Matagorda Bay Seagrass Restoration Pilot Study

Project of the
Coastal Management Program
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Table of Contents

This final report includes Outlines for Phase II as well as work done during Phase I, so that Phase II is the phase chiefly devoted to the restoration action, with its monitoring. Thus, there will be tables without the precise monitoring data and statistics since that is to be carried out in Phase II The general concepts and much background material has been worked out in Phase I with coastal boundary survey, permits, site set-ups, videos, and background research.

III. Seagrass monitoring plan (also in the Final Report CMP 23-020-013-D607 under "Methods")

IV. Permits

- GLO Permit Application
- Texas Parks and Wildlife Division (TPWD): letter of permission for donor material
- US Army Corps of Engineers: letter of permission SWG-2013

V. Table of Texas CCAC agencies interested in various aspects of Seagrass Restoration Pilot sites in Matagorda Bay. Background on Coastal Coordination Advisory Committee interest in CMP 23-020-013-D607

VI. Links to seagrass videos for Coastal Coordinating Advisory Committee (CCAC) members to use for public outreach (to be used by the websites of each agency needing outreach of seagrass to their publics). One of the videos to be used for consultant firms of CCAC members when they are required by permits to restore seagrass.

- Public Outreach Video about services of seagrass to the Texas public.
- Public Outreach video about success of Seagrass Restoration in Texas and elsewhere in subtropics and tropics.
- Public Outreach and to consultants to Texas government on "Restoration of Seagrass in Texas"

EXECUTIVE SUMMARY

Matagorda Bay is the third largest of Texas's Bays. It has experienced the least investigation of its estuarine food webs, particularly the subtidal vegetation, seagrass categorized as SAV (Submerged Aquatic Vegetation). Pulich's (1998) study of seagrass in all Texas estuaries recognized a large seagrass loss and degradation throughout the estuaries with Matagorda Bay only retaining less than 2% of its original over 125,000 acres of seagrass. Proceeding rapidly is human development growth particularly from the north (Houston, Texas City, Galveston) but also from the south (Corpus Christi, Mustang and Padre islands, Rockport) into the vacant land (agricultural and environmental areas) of Matagorda Bay requiring much additional infrastructure and housing stock (including 2nd homes). Additionally, Matagorda Bay is the only large Bay with no investigation of seagrass restoration (Review of Texas seagrass restoration found in Thorhaug, A, Belaire C.et al.,2020). The services seagrass provides are obviously diminished as seagrass was degraded: 1.) resilience of shorelines and stability of nearshore sediments; 2.) fish nurseries, food-web for endangered species nutrition (marine turtles and shorebirds); 3.) water clarity; 4.) mineral cycling, including sequestration. The increasing recreational and industrial usage of the bay would benefit greatly from an addition of substantial seagrass just as Galveston Bay has benefited from marsh additions. The question of what coastal sites is most amenable to seagrass restoration and what services return during restoration lies in a complex array of factors controlling various bay segments but leading to success in restoring the dominant species *Halodule wrightii* with its understory *of Halophila engelmanii*. That is the issue we investigate to have a scientific background for future actions. The array of 6 SAV species are chiefly found near passes to the Gulf of Mexico (GOM) are however, not found in the western portion of Texas bays where large rivers enter. Some types of sites appear more suitable for restoration, but these factors are yet to be defined.

During this project we have found a large number of publicly used areas which could potentially be subject to study for seagrass restoration. From these we have chosen 10 then during Phase I reduced to 8 (due to previously unknown future infrastructure projects occurring at 2 of the ten) which could serve the public far better than the presently barren sediments, these 8 necessarily appeared potentially successful for restoration. The permit from the Texas Parks and Wildlife Division, controlling the "taking "of plants to be restored at the pilot sites have been granted for a time in the several year futures to carry out the plating. The US Army Corps of Engineers has granted the project Federal permits. We have carried out Coastal Boundary Surveys of all 8 sites, registered with the Counties and submitted to the TGLO offices of leasing and of coastal surveys. Additionally, we have created aerial photos, sketches of each site's planting design, navigational charts with demarked sites, and ground photos. The methods we will employ for planting have been tested and found successful in our earlier investigations of large-scale seagrass plantings of nearly 70 acres in Laguna Madre (Thorhaug, 2001) and a series of large plots in Corpus Christi Bay, Galveston, and Aransas/St. Charles Bays (Thorhaug, Schwarz, Berlyn 2017). These methods we and others have employed around the worlds' tropics (Thorhaug et al, 1985; Thorhaug and Cruz, 1989; Thorhaug et al. 2022). The seagrass pilot monitoring will consist (unlike most seagrass

restoration studies) in examining the assembly of seagrass services as the developing restored seagrass areas change and mature from barren sediment to a seagrass bed over time: 1.) sediment changes (sediment composition, grain size); 2.) the key fisheries' animals recolonizing the seagrass; 3.) the increasing endangered and listed species of marine turtles, and shorebirds; 4.) the obvious physico-chemical factors of energetics, light, turbidity, depth, salinity, and depth. These will be statistically compared to barren plots at each pilot site, both measured from time zero, both using 7 monitoring replicates per time period. This also will be totally new information, because there is no assurance that all services will proceed or will stabilize at the same values in all types of restored sites. Some sites may offer a preponderance of fish nurseries, others may be extremely valuable sediment and shoreline stabilizers. Additionally, various CCAC partner agencies have differing interests and goals for the Matagorda Bay system as they have for other Bays. We have attempted to take these CCAC needs into account in our Phase I and in Phase II products. We have and will intend to present each agency with a portion of our new information to enhance their goals. After obtaining the new scientific data our goal is a Matagorda Bay Plan to enhance the seagrass services in various Matagorda Bay segments. This will be devised at the end of phase II when an array of areas likely for restoration success can be more scientifically determined, then their services will be predicted from this data. Foremost, the available areas with services with prime focus on shoreline and subtidal resilience, but also fish nurseries, and endangered species will be outlined. This predictive data can be applied to multiple Texas Bays and estuaries in principle. These "service-oriented sites" will be compared and selected as Tier 1 for a Matagorda Bay PLAN only when coupled with measured criteria for successful seagrass restoration. Both are needed for completing this goal: service to the public and successful planting. This project can define each. The recommendations of placing large scale mitigation within this array of publicly useful sites will be made.

A large amount of material has been assembled for this project which will be presented to various groups of the CCAC committee in direct presentations over zoom as well as in videos. One CCAC needed was education of staff and their outreach constituency about seagrasses, and seagrass restoration, especially agencies with staff turnover. The videos most requested are appended as the following: 1.) The services seagrass provides for coastal Texas; 2.) How to restore Seagrass; 3.) The successful seagrass restorations in Texas and elsewhere (information to substantiate this a Matagorda Bay Seagrass restoration Plan).

The literature review and site selection and overview lead us to a conclusion that areas in Matagorda Bay will be amenable to seagrass restoration and will deliver public benefits far exceeding the sites' present state (as barren sediment) after successful restoration. This was demonstrated in large scale by us in the area containing the bulk of Texas seagrasses, which is Laguna Madre (Thorhaug, 2001; Thorhaug et al 2020). For example, Predator Island, scraped down from the 55-year-old dredge island acted as a sediment stabilizer, endangered species rookery nutritional source, and a fisheries nursery. We also demonstrated excellent success this for Galveston, Corpus Christi, and Aransas/St. Charles Bay (see video seagrass restoration history). Partial goals of various CCAC partners can be satisfied for Matagorda Bay, the least intensely studied large bay in Texas, by activity of seagrass restoration. An example for CCAC goals is the "greening" of Texas DOT coastal structures of causeways and bridge abutments by utilizing these seagrass restoration techniques on subtidal sides of the projects such as the bridge from Port Lavaca to Port Comfort and others on Highway 35 (e.g. Lamar to Rockport). Another example is restoring fish nurseries in former fishing areas once rich shrimp and blue crabs (East Matagorda Bay & Palacios area). A third is restoring sites of seagrass food-webs now degraded for endangered Whooping Cranes or Kemp Ridley turtles. The Texas Sea Grant is co-operating in terms of locating likely turtle feeding habitat locations. We recognized Whooping Cranes feeding on blue crabs at one of our past restored sites (St. Charles Bay).

In summary, the pressing need for the additional resource of seagrass, created by restoration, is recognized due to Matagorda Bay losing 98% of its seagrass. However, presently there is no scientific basis on which to attempt this in large scale in the complex array of factors found throughout Matagorda Bay, although carefully selected sites in Laguna Madre, Corpus Christi, Galveston, and Aransas Bays have had seagrass restored by experts. An array of services, many meetings partial goals of the CCAC agencies could be re-established by seagrass restoration. This pilot study attempts to obtain information on both seagrass success in an array of differing sites and services provided in these differing sites. Educational videos are produced for CCAC agencies, their outreach efforts, and their staff and subcontractors (e.g. TDOT). A large-scale Plan for future action will be derived from this information created by this project.

I. INTRODUCTION

A. HISTORY OF MATAGORDA BAY SEAGRASS

The shoreline and navigational channel activities plus various riverine inputs and effluents from Industries and commerce along the shorelines of Matagorda Bay have diminished the seagrass resource for the citizens of Texas. This destructive loss of seagrass is unknown to them because seagrass is submerged and thus generally invisible. "When a resource is not visible, it is not valued." Pavon Shukhdev, World Wildlife Fund President. "Pollution is nothing but the resources we are not harvesting. We allow our resources to disperse because we have been ignorant of their value." Buckminster Fuller. These have been the contributing factors to the loss of societal consciousness that might otherwise protect seagrass resources in Matagorda Bay.

Seagrasses require light for survival and growth. Turbidity caused by unconsolidated sediment stirred by winds greatly diminishes light to the seagrasses even in shallow water. This can degrade or kill large areas of seagrass. The industrial growth in Texas over the last century has created the need for deep and continual maintenance dredging of navigational channels so that vessels can move from one embayment to the next, and the necessity of channels to ports and marinas within the bays. Unconsolidated sediments produced by this activity plus the action of spreading navigational channel dredged material into marshes (enhancement of marshes) subsequently washes this sediment into the Texas bays by rainstorms, creating more turbidity. Activities which fill shorelines along urbanized and industrialized portions of the bays have been very negative for seagrass. Rivers bringing upland soil from agriculture and urban centers also contribute to unconsolidated sediment, further adding to turbidity. Pulich (1998) estimated that almost 98% of Matagorda Bay's seagrass had been lost and then contained only around 3000 acres. Pulich compared Matagorda Bay to the hundreds of thousands of acres of seagrass in Laguna Madre. The Laguna had very light industrialization, and little human settlement (only at the two far ends). The chief disruption in the Laguna Madre was the intracoastal navigational channel. It has few rivers, except in the far south (the Rio Grande), putting fresh water and contamination into the lagoon.

B.) A REVIEW OF THE VALUE OF SERVICES SEAGRASS PROVIDE TO TEXAS

The services seagrass provides to the people of Texas are excellent, but currently diminished in Matagorda Bay due to the loss of the major part of the seagrass resource. This is a reversible situation. When the seagrass has been degraded or killed the service is not available. These services have clearly been shown in our previous studies and in our previous Texas restoration field work as well as Florida and Jamaica field work and in our work to define these pilot test plots include the following:

1.) Resilience and stability of shorelines. Seagrass roots and rhizomes create an "anchor", consolidating sediments, while seagrass blades dampen wave action on the shorelines. Seagrass blades slow the speed of water, so that particles fall through the seagrass and are trapped in the sediment. Example is Galveston Bay San Luis Pass where all the seagrass remained through Hurricane Harvey and several other hurricanes, although the marshes on the shoreline were decimated and disappeared.
2.) Water Clarity. A corollary result of seagrass reducing wave action is clearer water over seagrass beds. The sediment trapped by seagrass is taken out of the water column. Clear water is attractive, and people prefer to carry out water sports activities in clearer water. Example here is Predator Island restoration which was always so clear that aerial photo continually defined the quantity of seagrass at the almost 15-acre site over 25 years.
3.) Ecosystem habitat. Animals that are harvested in both sport and commercial fisheries use seagrass as a primary nursery habitat and a place to hunt for their own food. A complex food web supporting these animals is established, including the detritus feeders and associated micro-organisms. Example here is Aransas/St Charles Bays where large numbers of blue crabs, substantial pink and white shrimp with fish juveniles were consistently found over 8 years.
4.) Endangered species use of seagrass. Marine turtles directly feed on seagrass, as does the manatees. Some endangered shore birds feed chiefly on products of the seagrass such as Whooping Cranes feeding on blue crabs, and the Louisiana Tricolored Heron feeding on shrimp. Example, San Luis Pass, Galveston Bay where marine turtles fed along with

multiple shorebirds, particularly at periods of low tides. (Schwarz, Thorhaug and Berlyn, 2017)

5.) Mineral recycling. From sequestering a series of trace metals into the sediment, and Carbon compounds seagrass metabolize a series of compounds some of which are used as growth metabolites such as dissolve carbon and nitrogen and others are incorporated into the sediment under seagrass by detritus or root exudation.

C.) LESSONS LEARNED IN PREVIOUS SEAGRASS RESTORATION AND THIS PILOT INVESTIGATION

1.) Growth and Degradation. The restoration of seagrass pilots coupled with previous seagrass restoration work within Texas bays, elsewhere in the Gulf of Mexico (GOM) and in the subtropics and tropics has shown that much of seagrass growth is vegetative lateral spread of rhizomes around centers of newly planted seagrass (Van Katwijk, Thorhaug et al., 2016). In natural beds, as long as the roots and rhizomes in the center of the meadows are intact after a windstorm, then growth resumes and lateral spread continues. But if intolerable environmental factors occur, such as poisons or loss of light through turbidity, then the seagrass degrades and disappears in both natural and restored seagrass. The species *Halodule wrightii* mostly grows by lateral rhizomal growth although it seeds occasionally dependent on location, seasons, and other factors. No investigator has reported massive seeding being a causal factor in natural regeneration.

2.) Texas estuaries and bays tend to have *Halodule wrightii* as a dominant species, and in some areas, it occurs with a *Halophila engelmanii* as an understory. There are a few areas generally near passes with good flushing of GOM waters, where *Thalassia testudinum* and *Syringodium filiforme* appear. Once successfully restored, seagrass rapidly expands laterally to cover increasingly large areas. Hand planting is the most successful method attempted in Texas (Thorhaug, 2001). *Halodule wrightii* is the best species to concentrate on restoring, since it is naturally dominant and its success has been repeated in multiple estuaries from Galveston Bay (San Luis Pass) to Laguna Madre (Predator Island, Thorhaug, Belaire et al, 2020) and elsewhere (see Belaire, xxx and Thorhaug et al. (2020).

3.) The methods to be used in this pilot project include the key activity of selecting a site location. This selection process needs to integrate wave energetics, salinity variation, light values, and anthropogenic shoreline activities. In our opinion, ranking potentially successful restoration sites by user benefits to the human public (water-sports areas, fishing areas, or other recreational areas), or for infrastructure (bridges, causeways, coastal roads, ports, marinas) would be a basic priority beyond the essential criterion of a potential for survival. Applying the best techniques in wisely chosen patterns within the light range, would be the next step. To monitor these plantings periodically over a longer time period will benefit later restoration by analyzing the information of what best techniques are successful.

4.) Public education is an important part of this project. People desire the services provided by seagrass, but if there is a low level of public understanding of the role of seagrass in providing those services, the project will be less successful. CCAC members will receive material to acquaint their publics with seagrass by the incorporation of the short videos we will produce. The process of public education about the services of seagrass can hopefully be a part of the outreach by various government agencies (which we will provide).

D.OPPORTUNITIES AND CHALLENGES FOR THE FUTURE OF SEAGRASS FOR TEXAS COASTS

This project has exposed several significant future opportunities. First, the question, "Why tolerate a degraded bay of this size and importance when so much to enhance Texas seagrass resources can be done?" Why not initiate an important program to regenerate seagrass in Matagorda Bay?

Second question is "Why does the State of Texas, which owns the bottomlands and resources, not begin by designating seagrass mitigation banks, wherein those projects needing seagrass mitigation could "book-keep" against a set of restored seagrasses in a mitigation bank placed into areas of public service? In other words, "Why does the State of Texas tolerate small insignificant restoration attempts when large-scale, meaningful, and successful seagrass restoration based on renewing major seagrass services in locations of benefit to the public could substitute? "

A third question is, "How much seagrass restoration information learned for Matagorda Bay is applicable to other Texas Bays, especially the large bays with vigorous exchange of GOM water through passes? "The relevant bays are Galveston, Corpus Christi, and the northern and southern ends of the Laguna Madre. However, the Laguna Madre has more than 70% of seagrass in Texas, so the need to restore the Laguna Madre is not as great as other major bays. Two small bays, Red Fish and Aransas Bays appear amenable to restoration. The embayments to the west of the major bays appear less likely candidates for restoration due to extensive rivers drainage with slow flushing, plus periodic windstorm events. The submerged aquatic macro-vascular plants need to be investigated in these low salinity areas.

Challenges of Matagorda Bay:

1. The unconsolidated sediment from navigational channel dredging, placement of dredge fill into marshes or any other location in the bay, non-management of eroding shorelines, and soil coming into the bay from rivers is creating a far more turbid bay, than if these sediment particles were well managed. Resource management agencies should plan management of such turbidity-inducing sources. Particularly the unconsolidated sediment placed on wetlands are during storm periods likely to end up in the subtidal waters. As are dredging unconsolidated sediments for channels. The seagrass needs protection from these.

2. Many shorelines are not adequately stabilized upland from further erosion. Green Shorelines with stabilization incorporating living habitat should be highly considered by resource management agencies, while passing information on to private land owners so they do not lose valuable land. River mouths where riparian habitat has been removed or degraded should be also focused on in this shoreline evaluation for stability. Infrastructure and commercial/industrial shoreline projects should stabilize with "green" shoreline stabilization including seagrass on the Bay side of the intertidal zone. The Dept of Transportation should team with TGLO and TFWD to make multiple models of acceptable "green" shoreline stabilization so that this is a requirement not an alternative choice for vendors of coastal roads, causeways, bridges. Maintenance of aging DOT structures should also have these green alternatives for re-enforcing the eroding sides of transportation structures.

3. New projects with endangered, and listed species habitat as the goal from islands (either already in place such as dredge islands, or newly constructed islands) or points of land eroding should have buffer structures to stabilize sediment from eroding away especially during heavy storms. A well-known examples of **non-focus** on causing erosion are the artificial marsh islands off Goose-Island and the kayaking islands created at the northwest side of the causeway between Corpus Christi Bay and Nueces Bay which caused damage to seagrass.

E. KEY DATA SUMMARIZED FROM THIS INVESTIGATION:

The data is gathered from the eight sites is displayed below in several parts: The physical-chemical evaluation of each site; sediment data; the biological recolonization of each site as the seagrass grew; and the success of density and lateral spatial growth at each site.

PHYSICAL CHEMICAL DATA:

(See Appendix II for monitoring data at each period per site)

Site Mean	**Salinity**	**Temperature**	**Turbidity**	**Light**	**Depth**	**Species**	**Restoration success**	**GIS**
Raspberry						Hw		
Magnolia						Hw		
Sea Drift						Hw		
Lamar						Hw		
Keller						Hw		
Palacios						Hw		
Oyster						Hw		
Hog Island						Hw		

SEDIMENT DATA*: Summary of Geological, sedimentary data at each site:*

Summary of pilot sites' sediment chemistry over restoration planting period 2025 to 2026 Matagorda Bay, Texas: 7 replicates taken per site at each of 4 monitoring periods before & after restoration.

Site Mean	Type Sediment	Silicon	Calcium	Clay	Energy Level	Barren Control	Seagrass Pilot	Fauna	GIS
Raspberry									
Magnolia									
Sea Drift									
Lamar									
Keller Kayak									
Palacios									
Oyster Bay									
Hog Island									
Total									

Biological Recolonization: ***Key species Summary increase over 12 months***: post-restoration of *Halodule wrightii* plugs. Summary increase over 12 months from restoration 2025 spring to spring 2026: Push net sampled over 3.3m on bottom community in restored seagrass per site 7 replicates.

Site	Shrimp Pink	Shrimp White	Shrimp Gray	Shrimp Caridean	Blue Crab	Fish Flounder	Red Drum	Trout	Other Species
Raspberry									
Magnolia									
Sea Drift									
Lamar									
Keller Kayak									
Palacios									
Oyster Bay									
Hog Island									
Total change									

SUCCESS IN DENSITY AND LATERAL GROWTH: ***Summary over 12 months.***

Site	Species	Lateral Growth	Blade Density	Coalescence	GIS
Raspberry					
Magnolia					
Sea Drift					
Lamar					
Keller Kayak					
Palacios					

Oyster Bay					
Hog Island					
Mean					

II. METHODS (see section appendix restoration methodology, monitoring methodology) (Thorhaug et al., 2020)

DONOR SITE METHODOLOGY: *(See appendix XI for aerials of sites, sketches of sites, and navigation chart locations of sites) (Thorhaug et al, 2020)*

1.) Choose a site proximate to the site being restored so that transport and physical-chemical adaptations are simplified.

2.) Use PVC poles or other non-intrusive markers to indicate where areas of donation are occurring.

3.) In all phases of donor site activity, attempt to be as non-intrusive as possible, leaving most of donor area intact.

4.) As is the practice in other states and nations, use parts of previously restored areas as donor sites.

5.) In all cases, work from the outer edges into the donor bed, so that disturbance to the donor site is minimized.

6.) Plug removal should be minimized to 1 plug per square yard.

7.) Workers in the donor site should look at the health of the sample taken (all brown blades, or obvious decay would indicate lesser health).

8.) Donor plugs should be one species or a clear mixture of several species as decided beforehand (*Halodule* with understory of *Halophila engelmanii*, as example).

9.) What is harvested from the donor bed should be planted before the end of day.

10.) The director of the operations should be aware of adverse weather conditions to cease operations if necessary (lightning, hurricanes, etc.).

11.) The positive side of spring planting is that plants get a chance to root prior to hurricanes of fall storms. The negative side is heat of summer above the plantings exceeding 96F. The positive side of fall plantings is that the hurricane threats mostly occur mid-August, so this disruption has been avoided. The negative feature is that the fall cold spell may slow the growth of binding of roots to sediment.

TRANSPORT OF DONOR MATERIAL METHODOLOGY:

1.) The transport may require a separate set of workers, unless it is very close.
2.) The samples should remain moist during transport.
3.) Summer heat above 90-95^{o} F (32-35^{0} C) should be avoided if the samples must be taken from the water.
4.) The samples should be handled with care.

PLANTING METHODOLOGY:

DEPTH: Van Katwijk et al. (2016) conducted a review of almost 2000 seagrass restoration efforts over five continents. The one factor most clearly seen was that intertidal planting was far less successful than that in moderately shallow to medium water, which in turn is dependent on light penetration. It means that in the relatively turbid waters of the Texas coast, planting is restricted to shallow water.

SPATIAL: If the planting is at smaller intervals, it is more likely a seagrass bed without bare gaps emerges more rapidly. It is possible to plant the same amount at wider intervals in order to cover a larger area. This investigation attempted to see if the results at wider spacing was similar in seagrass blade density, indicating the potential for wider spacings than normally required in permits.

CONFIGURATION OF PLANTING**:** A group of very experienced and knowledgeable seagrass be simulated in restoration configurations investigators in the Netherlands, (Tjeed et al., 2023) has recommended that natural configurations of regrowth rather than straight rows presently normally planted.

ANCHORS' USEAGE**:** Various types of anchors have been devised to hold samples in the sediment, ranging from wood sticks, metal rebar, frames to which samples are tied, and plastic stakes. Generally, biodegradable objects are preferable over nonbiodegradable objects. Tests should proceed planting to make sure the wave energetics are severe enough to the need for anchors (Thorhaug et al.2022). Many studies not using anchors have been successful. Anchors create another step-in planting and thus increase time of planting.

PLANT PARTS USED:

1.) ***Seeds****: Halodule wrightii* produces seeds very intermittently in Texas. Since seed sources are unreliable, restoration efforts with seed have not been conducted in Texas in large scale. Restoration by seeding *Zostera marina* is successful in Chesapeake Bay, because this species of cool temperate waters is a prolific seed producer and 30 years of research of harvesting, planting and dormancy methods have occurred (Orth et al 20xx).

2.) ***Turions or sprigs***: A turion is an overwintering bud that some aquatic plants produce. A sprig is a section of rhizome that includes meristematic tissue and multiple blades. Bunches of turions have been planted at a series of areas by Belaire (199x, ….), Sheridan et al. (1999) with little success, and Thorhaug (1985), Thorhaug et al. (1985) with moderate success. These formed a large part of planting *Thalassia* in Biscayne Bay and other areas (Thorhaug, 1985; Thorhaug er al., 1985; Thorhaug and Cruz, 1987). Generally, turions or sprigs are planted with equal or less success than plugs and more success than seeds, dependent on species.

3.) ***Plugs***: Many of the pilot studies throughout Texas have used plugs (Thorhaug, 2001; Thorhaug and Schwarz, 2016; Thorhaug, Belaire et al., 2020). Early work of scattered few plugs without controls to compare to was found successful, so this technique has been used for subtropical and tropical restorations over a 40-year period (Thorhaug, 1985, 1987; Thorhaug, Miller et al., 1985; Thorhaug and Cruz, 1987; Belaire, 199x; Thorhaug, 2001). This technique includes the plant blades, rhizomes, and sediment as dug by an instrument such as post-hole digger.

PLANTING MANUALLY: A series of large-scale plantings, some by primitive underwater replicas of common farm equipment have occurred. Others which are experimental in nature and do not pretend to be for large scale planting. The important point is that most success to date has occurred from manual planting, and not from any of the more equipment-oriented methods. Thus, we continue to suggest manual planting be most effective for success.

