Galveston Island Sand Dunes

Maintenance Manual

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1.1 Purpose and Objective

The primary purpose of this manual is to provide a guidance document for the City of Galveston for coastal dune restoration projects. This document provides a background of Texas sand dunes and their associated plants, gives techniques for site preparation, plant propagation, and volunteer planting events.

Severe erosion from wind, waves, and storm water runoff address some of the long-term challenges that Galveston beaches along the Seawall experience. The efforts to replenish the beaches to combat these eroding factors cost the city in man-hours, money, and resources as each season new sand is trucked in to replenish the sand lost from natural causes. While this project may not prevent severe erosion caused by large storm events, vegetating the bare sand will reduce natural erosion that Galveston beaches experience on a daily basis and should reduce the frequency for yearly and bi-yearly replenishment efforts.

This project will enhance the city of Galveston aesthetically through natural dune habitat. Additionally, it will raise awareness of the importance of the beach/dune systems to both residents and tourists. The plants selected for this project are beneficial for the island's dune structure and the wildlife that inhabit these areas. Many of them are flowering species that have colorful blooms year round. This has the potential to benefit the island's economy as these habitats will increase the aesthetic appeal of the beaches and Seawall and attract wildlife such as more migratory birds wanting to feast on the seed stock these plants produce. Galveston Island is a great place to promote ecotourism, as it contains a very biodiverse ecosystem. Birdwatching is particularly popular, and this destination attracts birdwatchers form all around the world. Galveston Island is already on the track to promoting other eco-tourism and nature-based projects, thus, this project would be another great addition. Galveston Island has the potential to develop a reputation for restoring and enhancing natural beauty within the city limits, which will also attract other tourists that may not typically seek out eco-tourism locations.

1.2 Introduction to Texas Beaches and Dunes

Texas beaches are dynamic ecosystems that display immense variability and resiliency. Despite experiencing daily harsh winds, frequent water inundation, and the effects of multiple users, they are able to remain fairly stable, sustain numerous plants and animals, and serve as an irreplaceable natural ecosystem and place of recreation. The beach /dune system includes the area from the mean low tide line to the landward limit of dune formation. It is composed of the foreshore, backshore, foredune ridge, and backdune. The foreshore, known as the wet beach,

experiences daily tidal inundation, while the backshore, known as the dry beach, is only inundated on storm and spring tides. The foredune and backdunes comprise the sand dunes, which are naturally occurring sand formations covered with diverse vegetation. The foredune is the first, distinguishable vegetated dune that is closest to the coastline. Its purpose is to absorb the initial brunt of a storm surge and dissipate wave energy.. A backdune is the most landward dune, before the vegetated flats or prairies (Figure 1). There also may be a foredune ridge, which will form between a foredune and a backdune. It adds additional protection against storm surges. Dunes provide a natural buffer to storms, sustain a diverse array of plants and animals, and provide an aesthetic benefit to viewers.

Galveston Island is unique from the other six barrier islands in Texas in that is has a seawall along approximately 10 miles of its eastern end. This structure has replaced and enhanced some of the structural function dunes provide, however, fails to attain the ecosystem functions and aesthetic appeal of natural sand dunes. In a naturally occurring setting, the beach would extend from the low tide line to the beginning of the foredune vegetation. Currently, none or few dunes exist seaward of the Seawall, thus in this modified system, the beach is the area that extends from the low tide line to the seawall. After the restoration project, the beach will extend from the low tide line to the beginning of the dune line

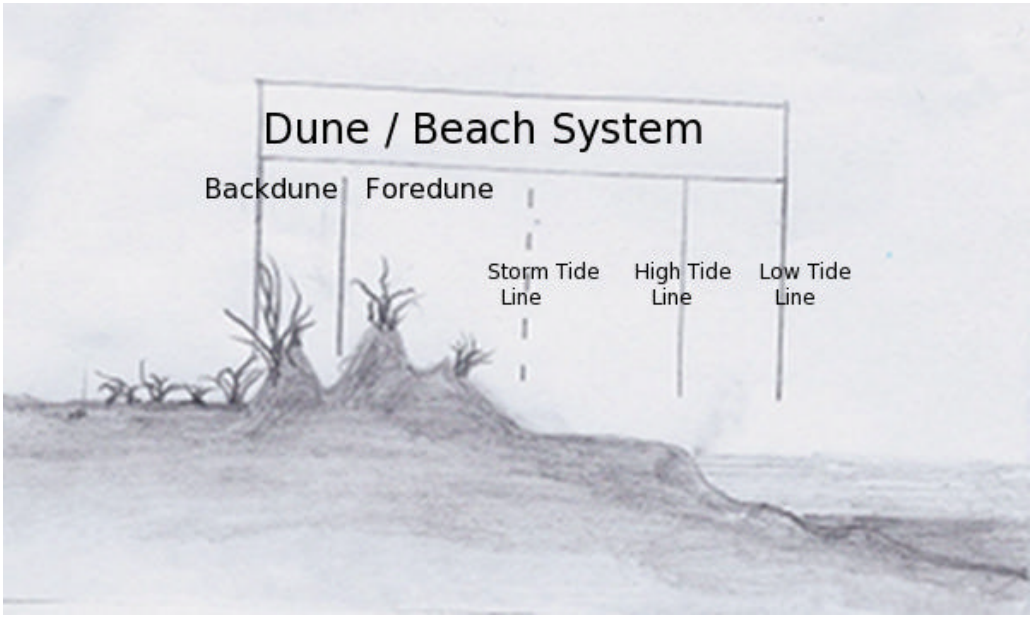

Figure 1. A normal beach profile
(Graphics by Zachary Podgorny)

1.3 Sand Cycles, Hydrology, and Erosion

Sand dunes are naturally formed by wind and wave driven sand. During the calm season, waves along the Texas coast are small (average of 2-4 ft.), allowing sand to be deposited from offshore sand bars to the beaches. These offshore sandbars are typically within 50 to 100 feet of the shoreline. As the sand is blown or pushed landward, it gets trapped in the vegetation on the foredune. This slow, natural process allows sand to continue to build upon itself, called accretion, until a storm event occurs. During a storm event or during active seasons, high-energy waves wash against the base of the foredune, disrupting vegetation and causing erosion of the dune face. The cycle continues as the waves that return seaward carry with them the sand from the dune. The sand is then deposited back to the offshore sand bars where it originated, and the cycle begins again. However, without the aid of vegetation, which acts as an anchor for the sand, the dunes are more susceptible to wind and water erosion while they are rebuilding. Natural dune vegetation is vital in the repair and rebuilding of dunes for three primary reasons: 1) the root systems anchor the existing sand, 2) the above-ground vegetation traps blowing sand, and 3) the surface area of the vegetation itself absorbs the wind and wave impacts that erode sand. In this way the foliage of the vegetation act as blanket covering the surface of the sand, slowing erosion.

