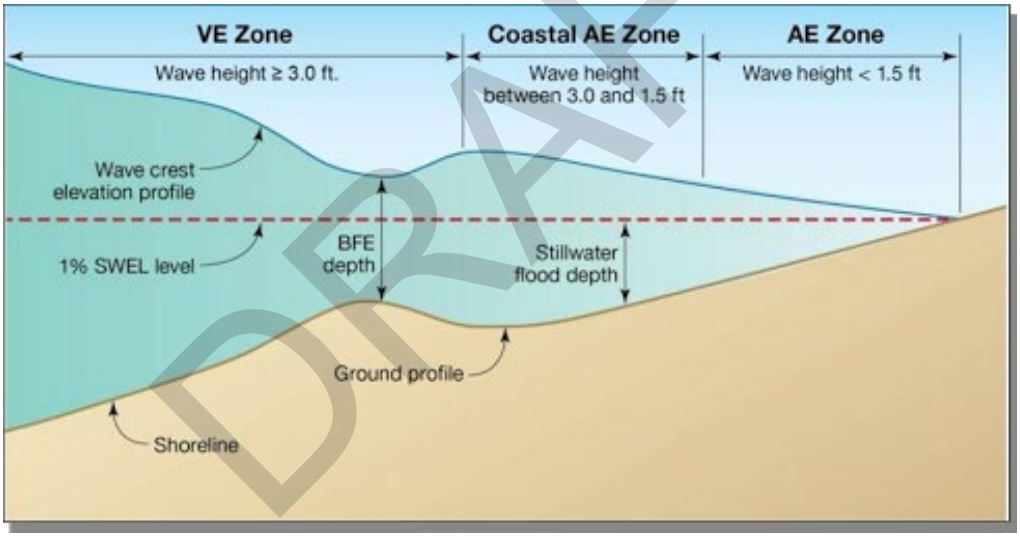

Figure 3: FEMA Depiction of Coastal Hazard Zones

FEMA has issued construction standards within V-zones (44 CFR §60.3) and also prohibits "any human-caused alterations of sand dunes which could increase potential flood damage." For more information concerning V-zones, and to obtain flood maps, contact a FEMA representative or the Cameron County Office of Emergency Management.

2.2. STATE AND LOCAL GUIDELINES

The Open Beaches Act (Texas Natural Resources Code [NRC] Chapter 61), passed by the Texas Legislature in 1959 and amended in 1991, states that the public "*shall have the free and unrestricted right of ingress and egress to and from the state-owned beaches bordering on the seaward shore of the Gulf of Mexico...extending from the line of mean low tide to the line of*

vegetation bordering on the Gulf of Mexico." The act makes it unlawful to declare a beach closed to the public or otherwise prevent or obstruct access to or use of the public beach, by either erecting barriers, posting signs, etc. As the state governing agency, the Texas General Land Office (GLO) is required to protect the public beach from adverse effects on public access and critical dune areas by regulating beachfront construction and other activities occurring along the shoreline of the Gulf of Mexico. The GLO has an experienced and knowledge staff that can help determine if any violations to the Open Beaches Act have occurred as well as assist with dune re-vegetation, restoration, establishment, and walkover projects.

The Dune Protection Act (NRC Sections 63.001 through 63.181), passed by the Texas Legislature in 1973 and amended in 1991, required the Cameron County Commissioners Court to establish a dune protection line on the Gulf shoreline. This requirement also applied to mainland shoreline that fronts the open Gulf as well as to the Gulf shoreline of islands and peninsulas. Cameron County accomplished this task in 1994 through the Cameron County Dune Protection and Beach Access Plan (last amendment December 11, 2018; Cameron County, 2018). As of the 2018 amended version, Cameron County has established a Building Setback Line (BLS) of 230 linear feet (LF) landward from the line of vegetation (LOV). In addition, as part of this countywide Plan, Cameron County delegated the authority to the City of SPI to develop and implement its own dune protection program within the City's corporate municipal limits only.

The Texas Coastal Management Program (CMP), funded mainly by the National Oceanic and Atmospheric Administration (NOAA) and managed by the Texas Land Commissioner, focuses on the state's coastal natural resource areas and ensures the continued focus on the state's environmental and economic functions and values. The primary directive of the CMP is to review federal actions, activities, projects, and/or applications for federal assistance to ensure their consistency with the current directives, goals, and policies of the CMP. CMP guidelines allow the Texas Coastal Coordination Council (CCC) to review coastal projects for consistency. The CCC may review local statutes related to dune restoration and walkovers, beachfront construction certificates, dune protection permits, and dune protection and beach access plans as well as applications for federal assistance for programs outside of the CMP.

In 1999, the Texas Legislature passed the Coastal Erosion Planning and Response Act (CEPRA) to provide funding to coastal communities for projects that mitigate, slow, or other offset the effects of coastal and shoreline erosion. According to NRC §33.603(e), beach nourishment projects require at least 25 percent match funding while other coastal erosion response studies or projects require at least 40 percent match funding, and under this structure, CEPRA is entering its 12th, two-year cycle. Dune restoration and beach nourishment projects may be funded through this program, and communities may submit proposals to the GLO for such projects.

Under NRC §61.211 through §61.227, the State of Texas regulates the removal of sand, marl, gravel, or shell from islands, peninsulas, and land perennial waterbodies and within 1,500 feet of mainland public beaches outside corporate limits. For SPI, the Cameron County Commissioner's Court issues permits for the excavation of any of these materials unless the material is to be moved by an individual landowner, or with an individual landowner's consent, from one location to another on the same parcel. Additionally, no permit would be required if the removal is undertaken by a federal, state, or local governmental entity. An incorporated city, town, or village may not

authorize the removal of sand, marl, gravel, or shell from a public beach within its boundaries for any purpose other than the construction of a public sponsored recreational facility or a shoreline protection structure.

Related to NRC §61.211 through §61.227, TPWD also regulates the disturbance and removal of marl, sand, gravel, shell, or mudshell located within perennial and marine open water areas for any purpose other than that necessary or incidental to navigation or dredging under state or federal authority (Parks and Wildlife Code [PWC] §86).

To provide clarity and efficiency in permitting process, the City currently operates a robust permitting program in place through the Office of Shoreline Management accessible here:

https://www.myspi.org/department/division.php?structureid=174

As part of the current permitting program, potential applicants are encouraged to complete the following steps to expedite permitting approvals through the City:

- Develop project purpose and need, and a detailed construction plan that is easy to interpret and understand
- Document site conditions through ground and aerial photography, as available, to provide the City with accurate, real-time information
- Contact the City of South Padre Island Shoreline Department as early as possible to allow adequate time for review and approval, while still meeting the applicant's schedule.
- Respond promptly within two to four business days to all requests for additional information or clarification from the City

3. DUNE MAINTENANCE ACTIVITIES

The primary purpose of this section is to provide guidance to the City for coastal dune restoration and maintenance portions of various projects. This section provides techniques for site preparation, planting efforts, dune repairs, fencing installation, and protective measures post-construction. Several methods may be used to increase the height and stability of existing dunes, repair damaged dunes, encourage sand accretion, or establish/repair dunes where a low sand supply exists or where dunes have been destroyed from adjacent development. The City should gauge and evaluate each proposed project in conjunction with other projects and in consideration of the City's over strategic goals.

In all cases, each project site or restoration area should be evaluated both individually and in combination with other foreseeable projects of similar size, scope, and scale for their potential for natural sand accumulation prior to restoration efforts. At their discretion, the City may also proactively reach out to landowners adjacent to a given restoration site to gauge interest in joint projects with larger potential footprints.

Given the history of storm-driven erosion on SPI (Integral, 2021a and 2021b), native vegetative re-establishment should be the primary and preferred method for dune construction, improvement, and repair. The approval evaluations should focus and prioritize restoration areas that exhibit fresh, natural sand sources forming around existing obstructions and structures and that are most capable of sustaining native vegetation communities. Since natural dune formation is the end goal, establishment of native vegetation would generally be the most economical and least intrusive option to accelerate dune formation, with the support of structural barriers and appropriate protective measures.

In areas where the local sand supply is insufficient for these two sand-trapping methods to be effective, dunes can be artificially constructed with imported sand from a local source or from GLO-established offshore sand sources.