III. MONITORING

A. MONITORING METHODOLOGY (see Appendix XII for details of Monitoring Methodologies)

- Randomness
- The barren-of-seagrass control
- replicates (7)
- Light
- Turbidity
- Sediment
- Salinity
- Key biological species
- Endangered/threatened species
- Seagrass blade length & width, lateral distance from center of planted unit

B. RESULTS

I. SUMMARIES OF RESULTS TABLE: Success of restoration vs. mean value post-restoration of sediment, water clarity, and animal recolonization after 12 months

Site	% sustain	Growth diameter	Height blades	Key animal	Shore birds	Sediment	Water clarity	Depth	Light	Salinity
Raspberry										
Magnolia										
Sea Drift										
Lamar bridge										
Keller Kayak										
Palacios										
Oyster										
Hog Island										
Mean										
Spatial										
Magnolia										
Sea Drift										
Mean										
Configuration										
Magnolia										
Sea Drift										
Mean										

II. PHYSICO-CHEMICAL RESULTS: Summary of Data of Mean value of physico-chemical results compared to success of restoration (Appendix in Phase II will contain raw data per site per monitoring period and statistical analysis).

Site	Salinity	Temperature	Light	Turbidity	Depth	Sediment Comp.	Sediment height	Blade Length	Success %	Species	Energetic Level
Raspberry											
Magnolia											
Sea Drift											
Lamar Bridge											
Keller Kayak											
Palacios											
Oyster											
Hog											
Mean											
Spatial											
Magnolia											
Sea drift											
Mean											
Configuration											
Magnolia											
Sea Drift											

Mean											
Total											

IV. OVERALL PLAN FOR MATAGORDA BAY SEAGRASS RESTORATION:

Public services derived from restoration include primarily the following: shoreline resilience, ecosystem restoration of fishery nurseries, food-web enhancement for endangered species (marine turtles, shorebirds), improved water clarity, and mineral recycling and sequestration. These are the services characterizing seagrass and returning with restoring seagrasses. Below we discuss how to select areas for these categories and then rank them in societal importance. Added to services must be high potential for successful replanting.

Obviously, the presence of seagrass in former decades, coupled with suitable present physico-chemical characteristics of the present surrounding environment are the features to be integrated into the Matagorda Bay Restoration Plan. Choices for sites are the first stage of selection for Tier One and Tier Two sets of sites for an overall plan for Matagorda Bay which need to be run through a selection filter of physico-chemical factors to find the potential for restoration success. Without the needed physico-chemical characteristics, perceived public services alone will not support a establishing a restoration site. Evidence of seagrass inhabiting a site in the past greatly strengthens the ranking of site, if no intolerable condition has been placed on the site (e.g. poisonous chemicals, high turbidity). Satellite images, land survey photos and oral histories provide evidence of past seagrass distribution.

Tier One should have all potential sites with characteristics indicating a successful seagrass physico-chemical restoration and little to no human interference (of the type to degrade restored seagrass). Knowledgeable people should be consulted as to future development plans for that area (infrastructure, industrial, commercial, coastline, etc.). The order of priority would then be the usefulness of the publicly accessible sites to Texans. When assembling a plan some multi-sited array of the above various types of publicly useful services as well as various areas of Matagorda Bay sites need to be considered. There are methods for making these environmental decisions which have previously been discussed. These include the Canadian methods for resources by Manning (19xx), and the more recent discussions for decision-makers by Costanza and de Groot et al. (2017) (https://www.robertcostanza.com/wp-content/uploads/2017/02/1998_J_Costanza_ESvalue.pdf). The filter of where seagrass existed in previous decades and records of man-made built spaces (e.g. dredge islands, navigational channels, etc.) should be placed across the publicly useful criteria to obtain an array of Tier 1 sites. Tier 1 may be influenced by the types of funds available for seagrass restoration. If funds are available for endangered species, then site choices may be modified accordingly. In the process of designing a plan, the inclusion of an array of sites providing multiple services is preferable to sites that focus on single seagrass services. High-risk events such as hurricanes, high winds or chemical spills can all impose setbacks on site restorations.

Tier two sites might be integrated to include a wider definition of types of sites (for example, sites for bird rookeries, or for marine turtles). These have no direct use by humans but may attract tourists for the purpose of wildlife watching. Tourism is a $70 billion business in Texas, a moderate amount compared to 42.4% of the Texas GDP from the energy industry. Nevertheless, tourism is growing in Texas, and Texans themselves regularly visit and use the coastal areas for recreational trips. The Tier Two sites can also include sites which for various factors were not included in the Tier one sites. Included in this are collateral services such as restoring for shoreline resilience and creating fish nurseries.

It is noted here that the ongoing process used for decades in granting seagrass restoration activity in Texas for mitigation by replanting small scale plots does not add up to the same results as a large-scale plan. “Mitigation for taking” sites are chosen by the applicant and fit into no cohesive plan or program but are small or usually insignificant sites designed for the convenience of the applicant and the consultants or employees. If these were incorporated into a rational plan for each Texas Bay area, the State of Texas would be far better off in achieving renewal of their submerged aquatic and marine resources, resulting in collateral enhancement in terms of fish, shellfish, shoreline birds, marine turtles, mammals and other organisms as well as shoreline resilience. We recommend a cohesive, rational total program for each bay. Over time, mitigation funds, government programs, private funding and NGO’s can add to the progress of restoring each bay. The progress made in marshes in Galveston Bay shows an example of the possibilities available.

THE AREAS OF PUBLIC SERVICES MOST LIKELY FOR SUCCESS. There are a series of publicly useful venues where seagrass has been degraded due to direct dredging and filling, channelization, or upriver activities causing change unconducive to seagrass growth (turbidity or salinity). In some cases, such as dredging and maintaining canals, the seagrass were directly killed by dumping sediment. These sites can be recognized by shoreline records dating from the 1930’s land surveys. Sometimes opportunities become available in which human modified areas are conducive for seagrass growth and protection. An example are the dredge islands in the Intracoastal waterway south of JFK causeway in the Laguna Madre, where successful restorations have occurred by purposeful planning around dredge islands making buffers from prevailing winds, and interior channelizations allowing flow into and out of a central concavity. Some of these have been used as rookeries especially for endangered species of shorebirds (Predator Island, Thorhaug 2001). Seagrasses on natural islands near passes to GOM have been shown to be excellent sources of nutrition for marine turtles (Plotkin et al 2017, 2021) indicating artificial islands near passes may also be turtle feeding grounds. The slope and sediment content of the beach area, salinity, water clarity, and patterns of use by humans must be taken into account when formulating a seagrass restoration plan.

THE PRIORITY SITES DISTRIBUTING AMONG VARIOUS SERVICES PROVIDED.

SECOND TIER SITES. Tier Two sites may be comprised of areas which did not present as many opportunities for public services. These types of sites may be comprised of two or three services such as stability and resilience of shoreline and habitat for endangered species as well as having excellent chance for long term survival of seagrass. Tier two is not contemplated for sites with less optimal potential, but simply for fewer services to the public (or fewer people using the site).

THIRD TIER SITES. The third-tier sites can be thought of in two phases. 1.) a single service to the public such as shorebirds habitat, or 2.) experimental studies of factors not covered by our investigation. An example might include best restoration success at salinities continually below 6 parts per thousand of SAV such as *Valiscenaria Americana*.

General considerations:

The large-scale plans should balance the potential success due to planting with the publicly needed useful services of seagrass. If special funds are available for restoring one seagrass service over another, then that service should be emphasized, but not at the peril of no seagrass restoration for other services. The seagrass restoration plan should have long term survival as the objective, which is partially dependent on the energetics of windstorms of fall and winter and hurricanes. The resilience of shorelines is to be balanced against other services and may occur at medium to low energetic sites. The amount and duration of low salinity in the western portions of protected bays with appreciable river input must preclude sites likely to experience more than 12 days at less than16 ppt total salinity, or longer periods below 16 ppt. We recommend that probability of success is higher in the eastern portions of Matagorda Bay than in the western portions due to the salinity tolerances of *Halodule wrightii*. Other species found in western areas near passes are *Thalassia testudinum* and *Syrigodium filiforme.* These have been successfully restored where small excursions for short times of low salinity occur (Thorhaug, 1985, Thorhaug et al 1985; Thorhaug, 1987; Thorhaug and Cruz, 1987 (Note: other Texas bays have either superior flushing rates, or less proportional freshwater input than Matagorda Bay. Laguna Madre, with abundant seagrass, is such an example.

V. CONCLUSIONS:

1. A Plan for Matagorda Bay seagrass regeneration is being created and described in this document and the subsequent documents for Phase II. Parts of this plan are designated as appropriate for other Texas bays and estuaries and described as to where these other bays and estuaries could be restored.

2. Seagrass restoration using ***Halodule wrightii*** with understory of ***Halophila engelmanii*** in Texas is successfully supported by conditions where salinities are above 24 ppt, light is at least 40% of ambient surface light, wave energetics are moderate to low, and turbidity allows more

than 25% of surface light at 6 inches from bottom. The texture classes for sediments best suited for restoring seagrass appear to be loam, sandy clay loam and sandy loam.

3. **Collateral effects of seagrass restoration on animal communities.** Substantial juvenile animals returned to seagrass restoration areas as blade density and the areal extent of the planted units increased laterally. This had not been documented in Texas previously but was documented in Florida (McLaughlin et al., 1983), Virginia (Orth et al., 198x) and elsewhere. This increase in juvenile benthic animal was highly significant statistically compared to nearby unrestored proximate barren controls. Blue crabs (*Callinectes sapidus*), several commercial shrimp species (*Penaus*), and several commercial and sport fish including flounder, mullet, and red fish were especially abundant in early restored seagrass. All of these recolonized rapidly within the first six months after planting, and continued to increase for the first (Thorhaug, 2001; Thorhaug and Schwarz, 2017). Other animals, comprising part of the food web, were prevalent in restored seagrass included schools of nursery years thereafter. This same pattern was found in Galveston Bay and Laguna Madrefishes such as mullet, a series of "grass" shrimp, other crabs, and other invertebrates. The shorebirds, including endangered and listed species were attracted to these animals, especially as shallows occurred where the intertidal "wrack" of marine debris including seagrass blades washed into the intertidal zone.
4. **Resilience and stability** of substrate below the intertidal zone increased by sediment accumulation and compaction by seagrass rhizomes and roots occurred at x seagrass restoration sites of the 8 pilot sites which results differed statistically from their nearby barren control sites. These barren control sites were not similarly stabilized. This evident change occurred over this monitoring period of 9 months to xx of the 8 sites.
5. **The best planting design for success** was at x ft unit intervals which grew laterally to xxft in yy months. The best planting design for cost-effective planting was at ww ft unit intervals which grew laterally to ss ft in 9 months. The configuration with the combined variables of highest success and most rapid lateral growth was the (star, circle, arrow) design with the "......." design as second. The design to restore seagrasses in "corn-planting rows" evenly spaced across the area did not result in as high a success rate as the "natural" patterns of planting as seen from naturally expanding areas post-degradation activity, such as filling shoreline. When the water was clear and other factors very favorable, rapid regrowth occurred. Then all methods showed good success and lateral growth throughout vacant areas between planted units.

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APPENDICES

I. Longevity and success of restored seagrass in Texas and other regions with literature cited

II. Planting design (also handled in the Final Report CMP 23-020-013-D607 under "Methods" "Restoration Design and Restoration Methods" including site aerials, sketches of sites, and navigational chart site locations)

III. Seagrass monitoring plan (also in the Final Report CMP 23-020-013-D607 under "Methods")

IV. Permits
- GLO Permit Application
- Texas Parks and Wildlife Division (TPWD): letter of permission for donor material
- US Army Corps of Engineers: letter of permission SWG-2013

V. Letters from adjacent shoreline land owners of "No Objection" to CMP -23-020-013-D607 project of pilot restoration of seagrass in the intertidal zone in the vicinity of their property to Matagorda Bay Foundation

VI. Table of Texas CCAC agencies interested in various aspects of Seagrass Restoration Pilot sites in Matagorda Bay. Background on Coastal Coordination Advisory Committee interest in CMP 23-020-013-D607

VII. Links to seagrass videos for Coastal Coordinating Advisory Committee (CCAC) members to use for public outreach (to be used by the websites of each agency needing outreach of seagrass to their publics). One of the videos to be used for consultant firms of CCAC members when they are required by permits to restore seagrass.
- Public Outreach Video about services of seagrass to the Texas public.
- Public Outreach video about success of Seagrass Restoration in Texas and elsewhere in subtropics and tropics.
- Public Outreach and to consultants to Texas government on "Restoration of Seagrass in Texas"

VIII. Close Out Form required by NOAA.

IX. Expenditures - Final CMP Project Budget

I. Longevity and success of restored seagrass in Texas and other regions

Appendix on Seagrass restoration efforts reviewed

There are two basic restoration reviews from which critical background information for Matagorda Bay can be integrated.

1.) **Van Katwijk, M.M., Thorhaug, A. et al. (2016).** Global analysis of seagrass restoration: the importance of large-scale planting. Journal of Applied Ecology 53 (2), 567-578. This is a global review of seagrass restoration which examines over 1750 restoration efforts from tropical to boreal and comes to conclusions that large scale efforts have much higher success rates than small efforts. The publication concludes that the longer term monitoring of restoration is needed to determine success, and concludes that some species have a far higher success rate than other species. In the temperate zone *Zostera marina* is one of successful species, which also is found throughout the world's temperate zones.

Below is a refinement of this global review with tropical/subtropical seagrass restoration results including Texas, Florida, Caribbean, and others.

2.) **Thorhaug et al. (2020). Restoration results of Seagrass restoration efforts in Texas and Gulf of Mexico, Jamaican Estuaries.** This was written as a sub-section of the larger report, so that the tropical and subtropical Atlantic restoration could be compared. A separate publication was written for the south Pacific and Southeast Asia region without the Indian Ocean, which latter water body has little seagrass restoration.

Atlantic Tropical/Subtropical Seagrass Restoration Examples:

A. Results of Texas seagrass restoration:

Seagrass restoration in Texas implemented during the past 25 years is outlined in Tables 1, 2 and 3. The trials show 1,042,669 planted units (PU) for Belaire plus 364,968 PU for Thorhaug (2001) and Thorhaug and Schwarz (2013, 2017). These plantings demonstrate various initial planted-unit survival rates from near 50% to above 90%, dependent on environmental site constraints. In all cases, seagrass was documented growing laterally, creating large meadows. Each of the Belaire/Thorhaug/Schwarz site plantings and results have been objectively examined jointly with State and some selected sites federal inspector monitored additionally. Together Belaire and Thorhaug/Schwarz have planted close to 1 km^2 which expanded into approximately 1.4 km^2 from the commencement of these efforts. These restorations were government certified, all examined State and most by several by Federal agencies granting mitigation permits. These individual restorations (especially Thorhaug/Belaire) survived the first year approximately 65-95% remaining of the original planted units (Texas mean survival of Planted units was Thorhaug=75.8%, Belaire=64.5%) as inspected and certified by government scientists monitoring the restorations (monitoring after 60 d and then monitored again after 1 y, wherein the resource agency criteria was 50% sustainable).

"Throughout these decades, the restorations tolerated repeated naturally-occurring intense events including tornadoes and hurricanes. Physiological results show species tolerances to anthropological variables to differ (Thorhaug and Marcus 1981; Thorhaug and Booker 1986, Thorhaug et al.1991). For example, natural populations of *Halodule* tolerated an existing series of pollutants and extremes of natural environmental variables more successfully than the *Syringodium* populations found in more tropical estuaries such as Laguna Madre (Thorhaug et al, 2015; Thorhaug and Marcus, 1981; Thorhaug and Booker, 1986). Several *Halophila* species tolerated large salinity variations and also tolerated large light intensity variations and were found on upper sides of anthropogenically-deepened channels (Thorhaug, 2001). The majority of Texas restored sites persisted over time including some withexpansion into adjacent bare bottoms as discussed in the individual publications cited for various locations. (Table 1). The largest percentage of the Texas restoration work was done by Belaire and Thorhaug and Schwarz (Tables 1, 2 and 3), and secondly by Carangelo and Maristany et al (2018) (Table 1). Historically, the first Texas seagrass restorations were carried out by Carangelo with Oppenheimer in the Corpus Christi and Laguna Madre areas using 415 sods and plugs planted chiefly of *Halodule wrightii* (Table 1). A history of Texas restoration is given in Table 1. Seagrass mitigation throughout the USA became a commonplace governmental requirement for infrastructure and private sector commerce estuarine activities including industrial spills and vessel accidents for “takings” as carried out by Belaire (1990 to 2010 in Table 2) and Thorhaug’s Laguna Madre large scale project commencing testing in 1993 (Thorhaug, 2001) (Table 3)**. T**horhaug’s first group of test plots occurred in the early parts of the planning process of Fina Gas and Oil Laguna Madre project (Table 1). Thorhaug‘s test sites in various areas, defined clearly which species and techniques would sustain most cost-effectively with various anthropogenic and environmental constraints. Belaire planted chiefly *Halodule wrightii*, but also *Ruppia maritima* and small amounts of *Syringodium filiforme* and *Thalassia testudinum (Table 2)*. Monitoring and/or observations were carried out more than 15 years in Belaire and in Thorhaug (Tables 2 and 3) including coalescence, abundance, health and recent Thorhaug results include key animal recolonization (Thorhaug, 2017), as well as for carbon (Thorhaug et al, 2017). A recent planting (10.24 ha) by Maristany, & Carangelo occurred in Corpus Christi Bay for the Port of Corpus Christi dredging project (Maristany, Carangelo et al, 2018) (Table 1). Existing major Texas pollutants in the restored areas included the following: dredge and fill, bottom and flow modifications, urban street runoff, sewage, heated effluents, nutrient, and chemical additions, salinity and depth alterations, flow alterations through channelization and land fill, soil erosion, rock mining and agricultural inputs through riverine effects. **1. *Site locations.*** The Texas sites ranged from South Laguna Madre to Galveston Bay by multiple investigators (Table 1, Figure 2). Many of Bellaire’s sites were between South Laguna Madre and the south end of the central estuaries in Redfish Bay. Thorhaug’s (2001) large scales sites were in North Laguna Madre. Thorhaug & Schwarz’s sites ranged (2017) from North Laguna Madre to Galveston Bay at the north extreme of Texas estuaries. These Belaire and Thorhaug planting sites were regulated and agreed to by State and Federal agencies (unless federally declared *de minimus*). Their geo-references, citations, descriptions of sediment, planting date, and original disturbances are found in Tables 1, 2 and 3 and Figures 2, 7-11 and Supplementary Fig 1-8. At some sites, substantial planning and preliminary 16 trials went into mutual federal/state/sponsor decisions on site selection (e.g. Fina

Gas & Oil of Texas 17 scrape downs, fill of major barge scar plus auxiliary sites, Thorhaug, 2001). Hammerstrom and Sheridan's sites were in Galveston Bay. "

2. Quantity and species of planting units (See Tables 1 to 4). The number of planting units (planted most frequently at one meter square intervals which Texas GLO and federal permits required) were as follows: The Belaire projects (1990 to 2010) in Table 2 shows 1,042,669 units planted into barren sandy 24 areas of approximately 1,012,777 m² *(Halodule wrightii* dominantly planted with occasional *Ruppia sp.,* some *Halophila engelmanii* as understory, and very small amounts of *Thalassia testudinum* and *Syringodium filiforme)* from South Laguna Madre northward to the central Matagorda Bay (Table 2, Figure 2). These Belaire sites included predominately barren bottom planting, but a few scrape-downs were included (of dredge islands and causeways). The first year Belaire survival rate of planted units was overall 64.5% (Table 2), rapidly fully coalescing into *Halodule* beds, on occasion mixed with other species. These plantings persisted as seagrass beds from the time of planting until present with monitoring and observations via field and aerial imagery. In 1999 at a series of depths (0.3 to 2+ m) in 34 Central North Laguna Madre, Thorhaug planted 357,735 planting units plugs of *Halodule wrightii* with some mixed with *Halophila sp.* at 1-meter intervals (into five locations of total 357,785 m2). (These occasionally included a small fraction of *Ruppia sp.* mixed into plugs.) The plantings resulted in a 71.7% 38 survival mean of planted units for the first 6 months which grew into *Halodule* beds sustaining until the present (except for changes due to Packery Channel described by Williams et al, 2007 more than a half decade post-planting causing disturbances resulting in severe water turbidity below JFK causeway, and along with the removal of piping below the Exxon Chanel fill creating additional turbidity. Key factors appeared energy regime and light. This was added to Hurricane Brett's effects on 2-3 ha in CCOG portion, which 2-3 ha regrew in 1-2 yr)**.** In Table 3, this 1999 Laguna Madre FINA Gas & Oil planting included the following: 1.) A partial scrape down of dredged island restored 5.94 ha (Fig. 5); 2.) A major 47 vessel scar from the Corpus Christi Oil & Gas Company restored 10.6 ha (scar created in the 1960-70's) (Figure S-3); 3.) The Exxon Channel was filled with dredge material from the scrape-down island, then planting including the impacted banks of the canal about 1.6 km; 4.) Two barren bottoms sites, one impacted in 1992, the other impacted decades earlier by oil rigs placement. Thorhaug (2001) planted 33.30 ha in depths from 0.3 to 2 meters in 17 weeks. Previous to this, Thorhaug planted trial test plots (1993 to 1996) in North Laguna Madre & Corpus Christi Bay which had numbered approximately 25,000 PU, which frequently grew laterally into far larger areas over time. In 2013, Thorhaug placed 15,000 PU (plugs) of *Halodule* into large one to one-fourth hectare test plots ranging in location from Galveston Bay (120,000 m2 to South Corpus Christi Bay at various and larger spacing intervals). The major 2013 plantings included a multi-hectare Galveston Bay area, a second multi-hectare in Aransas/St. Charles Bay, and in 4 sites in Corpus Christi Bay, all of which have differentially expanded (Thorhaug, 2017) (Table 3). Thorhaug' s (2001) plantings and 2013-2017 and previous test plots resulted in some large seagrass meadows in a series of distinct areas of Texas Bays, testing a series of ambient factors: water depth, sediment type, energy regime, light penetration vs. turbidity levels, salinity regimes, tolerance of seagrass to ongoing background contamination levels of various estuaries. The restored areas sustained through hurricanes and droughts, as did many of the original test plots and most of the Laguna Madre 11 planting (Table 3) except the anthropogenic opening of Packery Channel in 2005. [Footnote: The opening of Packery Channel from Bay to Sea (partially occurring with hurricane impact), appeared to change the circulation of North Laguna Madre from an Intracoastal Waterway dominated influx on the eastern side of the Laguna, to a Western shoreline influx into the northern Laguna (Williams et al, 2007).In turn, this new current created substantial continual turbidity in barren areas unconsolidated by seagrass within the western North Laguna shelf extending southward past the King Ranch docks (Williams et al, 2007). The turbidity of the Packery Channel circulation diminished light required for seagrass growth. Secondly, buried pipeline removal under the fill placed into the one-mile Exxon Channel during this project prior disrupted the plantings and allowed much unconsolidated sediment to be re-suspended by the Packery Channel current in the vicinity of the one-mile Exxon Channel.] ***3. Test plots sites and methodologies in Laguna Madre and Corpus Christi****.* From testing 4 various methodologies for restoring *Halodule wright* and *Halophila sp.* (including sprigs, sods, plugs with sediment, plugs with no sediment) the following results were derived. Plugs with sediment appeared to have the highest test-plot success rate for Thorhaug (2001). This was used for the large areas at various depths in the Laguna Madre. The types of original test-plot sites included extensive barren bottoms, scrape down or dredge island modification, large vessel scars not healed over decades, and areas of prior channelization which accrued sediment. About 40 ha were the final test plots which resulted after ensuing years of lateral growth. [Footnote: For tests preliminary to the success of the 1999 Fina and colleagues plantings the following areas were tested: the shelf behind dredge islands just southeast of JFK bridge, the channel sides running south parallel to this shelf, several flats on Flour Bluff side northwest of JFK causeway, and flats north of the channel between Mustang and Padre Island of Laguna Madre, barren flats near the Power Plant at Flower Bluff, a barren channel in the present Mustang Island State Park (Corpus Christi Bay), barren areas of dredged finger canals (abandoned development on Padre island), and in barren areas between the Intracoastal waterway and the Padre Island National Seashore.] ***4. Large-Scale Texas Results Methodologies Used.*** Thorhaug and Belaire seagrass restoration trials included five seagrass species at a series of recipient sites**.** Belaire used bare-rooted plugs in most areas about 0. 914 to 0.01 cm^2. In many locations bare roots showed success, with a variable range from 40 to 90%. Thorhaug (2001) and Thorhaug and Schwarz (2017) chiefly utilized *Halodule* plugs with sediment (plugs containing some *Halophila engelmannii* understory in several sites) about 0.00175 m. Choice by USA Army Corps, State of Texas, FINA, and project personnel was made in conferences from the results of test plantings 1993-95 with multiple methods (including sprigs and other species).