While the natural system along the Seawall portion of Galveston has been replaced by development, the west end of Galveston Island provides a better representation of Texas barrier island systems and how they interact with each other. In addition to providing protection to structures such as homes, businesses, and roads, they protect, the flats, marshes, and bays that lie behind them. Approximately 90% of all commercial fish, shrimp, and crabs use the wetlands and associated estuaries at some point in their life. Without dunes, storm surges would wash water and sand over the lowest points of the island and cover native prairie, wetland, and bay ecosystems. This sediment coverage can have devastating effects on these coastal ecosystems and can take months to years to recover naturally.

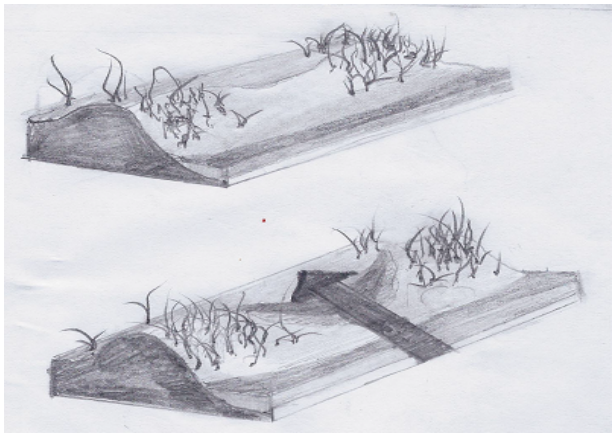

Figure 2. Wind driven dune erosion

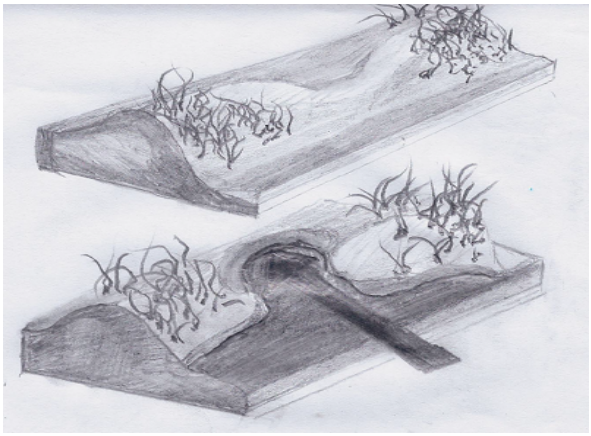

Figure 3. Wave driven dune erosion

(Images by Zachary Podgorny)

1.4 Soils and Substrates

Galveston Island was formed approximately 5,000 years ago from sediment deposits from the Mississippi River and other smaller surrounding rivers such at the Trinity River. The rivers contain fine-grained sediments that are easily suspended in the water column, creating the cloudy waters common to the northern western Gulf of Mexico. The dominant soil substrate comprising Galveston Island is categorized by the United States Geological Survey (USGS) as Mustang Fine Sand. This type of sand and related soil complexes are generally described as having a 0 to 1 percent slope in topography, poorly drained soils due to the high water table (found at 0 to 6 inches), and very low available water capacity. Because this soil has a very low water capacity, the vegetation found in the beach/dune systems is adapted to growing in near drought conditions.

Though Mustang Fine Sand dominates Galveston Island, soil salinity (or the salt content in the soil) varies throughout the island based on location. Areas along the backside of the island are influenced by the brackish water found in the estuary, while areas on the beach side are influenced by saltwater from the Gulf of Mexico. Therefore, the beach and dune systems typically have higher soil salinities than the middle and back sides of the island. Any vegetation that is established in the foredunes must be able to tolerate the high salinities, while any vegetation growing in the backdunes and behind the dunes are better adapted to handling lower quantities of salt.

2.0 Vegetation: Native Dune Plants, Anatomy, and Planting Guides

Sand dunes contain a wide diversity of native vegetation, each with a specific function that keeps the dune stable and healthy. Native vegetation is adapted to the local weather patterns, soil conditions, light requirements, and provide wildlife with food and shelter. Many plant species native to our dunes have specially adapted root systems, which hold sand in place. Dune plants along the Texas coast can be grow either as a vine or an upright. Each growth type presents a unique function to the stabilization of the sand dune. Section 2.2 gives a description of common sand dune plants on the Texas coast used in habitat restoration projects.

2.1 Plant Anatomy

The basic plant anatomy includes the below-ground parts (roots and rhizomes) and above-ground parts (stems, leaves, and nodes) (Figure 4). The below-ground structures are responsible for stabilization, nutrient uptake, and propagation, while the above-ground parts are responsible for photosynthesis and stabilization. Roots spread radially underground around the primary plant shoot or stem to stabilize the plant. This arrangement also allows the plant to absorb nutrients from the surrounding soil. Rhizomes are underground stems that grow horizontally under the soil and provide an alternative method for the plant to reproduce. Rhizomes send out vertical shoots, creating daughter plants that are genetically identical to the parent plant. The above- ground parts of a plant contains the stems, nodes, and leaves. Stems stabilize the plant and contain nodes. Nodes are evenly placed along the stem and are the site where new stems grow. Leaves store nutrients and primarily photosynthesize for plant food production. Some dune plants, particularly vines, will grow roots from the node, if it is exposed to soil and moisture.

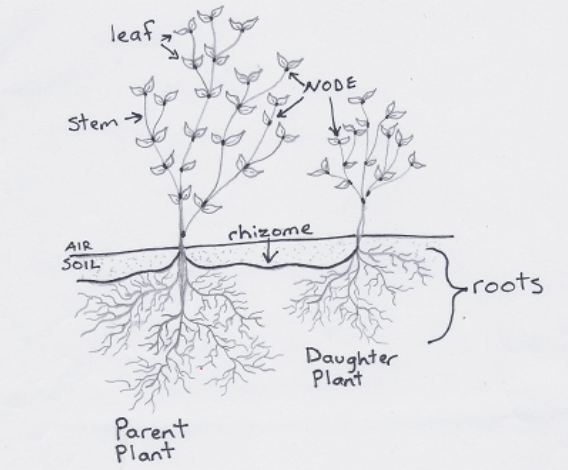

Figure 4. Basic Plant Anatomy
(Image by Kari Howard)

2.2 Plant Species by Profile

'**Gulfcoast' marshhay cordgrass** (*Spartina patens)*: Cordgrass is commonly found in high marshes, but can also be found on the foredune ridges and backdunes. This species grows well in the trough areas between the foredunes and succeeding dunes. Unlike most dune vegetation, *Spartina patens* grows well in saturated soils and inundated areas. 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.