3.1. SITE PREPARATION AND SELECTION

Each restoration area must be evaluated to determine the existing conditions of the site, available natural resources (i.e., sand) and obstructions, and construction access among other issues. Many factors will play a part in this determination, but the most important question is whether native plants would survive on their own once the planting is complete. The distance from the proposed planting site to the tide line must be considered; the GLO recommends a minimum distance of 200 feet from the mean low tide line and at least 50 feet from the storm tide line, which is generally defined by an offshore wrack line or layer of debris along the beach (GLO 2009). Both of these recommendations will help prevent individual plants from being washed away from high waves. Additionally, based on Integral's recommendations (2021a and 2021b), the minimum width of the restoration area should be 200 feet.

Figure 4 provides a typical dune cross-section that would conform to the recommended dune dimensions from Integral (2021b) and the GLO (2009).

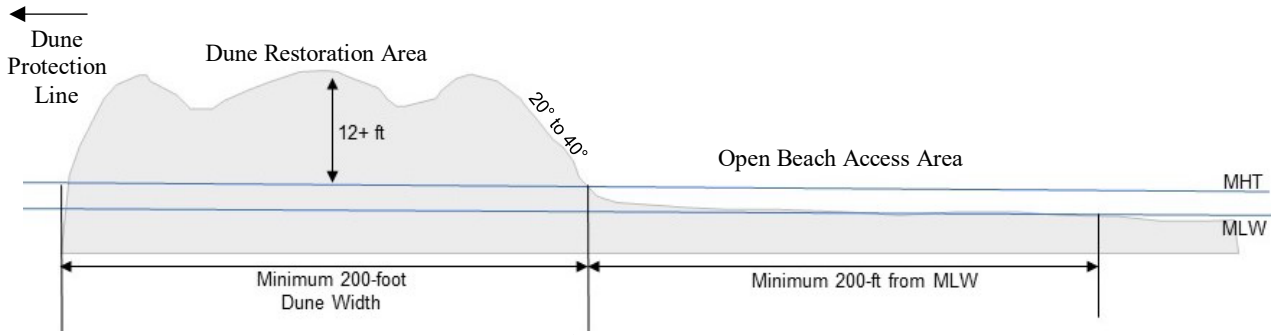

Figure 4: Typical Dune Restoration Cross-Section

It is important to consider future or existing residential structures or homes, frequently used walkways or plans for future walkovers, improvements to beach facilities, and future plans for construction or earthwork. Any major construction requiring machinery within a close approximation of the beach or dune system can be detrimental to newly planted sand dunes. Accessibility is also an important factor when bringing water and supplies to the restoration area; each planting location must be evaluated to determine the existing conditions of the site. Although the majority of restoration sites may contain suitable soils for planting, shallow subsurface geotechnical samples may be necessary to make sure a clay lenses or other inappropriate layer is not present that will inhibit vegetation growth. Samples should be focused on the top 24 inches of sediment and provided to the City if requested.

3.2. DUNE AND EROSION REPAIR

Some Texas beaches, particularly along the upper (northern) coast, are sand-starved. Natural sand accumulation occurs very slowly, and it may take as long as 20 years for a six-foot-high dune to form. Fortunately for SPI, sand is relatively available, and erosion and accretion patterns are variable as evidenced by Integral's Xbeach modeling efforts (Integral 2021b). According to the modeling results, erosion hotspots exist in the very northern portion of the shoreline, while accretion or low erosion rates are anticipated along much of the central portion of the shoreline (less than 0.9 feet/year), and moderate erosion (between -0.4 to -1.4 feet/year) is present a little further south between Corral Street (near Beach Access #3) and the Pearl Beach Access. South of this moderate erosional zone, the shoreline becomes accretional to the inlet jetty along the Brownsville Ship Channel.

Although there are erosion hotspots of in the northern portions of the SPI shoreline, the City has been successfully controlling erosion over a number of years, with a via a regular beach nourishment program, beginning in 2005. In fact, much of the current dune field has substantially increased in width between 2002 and 2020 due to an earnest rebuilding and replanting program by the City (Integral 2021a). Additionally, according to recent studies (Integral 2021a and 2021b), the primary cause of erosion and foredune scarping is wave and storm surge events. Although portions of the system tend to move back to a dynamic equilibrium state after these acute events, these studies also show that having an intact continuous dune system is important to the resiliency of the overall system. In locations where dunes have been removed completely or simply scalped (artificially lowered or cut down without complete removal) for recreation or other purposes, the system is inherently more vulnerable as large storm waves can reach the base of the buildings or infrastructure. These impacts are not limited to the area where the dunes have been removed; up-rushing waves reaching a seawall or building may deflect off hardened structures (i.e., bulkheads) and push water laterally, causing erosion of adjacent dunes.

To combat these issues, it is recommended that limited dune repairs and importation of sand from either offshore sources or reputable sand suppliers in Cameron County be used to repair and restore potential dune communities. As an important note, sand should not be taken directly from the beach, as doing so robs potential future donor areas of the material necessary for maintenance of the beach and dunes, and may increase erosion. As reported by Integral (2021b), dunes that have been removed completely by property owners should be replaced to create a continuous dune at SPI. Removal of sand and other materials from barrier islands and peninsulas is also regulated by state laws (See Section 2.2 above).

Man-made dunes should be of the same general height, slope, width, and shape as natural dunes in the vicinity. According to baseline reports (Integral, 2021a; Figure 4), natural dune heights historically have ranged from 10 to 12 feet above mean high tide (MHT), although multiple areas along the existing shoreline have been scalped to allow for first and second story residential views of the Gulf of Mexico.

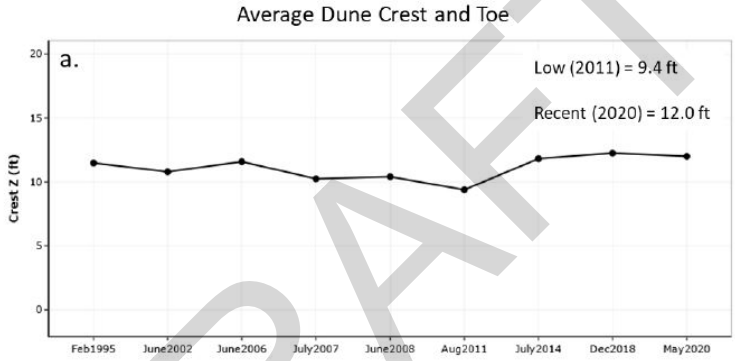

Figure 5: Historical Dune Crest Height (Integral 2021a)

Dune slopes tend to range from 15° to 55° along the SPI shoreline, depending on location, past development activities, and site protection measures. The GLO recommends a slope of between 20° and 40°, with gentler slopes the preferred option (GLO 2009). Based on the observed natural dune heights compared to the GLO's recommendations, the initial dune base widths for repair and restoration work should be at least 50 feet. A narrower dune base would not have the capacity to support the taller dunes normally associated with this shoreline and would not be sufficient to provide storm protection.

Dune restoration and erosion area repairs should be constructed slightly landward of the location where foredunes would naturally occur to allow for natural seaward expansion. Dunes built too close to the Gulf can be destroyed by wave action during even minor storms and may interfere with public access along the beach. Additional sand placement options are illustrated below in Figure 5, but should be coordinated with the City prior to placement activities.