Maristany and Carangelo (2018) experimented with sods and sprigs and experienced lateral growth in 10.24 ha**.** Sheridan et al (1998, 2004) used sprigs cast into a general area plus planted sprig. Seeds were not utilized in Texas for restoration of any species at any time as far as we can ascertain but were used in laboratory studies by McMillian et al (1976, 1981) for *Halodule***.** Few seeding *Thalassia* populations have been reported in Texas and none used for restoration. ***5. Donor beds for restoration material effects*** were monitored by each planting team and inspected by state (frequently federal) resource agencies with no reports of damage. This included donor beds in large-scale donor extraction of materials for the Laguna Madre Fina project of 1999 (Thorhaug, 2001). Care was taken to space donor intervals at 1m. About 50 meters square donor material total from 40 ha were taken to restore 10,000-meter square restored bed (1 ha) or about 0.5% of the 40 ha. **6*. Season of planting*** was chiefly spring and through early to mid-fall. Success is seen in Tables 1,2,3. The danger of peak hurricane season was apparent to planting investigators. An interaction between storm intensity peaking in mid-August to mid-September with newly planted units has been explored (Thorhaug and Wanless, 2001; Thorhaug 11 2001; Thorhaug et al, 2017). **7. Monitoring methods: *Blade Density increase over time and planting unit success.*** Blade density measured in Laguna Madre large-scale planting increased from time zero to 1-2 year monitoring period (time usually government required) as follows: time zero the blade density per meter square increased from 10 short shoots m *vs.* to 1-2 yr results of 1340 to 4000 m, dependent on site location when maturity occurred. This final blade density varied in the Texas estuaries, dependent on location including energy regime, depth, light intensity, sediment type, as well as previous and present impacts, (Thorhaug, 2001). The mean mitigation success overall for planting units surviving was near 60% (Tables 1 and 2) although a large number of revegetated sites were substantially higher PU survival than this, [e.g. Galveston Bay (San Luis Pass) (Thorhaug, 2015) and Predator (Thorhaug, 2001)] where they were above 90%. Research test plantings, ranged from 0 to 100% in plantings of Carangelo, Phillips, Sheridan, and Hammerstrom. The time of coalescence of the average planting unit in a one unit per meter square was a median of 4-12 months, dependent on light, depth, energy regime, turbidity, and other naturally-occurring site factors**.** Thorhaug and Belaire measurements included ground truth with blade measurements, and diameters of lateral growth during first 60 months. Checked by government agencies. In subsequent years, then observations by ground-truth, Google Earth Pro and commissioned aerial imagery observations occurred. **8*. Other factors of importance (light, turbidity, salinity) to sustainability:*** Water column depths of planting ranged from 0.1 to 2m. Light was not well measured and reported in most studies and varied greatly daily to monthly due to wind re-suspension of barren sediment, riverine inflow with substantial turbidity from upland soil through long rivers, mining runoff from inland and stock-piled 35 mine tailings, dredge and fill piled onto dredge islands and marshes, runoff from dredge material for real 36 estate and navigational and marinas, organic dissolved substances from urban domestic and street wastes, and other factors including upland agricultural fertilizer stimulation of phytoplankton which dimmed benthic light for seagrasses. Thus, no conclusions on precise required light can presently be drawn as occurred in light studies on natural seagrass in the southern Texas Bays (Dunton, 1994 and Onuf, 1994). The seagrasses appear to have far less tolerance to turbidity (therefore diminishing their required light) created by dredging and filling, riverine outflows of both particulate and dissolved substances creating turbidity from soil erosion (Dunton, 1994, Thorhaug et al, 2016), and nitrates and 45 phosphates from agricultural over-fertilization creating estuarine brown tide blooms cutting light (Onuf, 1994). Gulf of Mexico water inflow at the deeper stations of the 1999 planted one-mile Exxon channel 48 occurred chiefly through the navigational channels in the eastern Laguna Madre when a large seagrass restoration occurred (Thorhaug, 2001). The Packery Channel (North Padre to S. Mustang Island) was opened in July 2005 (Williams, Kraus, and Anderson, 2007) six years after the 1999 Laguna Madre planting. This artificial cut affected the circulation of incoming oceanic water in the North Laguna Madre. A large inflow of Gulf of Mexico water was circulated down the western shoreline of the Laguna Madre reinstituting a much earlier circulation pattern. It created more Gulf of Mexico salinity influence on the western shoreline of the Laguna Madre, coupled with large scale turbidity very apparent from aerial imagery when comparing "before and after" imagery of the opening of Packery Channel. Part of the impact was created by a new current pattern which placed unconsolidated sediments into suspension. Since this covered much of the 1-mile Exxon Channel, it resulted in a highly diminished light level to seagrasses in and at the sides of Exxon Channel. There appears to be a tolerance to the levels of pollutants currently sustained in the Texas estuaries by the dominant naturally-occurring Texas seagrasses from Laguna Madre and Corpus Christi Bay (*Halodule wrightii, and Halophila engelmanii)* northward to southern Galveston Bay. Anthropogenic impacts affecting water quality include levels of sewage (Sataschi et al, 2001), petroleum products as well as other refinery effluents (Benoit et al, 1994), levels of herbicides and pesticides seen in the results in Tables 1 and 2. The seagrass plantings were resilient enough to sustain meadows over decades in these impacted bays. **9.) *Sustainability and Longevity within Texas Seagrass Restored Meadows.*** In the Texas examples, most of the long-term footprints from restored beds can be observed throughout the year due to the perennial and dioceous nature of *Halodule wrightii* and *Halophila engelmannii (*the dominant seagrasses restored). Many of the restored sites had fixed natural boundaries which included shorelines, channelization edges, other seagrass beds, or dredged areas. Texas estuaries have been transformed into underwater checkerboards by channels, structures such as causeways, land fill, artificial filled islands, navigational channels, and other anthropogenic nearshore activities. In many cases after impact which denuded seagrass from the areas, natural lateral recolonization growth (normal mode of expansion) was not possible due to adjacent barriers (e.g. navigational channels). During growth phase, the restored areas' expanding footprint clearly was demonstrated in aerial imagery matched with ground truth. However, during our restorations of planting units, we inserted planting units into large barren bottom sites allowing substantial, lateral growth occurring within these site boundaries. **10*.) High Energy Wind Events Impacting Restoration*.** There have been regular high wind events at the restored sites such as hurricanes and tornadoes. (70 hurricanes, cyclones and other extreme wind events recorded from 1980 to present on Texas coastlines from NOAA website hurricane history). For example, Hurricane Bret occurred on August 20 to 21, 1999 (category 4 at 145 mph lowering to category 3 as it passed over Padre Island in the Laguna Madre north central section). Hurricane Bret swept away a 2-ha area of 6 week-old restored plugs along with the underlying 1998 fill in a larger area of 13 ha planted seagrass units. An adjacent naturally-occurring seagrass bed to the west, in less than 0.6 m water was also highly decimated. Subsequently, into this hole occurring over two years was the normal sand accretion process typifying the estuarine processes in this portion of the Laguna

Madre. Into this 2 ha-hurricane-impacted site with newly-accreted sand the densely growing restored seagrasses regrew from all sides. The deeper restored areas from this same vessel scar were not affected in the same way when Hurricane Bret passed over them (possibly partially due to lesser wind force at depths and compaction of the sediment over time after the original scarring decades prior). On the other hand, in Hurricane Harvey (2017) seagrasses showed resilience along shorelines in Galveston Bay plus in Aransas/St. Charles Bay and in parts of Corpus Christi Bay. The marshes on these same shorelines were decimated, while the seagrass at 0.3 m and more remained intact. The plantings in the tidal channel between one side of barrier islands and Corpus Christi Bay did not survive as well along shorelines post-Harvey. One documented tornado at Predator Island in March 1999 where holes of 1 m circumference were measured as blown away under newly planted seagrass units. Recovery of sediment and seagrass by lateral growth was 6 months (Thorhaug and Wanless, 2001)**. 11*.) Reassembly of services of restored seagrasses: animal observations, biodiversity Increase:*** This observation of restored seagrass biodiversity was captured chiefly in reports by McLaughlin et al 1983 for Florida's oldest site (Turkey Point), and by Sheridan (1998), and biodiversity was measured in naturally-occurring Texas seagrass by Stuntz et al (2002), Levin and Stuntz (2006). Thorhaug in the 2013 , 2017 reports for Texas sites describes: Birds—Whooping Crane (at St Charles Bay/Aransas Bay only), Great Blue Herons, Tricolor Herons, White and Brown Pelicans, terns, plovers, Roseate spoonbills, Herons, Ibises, skimmers, seagulls, and other marine shore birds; invertebrates-- various species of shrimp and crabs, conch, marine snails, micromollusks, clams, oysters, polychete worms, foraminifera on seagrass blades, and a variety of bivalves in adjacent sand, especially at San Luis Pass, Galveston Bay. The recolonizing fish included pin fish, snapper, grouper, red fish, flounder, sea bass, and others. Note that burrowing fauna did not appear to cause restoration failure, nor was there restored seagrass fish predation. Also note that epiphytes chiefly included microalgae of Chlorophytae, Rhodophytae, and Phaeophytae. There were attached macroalgal epiphytes in early stages of growth also. Rooted in the sediment Chlorophytae (Siphonales) were observed in the restored areas in the Laguna Madre. See Supplementary Table S-1 for sequestered carbon in 4 various Texas sites in including natural seagrass, restored seagrass, always barren sediment, and impacted barren sediment. This restored seagrass carbon was higher than natural seagrass organic sediment carbon and varied among estuaries as did the barren background controls.

B. Atlantic Tropical/Subtropical Seagrass Restoration Examples: South Florida-Biscayne Bay & Card Sound Results (Table 4, Figure 3)

In total 1,504,000 planting units were placed in Biscayne Bay, Card Sound, and Lake Surprise into 153.9 ha. Results were generally successful with several exceptions. Some lived for 47 years, while others for 35 years, dependent on planting date; all lived since time of planting with exceptions below due to massive anthropogenic events or high intensity natural wind events. ***1.) Turkey Point.*** The *Thalassia* restoration of 83,000 anchored seedlings planted by hand at Turkey Point on 28 August, 1973 (Thorhaug, 1974) has sustained 47 years (Table S-1) with over 2000 blades m^{-2} density and 116 Mg ha^{-1} organic carbon sequestered in the sediment (Thorhaug et al, 2017) plus a full array of food web animal species (McLaughlin et al,1983). Controls for the Turkey

Point seagrass restoration included a second fossil fuel power plant 15 miles north on the same bay, which closed several years after Turkey Point effluent canal closing occurred. This 56-ha control area required 20 years to fill naturally (Smith and Teas, 1977) as *Thalassia testudinum* meadow grew in from the adjacent bay by lateral rhizomal growth (Tomlinson, 1974). Second and third controls were barren areas between planted corridors, and natural vegetation 1km south which had not had effluent effects. The Turkey Point general physico38 chemical and ecosystem data in Bader et al, (1970) have been published (Bader and Roessler, 1971, 1972, 1973, 1974; Thorhaug, Roessler, and Segar, 1974) as well as general aspects of Biscayne Bay (Thorhaug and Volker, 1975). Two nuclear power plants plus 2 fossil power plants and control sites were described in the overall data. Published initial restoration description (Thorhaug, 1974) along with chemical, physical oceanography, faunal and fisheries and seagrass dynamics aspects of the Turkey Point (Thorhaug and Roessler, 1977) occurred for both the effluents of the nuclear power plant and larger test areas. Measurements included ground truth with blade measurements and lateral growth diameters during the first 48 months, then supplemented by ground-truth observations plus aerial imagery and Google Earth Pro observations in subsequent years. In some subsequent years, blade counts, and sediment samples were obtained. The faunal food web was also well documented (Thorhaug and Roessler, 1977, in Bader 1969, and then Bader and Roessler reports below 1970-1975) for controls of effluent and post-effluent faunal changes. The post-seagrass-restoration recolonized animal study carefully carried out by Smithsonian invertebrate experts (PA McLaughlin, Le Maitre, et al., 1983) indicates the entire food web returns 3 years after *Thalassia* seedling restoration in this *Thalassia*dominated seagrass habitat. They found a particularly large increase in shrimp, as well as fish, macro- and micro-invertebrates in this carefully executed McLaughlin et al study. ***2.) North & Central Biscayne Bay.*** The second series of plantings in north and north central Biscayne Bay are published in Thorhaug (1978, 1981, 1985, 1987, 2002). First, an array of restoration test plots was planted (Thorhaug and Hixon, 1975) in the Central and North Biscayne Bay, Florida, then large-scale restorations of 136.3 ha with more than 1.3 million planted units have sustained substantially for 35-37 years (exceptions noted below of one planting partially blown out at Mercy Hospital Project I). Four of these project sites are herein described as examples: ***a.) 24th ST*** (9.09 ha) planting in 1983 (200,554 *Halodule/ Syringodium* plugs, 73,440 *Thalassia* sprigs persisted throughout the planted area and extending beyond the perimeters (Supplementary Fig.S-4). (After planting in 1983, *Thalassia* sprigs were surviving at 89% survival at medium depth and 88% greater depth; *Halodule/Syringodium* were surviving at 35% shallow and 38% medium depth in first year and expanded and grew very long; although there were multiple disturbances several decades after planting (re-dredging Intracoastal waterway, 2015-8 Port of Miami Channel deep dredging and poorly-executed fill with much material loose dumping into whole in bay 17 above 36th St.). The prior pre-planting history of this site, included a sewage outlet; however, the healthy restoration site still survives. ***b.) Grove Is*****le** 32.2 ha with over 274,434 mixed plugs of *Thalassia/Halodule* PU with 73 planting areas within the site persisted since 1984 planting (Supplementary Fig. S-5) while post-planting included major hurricanes (Andrew, etc.), and many other intense storms. ***c.) The Port of Miami SE Island "oil spill"*** planting in 2000 of 12,000 *Halodule wrightii* with mixed *Thalassia* plugs, 3000

*Thalassia s*prigs restoration planted into area 12,212 m consisting of large patches of barren sand areas with deep propeller scars and other effects, which expanded into about 4.4 ha, including expansion of the deeper *Thalassia* plantings along the south edge of the fishermans' channel of this Island with 87% survival (for the State of Florida Emergency Management Department which Oil spill island planting has shown continued persistence from 2001). ***d.) The "outer area" of Mercy Hospital*** (bayward side) Phase III Mercy Hospital seagrass planting with 84.98 ha and 849,800 PU which has grown *Halodule* in the normal patchy pattern seen in previously impacted "mid-bay seagrass" found from Central Biscayne Bay to the south with groupings of *Thalassia*-dominated *vs. Halodule*-dominated large seagrass stands*.* These meadow large patches have been variable among years dependent on hurricanes and winter storms (due to large Atlantic oceanic fetch coming through the wide barrier between islands fringing the Atlantic side of the Bay, a 16.2 km gap known as "the Safety Valve" between the tip of Key Biscayne the Sands Key to the south). [Footnote: Two of the Biscayne Bay plantings are not herein used as examples of longevity but will be discussed elsewhere: e.) Viscaya channel done for the first time globally by demand by Port officials as a test of potential winter subtropical planting potential and f.) the first (1983) Mercy Hospital planting. The Vizcaya Channel was the first field experiment to test viability of winter planting, extent was 27,200 m2 into which 54,368 PU's of *Syringodium, Halodule* sprigs and *Thalassia* seedlings were planted. This January planting showed a low level of survival due to evidently harsh stress of winter conditions on anchored seagrass planting (season and anchoring had never before been tested in the subtropics). This test concluded that subtropical planting was a seasonally successful effort, not 12 months per year activity. The first planting at the Mercy Hospital site (Phase II) was 275,666 *Halodule* sprigs, and similar number of *Thalassia* seedlings into about 169,000m^2. This latter planting was the subject of several issues occurring from two symposia organized and convened by the late RR Lewis, President of several private sector Florida companies which restored mangroves and seagrass. These reports differed substantially from reports from planter to federal agencies, measured and reported by the planter. It is the only case we find in the 1876 trials of seagrass restoration (van Katwjik, Thorhaug et al., 2016) that a third party with no simultaneous permitting government agency participation or supervision, plus no planter participation became the only group monitoring data; it is also the only publication where a 3rd party data with no agreement with planter was published in grey or normal literature. The published accounts in Marine Pollution Bulletin (Thorhaug, 1985 & 1987), which data was inspected and approved by federal regulators indicated another concept and differing measurements. The initial 3rd party monitoring report occurred immediately after an intense winter storm where blades detached and blew off --as is normal in a gale force storm--without the monitors excavating for root/rhizome mass remaining. This has been quoted as proof of seagrass non-sustainability. This third-party monitoring report has been quoted by County environmental officials and several environmental restoration vendors. The original 3rd party report on only this site was by a monitor hired by Dade County who was a trained ornithologist using undergraduate biology students all of whom were without detailed knowledge of seagrass physiology, growth, or monitoring. This ornithologist's report was never corrected over time as storm[rd] -impacted seagrass rhizomes regrew blades from the site. These 3 party monitoring reports were published in the gray literature by the groups of whom (Lewis Environmental, Mangrove Systems, and the ornithologist's company) profited financially from this misinformation surrounding the long-term survival outcome. It is wisest to not include these two sites' plantings' results sustainability as part of this assessment in the final totals herein to avoid any controversy with such gray literature citation complications, as this issue will be resolved elsewhere. Additionally, these two sites' outcomes do not affect substantially the total data.] **3. Test plots' longevity:** Approximately 68% of the sum of planting units at thirteen of 0.4 ha each test plots (Thorhaug, 1985) have sustained over the 37 years' period each with considerable expansion. (Most of the non-surviving tests were chosen over the objections of the restoration expert by county resource management who were engineers.) Thirteen test plots originally included 52,500 PU planted (Thorhaug, 1985): 36 St Causeway western bridge abutment on both Southwest and Northwest sides, Bird Island, northwest flats at Sabal Palm Road, 24 to 28th ST offshore, (Supplementary figure S-4),a site northeast of 79th St Causeway, the several dredge islands "Pace Picnic islands", two sites at flats at northwest Virginia Key approximate to a buried sewage line, 800 m ENE of Mercy Hospital docks Figure S-8, (and later 2000 planting about 300m off N Bay Harbor Islands' on flats). The four test plot restoration sites in these two northern basins sustained well, although at the 79th St dredge island site (both deep and turbid), low survival occurred. There were several other plantings (Thorhaug, 1987; Thorhaug and Hixon, 1975) not herein discussed some of which included additional test plots (40,000 41 seedlings, 4000's *Halodule* and *Syringodium* plugs). An anthropogenic disaster occurred here. During dredging for the Port of Miami in mitigation, a dredge hole was filled in the central basin between 36th ST to 79th St, which uncontrolled fill decimated this excellent 35 yr planting on the North side of 36th St causeway. Some other sites had secondary disturbances at various time periods after restoration was completed such as proximate dredging sites. The governmental induced changing outflow from drainage canals by State and Federal government throughout Biscayne Bay areas which in turn induced changing turbidity patterns. Hurricanes and tornados occurring in the central and North Biscayne Bay areas also effected plantings. ***4.)*** **Card Sound, Barnes Sound**. At another successful planting site in an estuary to the immediate south of Biscayne Bay (15,000 PU in 12,412 m^2 *Halodule wrightii* survival above 90%) (Thorhaug, 1983). The Florida Dept. Transportation built a bridge decades later on top of the restoration site (FDOT) with the causeway, on the immediate east of the plantings, removed in Lake Surprise of Barnes Sound bordered by Key Largo, Fl. **5.) Measured services of restored Biscayne Bay seagrass**: ***a.) Animals' recolonization*****.** McLaughlin et al 1983 measured the invertebrates recolonizing the Turkey Point restoration for several seasons. After 3 years of regrowth this *Thalassia* bed showed no statistical difference between restored and natural, non-impacted seagrass beds in terms of invertebrates. ***b.) Carbon.*** The supplementary Table S-1 shows a series of sites (Turkey Point, Grove Isle, 24th St.) wherein sedimentary carbon with 3 controls (naturally-occurring seagrass meadows, always-barren sediment and impacted-barren sediment) plus restored seagrass carbon were measured for sedimentary organic carbon accumulation over time as well as carbon burial rate, carbon gain and loss, and age (from date of impact plus from date of restoration to monitoring). Restored seagrass showed more organic sedimentary carbon burial than naturally-occurring seagrass sediment. A substantial amount of carbon occurred in the “always barren” non-vegetated background sediment, which control in opinion of authors needed to be subtracted from “sequestered” carbon beneath seagrass beds (Thorhaug et al., 2017).

C. Atlantic Tropical Seagrass Restoration Examples: Jamaica Seagrass Restoration Results (Table 4, Figure 4)

Jamaica is a nation in the central Caribbean Sea Greater Antilles, independent from Britain since 1961. This first global tropical seagrass restoration training project (sponsored by US Government Agency for International Development) jointly tested and trained methodology and species with the Jamaican Natural Resource Department and University of West Indies Botany Dept. The objective was to test tolerances for restoration of near shore seagrass resources for various pollutants experienced especially in Jamaica but also as a general model to other Caribbean and Gulf of Mexico (GoM) nations. General sites of pollutant types were selected by the Natural Resource Department. The project restored 3 dominant tropical Atlantic seagrass species by 3 methods: sprigs, plugs, seedlings. Training for the seagrass restoration process were carried out with personnel from the Department of Natural Resources (Director, Beverly Miller) and University of West Indies Botany Department (Chairman, George Sidrack). Results in detail are found in Thorhaug, 1985); and Thorhaug and Miller, (1985). Results were in three parts: 1. Outreach to Jamaican public; 2.) Results of test studies and a larger planting based on test studies (Table 4); and 3.) seagrass policy (written and adopted) plus training of related Caribbean Government resource management groups through UNEP, FAO, and CARICOM. Three major Jamaican public conferences were held to share information about the success of the program with the citizens, other Jamaican government and international agencies, foreign embassies, and industries. Additionally regional training sessions with Caricom government personnel sponsored through the UNEP/Caricom process were successfully held. Later FAO held Latin American seagrass training workshops were held from this data. Mitigation policies for seagrass were written partnering with Director Beverly Miller after consulting with US agencies at State and Federal level and Caribbean nations and then adopted by the Jamaican Parliament and Prime Minister. Methods included planting at each of 19 sites with 2 species with 2 methods each of *Halodule, Thalassia,* and *Syringodium* into 0.4-meter quadrats. (1800 PU in each of 19 test areas.) Results showed the best restoration methodology results in a predominance of polluted sites and control sites were by utilizing *Halodule* plugs and *Thalassia* sprigs. At low to medium levels of the majority of the common Jamaican pollutants, one or two species could tolerate them (Thorhaug, Miller et al, 1985). Measurements of blade measurements and laterally expanding diameters of planting unit by divers (ground truth) occurred during first 18 months, then general ground observations and Google Earth Pro and other aerial imagery measurements in subsequent years. 14 or 74% of pollutant test sites sustained over 3 decades. Both seagrass growing by lateral extension (Tomlinson 1974) and by seeding many developed into substantially larger areas (airports and port dredge and fill, around Montego Bay breakwaters, power plant outer isopleths with *Halodule*, oil spill sites with *Thalassia* and *Halodule*, and a deep site of 5m near a river mouth at far western tip). Five other sites highly anthropogenically impacted did not survive well (cement plant with high level flocculent tailings, high salinity pond to over 75 ppt, high energy erosional sites at Hellshire with *Syringodium, next to ship channel Ocho Rios, at entrance to Port,* *Montego Bay)*. Sufficient light appeared to be a key requirement for restoration as was medium to low energy regime, daily mean temperatures up to 29.5^{0}C, and salinities from 22 to 44 ppt. Working with local fishermen at Kingston Bay, at Fort Augusta Causeway site (to Portland) a larger acreage was planted near-shore proximate to a bridge over the river mouth. The results were a vibrant set of 4500 PU *Halodule wrightii* plugs planted at 1 m intervals which coalesced into a seagrass bed within 6 months and has sustained and expanded for decades despite a proximate dredge and fill on the causeway (Supplementary Fig. S-7) at which point they grew back from decimated condition after the dredge and fill operation. "from Thorhaug, et al., 2020.

Table 1. The overview of Texas seagrass restoration projects, 1970's to 2010's (Thorhaug et al., 2020). Extent, species, number of planted units. *H=Halodule wrightii, HP =Halophila sp. S=Syringodium fileforme, T=Thalassia testudinum, R=Ruppia species*.

Investigator & Citation	**Site**	**Seagrass species**	**Planted area (m^2)**	**Type Planting Unit**	**Planting Units Numb.**	**Total**
Belaire (various dates 1980-2010)	Texas sites	H, HP , S, T	1,012,777	Plug	1,042,669	2,405388
Thorhaug 2001, 2014, 2016, 2017	Laguna Madre, CC, Aransas, Galveston Bays, Matagorda, Tx	*H, HP*	899,277	Plug	640,149	8,958893
Sheridan et al. (1998, 2004)	Redfish Cove, 27°365' (North) 97°15' (West) Snake Is, Galveston Bay, Tx	*H*		Plug, PP Mechanical	10,476	
Hammerstrom et al. (1993, 2006)	Galveston, Tx	*H*		Plug, Mechanical	3,518 1,720	
Kennedy et al.	Galveston,Tx	*H*			16,000	
Carangelo et al. (1979)	Corpus Christi Bay 27°94' (North); 97°02' (West); 27°84' (North) 97°4' (West)	*H*		Sod & plugs	307, 36, 72	
Maristany, Carangelo et al. (2018)	Corpus Christi Bay	*H*	10,600		108,610	
Phillips (1980)	Redfish Bay, 27°849' (North); 87°141 (West) Galveston Bay 30°009' (North); 84°335' (West)	*H*		Plugs Sprigs	200	
Total					1,823,787	

Table 2. Physico-chemical factors plus Extent, species, number of planted units, success, monitoring coverage in hectares from Belaire plantings in Texas 1987-2013.Species *H=Halodule wrightii, HP =Halophila sp. S=Syringodium fileforme, T=Thalassia testudinum, R=Ruppia species*. Projects monitored and approved by TGLO and USAEC (**).

Investi-gator & citation date	**Site Receptor & Georefer-ences**	**Salinity level**	**Turbi dity**	**Depth in ft. & energe tics**	**Distur bance Level**	**Area m^2 planted Still Alive?**	**Species planted**	**No. planting units.**	**Surv ival At 6 mo. (**)**	**Time 18-36 mo. (**)**
Belaire (1989)	CorpusChristi , AransasBays. CCOG. 26°10 (North) 97°17 (West)	hi	lo	3:hi	Hi	182,110 yes	H	225,000	90	90
Belaire (1990)	Copano Bay. 26°10 (North) 97°17 (South)	Med	lo		Hi	3055 yes	H	1750	90	74
Belaire (1987)	Redfish Bay. 26°10 (North) 97°17 (West)	hi	lo		Med	12,141 yes	H	7500	70	99
Belaire (1990)	S. Laguna Madre. (EDC) 26°10 (North) 97°17 (West)	hi	lo		med	180,087 yes	H	222,500	80	80
Belaire (1990)	C.Laguna Madre. (Bright Co) 26°10 (North) 97°17 (South)	hi	lo		Lo	3035 yes	H	3750	80	80
Belaire (1990)	N.Laguna Madre. Pipeline, fill in channel, Spoil Isld. (CC transmission Co.) 26°10 (North) 97°17 (West)	hi	lo		Lo	218,533 yes	H	270,000	74	90
Belaire (1990)	Matagorda Bay.	med	hi			14, 165 yes	H	17,506	40	47

	Restored pipeline. trench28°68 (North), 95°94 (West)									
Belaire (1992)	Upland scrape down. Central P&L. 26°10(North) 97°17 (South)	lo	hi		hi	4,047 yes	H	5000	44	56
Belaire (2002)	Laguna Madre. wave barrier const, (Mitchell Energy) 26°08 (North) 97°21 (West)	hi	hi		hi	99,464 Yes	H	0	N.A.	62
Belaire (1995)	N. Laguna Madre. scrape down barrier Island26°08 (North) 97°21 (West)	hi	hi		hi	84,966 yes	H	100,000	50	60
Belaire (1994)	N. Laguna Madre Refilled deep prop scar (Le Boef Bros.) °10 (North) 97°17 (West)	hi	hi		hi	24,282 yes	H	30,000	40	74
Total										

Table 3. Texas seagrass restoration projects of Thorhaug 1994 to 2017. Extent, species, sites, number of planted units, success. The species abbreviations are *H=Halodule wrightii, HP =Halophila sp. S-Syringodium fileforme, T=Thalassia testudinum, R=Ruppia species*. CC=Corpus Christi, LM=Laguna Madre All units monitored and certified by TGLO and TPWL the ones prior to 2005 also monitored USAEC.