Seaoats (*Uniola paniculata)*: This is a native perennial (lives more than two years) that propogates through rhizomes and seed dispersal. This particular species is very important to the production of foredunes since it has a very extensive, underground root system. Seaoats 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.

Sea purslane (*Sesuvium portulacastrum)*: This succulent is a low growing, sprawling perennial that is usually found in the foredune systems and brackish swales. It forms thick mats due to its sprawling root system. Roots are often formed at the nodes, allowing the plant to branch out in all directions. The succulent leaves occur as pairs on opposite sides of the stem, and the plant produces solitary flowers, which have bright attractive pink sepals. The succulent leaves store water, which makes this plant as adapted to drought conditions and dry sandy soils.

Beach evening primrose (*Oenothera drummondii)*: This species is a native perennial that grows on the edge of sand dunes and dune swales. It prefers drier soil, but will also grow in areas that receive occasional watering. However, it will not tolerate complete soil drying. It grows approximately 1 to 3 feet tall and the showy yellow flowers attract local and migratory butterflies. It is also the host plant for several larval butterflies, moths, and skippers that are important pollinators for plants and food sources for birds. This plant also is extremely valuable to native bee species. Propagation is generally successful through root division instead of seeds.

Railroad vine (*Ipomoea pes-caprae*): This species is commonly found at the base of foredunes, dune swales, high beaches, and coastal wetlands. It prefers more moisture than most dune plants. This species roots at the nodes, forming thick mats that can stretch up to 75 ft. The leaves are smooth, thick, and two-lobed, resembling a goat's footprint, which has given it the nickname goat's foot morning glory. The flowers, which open in the early morning and often close shortly after noon, are pink or lavender. The trumpet shaped blooms are very attractive to bees, butterflies, and hummingbirds. The seedpods produce regular amounts of seed stock, which feed local birds. This plant can be cultivated by seed collection and cuttings as new plant growth can easily develop from the nodes.

Beach morning glory (*Ipomoea imperati*): This species is mainly found in the frontal dunes and high marshes. It roots at the node, forming mats that can spread out to 30 ft. It also propagates by spreads by seed. The flowers are white with a yellow throat.

Bitter panicum (*Panicum amarum)*: Bitter panicum is an extremely hardy grass that is very prevalent along Texas dune systems. This species has been used in several 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 a small, viable seed, its main method of propagation is from rhizomes. Thus it is best propagated from stem cuttings. This is the species that is being grown at the Park Board nursery for the Seawall Pilot planting project.

3.0 Preparing the Planting Site

3.1 Sand Fencing

Sand fences are often used to naturally build sand prior to vegetation efforts. These are usually made of wood slats, plastic, or an approved fabric and placed at 45° angles to the predominant wind direction. These fences help promote sand build up and prevent erosion or flooding caused by wave over wash.

3.2 Dune Construction with Imported Sand

If time is an issue, a dune ridge can be built with imported sand. Sand with a similar grain size, mineral content, and salinity to Galveston beach sand should be used. If possible, avoid using clay-core dunes, because they do not provide the ideal substrate for plant growth. *Sargassum* is another material that can be used for dune construction. The city of South Padre Island regularly adds to their dune ridge by placing raked *Sargassum* at the toe of the dunes. Many of these *Sargassum* mounds have been planted with native vegetation through a city-wide restoration effort and have shown to be a great dune substrate. Christmas trees have also been used frequently for dune restoration projects along the Texas coast, although usually in conjunction with sand fencing. The created dune ridge should closely resemble a natural Galveston Island dune, which is low in elevation and has a gentle slope. The Texas General Land Office (GLO) recommends a height not to exceed 4 ft. and a 45°slope for constructed dunes. Time is required in order for settling to occur and for plants to become established.

3.3 Choosing a Planting Site and Site Preparation

Each planting location must be evaluated to determine the existing conditions of the site, available natural resources, and access. Many factors will play a part in this determination, but most importantly all evidence at the site must answer the question of whether the plants would survive on their own once the planting is complete. One factor is how far the proposed planting site is from tide lines. The GLO generally recommends that any project along the coast should be at least 200 feet from the mean low tide line. This will prevent the dune plants from being washed away from high waves. It is recommended that the planting project boundary remain at least 50 feet from the storm tide line, which can often be identified by the layer of offshore debris along the beach. It is also 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 an important factor when bringing water and supplies to the

planting site as well as providing suitable access for pedestrians or volunteers to attend planting events. It is always better to access a non-vegetated dune from the shoreline instead of the backside of the dune to prevent any unnecessary destruction from foot traffic or vehicles. These systems are extremely delicate, and it is reasonable to believe that if the site is a good candidate for restoration, it will need to be treated carefully. Another factor to consider is whether or not the site is covered with annual or invasive species that may need removal or that may cover native species. The diversity or different types of plants is extremely beneficial to wildlife so if a certain native species is dominating the area, creating an area with variety will greatly improve the ecosystem.

The site visit should include activities such as measurements of the proposed planting areas, pictures of the existing site conditions in several directions with a scale reference to any obstacles that may exist, and identifying the current elevation of the existing site to determine if the site needs to be built artificially, or whether the area would benefit from installing sand fencing. These construction activities have to be done prior to planting. Any large objects such as large pieces of driftwood, hazardous items, or unnatural obstacles will need to be removed before planting activities and to maintain safety for the individuals working on the site. Any resources that volunteers may need during the events such as restrooms, fresh water access for plants, and parking space for multiple vehicles need to be scouted and identified during the initial site visit. Understanding what these factors are and how to address them will help in preparing the site for future restoration work. Workdays to remove invasive plant species and trash need to be scheduled prior to the planting activities begin.