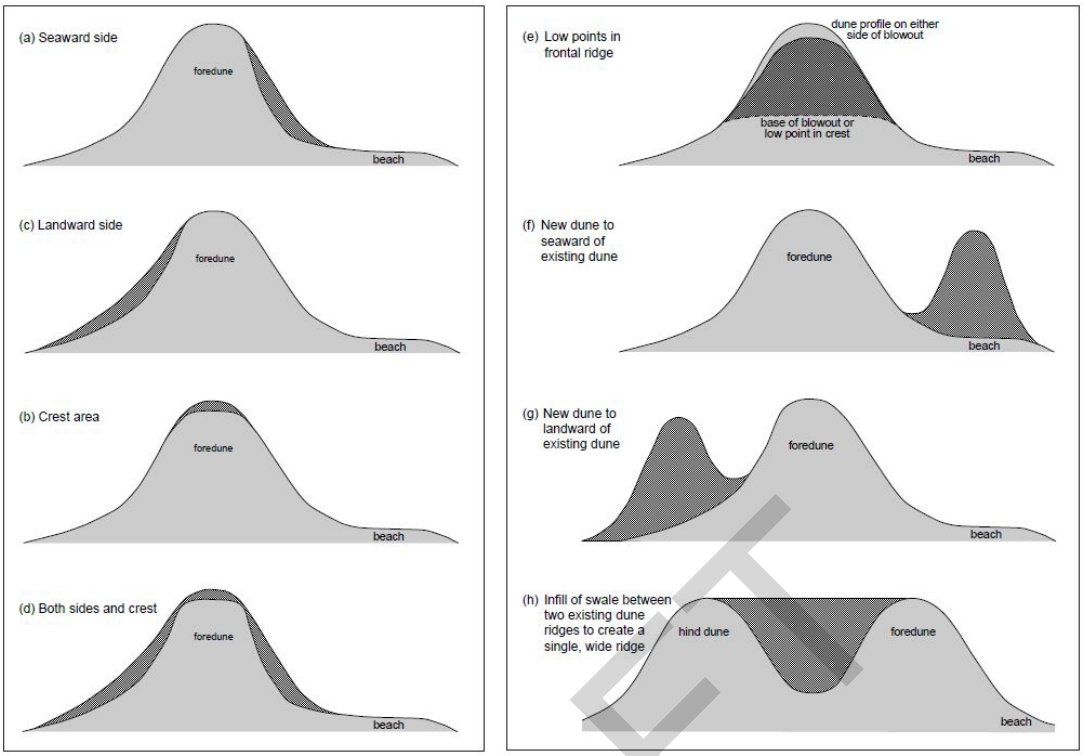

Figure 6: Sand Placement Alternatives (Pye et al 2007)

Note that the dune is a phalanx line, therefore a weak spot, e.g., an unvegetated area, can ultimately be the entry point for overwash, exacerbating erosion or system change without the need for the crest to be breached. An important consideration is that dunes take in the order of 7+ years to gain a real foothold (B. Charbonneau – Pers. Comm.), and they cannot exist without a beach to seawards.

3.3. PLANTINGS AND VEGETATION

Coastal dunes exhibit a wide diversity of native vegetation, each with specific habitat requirements and specific functions that keeps the overall dune system stable and healthy. Native species have adapted to different dune structures, local weather patterns, sand conditions, light attenuation, and provide wildlife with food and shelter. Some native species have specially adapted root systems that can stabilize sandy soils, or are deep-rooted in the swale communities between dune ridges to take advantage of moisture content due to daily shading and lower elevations. Other species tend to grow in the partially shaded areas under clump grasses while some are pioneer species to newly established and barren dunes. Dune plants along the Texas coast can grow either forbs, vines, woody species, or upright bunchgrass, and each growth type presents a unique function to the stabilization of the sand dune. Figure 5 provides a simple diagram of a typical beach profile, illustrating the various components of a dune system that are colonized by native vegetation.

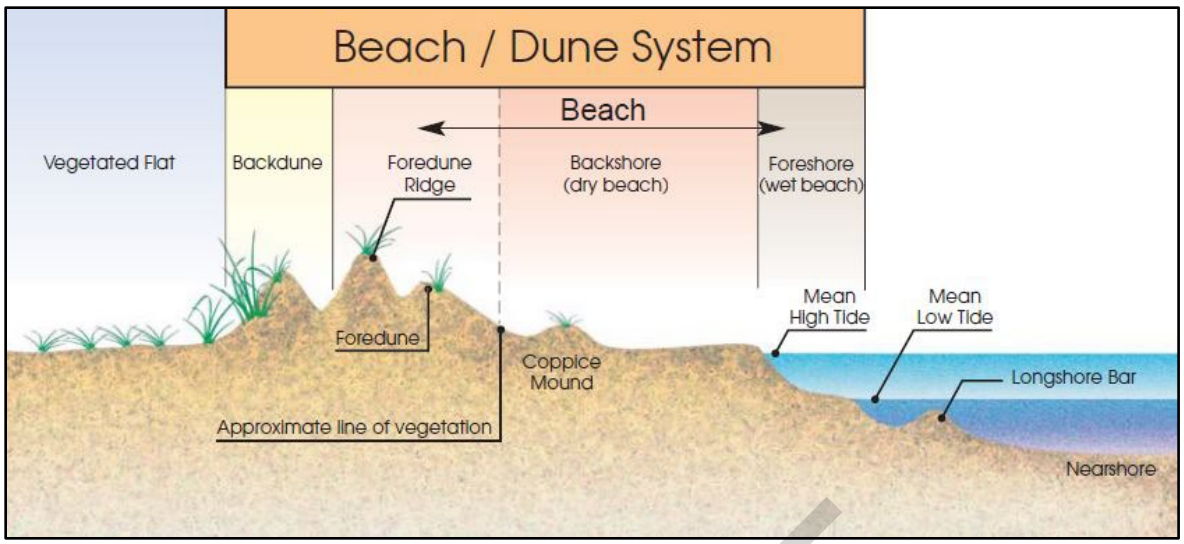

Figure 7: Typical Barrier Island Beach Profile (GLO 2009)

Based on a review of multiple sources (GLO 2009, GPB 2014, Craig 1984, Mendelssohn et al 1991, and Morton et al 2004), three species of grass are historically appropriate for dune restoration projects on the Texas coast: bitter panicum (*Panicum amarum*), sea oats (*Uniola paniculata*), and marshhay cordgrass (*Spartina patens*). Vegetation assessments of the SPI shoreline dune communities were performed in September 2021 and confirmed that these three species were most prevalent in dune communities that also exhibited the most diversity in dune structure (i.e., multiple crests, swales, and slopes) and vegetation.

Sea Oats

An icon of the Texas coastal shoreline, sea oats are one of the few natives that is perennial and has an extensive, deep root system. It propagates through rhizomes and seed dispersal, and grows rapidly enough to avoid being smothered in rapidly shifting sand. Although less tolerant of salt spray than bitter panicum and marshhay cordgrass, this particular species is very important to the production of foredunes due to its roots. Sea Oats thrive in loose sandy soil and tend to be very productive on the top of sand mounds or the higher parts of the sand dune ridges. They also have very large flowering plumes that are attractive to both people and wildlife. Interplanting sea oats and bitter panicum tends to reduce the risk of disease or pest infestation.

Bitter Panicgrass


Lonard and Judd, 2011

According to the GLO, bitter panicum is one of the most suitable species for dune stabilization and restoration along the Texas coast (GLO 2009). This native beach plant is an extremely hardy grass, is already prevalent along the entire Texas coast, and has a higher salt tolerance than many other coastal species. Its leaves are smooth, bluish-green, ¼ to ½ inch wide, and four to 110 inches long. New plants are generated from tillers - shoots that grow from nodes on the roots. Bitter panicgrass has been used in multiple coastal areas to prevent erosion along

sand dunes and sandy hillsides. It prefers sandy loam, well-drained soil and is extremely drought tolerant. The species is a perennial warm-season grass that grows from short, strong rhizomes. Over time, these rhizomes form open clumps, which can fuse to form a dense mat of vegetation. The blooms, which arrive in late summer and fall, produce abundant seeds that attract a variety of resident and migratory birds. Although bitter panicum produces small, viable seeds, its main method of propagation is from rhizomes and is therefore best propagated from stem cuttings.

Marshhay Cordgrass

Marshhay cordgrass, a small, wiry-bladed perennial clump grass, is commonly found in high marshes, but can also be found on the foredune ridges and back dunes. It does well on the landward side of dunes, but if planted on the seaward side, is easily buried and destroyed by shifting sands. Unlike most vegetation, marshhay cordgrass grows well in saturated soils and inundated areas, is halo-tolerant and grows well in the trough and swale areas between the foredunes and succeeding dunes. It spreads using rhizomes, which allow the shoots, or blades of grass, to grow horizontally. These rhizomes form dense mats beneath the surface, which aid in preventing erosion. Mixing marshhay cordgrass with bitter panicum produces excellent results.