Investi-gator; Citation	Receptor site	Area m2	Sal. ppt	Tur-bid-ity	Depth Ft. & en-erge-tics	Distur-bance Level	Spe-cies	PU number	Success (%)
Thorhaug (2001)	Test Canal Head Laguna Madre 27°319357' (North); 97°19158' (West)	533 yes	*hi*	*lo*	*1.5:med*	*Hi*	*H*	1533	65
Thorhaug (2001)	Test Canal Head Laguna Madre 27°313842' (North); 97°192207' (West)	35 yes	*hi*	*lo*	*1.5:med*	*hi*	*H*	90	85
Thorhaug (2001)	Various locations TX, USA	275,181	*hi*	*med*	*4:hi-med*	*Lo-hi*	*H*	91,666	70
Thorhaug (2001)	Laguna Madre Mid-Exxon 27°313842' (North); 97°192207' (West)	29,538 partial	*hi*	*hi*	*5:hi*	*Hi*	*H*	29538	65
Thorhaug (2001)	Well Head, Exx., Laguna Madre 27°310969' (North);	40,468 Yes	*hi*	*hi*	*6.5;hi*	*hi*	*H,HP, R*	40468	70

	97°193568 ' (West)								
Thorhaug (2001)	Canal Head, Laguna Madre 27°310969 ' (North); 97°193568 ' (west)	40,468 yes	*hi*	*Very hi*	*6.5:med*	*Hi*	*H,HP*	40468	73
Thorhaug (2001)	Predator Island, Laguna Madre 27°322022 ' (North); 97°111341 ' (West)	59,489 yes	*hi*	*hi*	*1:med*	*Med*	*H,R*	59489	93
Thorhaug (2001)	Laguna Madre, CCOG 27°313076 ' (North); 97°194392 ' (West)	105,218 Yes, greatly expanded	*hi*	*hi*	*5:hi*	*hi*	*H,HP*	105218	77
Thorhaug (2001)	Laguna Madre. N-Middle canal 27°310969 ' (North); 97°193568 ' (West)	40,468 partially	*hi*	*hi*	*4.5:hi*	*hi*	*H,RP*	40268	77
Thorhaug (2001)	Laguna Madre. Mid-Exxon 27°310969 ' (North); 97°193568 ' (West)	40,468	*hi*	*hi*	*4.7:hi*	*hi*	*H,HP*	40468	65
Thorhaug (2013, 2016)	San Luis Pass in Galveston Bay	120,000 yes	*hi*	*med*	*2.5/hi*	*med*	*H*	3488	92

	27°313076' (North); 97°194392' (West)								
Thorhaug (2013)	Aransas/St. Charles Bays 27°310969' (North); 97°193568' (West)	40,000 yes	*med*	*med*	*3.5/hi*	*Hi-med*	*H*	1177	72
Thorhaug (2013)	Aransas/St. Charles Bay 17°59' (North); 76°48' (West)	1,728 yes	*med*	*hi*	*1.2:med*	*Hi*	*H*	55	100
Thorhaug (2013)	Shamrock 25°454232' (North); 80°090856' (West)	12,000 partial	*hi*	*med*	*5.5/hi*		*H*	366	79
Thorhaug (2013)	Croaker Hole Stream 25°481334' (North); 80°110640' (West)	53,683 partial	*hi*	*med*	*3.0:hi*	*hi*	*H*	1287	63
Thorhaug (2013)	Croaker Hole Flats 30°245708' (North); 81°244509' (West)	20,000 yes	*hi*	*med*	*5.5/hi*	*med*	*H*	555	74
Thorhaug	Croaker Hole Shelf	20,000	*hi*	*low*	*1.3/med*	*med*	*H,HD*	500	69

(2013)	30°245708 ' (North); 81°244509 ' (West)	Yes. expanded							
Total		899,277						456,633	Mean= 75.8

Table 4. POST HURRICANE HARVEY. Abundance of our measured restored seagrass at sites restored in 2013 with salinity and light 3 months post-Hurricane Harvey in Texas. Measurements are mean of 9 replicates within each subplanting area at a site (Croaker Hole fringe 6, Stream 6, Flats 2, Shamrock 2, Aransas 4, Galveston 8). Light is measured among blades at 30cm depth in micro-Einsteins/m2. Salinity is measured in ppt (Thorhaug, Schwarz, and Berlyn, 2019)

Site	**Date**	**Sg Abundance Mean**	**Blade length (cm) Mean**	**Blade Width mean (cm)**	**Tem-pera-ture**	**Halo-phila under story bld**
Mean	**Salinity (Ppt)**	**Lite UE at 30cm**				
Croaker Hole. Fringe CC	11/22/17	4510	7.6	0.1	29.5	1138-1209
Crk. Hole Flats, CC	11/22/17	4080	11.3	0.1	30.3	1163-1603
Crk Hole stream, CC	11/22/17	2590	15.25	0.1	33.3	Many varied from 972-1600
Shamrock shallow, CC	11/21/17	6910	12.9	0.1	33.8	826.8-1030.2
Shamrock deep N.	11/21/17	6760	15.1	0.1	33.8	397.7-720.3
Aransas lg	11/20/17	6900	9.9	0.1	15.2	832-1067.3
Barren Arn. Lg	11/20/17	0	0	0	15.2	510
Aransas Small	11/20/17	3251	13.5	0.1	15.2	-
Galveston SLP	11/24/17	3283	22.5	0.1	22.5	-

Figure 2. Map of Texas Bays with their names (from State of Texas Parks and Wildlife Department). Arrow points to major plantings.

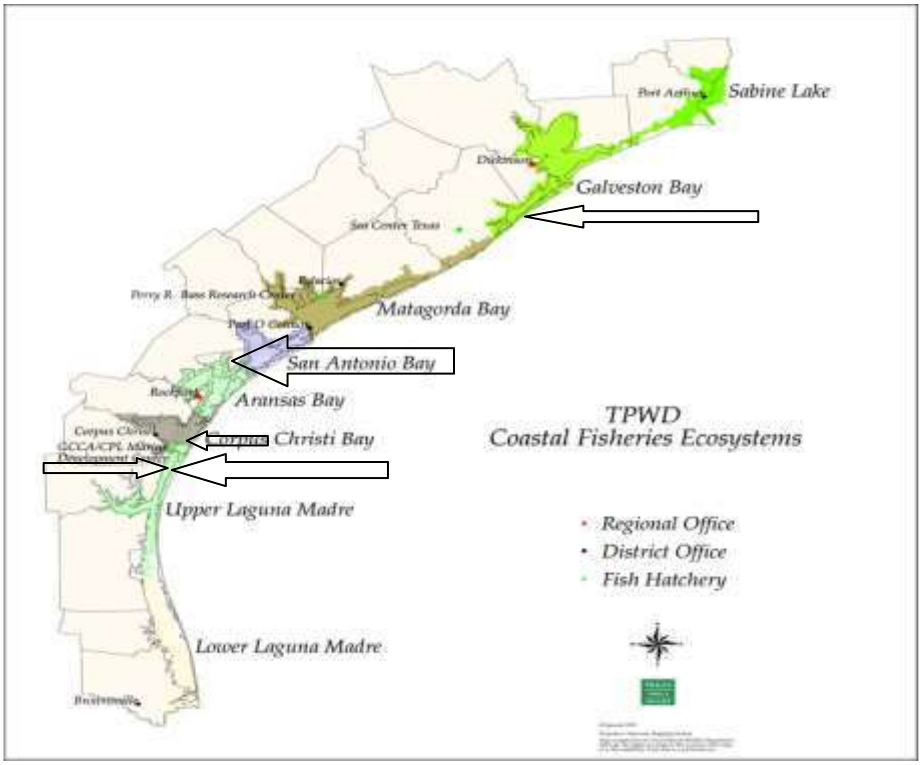

Figure 3. Biscayne Bay, Florida. From National Park, showing aquatic preserve and national Park. Arrows are in regions of major seagrass restoration.

II. Planting design (site aerials, sketches of sites, and navigational chart site locations)

Restoration Design

There is a video which has graphics of restoration of *Halodule* in Texas.

A. PLANTING DESIGN METHODOLOGY:

There will be 8 text plots. At all sites there will be a design number one of one unit planting spaced at 4-foot intervals. At Magnolia Beach and Sea Drift spatial distances and configurational plantings will additionally be done with controls and will use controls.

1.) SPATIAL DISTANCE BETWEEN UNITS PLANTED*:* If the planting is at smaller intervals, it is probable that a seagrass bed emerges more rapidly. It is possible to plant the same amount of units at wider intervals in order to cover a larger area. This pilot study will attempt to investigate if the results at wider spacing are similar in seagrass blade density after a longer period of growth. This would indicate that the potential for wider spacings may allow people to plant more seagrass over a larger space to return larger amounts of seagrass to Matagorda Bay and other estuaries of Texas. Normally three foot spacing or one unit per 9 square feet have been required in permits. This first occurred in the transition between my first large scale seagrass restoration at the Turkey Point, Biscayne Bay Florida plantings at 1 unit per 4 sq ft. (Thorhaug, A. 1974. Aquaculture 4, 177-183) and my second large plantings at the Port of Miami (Thorhaug, A. 1985. Large Scale Restoration of Seagrass in a Polluted Estuary. Bull Mar Sci. 16(2): 55) which was determined by the National Marine Fisheries to be at one unit per 9 square ft, but over a much larger area. Then that became the normal planting required by NOAA, ACE, State of Texas and Florida and others.

An array of differing spatial plantings will be carried out at two pilot sites. One in Sea Drift; A second at Magnolia Beach in Port Lavaca. The intervals between plantings will be 3 foot, 4 feet, 5 feet. In a hectare, there is much difference in cost and time between these spatial plantings. The success in a variety of pilot plots will be a good test of the success of various plantings.

B. CONFIGURATION OF PLANTING

The two test sites for configurational Increasing spatial dispersion in ecosystem restoration mitigates risk in disturbance-driven environments.

1.) DESIGN TESTING: A group of very experienced and knowledgeable seagrass investigators (Fivash et al., 2022) in the Netherlands has recommended that natural configurations of regrowth rather than straight rows with units at regular planting intervals such as corn is planted agriculturally (presently normally seagrass is planted) be an alternative design for planting. The situation of seagrass can be divided into two basic situations: 1.) A series of scattered small round circles from which the *Halodule* expands outward in spider webs of increasing circular diameters.

This will be planted at 10-foot intervals between the centers of circles. In a pattern of triangles and reverse triangles. The diameter of the circles will be 4 ft at each corner of the triangle. One triangle will be planted with the point going toward deeper water, the next triangle 10 feet away will have the point going toward shallower water. And the next toward deeper. 2.) The next configuration will be arrowhead s pointing in the direction of the normal daily water flow. The upper planting will be 12 feet from the lower back of the arrowhead with the tip of the arrowhead 6 feet between upper and lower plantings with a diagonal line of planting moving from the upper back corner to the lower corner. A series of arrowheads will be in one line. The next row of arrowheads will be offset 6 feet so that the arrowheads are staggered in rows.

“Once degraded, the restoration of these systems entails a high risk of failure due to the uncertainty in timing and intensity of future disturbances. Risk-mitigation strategies like bet-hedging (i.e. spreading risk over diverse options) have been proven in cross-disciplinary contexts to optimize yield when uncertainty is high. Yet, restoration designs commonly homogenize resources by planting vegetation of similar sizes in grid-like patterns. This decision may unwittingly contribute to the high rate of restoration failure in these environments. Using numerical simulations mimicking vegetation patch dynamics, we demonstrate how avoiding uniform planting designs substantially improves the likelihood of restoration success. These simulations also suggest that the intrinsic risk of failure associated with any planting pattern can be identified a priori by calculating the variance-to-mean ratio of vegetation cover. Synthesis and applications. By introducing a level of spatial overdispersion (variance in vegetation clustering) into restoration planting designs, projects will insure themselves against the uncertainty imposed by disturbances, limited by their willingness to accept a lower rate of recolonization” (Fivash et al., 2022). Increasing spatial dispersion in ecosystem restoration mitigates risk in disturbance-driven environments).

2.) DEPTH: Van Katwijk, Thorhaug et al. (2016) conducted a review of almost 2000 seagrass restoration efforts over five continents. The one factor most clearly seen was that intertidal planting was far less successful than that in moderately shallow to medium water, which in turn is dependent on light penetration. It means that in the relatively turbid waters of the Texas coast, planting is restricted to shallow water, but not the intertidal zone.

3.) ANCHORS: Various types of anchors have been devised to hold samples in the sediment, ranging from wood sticks, metal rebar, frames to which samples tied, and plastic stakes. Generally, biodegradable objects are preferable over nonbiodegradable objects. Tests should proceed planting to make sure the wave energetics are severe enough to require anchors (Thorhaug et al.2022). Many studies not using anchors have been successful. Anchors create another step-in planting and thus increase time and cost of planting.

4.) PLANT PARTS USED:

a.) Seeds*: Halodule wrightii* produces seeds very intermittently in Texas. Since seed sources are unreliable, restoration efforts with seed have not been conducted in Texas on a large scale. Restoration by seeding *Zostera marina* is successful in Chesapeake Bay because this species of cool temperate waters is a prolific seed producer and 30 years of research of harvesting, planting and dormancy methods have occurred (Orth et al., 2006).

b.) Turions or sprigs: A turion is an overwintering bud that seagrasses produce. A sprig is a section of rhizome that includes meristematic tissue and multiple blades. Bunches of turions have been planted at a series of areas by Belaire (199x), Sheridan et al. (1999) with little success, and Thorhaug (1985), Thorhaug et al. (1985) with moderate success. These formed a large part of planting *Thalassia* in Biscayne Bay and other areas (Thorhaug, 1985; Thorhaug et al., 1985; Thorhaug and Cruz, 1987). Generally, turions or sprigs are planted with equal or less success than plugs and more success than seeds, dependent on species. Individual sites differ in terms of which technique is best.

c.) Plugs: Many of the pilot studies throughout Texas have used plugs (Thorhaug, 2001; Thorhaug and Schwarz, 2016; Thorhaug et al., 2020). Early work of scattered few plugs without controls to compare to was found successful, so this technique has been used for subtropical and tropical restorations over a 40-year period (Thorhaug, 1985, 1987, 2001; Thorhaug et al., 1985; Thorhaug and Cruz, 1987; Belaire, 1998, 1999). This technique includes the plant blades, rhizomes, and sediment as extracted by an instrument such as post-hole digger.

5.) PLANTING MANUALLY: A series of large-scale plantings, some by primitive underwater replicas of common farm equipment have occurred. Others which are experimental in nature and do not pretend to be for large scale planting. The important point is that most success to date has occurred from manual planting, and not from any of the more equipment-oriented methods. Thus, we continue to suggest manual planting be most effective for success.

Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots

(GLO Contract No. # 23-020-013-D607)

MATAGORDA BAY SEAGRASS RESTORATION PILOTS

Bill Balboa
Executive Director
Matagorda Bay Foundation

Anitra Thorhaug
President
Greater Caribbean Energy & Environment Foundation

March, 2023

Raspberry Island off Port O’Connor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Raspberry Island off Port O’Connor
- Calhoun County, Waterbody Name - Matagorda Bay, and State tract number - 242

Raspberry Island off Port O’Connor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
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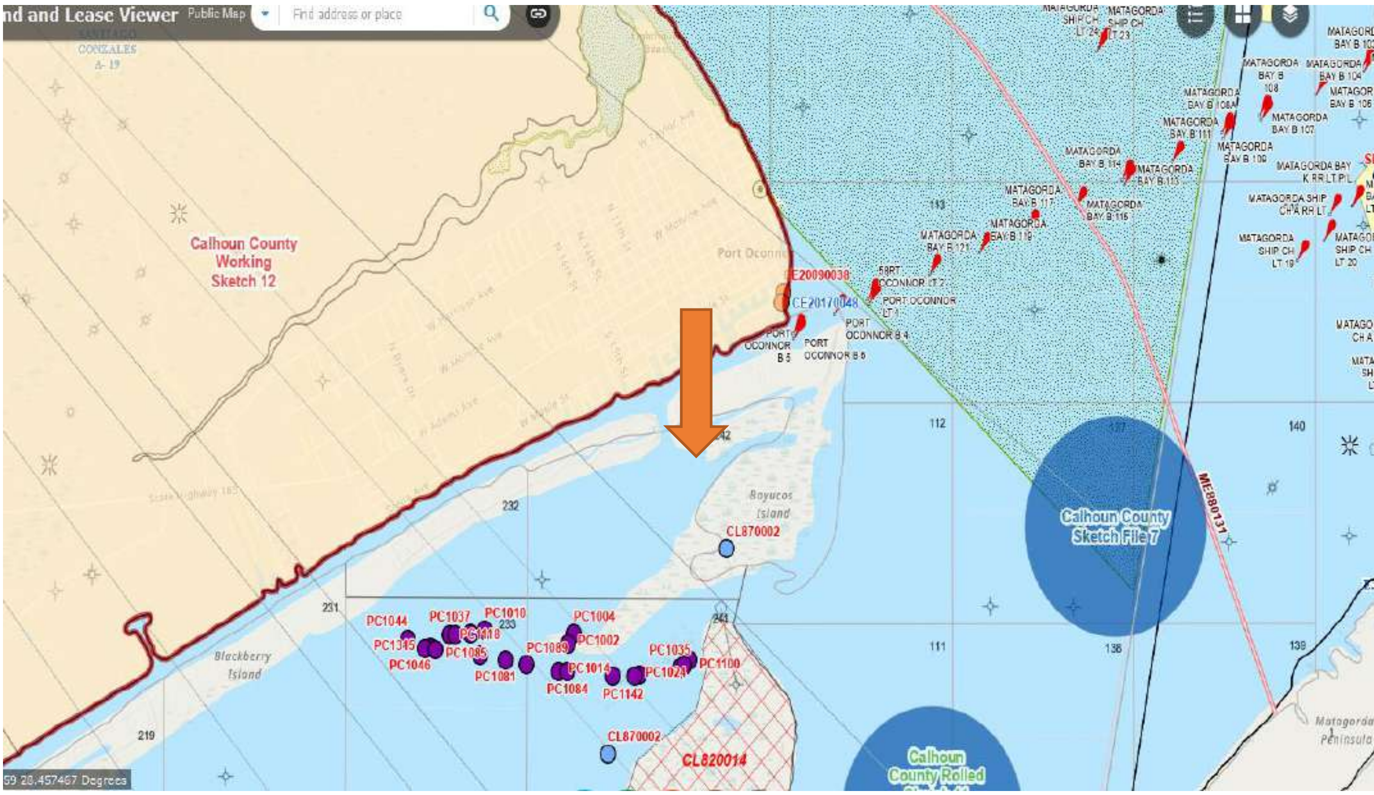
Raspberry Island off Port O’Connor

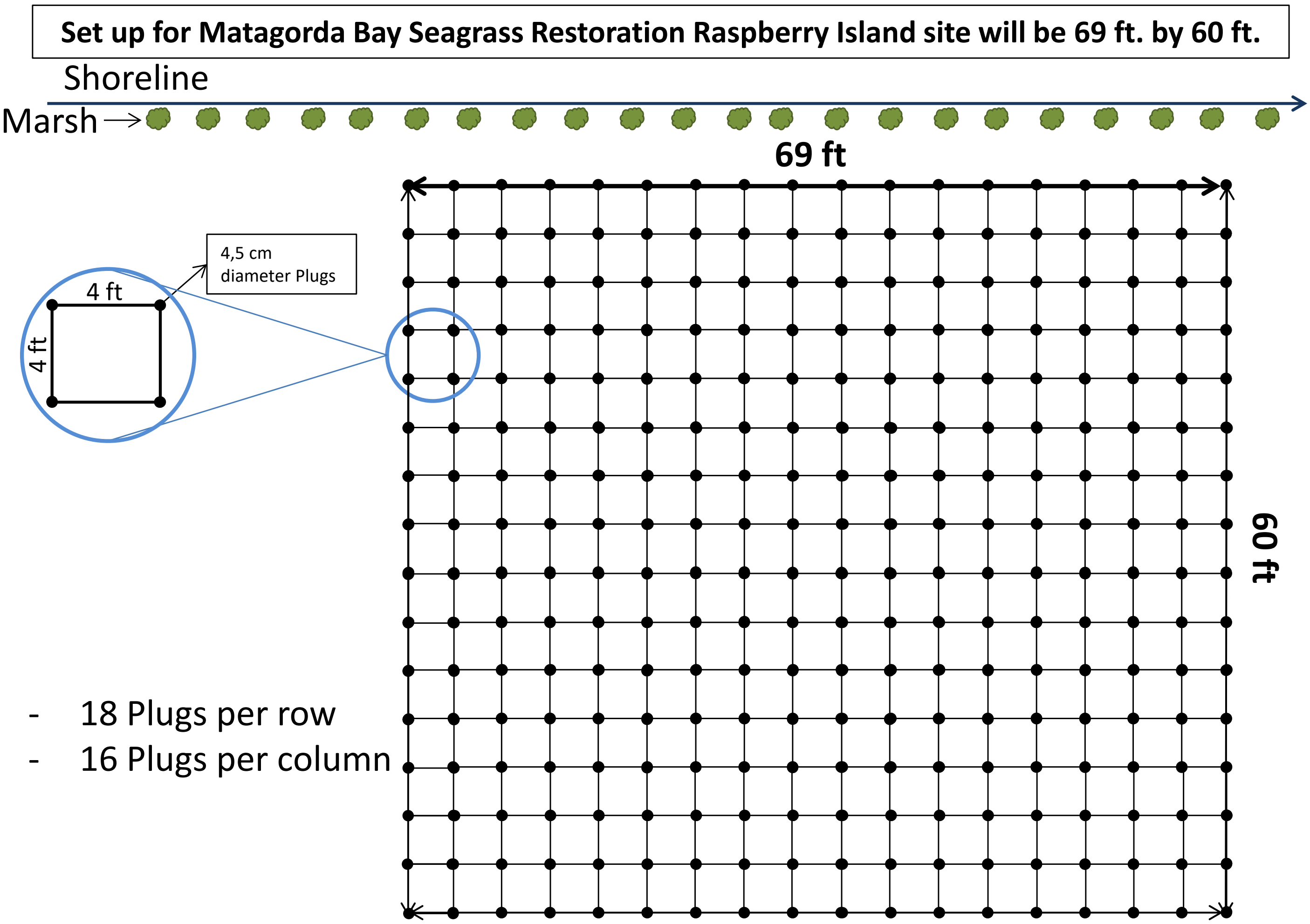


#1	Raspberry Island - Port O’Connor	28°26'0.03"N	96°24'35.55"W	69 ft x 60 ft

Raspberry Island off Port O'Connor - Plot aerial

Raspberry Island (POC)	#1	28°26'0.31"N	96°24'35.95"W	69 ft x 60 ft
	#2	28°26'0.32"N	96°24'35.16"W	
	#3	28°25'59.73"N	96°24'35.18"W	
	#4	28°25'59.71"N	96°24'35.88"W	

Raspberry Island off Port O'Connor

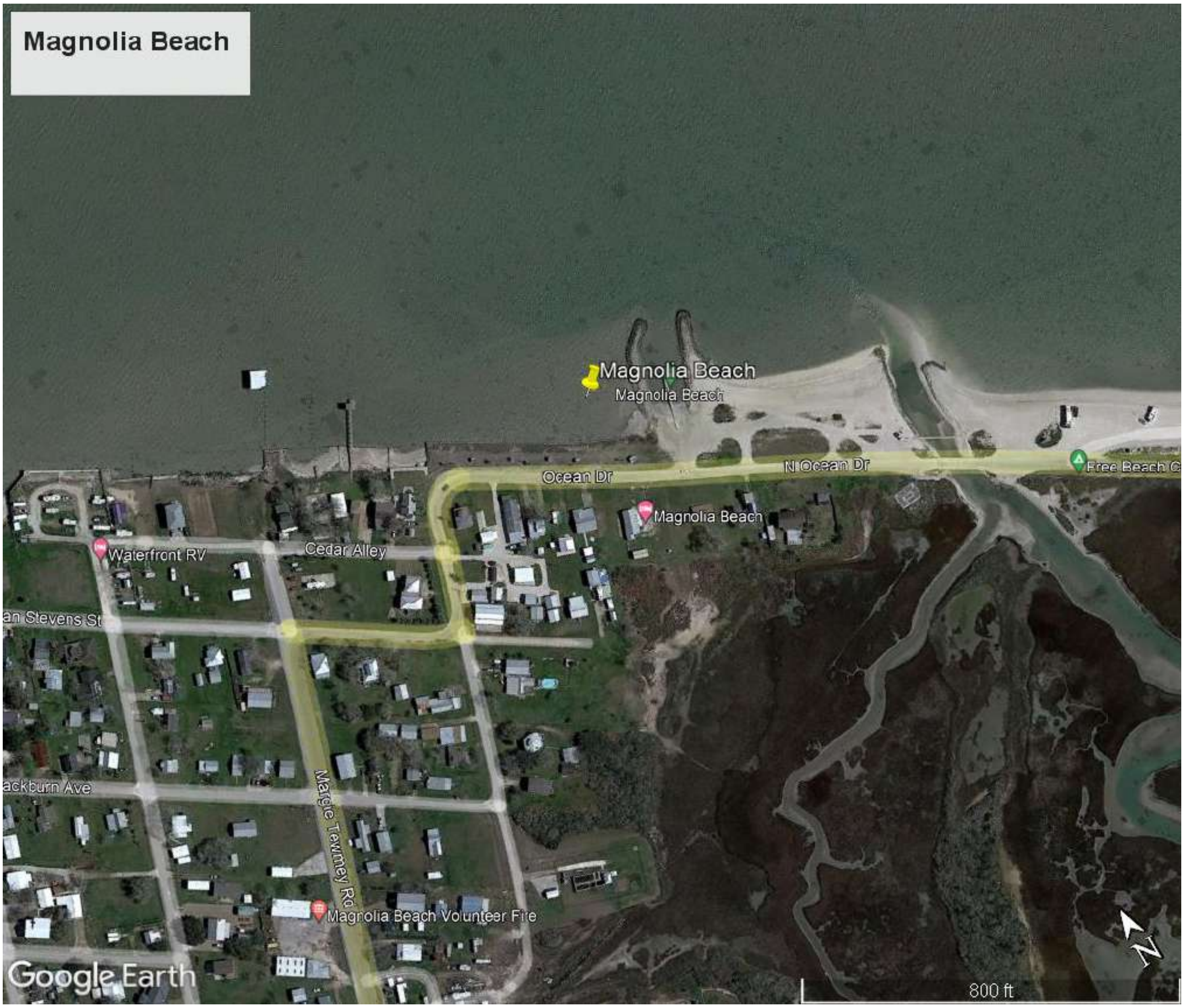


- 18 Plugs per row
- 16 Plugs per column

Magnolia Beach Pilot

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Magnolia beach Texas.
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 33