3.4 Determining the Number of Plants

Once the site has been prepared, it is ready for planting. For areas that are completely bare, a rectangular planting area can be used which makes calculations for plant numbers and total restored area easy to quantify. If the area is irregularly shaped and/or has existing native plant material, it is best to divide the area into sections to calculate area. The entire area can be calculated roughly with straight lines as well, however, this may overestimate the required plant material needed and may be misleading when reporting on total area restored. The amount of plants needed for the project depends on how far apart the plants are spaced. Plants spacing varies depending on the plant type, however 2-3 ft. is the normal spacing used in most restoration projects. To determine the number of plants needed, square the spacing and divide that by the amount of feet squared in one acre (there are 43,500 ft^2per acre).

Here is a sample calculation:.

- 3 ft. centers = 4,840 plants/acre (3^2=9; 43,560/9 = 4,840)
- 6 ft. centers = 1,210 plants/acre (6^2= 36; 43,560/36 = 1,210)

4.0 Propagation and Growth

4.1 Temporary Propagation Ponds

Creating a functional nursery requires five easy steps:

1. Choosing and preparing the site
2. Constructing the nursery
3. Obtaining and preparing planting containers, supplies, etc.
4. Obtaining plants
5. Planting the nursery (if plants are pulled from a donor site, they should be planted in the nursery within 24 hours)

4.2 Preparing the Nursery Site

The location of the nursery and preparation of the site is crucial to the success of the project. The following criteria should be used when selecting and preparing the nursery site:

1. The area must be able to accommodate an 8' X 16' nursery plus a surrounding workspace. Adjustments can be made to the area of the pond based on available space at the site. However, it can be difficult to reach and water plants that are grown in ponds wider than 10 feet. Multiple ponds should be constructed to add more plants instead of increasing the size of the pond.
2. A source of fresh water should be as close as possible for irrigation. Rainwater catchments are ideal, as well as the use of resaca or canal water. City water may be used as a last option.
3. Dune plants need plenty of sunshine. The nursery site should receive full sunlight for most of the day. An open area, without overhanging trees or rooftops, is an excellent spot to build the nursery. Protection from excessive wind, people, and animal traffic are other considerations. Often small cuttings or seedlings will need additional protection from harsh sunrays with a shade cloth, especially during summer.
4. The site should be flat (level) to prevent dry spots or flooding. Uneven spots can be leveled with fill dirt or sand.
5. The site should be cleared of any sharp or pointed objects such as rocks or sticks that could puncture the liner.
6. Once the pond is constructed the shade cloth can be attached to T-Posts on the outside perimeter of the pond and secured with zip ties or ropes.
7. The site should be in a secure area to prevent vandalism and unintentional impacts (i.e. stray animals, sporting equipment, runoff from nearby roofs, etc.). A secured, fenced area is ideal.
8. The site should be easy to access for monitoring, maintenance, and recycling of the nursery.

4.3 Construction Supplies

The following supplies are needed to build one nursery

- One pond liner
- Two pieces of 2" X 4" X 16' lumber
- Two pieces of 2" X 4" X 8' lumber
- Three consecutive pieces of 1" X 2" X 16' cedar strips (you will cut ONE in half)
- Four 3" brace corners (in one package)
- Four 2 ½" brace corners (in one package)
- Four 6" X 6" L metal straps
- One pound 8D galvanized common screws
- One pound 6D galvanized nails (for the 1" X 2" X 8' wood strips)
- Four T-post or U-posts for shade cloth
- One to two shade cloths to cover the pond area
- One package of zip ties or solid rope to secure shade cloth

Construction Tools

The following tools are needed to build one nursery

- 3' long level
- Two or three rakes
- Ground temper
- Hammer
- Power drill (if using screws)

4.4 Constructing the Nursery

After selecting an appropriate location (based on the above requirements) construct the nursery as follows:

1. Remove debris from the site. **This is very important to prevent damage to the liner.**
2. Level the ground using rakes and the tamper. Use fill dirt or sand where necessary to raise low spots. Check with the level.
3. Using the 2" X 4" boards, outline a rectangular area on the ground measuring 8' X 16'. Make sure the ends of the boards meet at right angles at the corners.
4. Join the boards along the sides of the pond using the L metal straps as connectors. Place the straps on the **TOP** of the boards and use the galvanized screws to attach the L straps to the boards. **Place all hardware and nails in such a way as to avoid puncturing or tearing the liner, once it is in place.**
5. Use the corner brace to join the boards at the corners using the galvanized screws.

6. Cover the pond area with liner. Start at one side of the pond and pull the liner over the entire pond. Make sure extra liner is laid on top of the posts and **fits well into all edges and corners.** It might help to walk along the inside edge of the nursery to flatten the liner and help make a better fit, or add an inch of water.
7. You will need to cut **one** of the three 1' X 2' X 16' wood strips into two equal halves. Place the four wood strips over the plastic on the top surface of the pond frame (2" X 4"s) and nail in place using the smaller nails. Be sure the wood strips are directly over the boards and meet at the corners before nailing them. **Keep the liner loose while nailing it down. If it is too tight, then the weight of the water and plant trays will stretch and eventually tear the liner.**

4.5 Plant Propagation

- Collection: Some plants will grow vegetatively (i.e. from sprigs or smaller pieces with roots), while others will need to be grown from seed. Vegetative plants include: bitter panicum, gulf cordgrass, marshhay cordgrass, railroad vine, morning glory, and sea purslane. For the sea purslane, railroad vine, and morning glory, a plant can be grown from a small piece of the rhizome, as long as it has roots on it. Plants that are better grown from seed include: sea oats and beach-evening primrose. For assistance on these techniques, contact Tom Solomon from the Harris County Precinct 4 Master Gardeners or Dick Benoit from the Galveston Bay Chapter Master Naturalists. It is important when collecting plants to use the one-third rule when harvesting from a large parent plant. Harvesting only one-third of a large established plant will pull a limited amount of energy from the plant, yet allow the plant to focus the remaining energy in the center of the plant which will promote more growth. This is typically healthy from time to time. Once one-third of the plant is harvested, move on to another large healthy established plant to collect more stems or plant parts.
- Vegetative growing:
    - Marshay cordgrass and Gulf cordgrass- Look for smaller plants with lots of new growth. Dig up a large grass with roots attached and put into a bucket. A large plant (about one foot in diameter with the root) can be split into about 10 plants. Simply pull them apart to make smaller pieces. A serrated bread knife can also be used.
    - Bitter panicum- Find a large stand and gently pull the rhizomes or take cuttings from larger stems. If a rhizome has multiple root parts on it, cut just below the nodes. Panicum will likely grow, as long as at least two nodes are buried in the soil.
    - Sea purslane- Pull on the rhizomes. Purslane roots at the node so pulling gently will allow for the plant to come right out of the sand. Using scissors, cut the plants into smaller pieces. As long as a piece has a root, it will grow.
- Seed collection- Make sure the seeds are dry enough. If the seeds are still too green, they will not sprout. Some plants have special processes that must occur for them to sprout. If you have time, you may research this to see what they may need. Sea oat seed collection is restricted on the Texas coast, so it may be best to purchase these seeds form a local native plant supplier. Additionally, a permit may be able to be obtained from the General Land Office and/or Texas Parks and Wildlife Department.
- Potting Up-