Other Recommended Dune Restoration Herbaceous Species Include:

- *Schizachyrium littorale* (shore little bluestem)
- *Paspalum monostachyum* (Vasey gulfdune paspalum)
- *Sorghastrum nutans* (Indiangrass)
- *Muhlenbergia capillaris* (Gulf hairawn muhly)
- *Eragrostis secundiflora* (Red lovegrass)
- *Andropogon glomeratus* (Bushy bluestem)
- *Borrichia frutescens* (Bushy seaoxeye)
- *Distichlis spicata* (Saltgrass)
- *Ipomoea pes-caprae* (Goat-foot morning-glory)
- *Ipomoea imperati* (Beach morning-glory)
- *Oenothera drummondii* (Beach evening primrose)
- *Passiflora foetida* (Fetid passionflower)
- *Eriogonum multiflorum* (Heartsepal wildbuckwheat)
- *Vigna luteola* (Hairypod cowpea)

As with most re-planting efforts, not every recommended species will be available when required for restoration. Therefore, coordination with the City's Shoreline Management Department will be necessary to approve any planting plan. Additionally, based on the existing species recorded along the SPI shoreline as of September 2021, no woody species are recommended at this time. Invasive, noxious, and exotic species management and prevention is included in Section 4.3 below.

When comparing options for restoration, the choice is generally between transplants and nursery-grown plugs. As with all restoration projects, transplants from the project are more likely to survive as they are already acclimated to the climate and region. If suitable stands cannot be

found within the same location as the restoration project, they may be able to be sourced from adjacent dunes. Permits from Cameron County and/or the Office of Shoreline Management will be required if the harvesting or planting site is seaward of a dune restoration project.

For the SPI shoreline, the best time of year to either plant or transplant vegetation is January to February. Plants should not be taken from foredunes or other degraded areas that are sparsely vegetated or exhibited signs of erosion. Transplants should only come from existing, healthy, dense stands of native vegetation with no invasive, noxious, and exotic species present within 50 feet due to the potential for seed presence in the root balls. Care should be taken to avoid trampling plants that are not being harvested, and transplants should be removed in a dispersed grid-like pattern at intervals of at least three feet (GLO 2009, Wooten 2016). Plants should not be pulled or tugged out of the ground since each plug requires an intact root system for successful transplant. Individual plants should be excavated with a hand tool like a dibble bar, sharpshooter or similar device to maintain a good root structure to increase survival chances. Small areas and steep slopes at the project site are best vegetated by hand.

When transplanting at the restoration site, place single plants into individual holes made with a shovel or dibble bar, and pack each planting firmly into its hole. Larger, flat areas with less than 5% slope can be planted with conventional transplanters with their shoes extended to make holes six to nine inches deep. According to the GLO, 1,000 plants should stabilize an approximately 50- by 100-foot (5,000 square feet) strip within a year on 2.25-foot centers (GLO 2009).

Due to the drier nature of dune communities, post-transplant irrigation is generally not required, and regular watering is necessary only in drought conditions as defined by NOAA (2022). Mulch is a good option after planting to regulate soil temperature, minimize wind erosion, and retain moisture. Hay, natural fiber mesh like jute, and burlap may be used as it is on similar projects along the Texas coast. All of these materials are biodegradable and will eventually break down. In areas where high winds are common, burlap or screen anchored with stakes is recommended instead of hay.

Generally, nursery-grown and transplanted vegetation needs little maintenance. While watering new plants is helpful, fertilization may be used during the first year after transplanting but is usually unnecessary thereafter. An approved soils testing laboratory can provide fertilizer recommendations for a particular location, after approval from the City. Mowing is not recommended since it destroys dune grasses' ability to trap sand by removing leaf and blade materials, and may even kill individual plants if the mower deck height is set too low.

Monitoring should be conducted within 60 days of the restoration effort and again between April and June each year for a period of five years, for a total of six monitoring events. Typical monitoring events should include both qualitative and quantitative vegetation assessments using appropriately sized linear quadrat sampling, photo-documentation, and data analysis, at the discretion of the City. A simple letter report should be submitted to the Shoreline Management Department within 30 days of a monitoring event.

A planting restoration project is considered successful if the percent coverage reaches 75% after the first two monitoring years (three monitoring events), at which point the Office of Shoreline Management may elect to modify or discontinue monitoring at their discretion. This percentage

reflects a healthy community, based on past vegetation assessments of the SPI shoreline.

If the survival rate is between 45% and 75% after five monitoring events, the monitoring should continue until the percent cover reaches 75% as referenced above.

If the survival rate is less than 45%, the area should be replanted during the next suitable planting window. Planting requirements should follow the methodology presented above.

3.4. SAND FENCING

Sand fencing installed in a beach or dune gap can assist in building a new foredune or fill gaps in dune ridges, and successful sand fences become buried as sand is trapped. Fencing reduces wind speeds, allowing sand to fall out of the wind column and accumulate. Different fence configurations also can create different dune forms and heights. For example, fencing running parallel to the shoreline can assist with repairing foredunes and sealing breaches and blowouts (Grafals-Soto and Nordstrom 2009; Etienne, K., et al. 2016; see Figure 6 and Figure 7) and are the easiest to install over large areas with medium to heavy foot traffic.

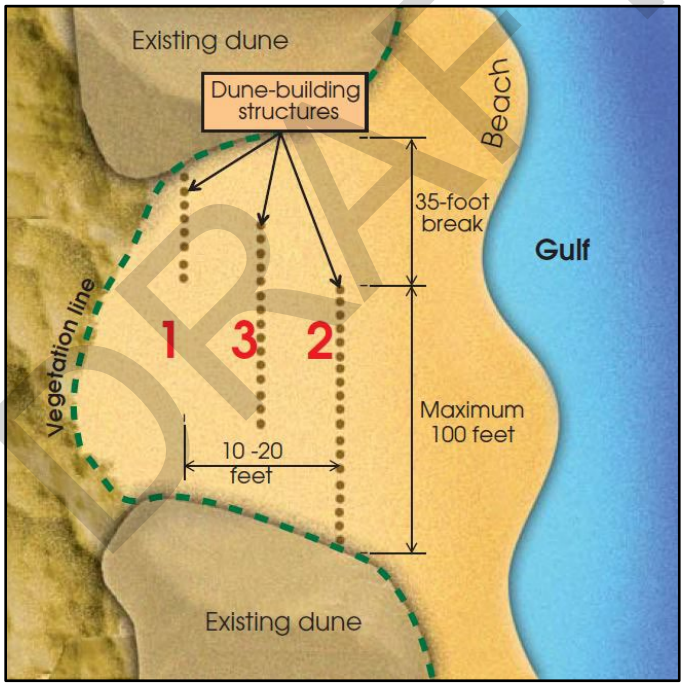

Figure 8: Parallel Sand Fencing for Blowout Repair (GLO 2009)

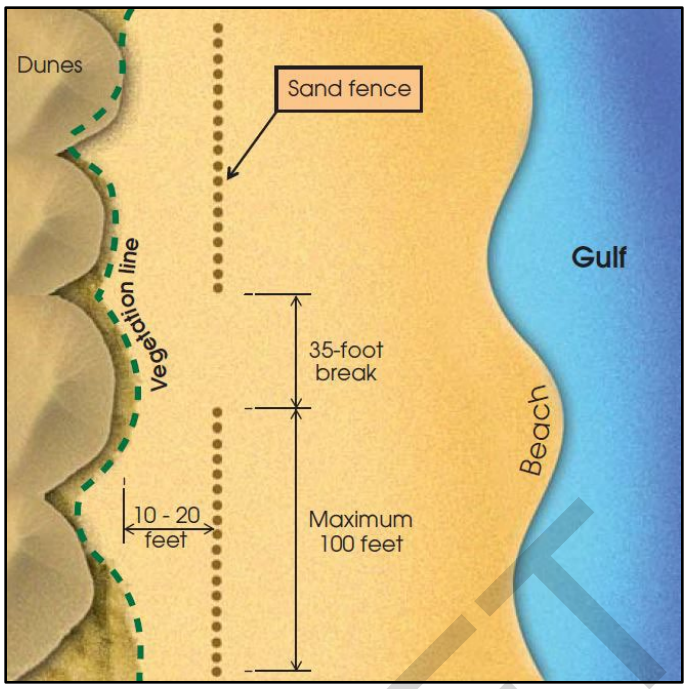

Figure 9: Parallel Sand Fencing for Foredune Repair (GLO 2009)

Angled patterns can create a wider, more meandering dune system that can be considered more natural looking and provide more area for vegetation growth (Grafals-Soto and Nordstrom 2009; Eichmanns et al, 2021; see Figure 8 and Figure 9). These patterns generally require more fence material than the shore-parallel style and can limit pedestrian access. Additionally, the fence installation angle to prevailing winds should be a minimum of 35° to maximize sand capture, while not adversely affect seat turtle nesting and other threatened and endangered species (GLO, 2009; Grafals-Soto 2011). Angled patterns can also be constructed in either single row or double row configurations, depending on existing, local site conditions and the restoration goal.