Magnolia Beach Pilot



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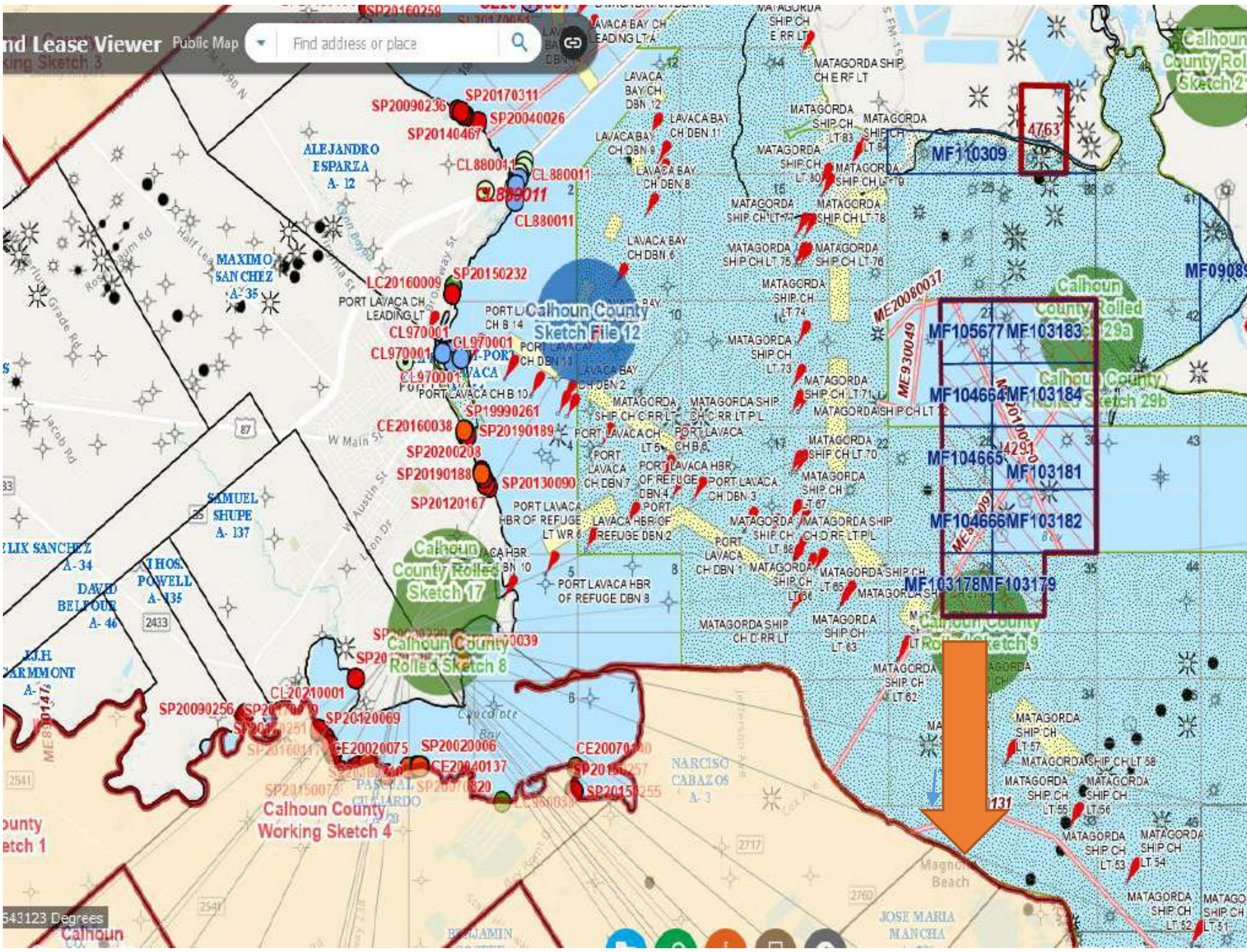
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Magnolia beach Texas.
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 33

Magnolia Beach Pilot



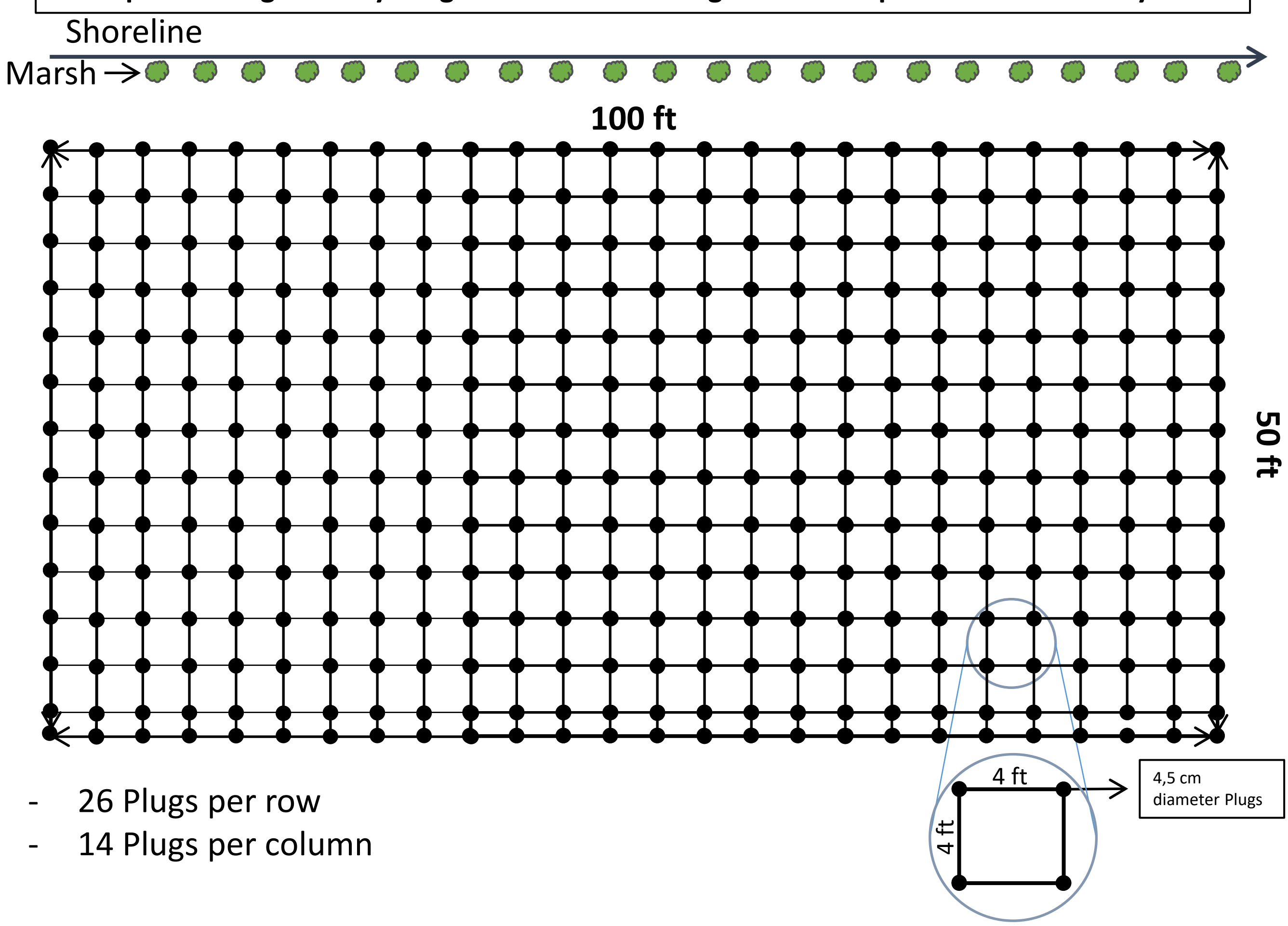
Magnolia Beach	28°33'40.99"N	96°32'23.59"W	100 ft x 50 ft

Magnolia Beach Pilot - Plot aerial

Magnolia Beach	#1	28°33'40.50"N	96°32'23.24"W	100 ft x 50 ft
	#2	28°33'40.97"N	96°32'24.26"W	
	#3	28°33'41.49"N	96°32'24.06"W	
	#4	28°33'40.96"N	96°32'23.05"W	

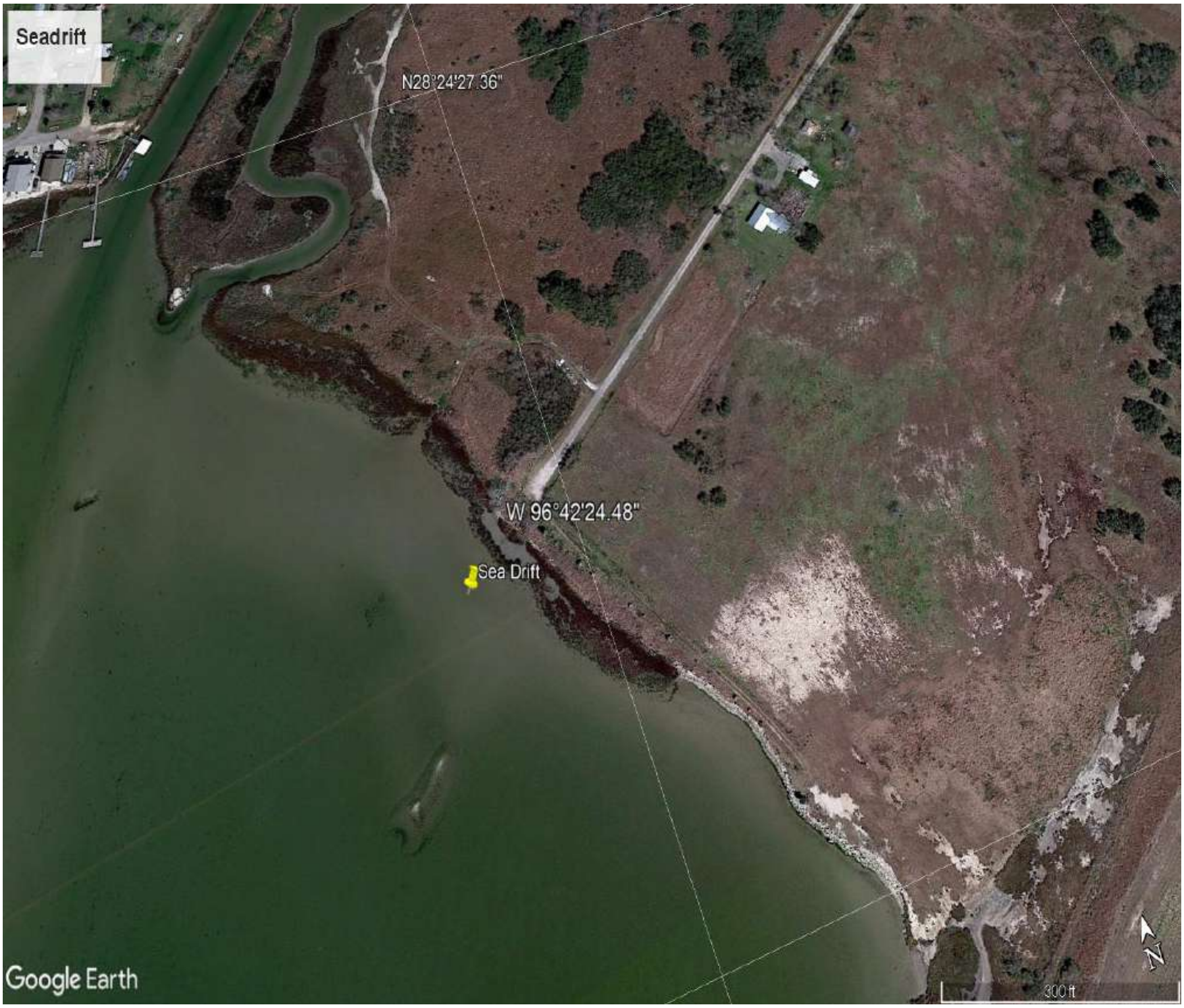
Magnolia Beach Pilot

Set up for Matagorda Bay Seagrass Restoration Magnolia Beach pilot will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

Sea Drift



- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Seadrift.
- Calhoun County, Waterbody Name – Hynes Bay, and State tract number - 133

Sea Drift

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Seadrift.
- Calhoun County, Waterbody Name – Hynes Bay, and State tract number - 133

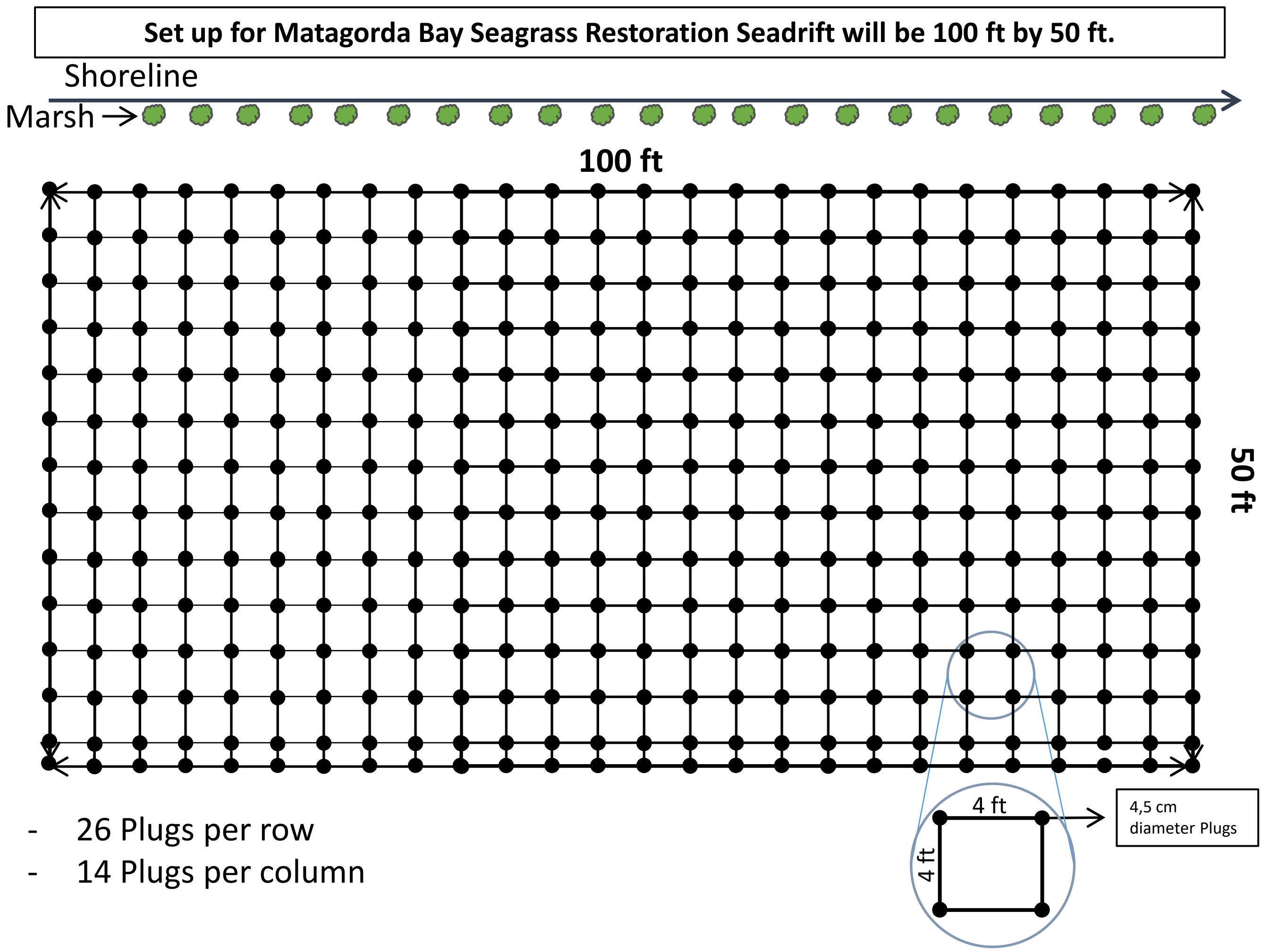
Sea Drift

Seadrift	28°24‘19.52"N	96°42'26.51"W	100 ft x 50 ft

Sea Drift

Seadrift	#1	28°24‘20.13"N	96°42'26.54"W	100 ft x 50 ft
	#2	28°24‘19.27"N	96°42'26.00"W	
	#3	28°24'19.02"N	96°42'26.48"W	
	#4	28°24‘19.88"N	96°42'27.02"W	

Sea Drift



- 26 Plugs per row
- 14 Plugs per column

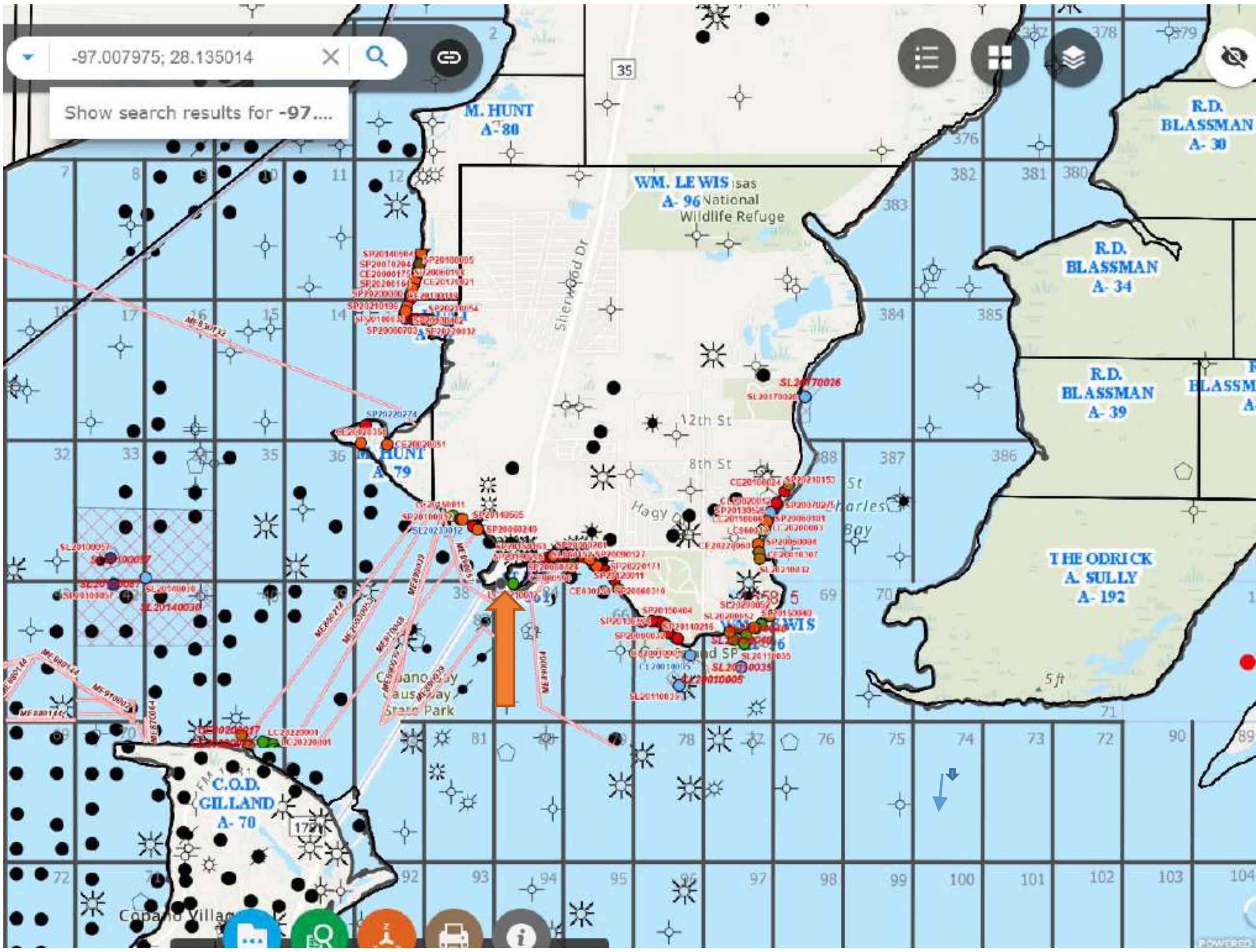
Lamar Bridge Abutment

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Lamar Bridge Abutment.
- Aransas County, Waterbody Name – Aransas Bay, and State tract number - 84

Lamar Bridge Abutment

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Lamar Bridge Abutment.
- Aransas County, Waterbody Name – Aransas Bay, and State tract number - 84

Lamar Bridge Abutment

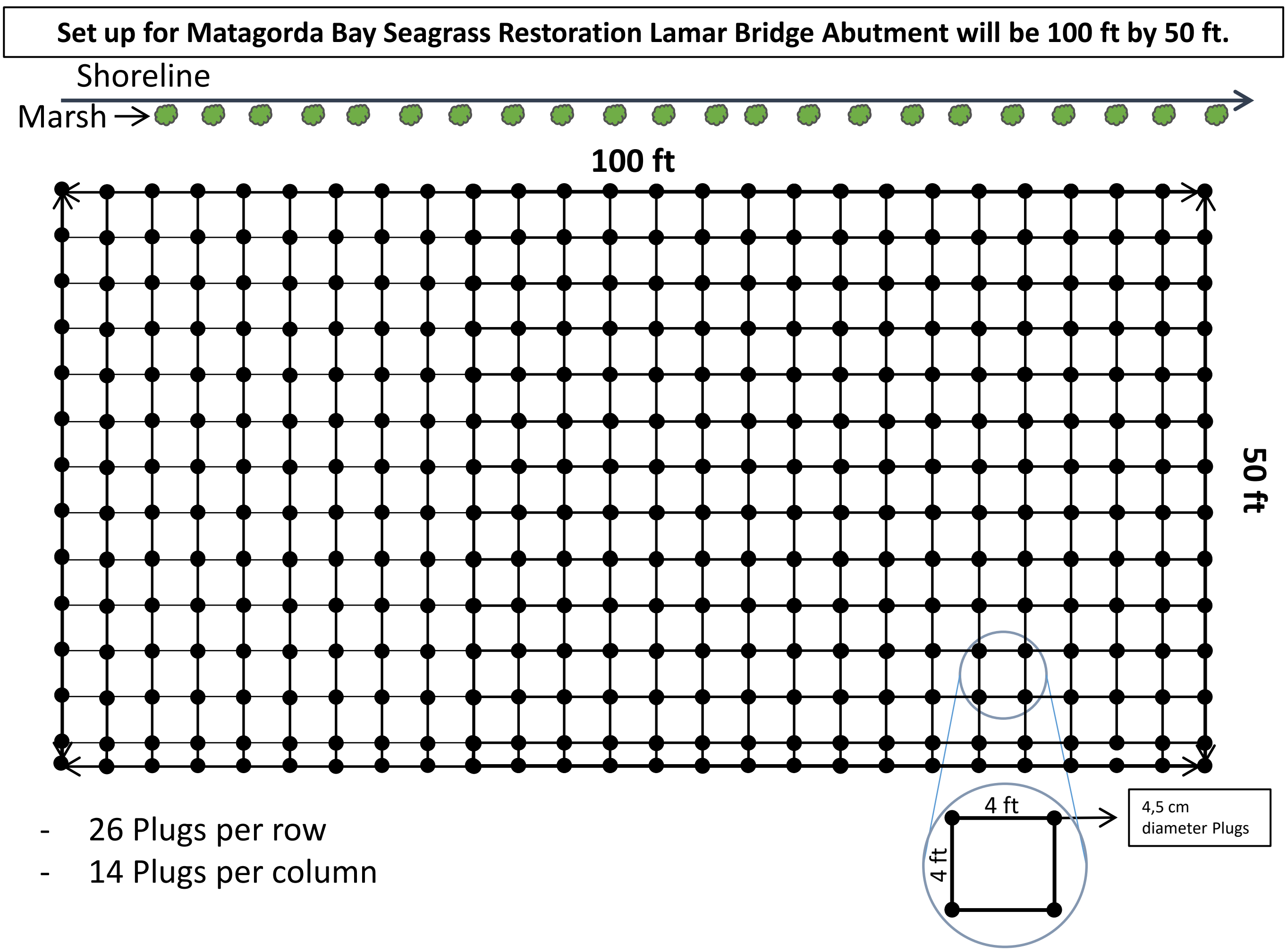


Lamar Bridge Abutment	28°08'06.05"N	97°00'28.71"W	100 ft x 50 ft

Lamar Bridge Abutment

Lamar Bridge Abutment	#1	28°08'06.39"N	97°00'29.13"W	100 ft x 50 ft
	#2	28°08'06.10"N	97°00'28.06"W	
	#3	28°08'05.66"N	97°00'28.29"W	
	#4	28°08'05.93"N	97°00'29.31"W	