- Fill the container up halfway with dirt (or ¾ if a small liner plant). Put plant in and fill up the rest of the way. Pat down to get rid of air spaces. Dune plants actually like to be buried quite deep. This makes them continue to grow upward. In a natural setting, the plants are continuously being buried by sand, and have adapted to being buried deep beneath the surface.
- Put plants in rows or columns of ten. This makes it much easier to count them later.

4.6 Obtaining and Preparing Planting Containers and Supplies

Once the pond is constructed and the liner is holding water properly, it is ready to house the plants. When growing cuttings, one-gallon pots are preferred because they provide the perfect amount of soil around the nodes. One gallon containers can be purchased online, such as from Hummert International, however, most plant nurseries receive these pots when they purchase their plants in bulk and may offer to donate them (especially if the project is explained) or sell them for a discounted rate. The most common pots will have between one to five small drain holes at the bottom of the pot.

The ideal soil mix for growing new plants is a 50/50 mix of potting soil and regular native soil. The potting soil retains much more moisture to assist new root establishment and the mixture of native soil helps the new plant acclimate to the soil it will be planted in. For this project beach sand taken from the east end of Galveston was used in the 50/50 mix with potting soil. A small amount of hibiscus fertilizer was used, along with a small amount of a rooting hormone powder to stimulate growth.

The number of tools needed for potting up the plants depends on how many people will be working on this project. A good list to start with is:

- Shovel (for digging sand, mixing, and moving soil mixture)
- Hand spades (for mixing sand and dirt)
- Water hose or watering can
- One gallon pots or six inch pots
- Liquid seaweed or hibiscus time release fertilizer
- A table on which to work (prevents bending over and back strain)
- Rooting hormone powder when using cuttings
- Secure place/locking closet in which to store tools, supplies, fertilizer, etc.

Other items to consider:

- Plants should be kept away from high traffic areas and protected from high wind.
- Individual workers or pairs of workers can be assigned on a rotating schedule.
- If aphids or “mealy-bugs” appear, call Artist Boat for advice on how to eradicate pests.
- A weatherproof table is handy for working with plants as it gets quite dirty.
- All gardening tools should be kept clean and dry in a designated place.

4.7 Watering and Water Levels

When maintaining dune plants growing in nursery ponds, it is recommended to check the plant health weekly or bi-weekly depending on the season. Summer seasons will require more maintenance due to the extreme heat. Water is vital to the growth and survival of the plants, however, too much can be detrimental. Depending on the type of plants grown in the ponds watering requirements need to mimic the amount they would receive in their natural environment.

Dune plants are typically found in areas that receive low to moderate rainfall, but because they contain sandy soils that drain the water away, they are adapted to dry conditions. The general rule for watering establishing plants is once a week in the winter, twice a week in the spring and fall, and three times a week in the summer, but this is for normal landscape conditions. For dune propagation, water levels need to be between one to three inches along the bottom of the nursery pond liner. The plants need periodic watering with a chance to dry out between rainfall or hand watering to prevent saturation of the soils. Many of these plants obtain oxygen through their root system, thus long periods of saturation can suffocate the plant. Water levels within the pond liner should be checked prior to each watering and if one to two inches of standing water is observed and the top of the soil is moist, then adding additional water should be avoided. Moist soils can be identified through visual observation as wet soils are much darker than drier soils or can be identified by the feel of the soil. Just as you would check a baking cake with a tooth pick, stick your finger one inch into the soil. If your finger comes up with dirt around your cuticles, the soil is still wet and does not need water. If your finger comes up clean or dry, then it may require some additional water. Watering with a watering can will best replicate the intensity of water flow that these plants would receive during rainfall, but when watering with a hose, be sure to distribute the pressure so that the soil is not pushed out of the pot from the intense water spray.

4.8 Survival and Growth Rates

After 3-4 weeks of warm temperatures, growth should be visible from the existing nodes above ground. Checking for new growth can be done as early as two weeks after the initial potting. Often parts of the stem furthest from the soil and roots will appear dead as the plant pulls nutrients from the cells, causing the cells to dry up and die. A percentage of die off from the older parts of the plant is to be expected, however, as long as there is there is healthy new growth, there is no cause for concern. Making observations near the lower nodes for new stems and leaves will reveal the activity that cannot be observed below ground. Signs such as green or reddish stems just above the soil line or growth from the nodes is a sign that the plant is alive and growing. The base of the stem can also be gently squeezed between two fingers to feel for firmness. If the stem near the soil line is firm, but has no color, chances are the plant may be focusing its energy below ground. If the stem has no firmness when squeezed it is likely that the

plant did not survive the transplant or propagation activities. To help promote healthier foliage, cut back any dying parts of the plant, as this will save energy and allow the plant to grow new matter elsewhere.

Any impacts from insects or disease will be visible along the stem of the newly planted plant. Most insects can be killed with an organic pesticide. Ants typically prefer creating nests inside cavities like the pots used to grow these plants and can be identified by small mounds of crumbled soil near, on, or outside the pots or nursery pond. Disturbing the mounds will often stir ants from the internal tunnels, but be aware that many ant colonies will create additional nests when disturbed so it is always best to apply ant killer shortly after they are discovered or disturbed to keep populations under control.

5.0 Preparing For Events

5.1 Planting Logistics

Use the same formula from Section 3.4 to determine the amount of plants needed for each planting event. Knowing the number of plants provides a foundation to determine how much fertilizer and other materials are required. When deciding how much fertilizer and moisture retention product to use, read the directions on the container to provide a general amount needed, as less is recommended for use in natural environments.

5.2 Project Design and Materials

In order to make have a successful planting event, certain materials and site preparation is needed. Each team will need a dibble, fertilizer, moisture retention product, water, and plants. In order for an easier planting, the sand should be loose. This is accomplished by planting on a day that is preceded by two to three dry days.