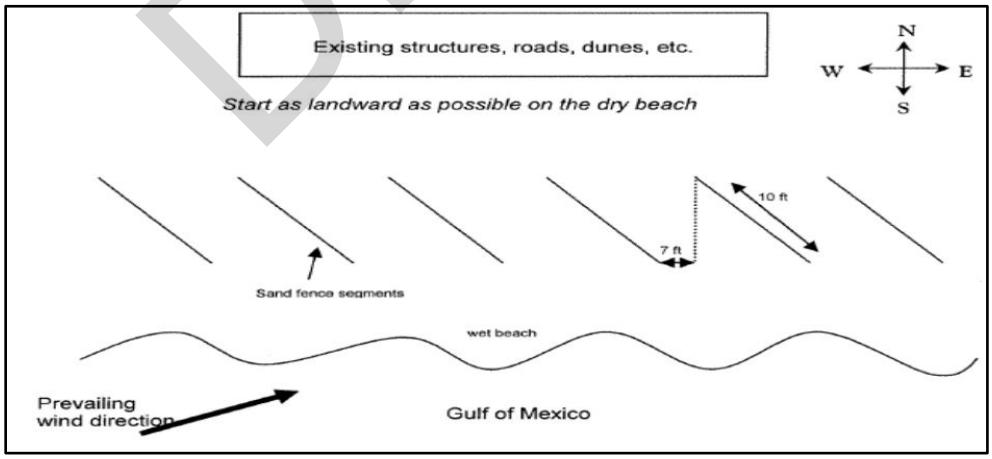

Figure 10: Single Row Angled Sand Fence Installation (FDEP, 2020)

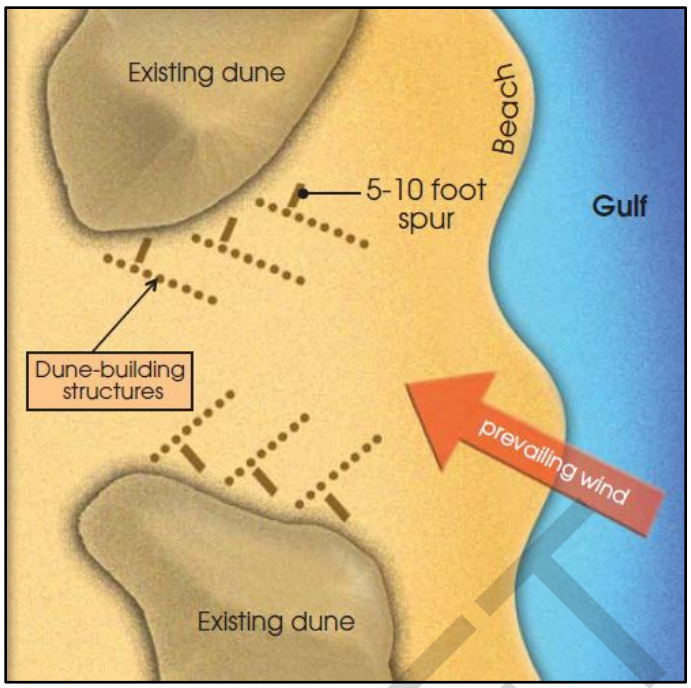

Figure 11: Double Row Angled Sand Fencing Installation (GLO, 2009)

Based on Integral Phase I and Phase II reports (2021a and 2021b), storms are the primary driver of dune erosion within SPI. Specifically, most of the beach width change within the SPI shoreline is due to changes in the shoreline position as opposed to changes in the dune toe position, and the wave impacts are concentrated along the lower beach face, causing erosion or accretion at or near the shoreline, and the dune toe is not eroding in most cases (Integral, 2021a and Integral, 2021b). Wind-borne sand supply is anticipated to be lower after a large storm, and there is no expectation that sand will quickly collect in large volumes within the project area. Therefore, the proposed primary purpose of sand fencing along the SPI shoreline would be to restrict access to recently restored dune areas, promote growth of naturally occurring dunes, and planted vegetation by creation of a lower-energy microclimate.

As referenced in several beach restoration guides and reference manuals (GLO 2009, GPB 2014, and Wooten et al 2016), a slatted wood sand fencing is standard practice for dune-building because it is inexpensive, readily available, easy to handle, and can be erected quickly. While plastic fencing options have the advantage of being non-flammable, stronger than wood, non-degradable, and reusable, it is generally more expensive than wood alternatives.

Slatted fencings should be a minimum four feet tall after installation as measured from the ground surface for successful dune-building and restoration. In areas where sand conditions are poor or lacking existing dune structures, a minimum of two feet can be utilized. The fencing can be supported with wooden posts or metal poles at intervals between eight and ten feet. Wooden posts should be cedar, cypress, or similar wood capable of withstanding the weather and winds for at least one year. Treated pine may be used as well if no other sources are available. The minimum practical length for support posts is six feet, but a length of seven to eight feet is preferred. The post should be buried to a minimum of ½ the depth as height above ground. As an example, a post with five feet above ground would need to be buried at least 2.5 feet into the ground and a post with four feet above ground would need to be buried two feet in the ground. Wooden posts should

be between two and three inches in diameter, and be secured to the fencing material with three or four, 10- or 12-gauge galvanized wire ties. The slatted fencing should also be weaved between the posts so that every other post has fencing on the seaward side (O'Connell, 2008). Figure 10 provides a typical fencing panel layout.

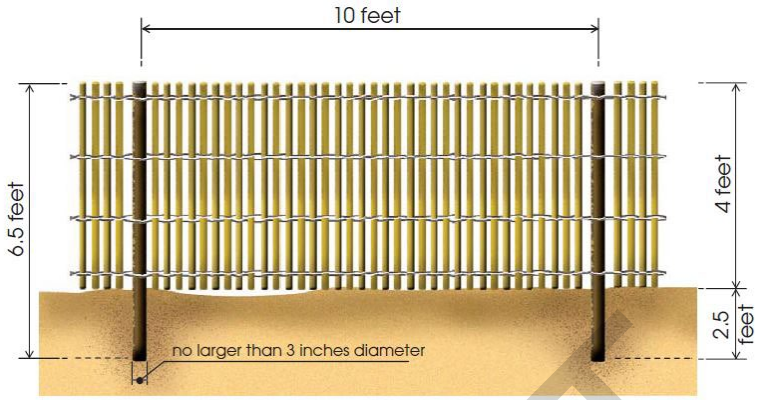

Figure 12: Typical Fencing Measurements (GLO 2009)

If the base of a sand fence is placed at ground level, dunes can build over the fencing resulting in a dune lift over the course of several years, as demonstrated in Figure 11. Although the fencing material may be buried, a new line of fencing can be constructed at a higher elevation up the dune face, resulting in a positive feedback loop and growing the foredune system toward the Gulf of Mexico.