Lamar Bridge Abutment



- 26 Plugs per row
- 14 Plugs per column

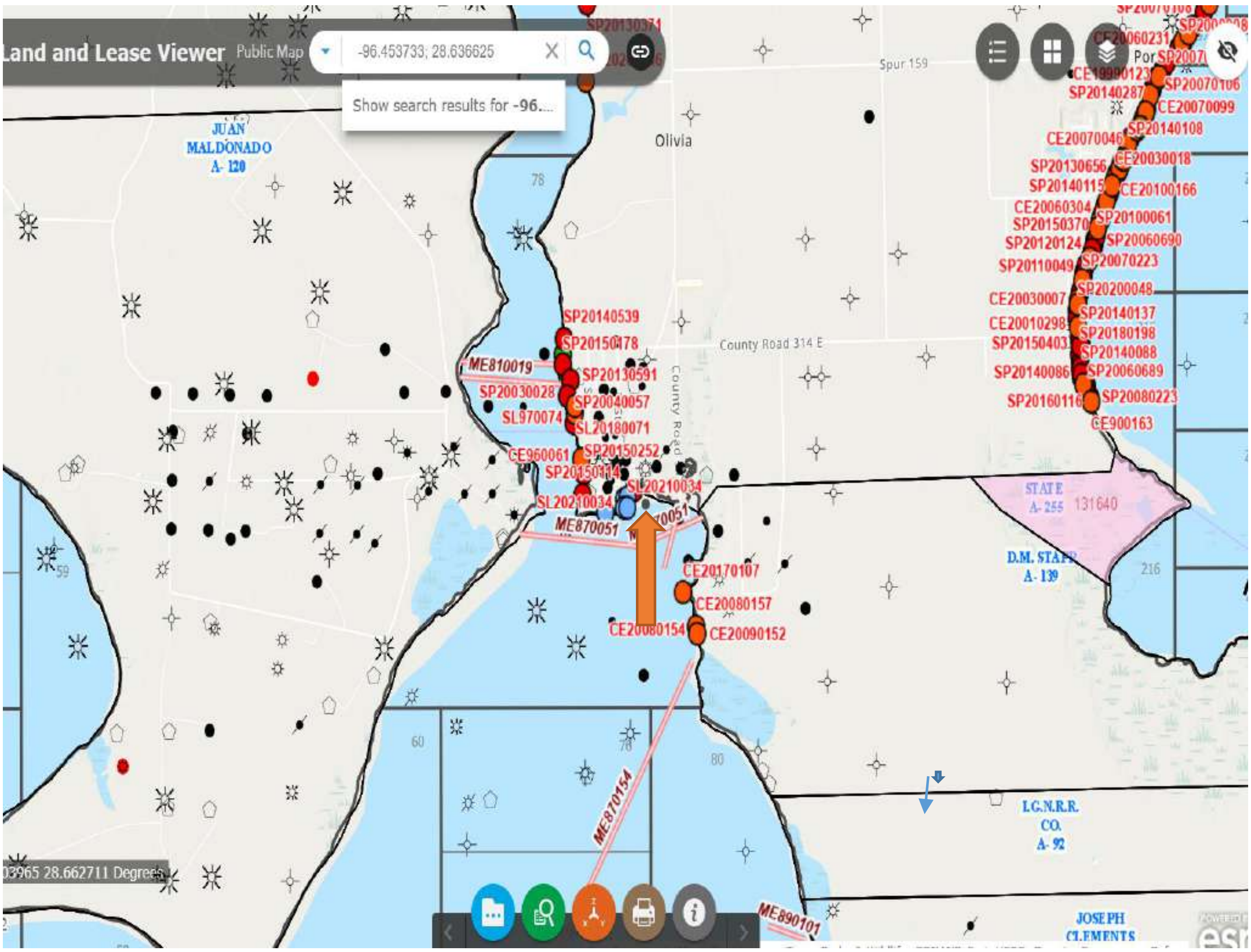
Keller Bay Kayak Launch

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Keller Bay Kayak Launch.
- Matagorda County, Waterbody Name – Keller Bay, and State tract number - 77

Keller Bay Kayak Launch

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Keller Bay Kayak Launch.
- Matagorda County, Waterbody Name – Keller Bay, and State tract number - 77

Keller Bay Kayak Launch



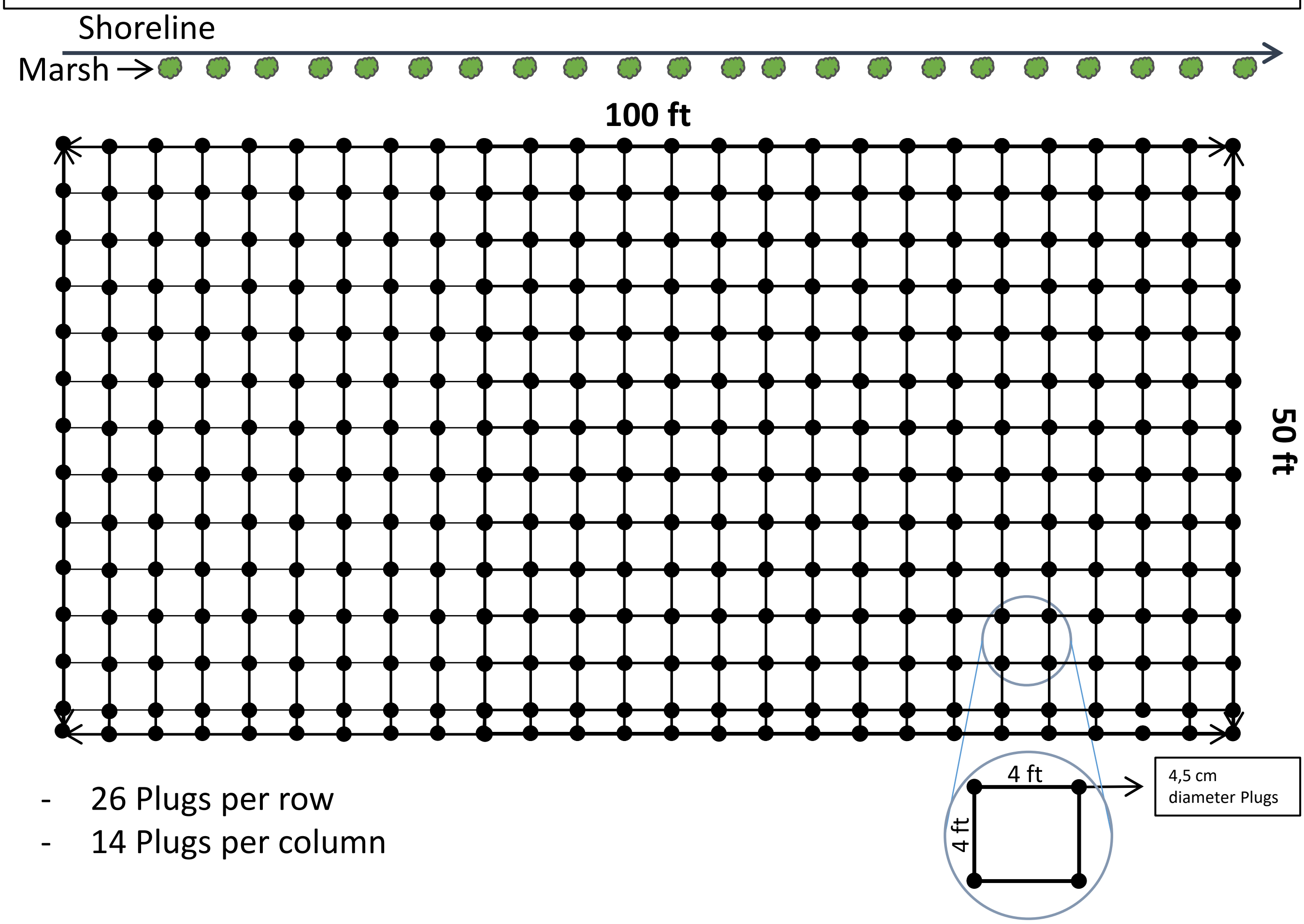
Keller Bay Kayak Launch	28°38'11.85"N	96°27'13.44"W	100 ft x 50 ft

Keller Bay Kayak Launch

Keller Bay Kayak Launch	#1	28°38‘12.13"N	96°27’14.03"W	100 ft x 50 ft
	#2	28°38‘12.13"N	96°27’12.90"W	
	#3	28°38‘11.65"N	96°27’12.89"W	
	#4	28°38‘11.65"N	96°27’13.95"W	

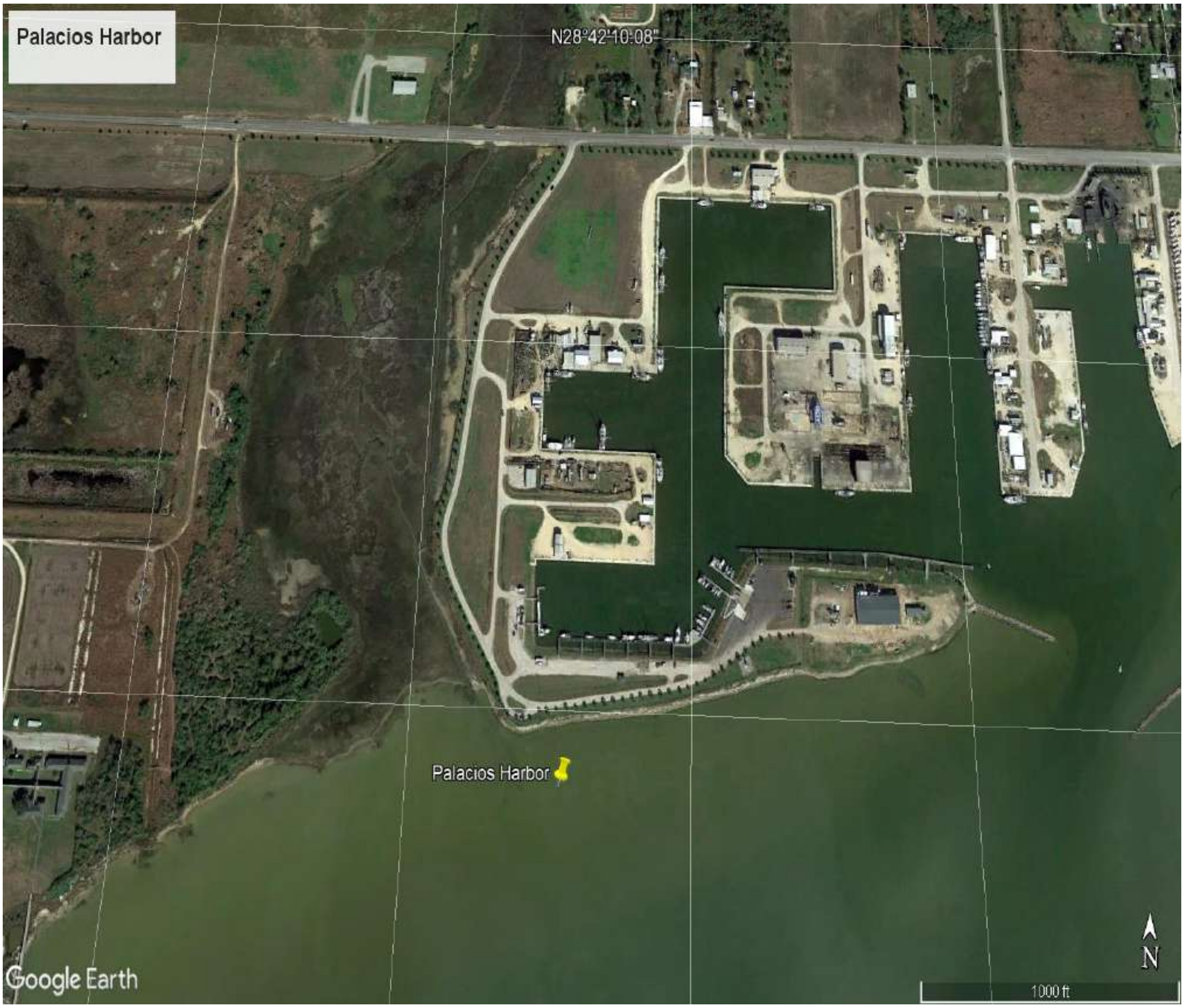
Keller Bay Kayak Launch

Set up for Matagorda Bay Seagrass Restoration Keller Bay Kayak Launch will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

Palacios Harbor

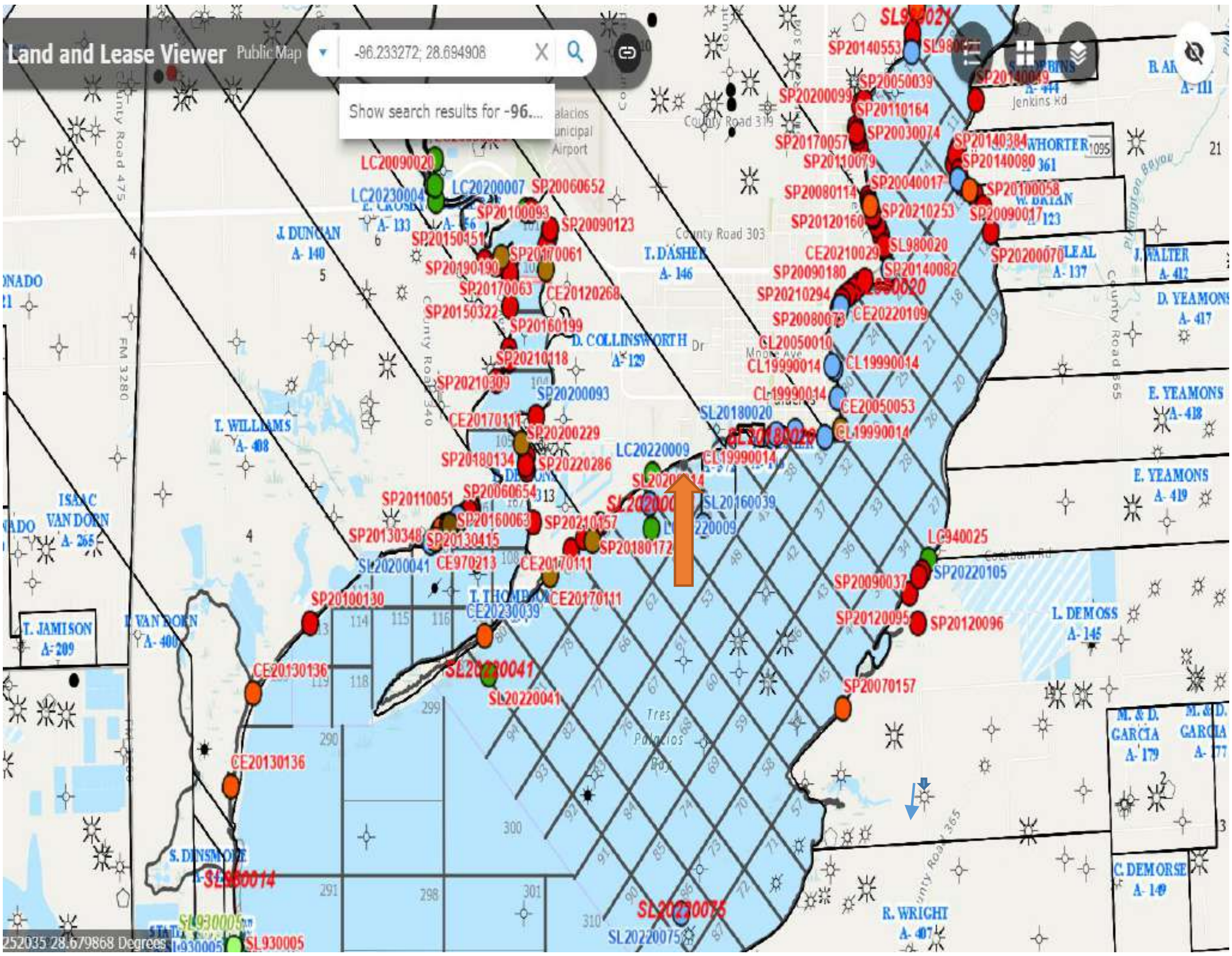


- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Palacios Harbor.
- Matagorda County, Waterbody Name – Tres Palacios Bay, and State tract number - 50

Palacios Harbor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Palacios Harbor.
- Matagorda County, Waterbody Name – Tres Palacios Bay, and State tract number - 50

Palacios Harbor



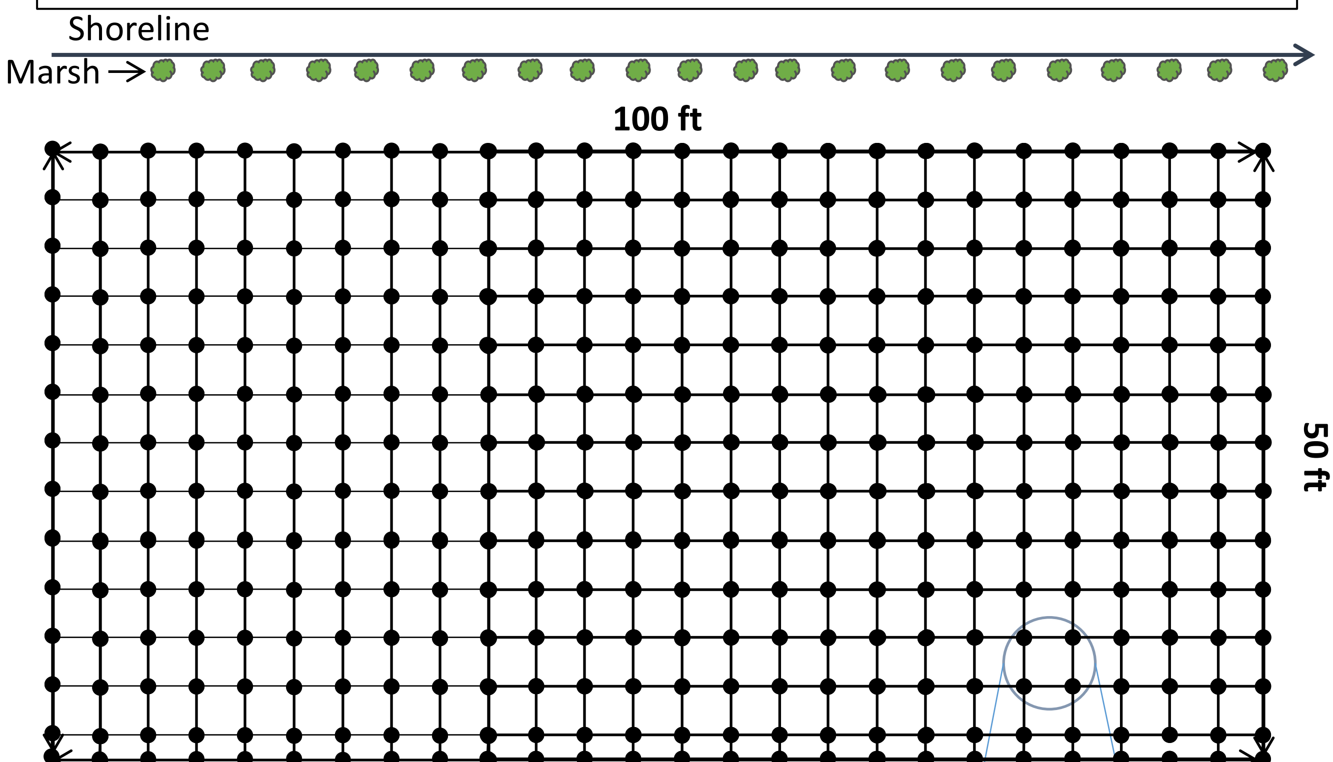
Palacios Harbor	28°41’41.67"N	96°13’59.78"W	100 ft x 50 ft

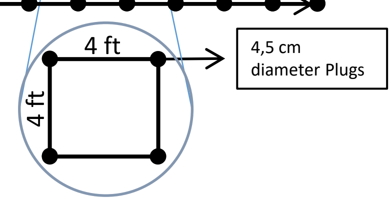
Palacios Harbor

Palacios Harbor	#1	28°41'41.80"N	96°14'00.45"W	100 ft x 50 ft
	#2	28°41'42.07"N	96°13'59.37"W	
	#3	28°41'41.60"N	96°13'59.20"W	
	#4	28°41'41.34"N	96°14'00.23"W	

Palacios Harbor

Set up for Matagorda Bay Seagrass Restoration Palacios Harbor will be 100 ft by 50 ft.





- 26 Plugs per row
- 14 Plugs per column

Oyster Lake Park

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Oyster Reef Park
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 315

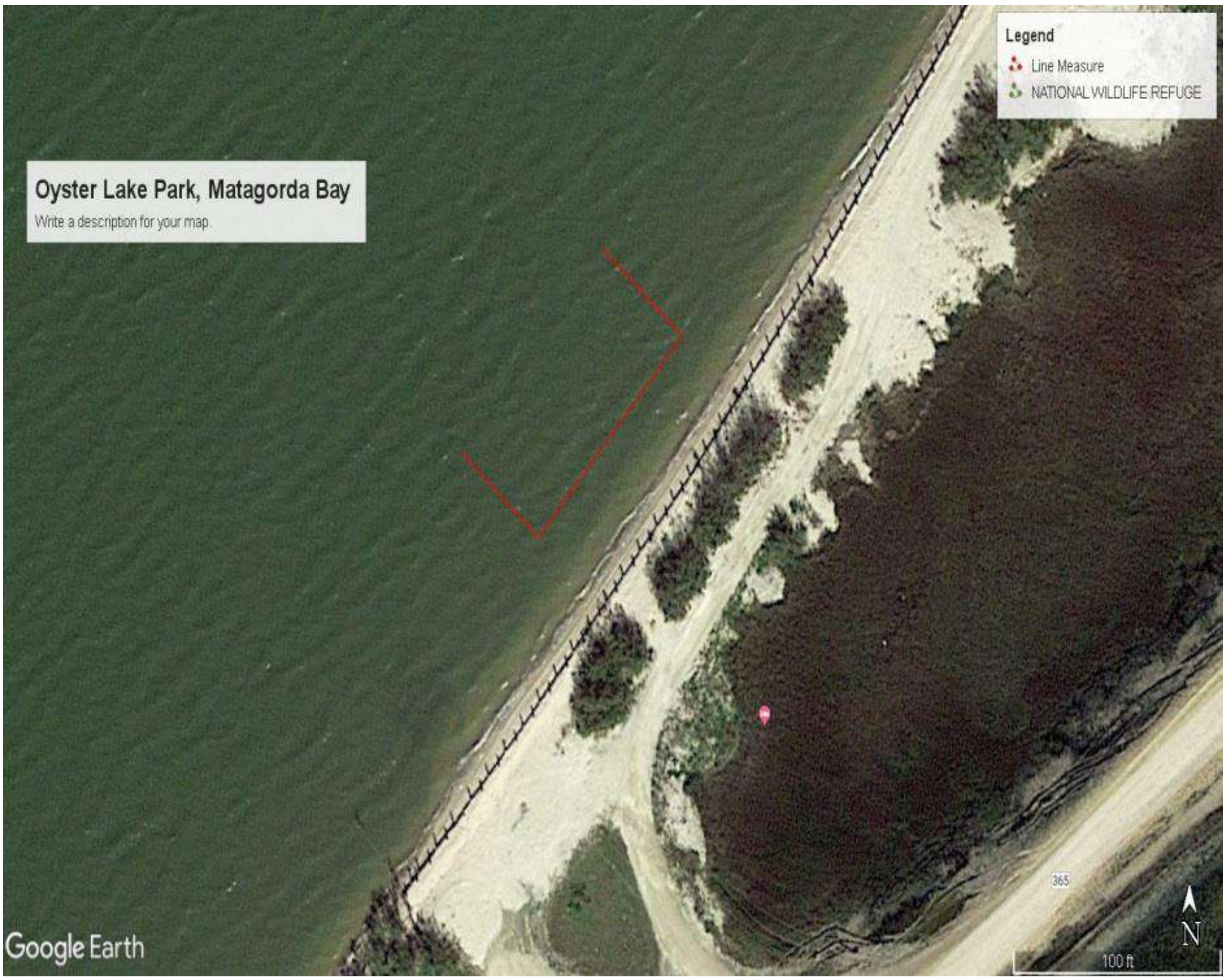
Oyster Lake Park

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Oyster Reef Park
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 315

Oyster Lake Park

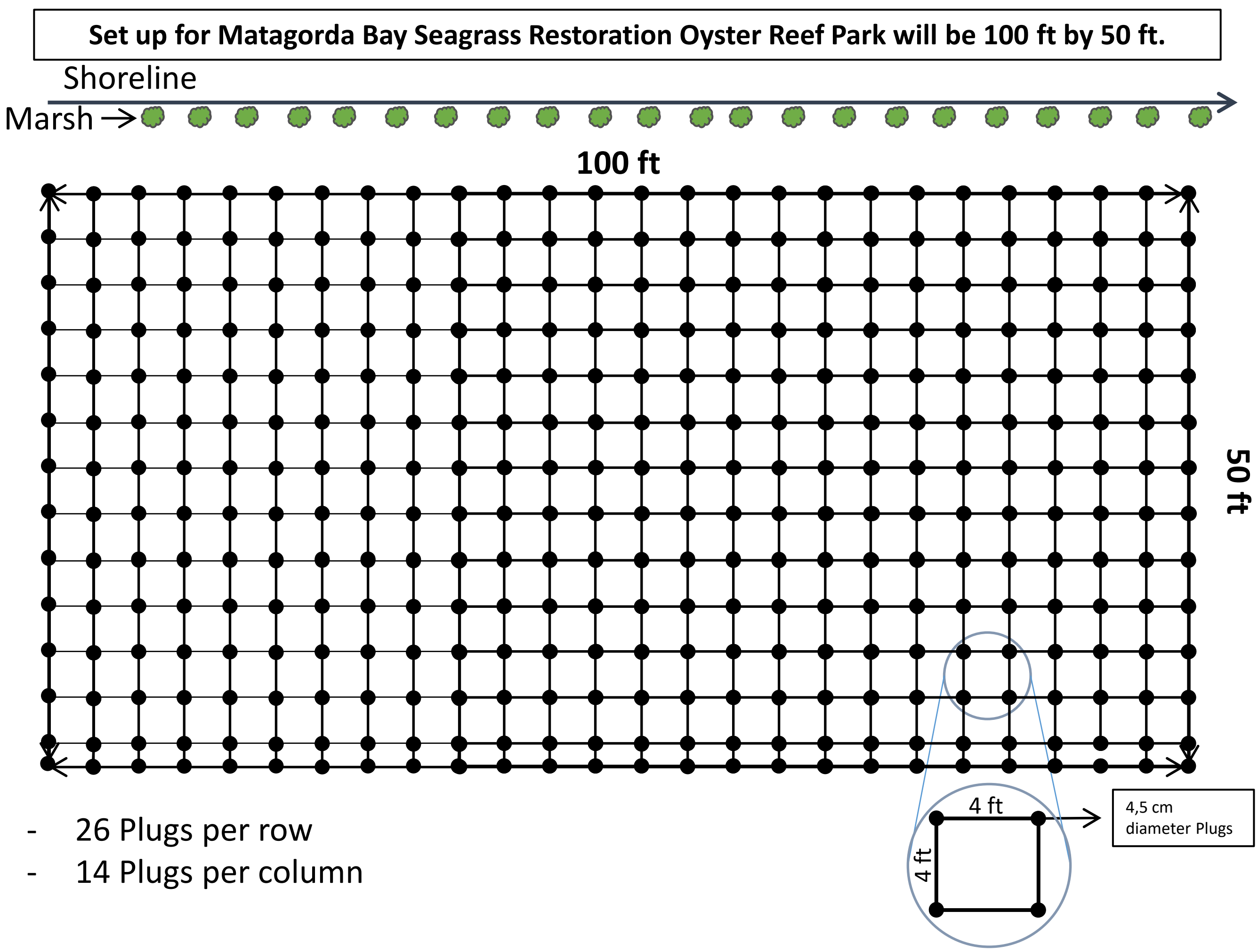
Oyster Lake Park	28°36‘42.15"N	96°12’54.24”W	100 ft x 50 ft