Plants-

- Bitter panicum- *Panicum amarum*
- Sea purslane- *Sesuvium portulacastrum*
- Sea oats- *Uniola paniculata*
- Beach evening primrose- *Oenothera drummondii*
- Railroad vine- *Ipomoea pes-caprae*
- Beach morning glory- *Ipomoea imperati*

Materials

- Dibbles- 25
- 20 gallon buckets to transport water or plants- 15
- 100’ water hose if outdoor connections are available- 2
- Beach pails- 15
- Pots
- Plants
- Fertilizer
- Moisture retention product
- Wagons for transporting plants

5.3 Training Team Leaders

When training volunteers or team leaders, it is important to provide them with as much information about the tasks they will be responsible for performing and supervising. Ideally, team leaders will be met with prior to the planting event. Receiving education on the particular

project is a large part of what makes stewardship so effective. The philosophies behind the activities will strengthen the bonds people form with the environment, and understanding why stewardship is so important will develop an appreciation that will last long after the site is restored. Fostering an appreciation of stewardship activities may be the only way to ensure that future generations will enjoy and protect these ecosystems and the wildlife that utilizes them.

To appeal to a person's self-interest, share how dunes play an important role as protective barriers for storms, which can reduce damage to properties. Those who are already nature enthusiasts may be motivated by the nesting habitat dunes provide for sea turtles and birds. Also be sure to teach them about the plant species that they will be working with by common names so they can remember them easier such as: marshhay cordgrass (*Spartina patens*), railroad vine (*Ipomoea pes-caprae*), beach morning glory (*Ipomoea imperati*), sea oats (*Uniola paniculata*), bitter panicum or panic grass (*Panicum amarum*) and sea purslane (*Sesuvium portulacastrum*).

Additionally, ensure they are very familiar with and understand the importance of strictly following and enforcing planting guidelines such as plant spacing, planting depth, the use of water or soil moisture products, and fertilizer.

5.4 Volunteer Management and Introduction to the Environment

Working with volunteers involves a special dynamic that combines discipline with fun. After all, they volunteering to learn about, enjoy, and restore this critical natural environment. However, too loose of a system can lead to poor planting techniques and subsequent poor plant success. Here are some guidelines to follow when working with volunteers.

Lead your group to the site, and have them line up shoulder to shoulder so that everyone can see. Give a brief talk about the habitat they are in (sand dune habitat), and that it is part of the back beach habitat, which is quite dry. Explain that this habitat is important for two main reasons:

1. Habitat: Galveston lost a lot of habitat due to Ike, and these plants will grow and provide habitat for animals. Have the volunteers list some animals that live in dunes, including crabs, insects, snakes, small mammals, birds and nesting sea turtles. This habitat provides a place for these animals to hide, nest, and food to eat.

2. Protection: Sand dunes provide a natural line of defense for Galveston Island, absorbing energy from storms. Dunes are preferable to hard structures because they allow the beach to migrate, and also store sand that is used to replenish beaches at later times. The roots of the plants will help hold the soil together, and the tops of the plants will trap sand as it blows across and build the dune up, making it larger.

5.5 Teaching the How To's- Importance of the planting steps:

Putting a plant in the ground may seem like common knowledge that should not need explaining, however, it is important to keep the audience in mind, who may not be familiar with natural

environments or gardening techniques. Additionally, this particular technique has been developed over a long trial and error period, and has proven to be an effective and efficient way for dune restoration

1. Dig a hole: Sounds very simple, but is the single most important step next to the last step. The depth of the hole needs to be four to eight inches deep (four inches for the shorter plants, eight inches for the taller plants). These areas are constantly being exposed to high winds, which causes the sand to move along the beach. If these dune plants are planted in too shallow a hole, the wind will drive the sand away from the root ball and cause the roots to dry up. Once the roots are disturbed and dried out, the plant goes through tremendous stress, which can eventually lead to death.

Figure 5. How to use the dibble and the ideal hole depth for planting

2. Sprinkle fertilizer in the hole: A slow release fertilizer will give these plants a boost: some plants typically do not receive high amounts of nutrients so **too much can kill them!** Approximately ¼ of a teaspoon should be used for these plants or just pinch a small amount between your thumb and index-finger. The fertilizer will come in prepackaged bags for each group. If they run out of fertilizer before they run out of plants, they are using too much! Mention this to them before the planting event starts.

Figure 6. The proper amount of fertilizer to use

3. Planting the plant and holding it upright: Once the hole has been sprinkled with fertilizer, the plant's root ball is ready to be placed in the hole. The hole is much larger than the plant, so the plant must be held upright for the remaining steps of planting.

Figure 7 . The proper way to hold the plant in the pre-dug hole

4. Watering the root ball: This is a two-step process. Have one-person hold the plant upright into the hole and another person pour the water around the root ball. This will coat the new plants with moisture retaining product while giving it a fresh drink of water. The moisture retention product, Soil Moist, needs 5-10 minutes to absorb water prior to watering.

Figure 8. Soil Moist dry (left) and wet (right)

5. Covering the root ball and packing down the sand: Once the water has been poured, it will be quickly absorbed into the sand. Be prepared to cover the root ball shortly after watering. To cover the root ball, push the surrounding sand around the root ball and pack the sand around the plant. You should see leaves and stems above ground and all the roots should be below the ground. Surrounding the roots with soil will help stabilize the plant and keep it upright, while packing the sand down around the stem will prevent trapped air bubbles and reinforce the security of the plant in the ground.

Figure 9. The dune plant once properly packed with sand

5.6 Setting the Planting Area

1. Gather the materials needed for your plot. Depending on the size, you may have two sets of materials for two different groups. Each group should have the following:

    - 1 dibble
    - 1 pair of gloves
    - 1 small orange bucket of water
    - 1 small moisture retention product (such as Soil Moist or Hydrosoil)
    - 1 small bag of fertilizer
    - 1 cup for pouring water
    - Plants

Each plot should have the following supplies:

- 20 gallon bucket full of water to refill small orange buckets
- 2-4 stakes
- 32-34 pin flags
- 1 roll measuring tape

If using Soil Moist as the moisture retention product, sprinkle a small amount of Soil Moist into the hole directly after the fertilizer or mix in the cup of water prior to pouring the water around the root ball. Do not mix a large amount of Soil Moist in the large container of water as the product settles to the bottom and it is difficult to distribute evenly once mixed. If using Hydrosoil, which is an organic by-product from rice hull ash, use roughly three cups of Hydrosoil with six to ten cups of water. Use the dibble to stir as the ash can temporarily stain your hands. The ash needs to be stirred each time before watering the plants with the mixture as the ash can settle to the bottom quickly.