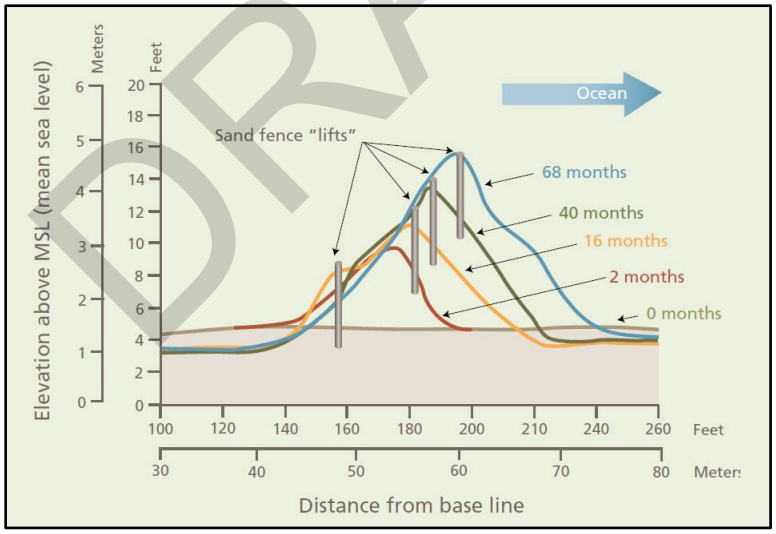

Figure 13: Dune Growth Through Sand Fencing (Savage and Woodhouse, 1969)

By contrast, if the base of the sand fence is elevated between three and six inches above grade, dunes can build on the downwind side, and the fencing can be retrieved and reused, especially plastic fencing material. Figure 12 illustrates this landward movement of the dune system.

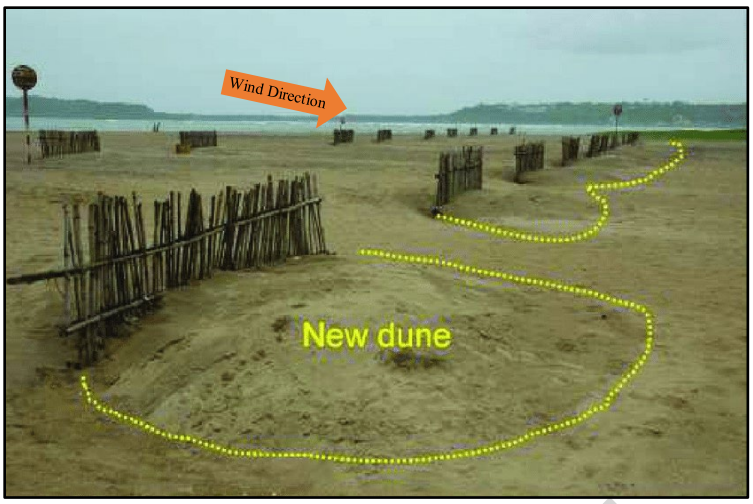

Figure 14: Dune Accretion Landward of Sand Fencing (Mascarenhas, 2008)

In either scenario, care should be taken to determine which direction dune growth and accretion is needed. Sand fencing should be placed 10 to 15 feet seaward of the damaged area, in non-continuous, diagonal segments at least 35 degrees to the shoreline so as not to adversely affect nesting sea turtles.

3.5. ALTERNATIVE METHODS

Several other dune restoration and creation, and sand accretion methods exist that may assist a potential applicant in enhancing and reestablishing a healthy dune community on or adjacent to their property.

Sargassum sp. is a genus of large brown seaweed (a type of algae) that floats in island-like masses and never attaches to a hard surface like other algaes or seagrasses (Casazza and Ross, 2022). As a locally abundant and very inexpensive material, it is well suited as a core material for dune construction. When it generally begins to accumulate in January and February, it provides a heavy and stationary foundational core for sand accumulation and accretion along the foredune line. Historically, the City has maintained a program that rakes and collects sargassum mounds, and adds them to the toe of existing, degraded dunes. These smaller mounds have formed the core of new sand dunes, and tend to retain high levels of moisture (Figlus et al, 2015). They have subsequently been planted with native vegetation through a city-wide restoration effort, resulting in higher functioning, more resilient dune communities. When used as either slight to moderately compacted bales or unconsolidated mounds, the resulting dune communities can be designed to resemble the more natural dunes north of SPI. Figure 13 illustrates a typical placement of sargassum at the toe of a foredune for a dune restoration project. The raked and collected material is placed equidistant from the toe of slope, with even volumes on either side of the elevation break. This ensures adequate support for dune formation while providing sufficient surface area for accretion (Figlus et al, 2015).

Figure 15: Typical Placement at the Toe of the Foredune (Miller at et 2018)

Christmas trees have also been used frequently for dune restoration projects along the Texas coast, although usually in conjunction with sand fencing. With decorations removed, the trees can be placed on their sides and secured by kicking sand over the lower branches or staking in a similar arrangement as standard sand fencing. Effective at trapping sand, needles fall off in the first year, and branches decay during the second and third year, depending on sand accumulation and coverage. Similar to fencing, individual trees or small groups of trees can also be useful in patching pedestrian and vehicular pathways, as they act as a visual barrier and discouraged unnecessary pedestrian and vehicular traffic. Trees with "flocking" or other paint or chemical applications should not be used for these efforts, as they present a potential chemical hazard to the future dune community.

Both potential organic core options (sargassum and Christmas trees) also exhibit higher organic content and percent moisture compared to natural dune creation cycles, resulting in two to four times more vegetation by biomass and stem counts (Figlus et al, 2015, and Williams and Feagin, 2010) compared to natural systems. Additionally, the benefits of these organic core methods were amplified when coupled with proper vegetation planting as referenced in Section 3.3. Figure 13 below illustrates a typical Christmas tree or sargassum line at the toe of a foredune.

Figure 16: Typical Christmas Tree Placement (Pye et al, 2007)

Due to transportation costs, material composition, and poor suitability for root system establishment, clay-core dunes are not recommended within the SPI region. Additionally, inorganic materials such as plastic netting, wire, concrete, automobiles, or tires is not recommended, as these materials can present safety hazards and are not biodegradable.

3.6. PROTECTION MEASURES

Even the best-vegetated or constructed dune will not remain that way unless site restrictions are implemented and reasonable protection measures are followed. Planted and fenced areas should be protected from vehicles, pedestrians, and grazing animals with temporary fencing, and signs should be placed at the site to explain the purpose and importance of the project. The City should will also maintain a compliance program in coordination with local law enforcement to ensure restored sites are protected and restricted.

4. DUNE MANAGEMENT

Beach and dune ecosystems along the Texas Coast are dynamic ecosystems that display immense variability and resiliency. Despite experiencing daily harsh winds, frequent water inundation, and the effects of intensive development, they have been able to remain fairly stable, sustain numerous plants and animals, and serve as an irreplaceable natural ecosystem and place of recreation. Specific to SPI, land development and severe erosion from waves and storm surge comprise some of the long-term challenges with restoration projects. The efforts to replenish the beaches to combat the eroding factors costs the City in man-hours, money, and resources as new sand is pumped in to replenish the sand lost from natural causes. This section will cover several fundamental techniques aimed at preventing the loss of newly established dunes and installed vegetation, and reducing both short-term and long-term management costs.

4.1. WALKOVERS

Typically, any break or gap in a dune becomes an area where the erosive power of storm surge, waves, and winds are concentrated. In order to avoid creating the potentially hazardous condition of the concentration of the water and wind through breaks in a dune line, dune walkovers are considered the preferred means of beach access, since they allow the dune line to remain continuous. Damage to dunes from pedestrian traffic can also be avoided by the use of elevated walkovers. Walkovers that are conveniently placed near access points, parking areas, subdivisions, and public facilities, pedestrians will be less likely to cut their own footpaths through the dunes. Also, providing walkovers should funnel pedestrian traffic and allow for targeted education through signage and educational placards that increases public awareness of the importance of dunes and promotes an appreciation of the sensitivity of the dune environment.

A walkover should begin landward of the foredune (see Figure 5) and extend no farther seaward than the most landward point of the public beach that does not interfere with public use of the beach at normal high tide. If any coordination is required, a request should be made to the City. The walkover should be oriented at a minimum 30° angle to the prevailing wind direction, which is south-south east. With a south-south east prevailing wind direction, most of the walkways and walk-throughs at SPI are oriented 40-45° from the prevailing wind. Figure 13 provides a potential option for combining walkovers in an appropriate orientation to limit dune impacts while still providing public and private access. Whenever practicable, individual proposed walkovers should be evaluated in combination with potential adjacent locations to determine if one walkover can safely and efficiently service multiple property owners.