Oyster Lake Park - Aerial photo with pilot drawing



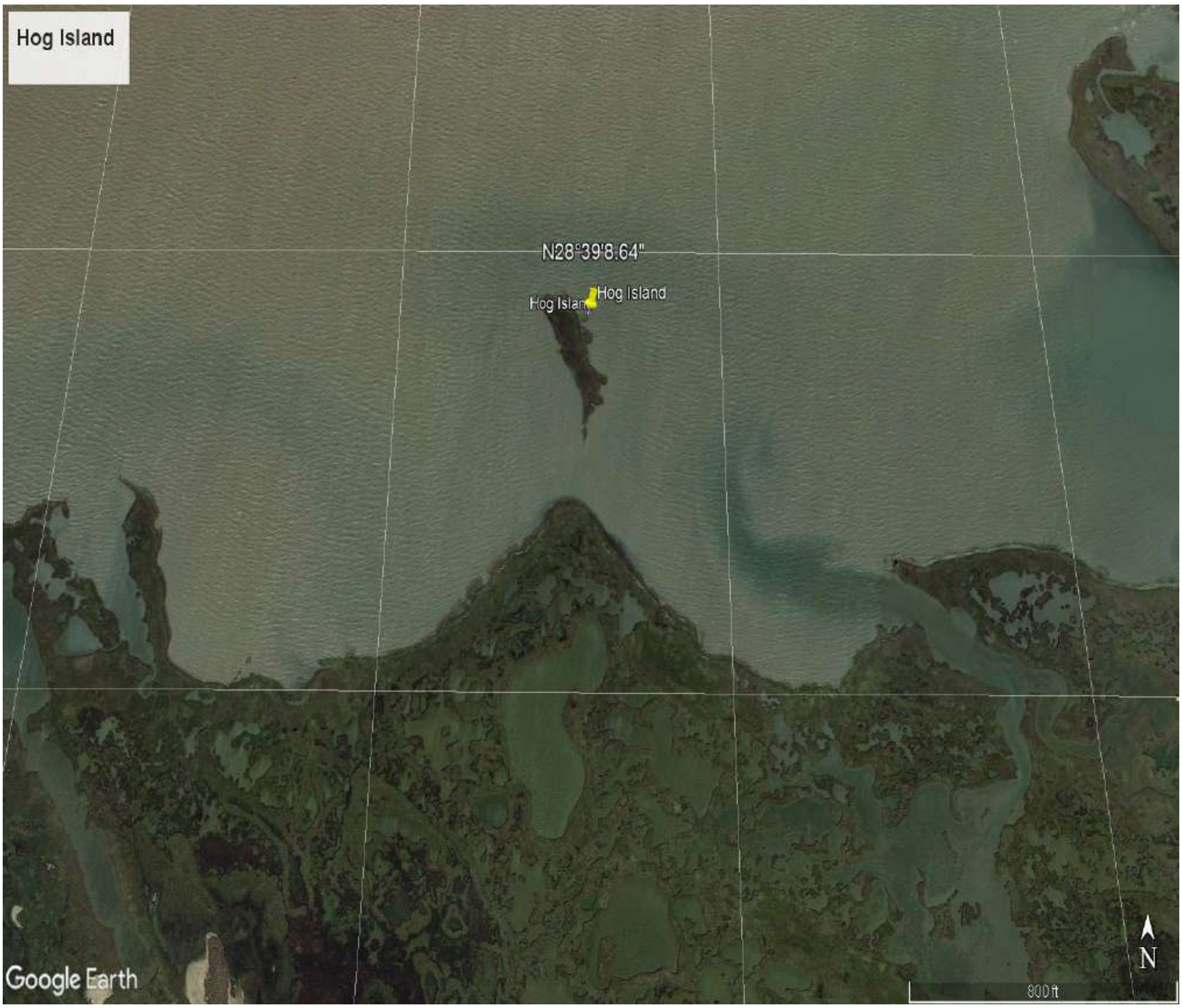
Oyster Lake Park	#1	28°36'41.60"N	96°12'54.42"W	100 ft x 50 ft
	#2	28°36'42.36"N	96°12'53.71"W	
	#3	28°36'42.65"N	96°12'54.17"W	
	#4	28°36'41.88"N	96°12'54.89"W	

Oyster Reef Park



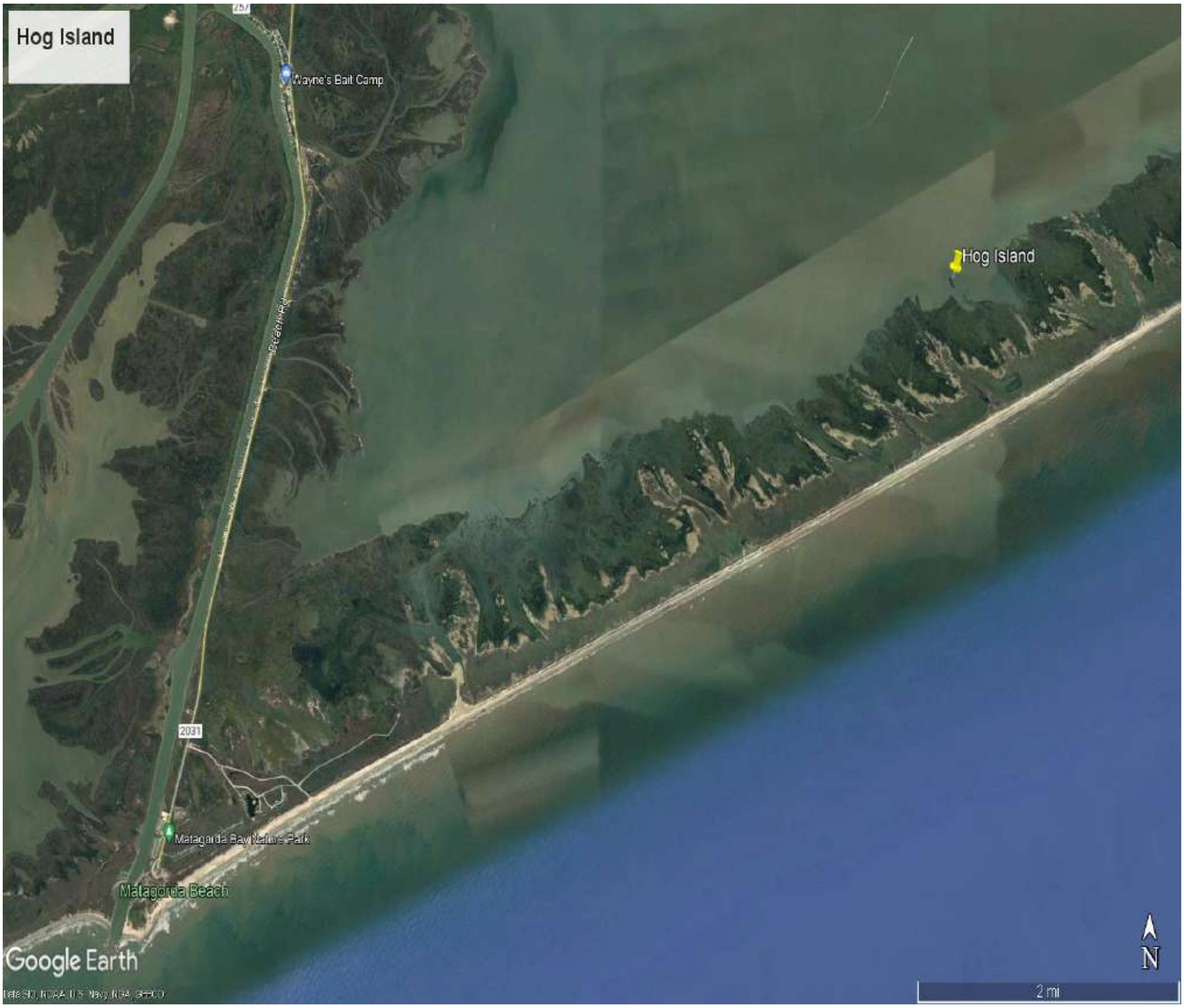
- 26 Plugs per row
- 14 Plugs per column

Hog Island



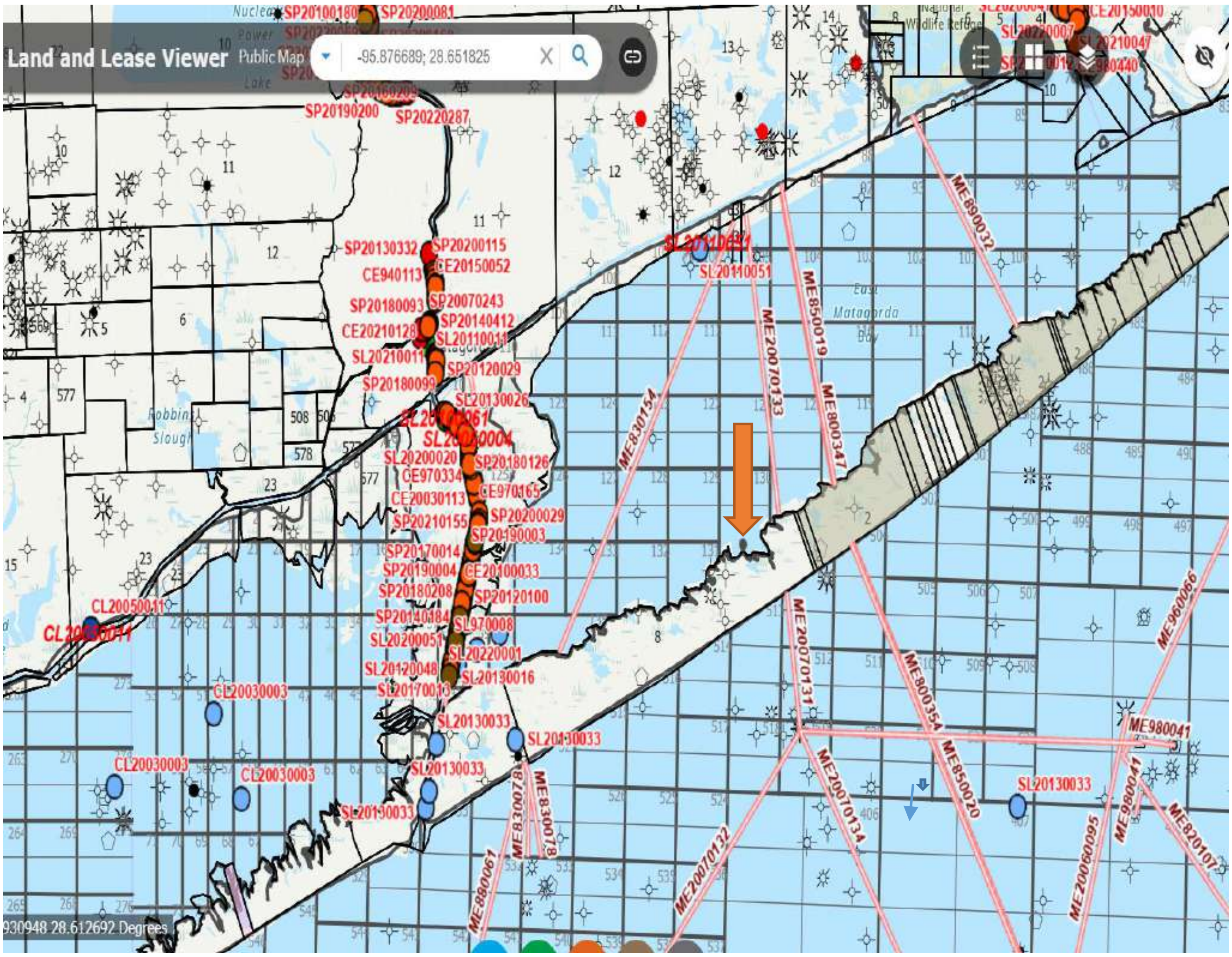
- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Hog Island .
- Matagorda County, Waterbody Name – East Matagorda Bay, and State tract number - 130

Hog Island



- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Hog Island .
- Matagorda County, Waterbody Name – East Matagorda Bay, and State tract number - 130

Hog Island

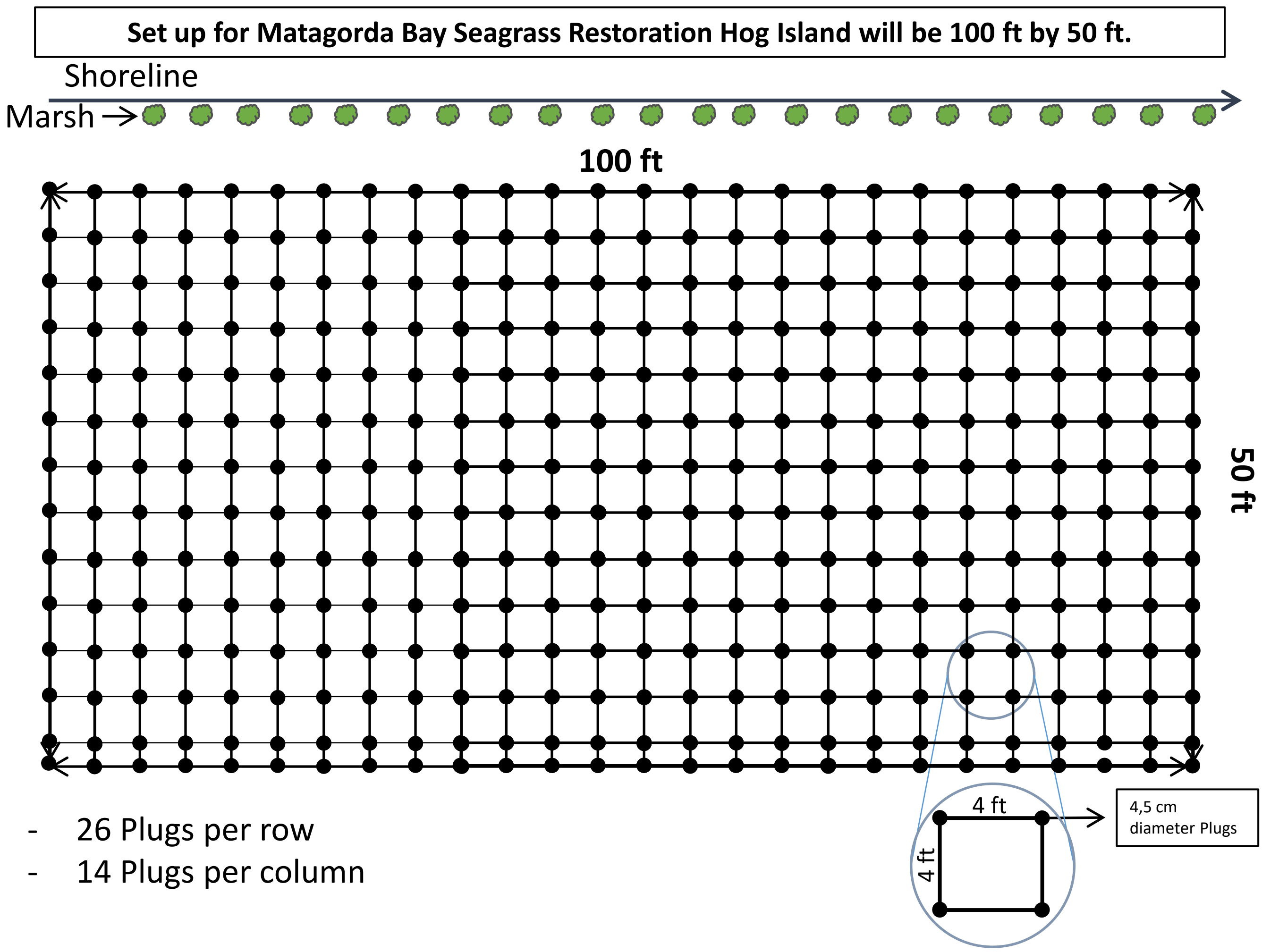


Hog Island	28°39'06.57"N	96°52'36.08"W	100 ft x 50 ft

Hog Island

Hog Island	#1	28°39’06.98"N	95°52’36.52"W	100 ft x 50 ft
	#2	28°39’06.05"N	96°52’36.14"W	
	#3	28°39’06.25"N	96°52’35.63"W	
	#4	28°39’07.19"N	96°52’36.01"W	

Hog Island



- 26 Plugs per row
- 14 Plugs per column

Project Sites - Land maps of TGLO Texas

Site	Name	Long.	Lat.	Area	Obs.
#1	Raspberry Island - Port O'Connor	28°26'00.03"N	96°24'35.55"W	69 ft x 60 ft	
#2	Magnolia Beach	28°33'40.99"N	96°32'23.59"W	100 ft x 50 ft	
#3	Seadrift	28°24'19.52"N	96°42'26.51"W	100 ft x 50 ft	
#4	Lamar Bridge Abutment	28°08'06.05"N	97°00'28.71"W	100 ft x 50 ft	
#5	Keller Bay Kayak Launch	28°38'11.85"N	96°27'13.44"W	100 ft x 50 ft	
#6	Palacios Fish Harbor	28°41'41.67"N	96°13'59.78"W	100 ft x 50 ft	
#7	Oyster Lake Park	28°36'42.15"N	96°12'54.24"W	100 ft x 50 ft	
#8	Hog Island	28°39'06.57"N	96°52'36.08"W	100 ft x 50 ft	

Location Map - Project Sites
Aerial Photos & Project Site Plan

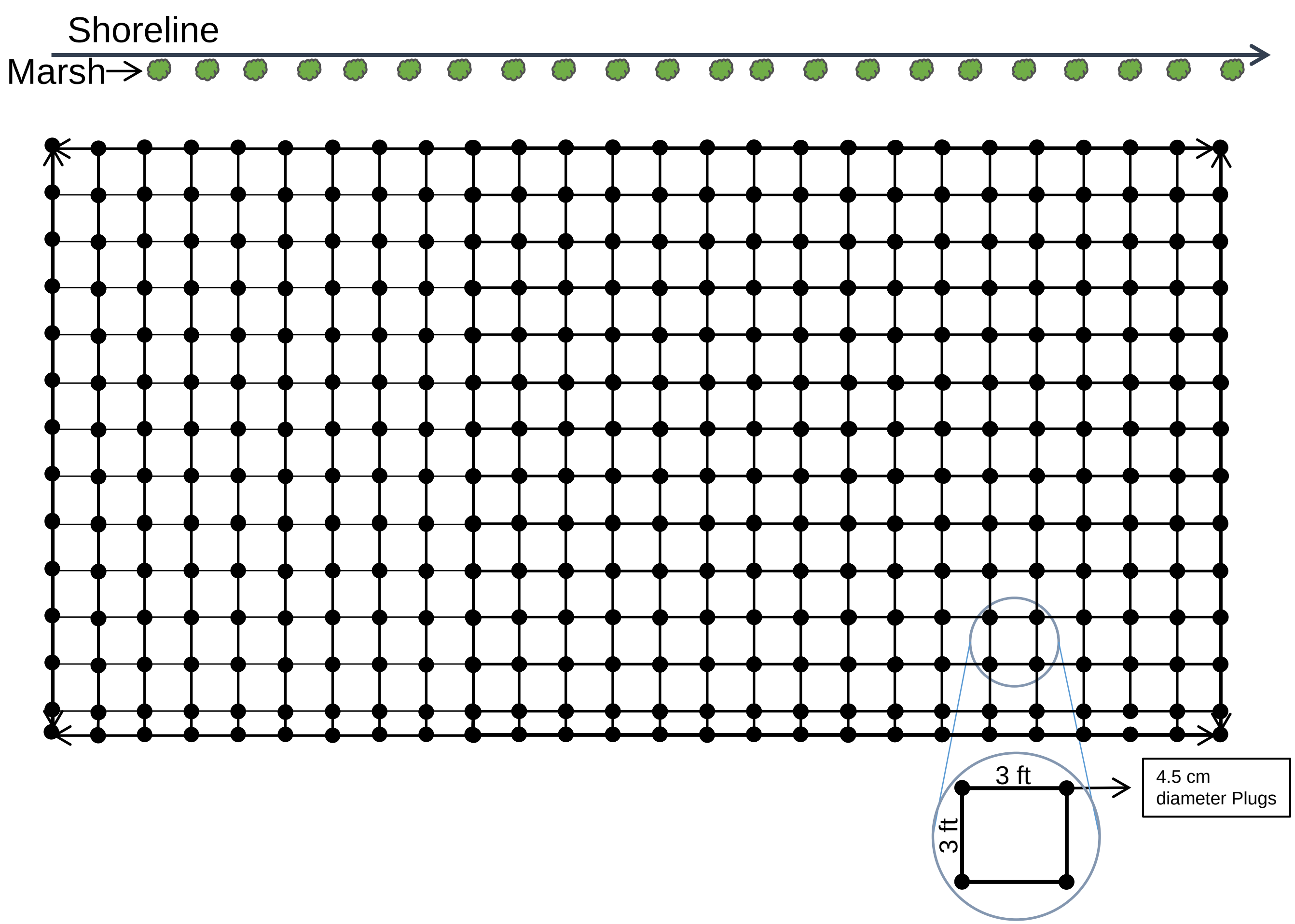
Planting Cost Effective Spatial Sites

Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

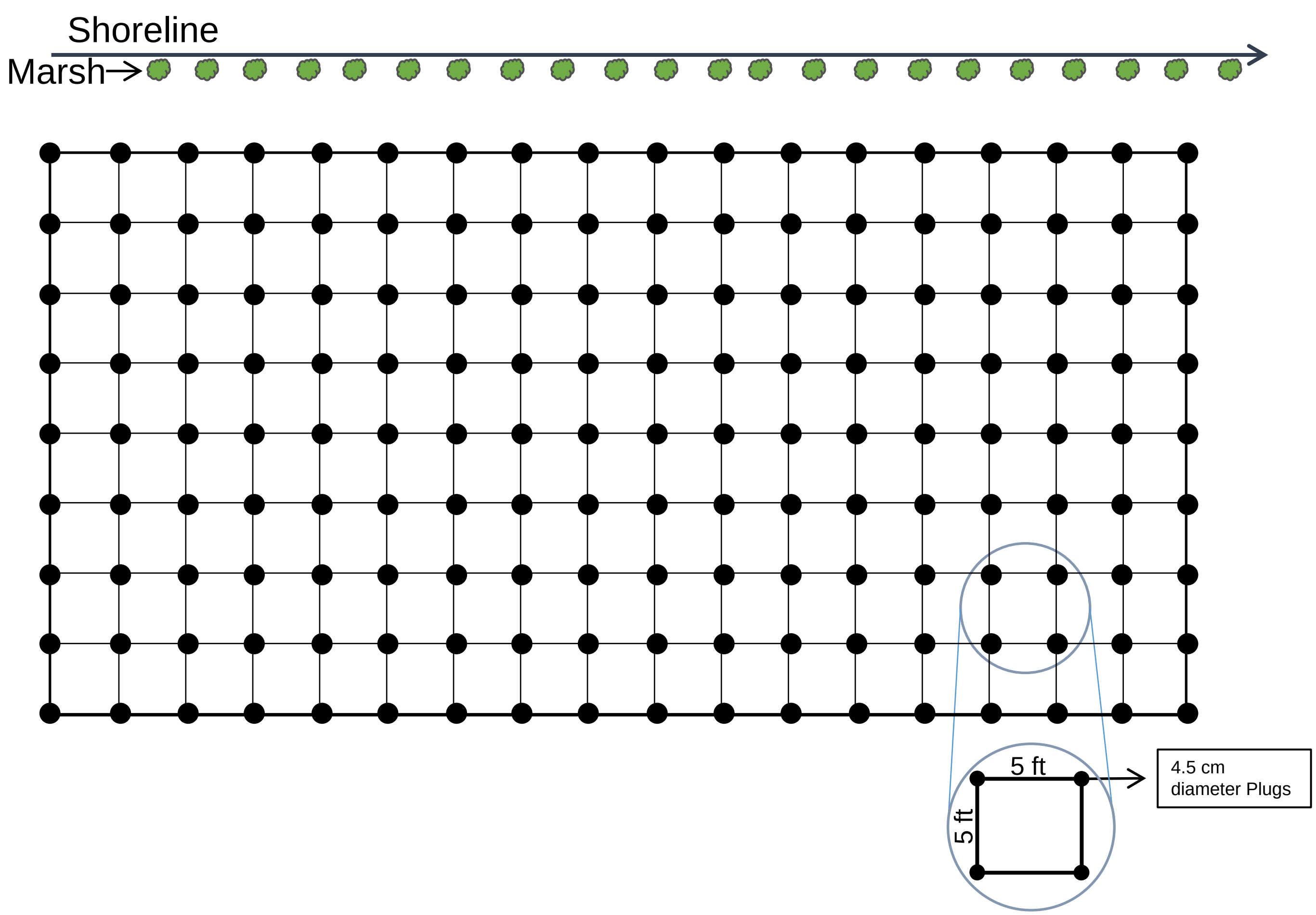
Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

Set up for Planting Cost Effective Spatial Sites Magnolia Beach pilot.