2. Begin the set up stations, using diagram in Figure 10. Divide the group into smaller groups of four, and put two groups of four at opposite ends of the plot and have them work from the outside edges towards the middle. Use stakes to mark the four corners of the plot and orange flags to mark planting areas three feet apart. The initial measurements need to need to be taken with the measuring tape. However, the flags can be placed three feet apart by estimating the distance. In Figure 10, the orange flags are represented by orange dots and the plants that will be planted within the boundary created by the flags are represented by the green dots. By creating a grid with the orange stakes and flags, the groups will only have to line up with two perpendicular flags to maintain proper spacing during the planting process.

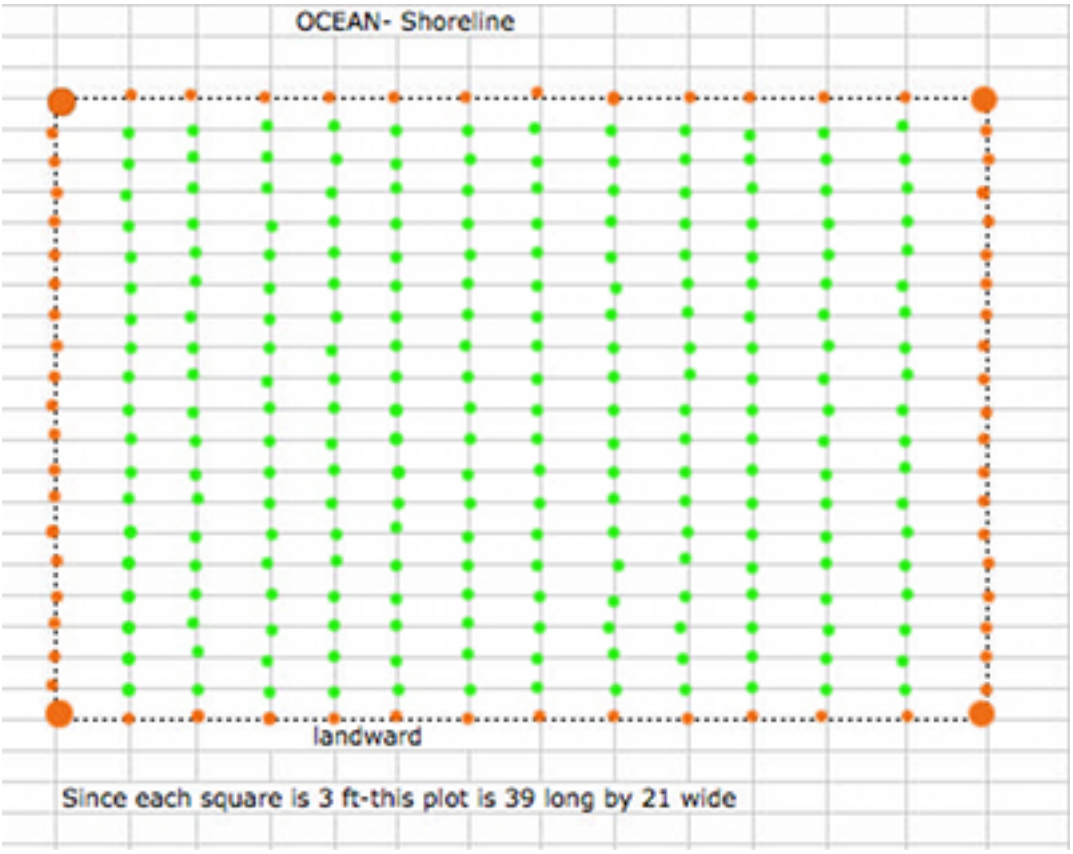

Figure 10. Diagram of planting plots

3. Discuss the group structure and the role of each participant in each group while you demonstrate.
    - Each group will have four or five people

        #1: Digger- To dig a hole with a dibble, simply press it into the ground and rock it back and forth, using your foot to push down. This will make a long, skinny hole. The hole is deep enough when the L-part of the dibble hits the ground (approximately eight inches).

        #2: Fertilizer- Place a pinch of fertilizer (a small amount that fits in between your index-finger and thumb) into the hole.

        #3: Planter- Carefully place the plant into the hole, making sure it stays upright.

        #4: Water: After the plant is in the hole, pour six to eight ounces of the moisture retention product mixed with water into the hole surrounding the root ball before sand is pushed around.

        #5: Last step- Then gently push the sand around the plant and root ball to surround and secure it in the ground. Firmly pack the sand around the stem to make sure the plant is secure in the ground.

4. Assign groups to a station. Go around and help groups that need clarification, and keep them on track. If a group finishes first, ask them to help another group that may be struggling. You may also need to check each group and assist them if they run out of water, fertilizer, plants, etc.
5. On your clipboard, keep track of the plot size, and how many plants get planted within each plot.

6.0 Site and Plant Monitoring

6.1 Site Selection and Random Plots

Due to the linear nature of the shoreline, the entire stretch of beach parallel to the shore can be represented as an invisible line (referred to as a transect since it transects the restoration area) to which random sample points can be identified. To properly select random points within the restoration site, prepare a map of the entire restoration area. Choose randomly select points along the transect or within the restoration area prior to the site visit. A good rule of thumb is to choose approximately one to two points every ¼ acre or ½ mile of restored area. The points selected this first time will need to be revisited each time monitoring is conducted on the site.

Once random points are identified on the map, be sure that the selected points can be easily located on site. The best way to ensure the location of your selected points is by using a GPS unit with Latitude and Longitude coordinates. There are programs to help you identify these coordinates such as Google Earth. If GPS technology is not available, determine the approximate location based on significant landmarks such as houses, streets, or other permanent structures.

6.2 Sampling Gear- Quadrat

At these locations a sampling tool called a quadrat will be used to quantify and collect data about the site. Quadrats have proven useful in scientific research when studying vegetation and quantifying trends. The quadrat is a simple, useful sampling tool made of four 5-foot long PVC pipes with corner caps to create a hollow squared structure (Figure 11). This simple and cost effective tool will reveal how much the plants have grown over a certain amount of time, which is referred to as percent cover. The percent cover of native plant vegetation will adequately determine the success of the project as more vegetation grows and covers the bare areas. Using these same sampling points each time that data is recorded will allow comparisons to be made to previous data and show how much growth has occurred between sampling dates. Besides percent cover, quadrats can be used to determine species diversity, or the number of different species present on the restored site. A healthy dune system should have a high species diversity.