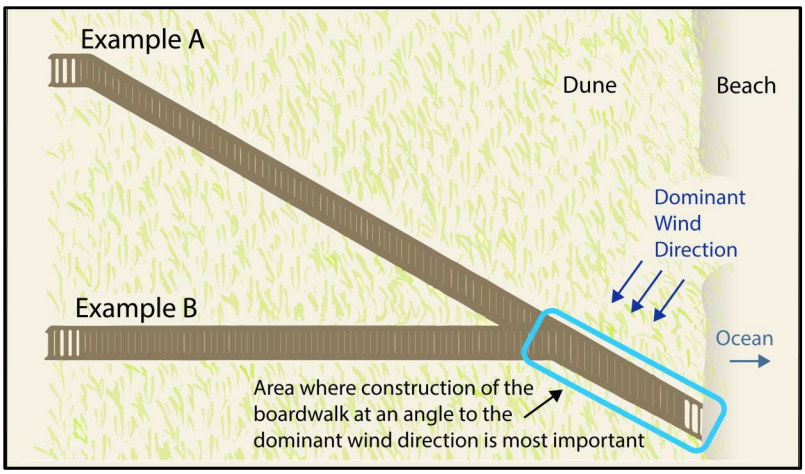

Figure 17: Potential Walkover Layouts (MOCZM, 2022)

As recommended by the GLO, a typical walkover cross-section is included in Figure 14. Walkovers should be constructed of wood as it is generally less expensive than steel, aluminum, or composite materials, does not collect and retain heat like steel or aluminum, and is easy to utilize for different construction designs. Although composite or polyvinyl chloride (PVC) walkovers currently exist, treated lumber and galvanized nuts and bolts are still the preferred option for walkover construction.

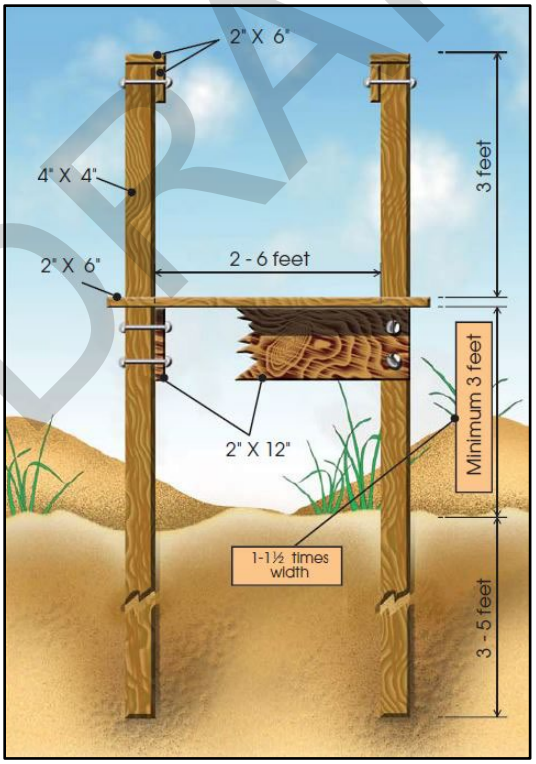

Figure 18: Typical Walkover Cross-section (GLO 2009)

The width of a walkover should be based on the expected volume of pedestrian traffic. If a walkover will be infrequently used, a width of two feet should be sufficient. Walkovers intended for two-way passage should be wider, with a max width of six feet. Consideration should be given

for heavy traffic walkovers and Americans with Disabilities Act (ADA) compliance. With all construction in dune areas, priority should be given to least intrusive, minimal necessary design that still meets the project need.

The structure's height should be at least one to one and a half times its width to reduce light attenuation and allow daylight to reach potential shaded vegetation. The spacing between wooden deck boards should be a minimum ½-inch so sunlight and rainfall can reach to underlying vegetation below and rainfall will not accumulate on and potentially rot the deck material.

Since the supporting piers could aid in dune creation and sand accretion if constructed properly, consideration for future underlaying dune expansion and growth should also be a factor in height evaluations. The supporting piers should be spaced as far apart as practicable along the length of the structure, with a minimum distance of six feet between piers. As with sand fencing, each supporting piers should be planted in the ground at least three feet to ensure stability, but a depth of six feet or more is recommended to allow for erosion around the piers during large storms, similar to the events referenced in the baseline reports (Integral 2021a and 2021b). Supported pilings should be installed with a hand auger or posthole digger rather than with a tractor to reduce site specific erosion potential, and cement footings are not recommended. Since dune systems are dynamic and very suspectable to minor impacts, care should be taken to repair damage to the surrounding area as soon as practicable.

Handrails at least three feet high from the decking on both sides of the walkover are also the recommended design standard from a safety perspective, as well as to discourage people from leaving the preferred beach access route. To enable wheelchair use of a walkover per ADA, ramps should not exceed a 20% slope or a one-foot rise for every five feet in length at each end of the structure. Large walkovers with heavy pedestrian traffic (i.e., city access areas, subdivisions that combine resources, state parks, etc.) are highly encourage to utilize ramps.

All walkovers should be inspected on a regular basis and repaired as needed. For repair activities, workers should enter the dune area on foot rather than by vehicle. In the case where a vehicle or machinery is required, the City should work with the walkover owner to allow vehicle access down the beach but will not allow vehicular access over dune areas through the current Beach Access Permitting program. As states earlier, we strongly recommend that the City provide incentives or other regulatory measures over single subdivisions to pool their resources and consolidate walkover structures to minimize damage to dunes by the proliferation of walkovers.

Figure 15 and Figure 16 show two of the most common designs for dune walkovers and are variations of the common pier-supported structure employing telephone pole or fence post piers. Figure 15 follows the dune elevation with flat deck and steps at each end. Figure 16 has ramps instead of steps, and the deck is arched where dune formation is highest. The conventional pier-supported walkover is relatively easy to build, but the services of a qualified contractor or architect may be required for more accommodating designs. Prior to construction, a permit would be required from the Office of Shoreline Management.

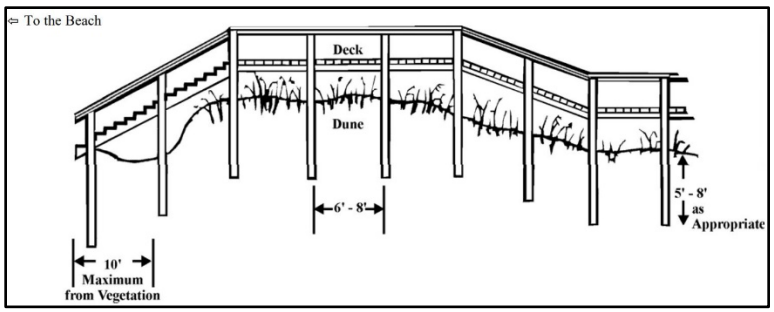

Figure 19: Pier-Supported Walkover with Steps (FDEP 2016)

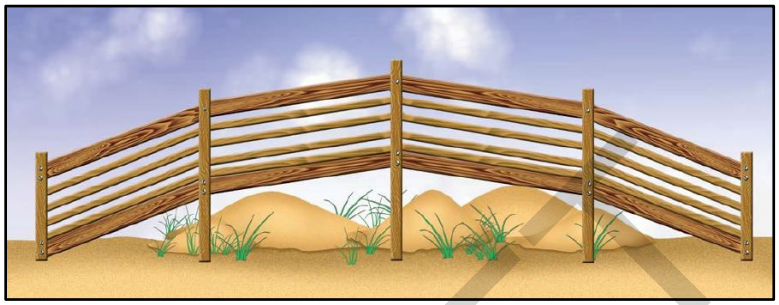

Figure 20: Pier-Supported Walkover with Ramps (GLO 2009)

4.2. ACCESS ROADS AND PATHS

Unrestricted off-road vehicle use and pedestrian traffic can do significant damage to the delicate and often relatively unobtrusive plants that grow in coastal dune communities, as well as crush the eggs of beach-nesting birds and frighten birds from their nests. Additionally, as the public drives or walks on foredunes in particular, they can crush the expanding dune grasses as they spread seaward, preventing the growth of the dunes and increasing erosion (Kluft and Ginsberg 2009).

The need for public roads to provide access to beaches often conflicts with the need to protect dunes especially with the state laws in effect in Texas; however, damage to dune areas by access roads can be minimized if the roads are properly designed. To minimize dune destruction, access roads should be as narrow as practicable, usually between 14 and 18 feet wide, and lined with regularly maintained sand fencing to restrict erosion potential and confine vehicular and pedestrian traffic. More durable slatted plastic fencing may be appropriate in for road installation, to decrease long term maintenance costs. Additionally, any dune area damaged during road construction should be revegetated.

If roads are constructed parallel to the shoreline, they should be located as far landward of the dunes as possible. Beach access roads built perpendicular to the beach should be located in washover or blowout areas whenever possible and follow natural land contours. Beach access roads should be oriented at a 20° to 35° angle to the prevailing wind direction (Figure 17), similar to sand fencing placement, to reduce the chance that water and wind will be channelized and erode the dunes during storm events.

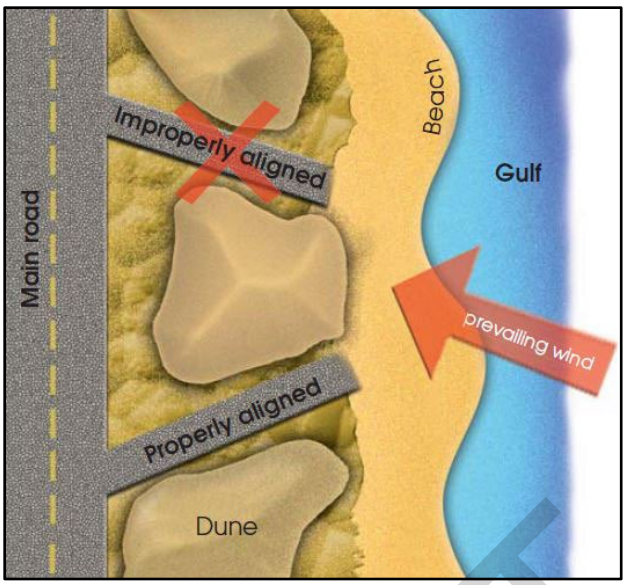

Figure 21: Recommended Access Road Alignment (GLO 2009)

Access roads near beaches should also be elevated over existing dunes to reduce the chance of water channelization and erosion during storms and high tides. Additionally, drainage patterns resulting from access road construction must not erode dunes, the public beach, or adjacent properties. New roadside channels should be graded to drain to the bayside of SPI and away from critical dune areas. Where practicable, these drainages should be directed into the naturally occurring dune swales on bayside or landward side of the back dunes (see Figure 5 above). If necessary, the installation of a small retention pond to collect and contain rainwater until it can seep into the ground or the installation of flow reduction materials like small sediments traps or riprap-lined swales may be required based on the proposed footprint of the access road. A pond should be large enough to contain the anticipated volume of runoff and located where it will receive the maximum amount of drainage, but not impact any critical dunes areas. Riprap-lined swales or sediments traps should be periodically inspected and cleaned out as necessary. A qualified professional should design any potential access road system, seek approval from the City, and oversee its construction to ensure compliance with applicable local and state laws and there is no damage to the existing dune communities.

Aside from access roads and walkovers, the public may attempt to access the beach via pedestrian trails that are inaccessible to vehicles, carts, or conveyances. If a ground level path is required, then an applicant should seek approval prior to installation and follow similar guidelines for access roads and walkovers. The planned path should follow existing contours and not excavate or other move any sand or existing dunes. A curved path is preferred to reduce wind and water erosion potential, and the path should be sand fenced on both sides to prevent wandering and impacts to adjacent dunes. As standard sand fencing is designed to retain sand and build dunes, symbolic (string and post) fences may also be used instead to channel public use away from sensitive vegetation or wildlife habitat but it must be regularly maintained.

4.3. INVASIVE PLANT MANAGEMENT

The loss of coastal dune ecosystems to human development can mean vegetation specialized to

these habitats can become uncommon and rare. To exacerbate this issue, additional threats can be posed by noxious, exotic, and invasive species that outcompete native species and lead to monocultures. Non-native species compete with and overwhelm more stable native dune plants, threatening the stability and biodiversity of the dune system. Reducing the presence of aggressive, non-native vegetation preserves and promotes the structural integrity and biodiversity of the dune. Species of concern in SPI include common reed (*Phragmites australis*), popinac (*Leucaena leucocephala*) and salt cedar (*Tamarix* spp.). Potential sources for these undesired species include windblown and water-washed in seeds, restoration and planting efforts that transplants root balls from infested areas, trampling of native species from trespassers (e.g., general public, vagrants), unauthorized trimming or mowing, homeless and vagrant activities, and man-made fires.

It is recommended that any areas that contain noxious, exotic, and invasive species be monitored and these species fully removed as soon as practicable after identification. Removal consists of physical removal of all vegetative mass, including leaves, stems, and trunks, and roots, and legally disposed of off-site. As with planting efforts, all removals activities should be undertaken with hand tools; mechanized equipment is not recommended. If mechanized equipment is required and can be used without impacting existing dune communities, it should be coordinated with and approved by the Office of Shoreline Management.

Post and rope fencing and sand fencing may be temporarily removed for access prior to removal, but it should be replaced upon completion of each section as soon as practicable. If approved, mechanized equipment may also be permitted on the soft sands of the beach, access roads, boardwalks, or beachwalks on a case-by-case basis.

Additionally, no on-site shredding, mulching, or chipping should be allowed. During removal, care and special precautions should be taken to ensure minimal impact to the existing dune during the exotic removal efforts. The use of herbicides should also be prohibited at the discretion of the City.

5. SUMMARY AND RECOMMENDATIONS

The primary purpose of this Plan is to develop a set of guidelines and rules that will assist the SPI community in developing and maintaining a stable, ecologically functional dune system appropriate for the south Texas coast that reduces maintenance costs, alleviates public safety concerns, and benefits the aesthetic and culture of SPI. The Office of Shoreline Management has been instrumental in developing a program to guide development activities toward a more sustainable and resilient dune system. The baseline reports (Integral 2021a and 2021b) also support the conclusion that an intact continuous dune system is important to the resiliency of the ecosystem, and the system is inherently more vulnerable as large storm waves can reach the base of the buildings or infrastructure without that protective dune line.

Implementing this Plan is anticipated to provide the framework to continue and further dune restoration efforts within the City of SPI in both the short and long term. Common sense construction and re-vegetation processes should provide the consistency and efficiency the public and private sector need to reinstall the resiliency into the coastal dune systems that were once prevalent along the entire Texas Coast.

Based on coordination with Integral and the Office of Shoreline Management, developing industry standards related to beach and dune restoration, and our professional experience, BIO-WEST recommends the following supplemental actions in addition to the three sections above that would further increase the resiliency of the SPI coastal dune system:

- Reduce the number of permitted walkways, have walkways converted to walkovers, and combine future walkovers to service multiple properties.
- Limit or restrict the current dune scalping that decreases the dune crest height below 10 feet and maintain a minimum dune height of 12 feet (Integral 2021b)
- Implement mandatory re-vegetation requirements for dune restoration applicants through the current city permitting program that could include the following:
    - Re-vegetation plan with location, methods, and plant list clearly defined
    - Re-vegetation success criteria (see Section 3.3)
    - Yearly monitoring and reporting requirements
- Consider additional city funding, public grants, and/or other incentive programs for volunteer dune restoration activities
- Consider providing city employee assistance, coordination, and support to potential volunteer dune restoration projects in locating and obtaining non-city funding and grant monies
- Continue existing incentive programs for volunteer planting/revegetation programs
- Continue public involvement initiatives including the beach access handbook and volunteer-led restoration efforts
- Increase access restrictions to current and future beach restoration and enhancement projects by implementing a project protection permitting process, increasing signage and fencing requirements, providing incentive programs for voluntary access restrictions, and engaging compliance officers or local law enforcement

- Implement a compliance program to identify and remediate any unauthorized paths and trails
- Consider changes to City ordinances to ensure restoration of dunes removed by property owners

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