To use the quadrat to collect data, locate the sample plots predetermined on the map and within a 30 foot radius randomly select a place along the transect to place the quadrat on the ground. This can be done by lightly tossing the quadrat within the sample area.

Figure 11 A quadrat within a sample plot area

6.3 Data Collection

The data collection method used for this grant will be the visual cover estimate technique. To do this, the observer will stand over the quadrat and visually estimate the percent cover of the species present within the quadrat. The total coverage inside the quadrat must equal 100%, so carefully determine the coverage that may overlap and always include the vegetation that is touching and located inside the quadrat. If there is an area with no plants, it is considered bare and should be recorded as bare, or 0% coverage. Any vegetation that is touching the quadrat, but is outside the area will not be counted. A good rule of thumb is if the base of the stem where the plant emerges from the ground is within the sample area, then count that species in your data collection. Below, Figure 12 shows a sample of the data to be collected during monitoring.

Follet's Island		Year 1 monitoring	
Date	Plot #	% vegetation cover	% bare
5.30.12	Q 1	60%	40%
5.30.12	Q 2	40%	60%
5.30.12	Q 3	55%	45%
5.30.12	Q 4	60%	40%
5.30.12	Q 5	50%	50%
5.30.12	Q 6	55%	45%
5.30.12	Q 7	60%	40%
5.30.12	Q 8	45%	55%
5.30.12	Q 9	45%	55%
5.30.12	Q 10	85%	15%
	Total Average		**55%**

Figure 12 A Datasheet Sample for data collection

6.4 Site Photography

Photographs of each site and of each quadrat sample point should be taken. A photo of the general area will show the overall health of the area surrounding the sample plot and will reflect the data collected during the monitoring activities. Having pictures of each plot and the surrounding plots can be extremely useful in referencing past sampling totals, in identifying unknown plant species, or isolating problematic issues related to overall survivability.

6.5 Analysis of Data

The datasheets prepared for this monitoring protocol allow for the data collection of species diversity and abundance to be recorded for each plot. For this protocol, calculate the sum of the percent coverage values for each quadrat and then divide the sum but the total area coverage within each quadrat. For example, we will accept that each quadrat has a 100% coverage total, therefore any percent coverage from the vegetation will be divided by or subtracted from the original coverage total and any remaining coverage without vegetation will be considered as bare ground. The percent coverage for each species and bare ground should equal 100%.

6.6 Reporting

The reporting format has already been prepared and will include the following information: 1) history of the project, 2) site and location descriptions, 3) target species for the project, 4) analysis of data collected, and 5) results of projects success based on the analysis. Site photography will also be included to further support the accuracies of the researcher and substantiate their findings. The purpose of reporting is to document data for each monitoring site visit so that growth rates can be compared and the successes or failures of the project can be identified.

7.0 Laws and Regulations

Sand dunes are areas protected and covered by certain coastal laws and regulations. Below is a summary of these regulations:

Natural Resources Code

Title 2. Public Domain

Subtitle E. Beaches and Dunes

Chapter 63. Dunes

Subchapter A: *General Provisions*

Sec. 63.001. Finding of fact. The legislature finds and declares:

1 that the mainland gulf shoreline, barrier islands, and peninsulas of this state contain a significant portion of the state's human, natural, and recreational resources;

2 that these areas are and historically have been wholly or in part protected from the action of the water of the Gulf of Mexico and storms on the Gulf by a system of vegetated and vegetated sand dunes that provide a protective barrier for adjacent land and inland water and land against the action of sand, wind, and water;

3 that certain persons have from time to time modified or destroyed the effectiveness of the protective barriers and caused environmental damage in the process of developing the shoreline for various purposes;

4 that the operation of recreational vehicles and other activities over these dunes have destroyed the natural vegetation on them;

5 that these practices constitute serious threats to the safety of adjacent properties, to public highways, to the taxable basis of adjacent property and constitute a real danger to natural resources and to the health, safety, and welfare of persons living, visiting, or sojourning in the area;

6 that it is necessary to protect these dunes as provided in this chapter because stabilized, vegetated dunes offer the best natural defense against storms and are areas of significant biological diversity;

7 that vegetated stabilized dunes help preserve state-owned beaches and shores by protecting against erosion of the shoreline; and

8 that different areas of the coast are characterized by dunes of various types and values, all of which should be afforded protection.

Subchapter C: *Permits*

Sec. 63.057. Permit for certain activity

(a) No permit may be issued that allows the operation of a recreational vehicle on a sand dune seaward of the dune protection line.

(b) No permit may be issued that allows any activity in a critical dune area inconsistent with rules promulgated by the commissioner for protection of critical dune areas.

Subchapter D: *Prohibitions*

Sec. 63.091. Conduct Prohibited. Unless a permit is properly issued authorizing the conduct, no person may damage, destroy, or remove a sand dune or portion of a sand dune seaward of a dune protection line or within a critical dune area or kill, destroy, or remove in any manner any vegetation growing on a sand dune seaward of a dune protection line or within a critical dune area.

Sec. 63.093. *Prohibited operation of recreational vehicles:*

No person may operate a recreational vehicle on a sand dune seaward of the dune protection line in any county in which a dune protection line has been established.

Subchapter G. Penalties

Sec. 63.181. *Enforcement*

(a) Any county attorney, district attorney, or criminal district attorney, or the attorney general at the request of the commissioner, shall file in a district court of Travis County or in the county in which the violation occurred a suit to obtain either a temporary or permanent court order or injunction to prohibit and remedy any violation of this chapter or any rule, permit, or order under this chapter and to collect damages to natural resources injured by the violation and to recover civil penalties.

(b) A person who violates this chapter or any rule, permit, or order under this chapter is liable for a civil penalty of not less than $50 nor more than $2,000. Each day that a violation occurs or continues constitutes a separate offense. A violation of Section 63.091 is considered to be a continuing violation from the date of the initial unauthorized conduct until the earlier of:

(1) the date on which a proper permit is issued authorizing the conduct; or

(2) the date on which restoration of dunes or dune vegetation damaged by the violation is completed.

8.0 References

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