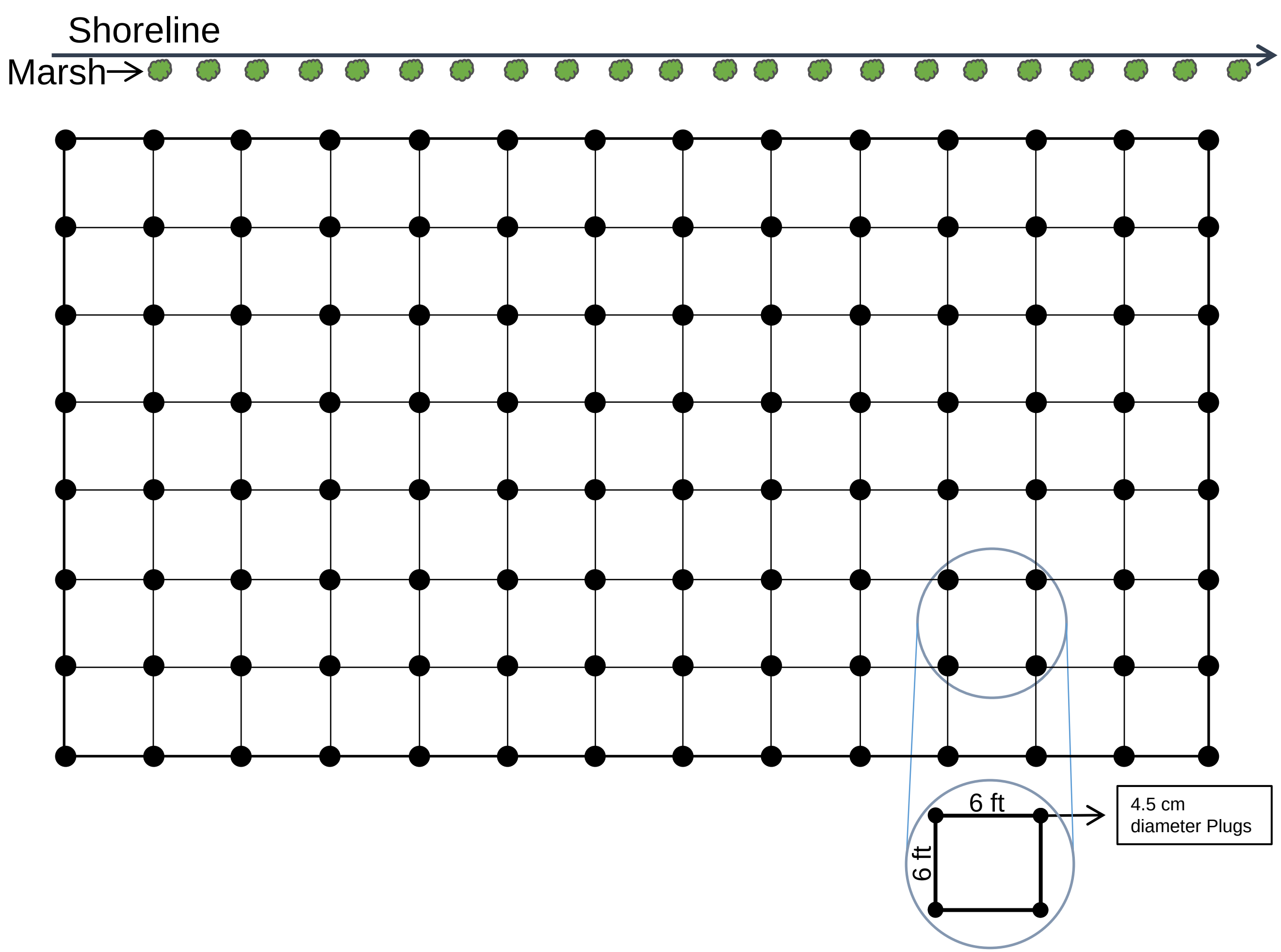
Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

Set up for Planting Cost Effective Spatial Sites Magnolia Beach pilot.



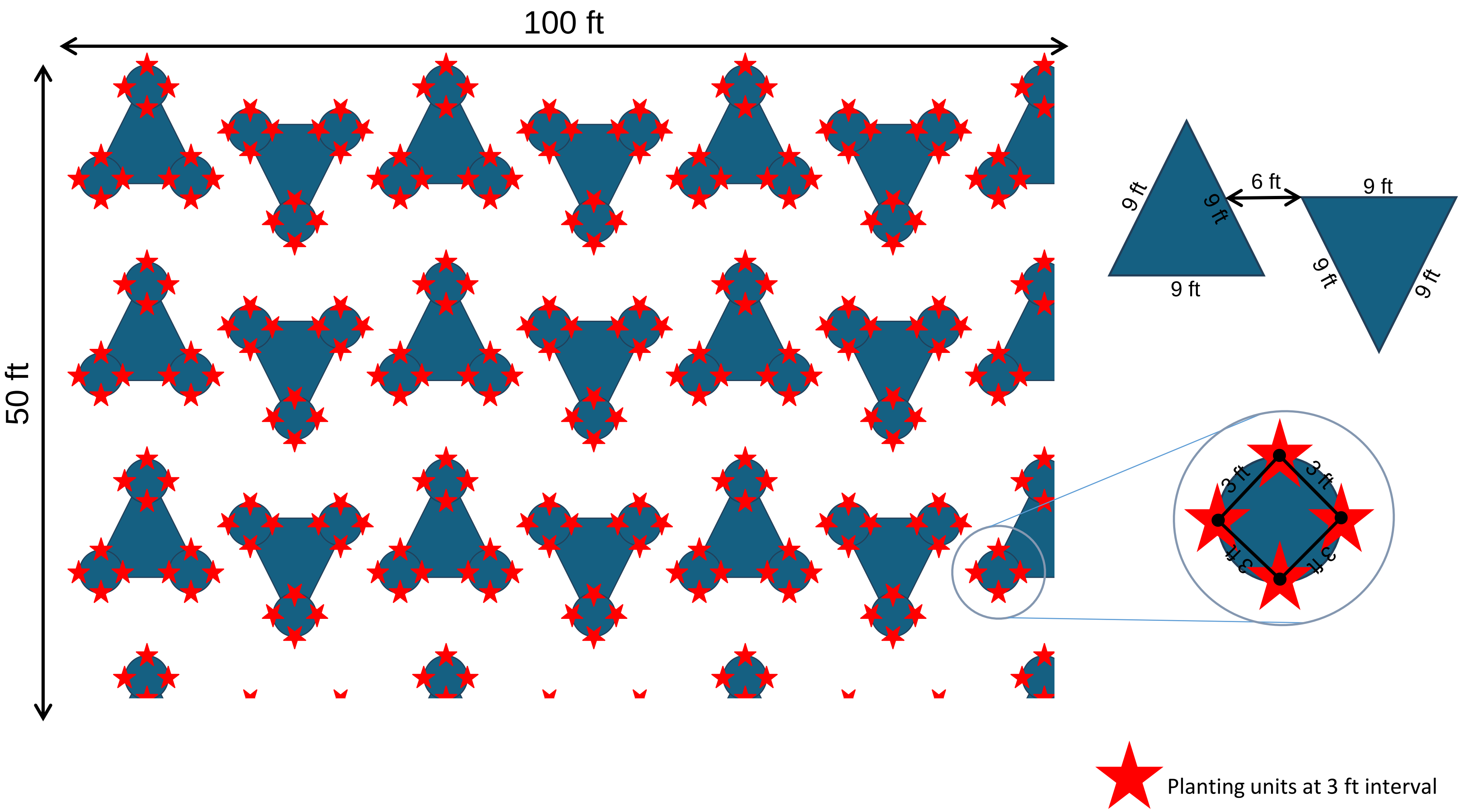
Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

Set up for Planting Cost Effective Spatial Sites Magnolia Beach pilot.



Planting Cost Effective Spatial Sites
Site #1 - Magnolia Beach

Planting Design - Spatial and configurational design Magnolia Beach pilot.



Planting Cost Effective Spatial Sites
Site #2 - Seadrift

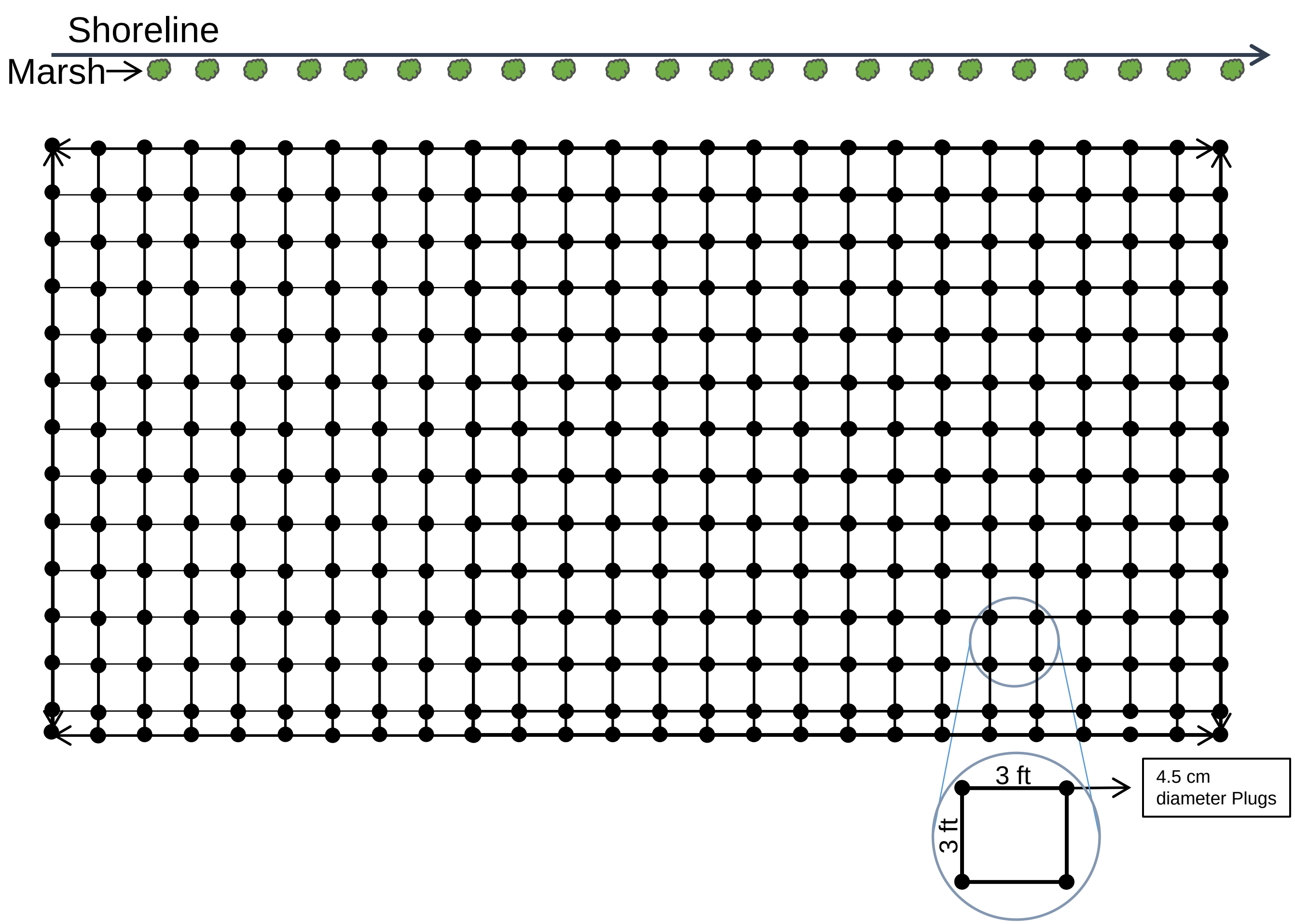
Planting Cost Effective Spatial Sites
Site #2 - Seadrift

Overview

Planting Cost Effective Spatial Sites
Site #2 - Seadrift

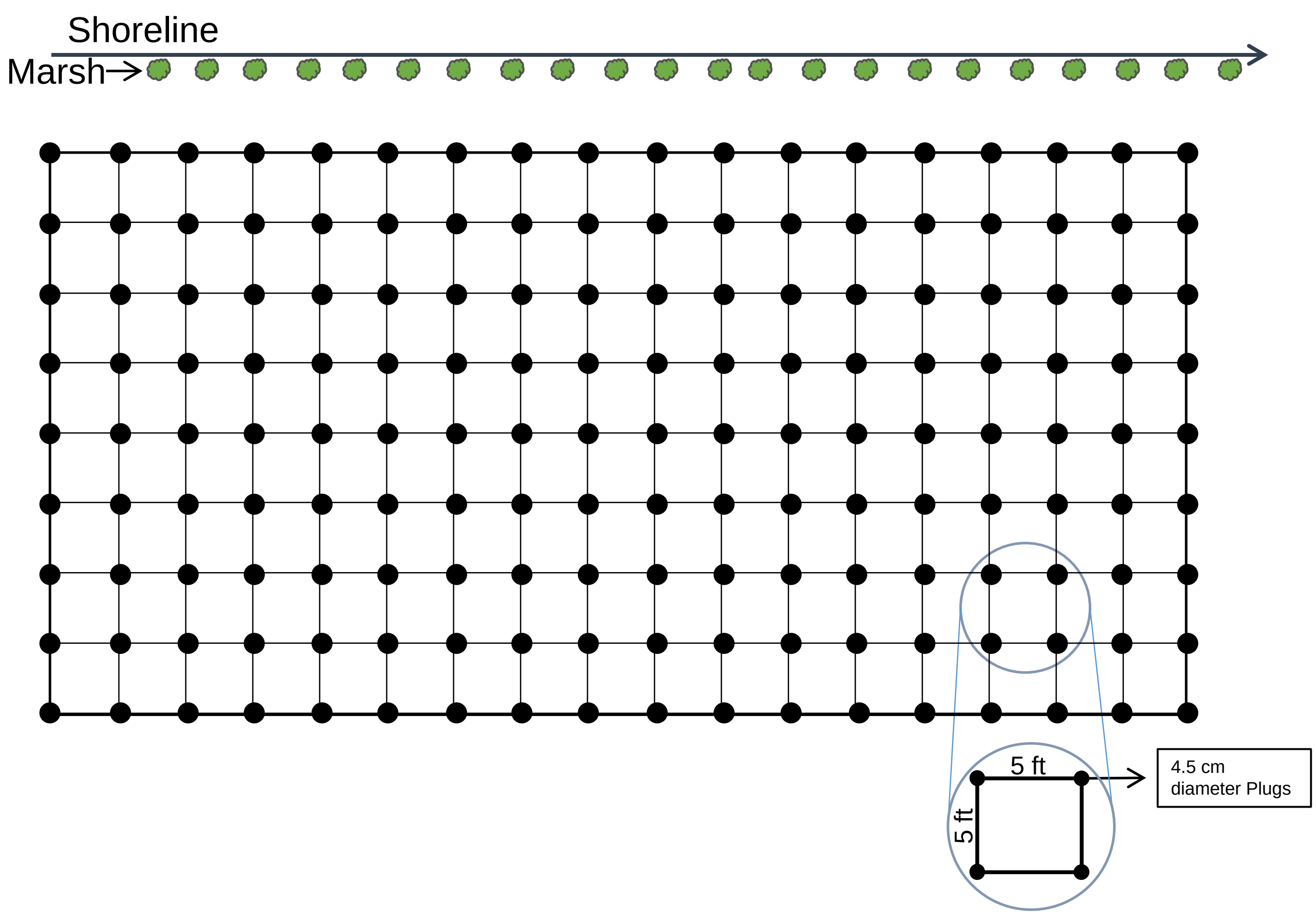
Planting Cost Effective Spatial Sites
Site #2 - Seadrift

Set up for Planting Cost Effective Spatial Sites Seadrift pilot.



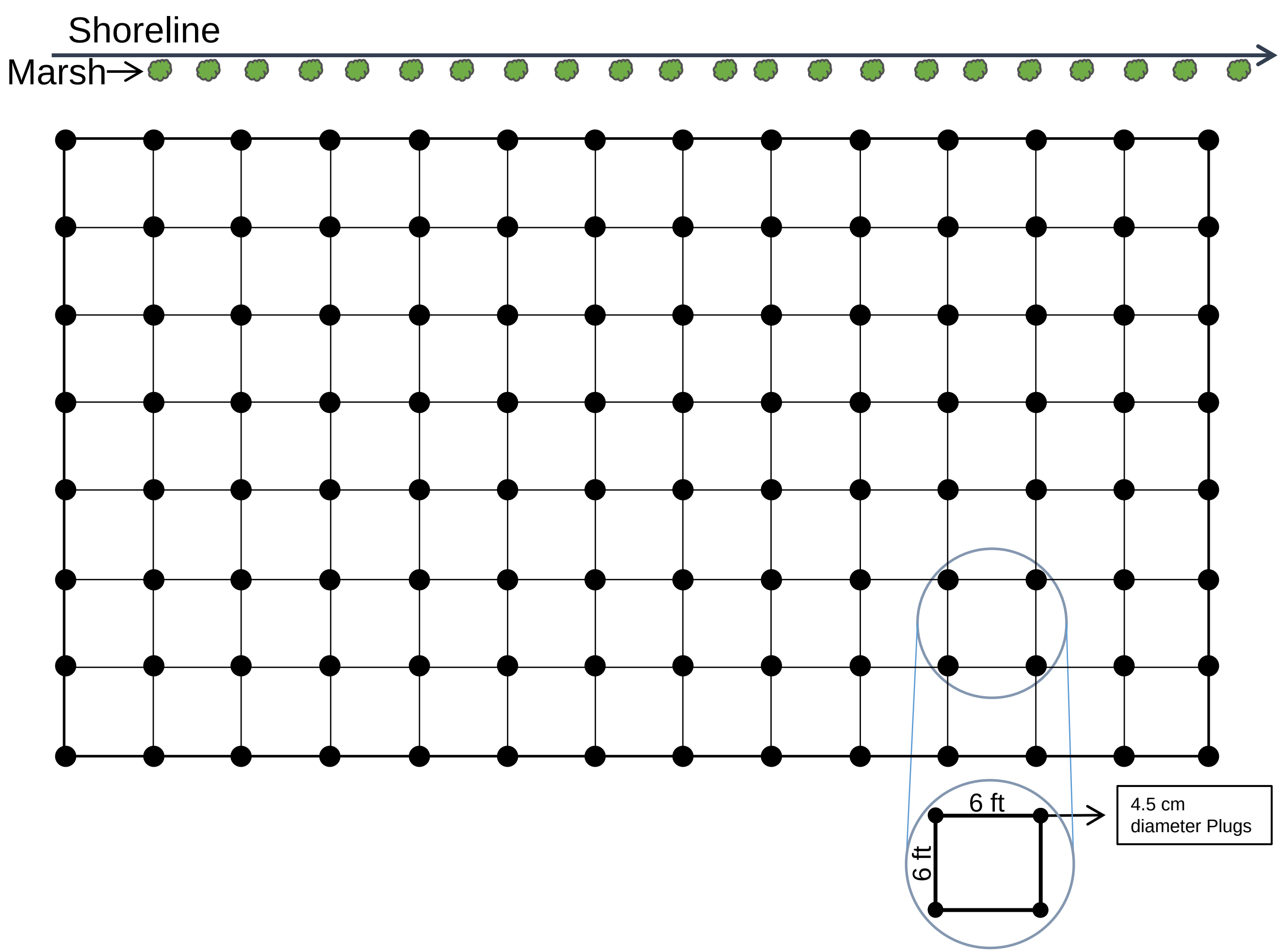
Planting Cost Effective Spatial Sites
Site #2 - Seadrift

Set up for Planting Cost Effective Spatial Sites Seadrift pilot.



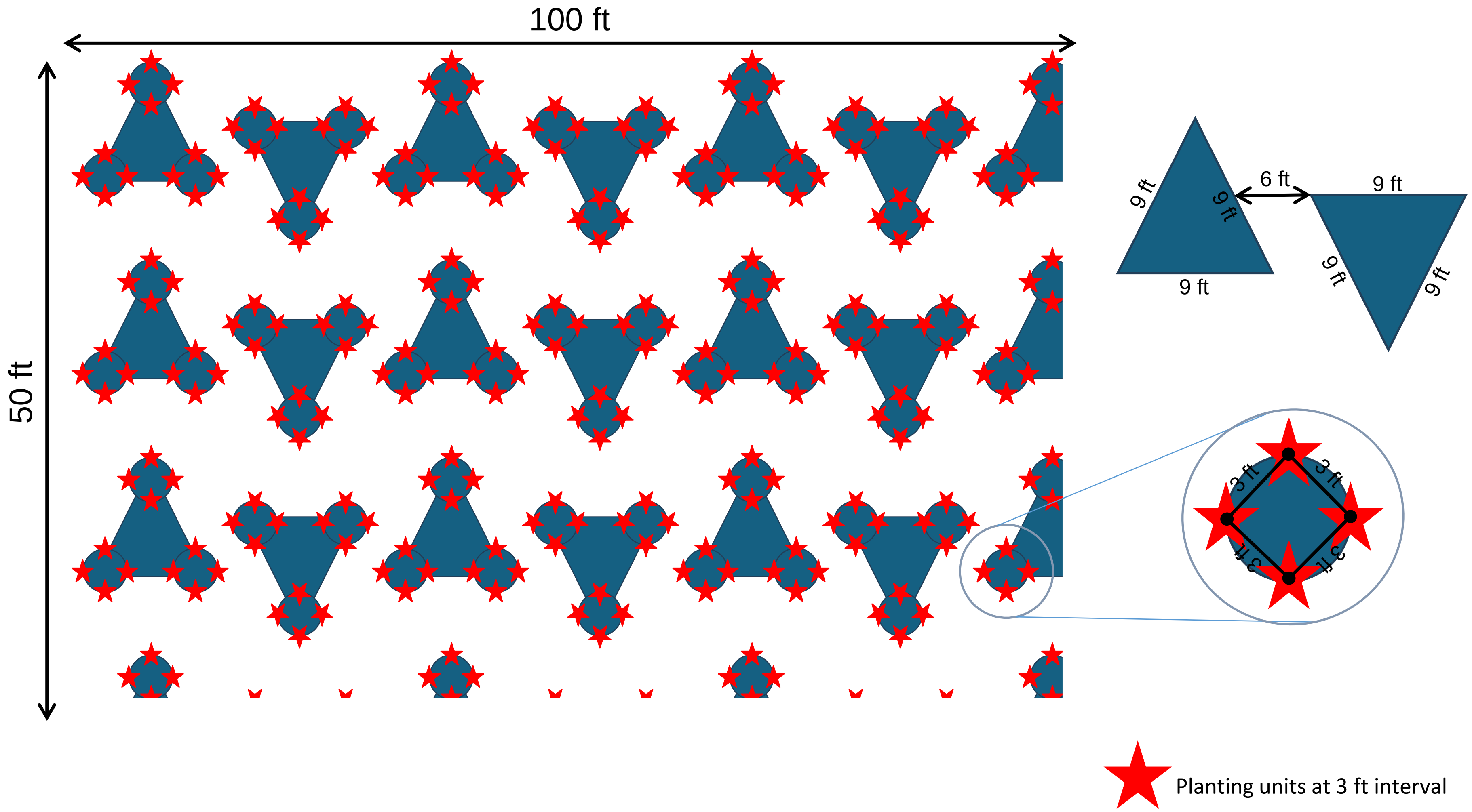
Planting Cost Effective Spatial Sites
Site #2 - Seadrift

Set up for Planting Cost Effective Spatial Sites Seadrift pilot.



Planting Cost Effective Spatial Sites
Site #2 - Seadrift

Planting Design - Spatial and configurational design Magnolia Beach pilot.



Location of Project Sites
Planting Cost Effective Spatial Sites

Site	Name	Lat.	Long.	Planting Spatial Interval	County	Waterbody	State Tract
#1	Magnolia Beach	28°33'40.99"N	96°32'23.59"W	3, 5, 6 ft	Calhoun	Matagorda Bay	33
#2	Seadrift	28°24‘19.52"N	96°42'26.51"W	3, 5, 6 ft	Calhoun	Hynes Bay	133

III. Seagrass monitoring plan

MONITORING OF SEAGRASS RESTORATION

The present schedule if phase II funded for 2025-2026 is plant in planting season spring 2025, monitoring 1 at time of planting, monitoring 2 in fall 2025, monitoring 3 in early spring 2026.

Monitoring Methodology to be carried out in Phase II

1.) RANDOMNESS as factor built into design. The project design includes at each site sub monitoring sites for the below factors to be measured chosen on random tables. There will also be controls such as barren sites to be statistically compared to restored sites, and adequate replicates.

2.) THE BARREN-OF-SEAGRASS CONTROL built into design as control. These will be chosen to be proximate to the sites to be restored. They serve to provide information about seagrass events occurring in this general vicinity since so little information is known about general seagrass patterns of distribution and response to environmental variables in Matagorda Bay and surrounding areas.

3.) REPLICATES built into design to give adequate statistical spread of data. Seven replicate samples for monitoring each restored and barren site (associated with the restored) will be undertaken. These will be tested with adequate anova statistics.

4.) LIGHT Measurements. Light will be measured by a Li-Cor lightmeter 250Cor lightith an underwater spherical sensor LI-193 set up from the seafloor bottom. A measurement instrument measures how far from the bottom this is.

5.) TURBIDITY Measurements. The Secchi disc is used with a measurement stick measuring light extinction from the Seafloor bottom. It changed up and down until the depth when it is first visible. That is the measurement. This is repeated 7 replicate times in various portions of the pilot plot.

6.) SEDIMENT Measurements. Several samples within the pilot restoration space will be extracted prior to the planting. Loam, clay loam, and clay, as well as granular sediment will be taken. These samples will be taken back to the lab and analyzed. Monitoring includes spring planting period, fall 2025 monitoring, spring 2026.

7.) SALINITY Measurements. The YSI salinometer will be used. The procedure is to calibrate the instrument first. (If batteries are changed, then recalibration must occur). Salinity is taken at several depths in deeper water, only one in 0.5 m or less. Replicates are taken in the restored and barren areas for statistical comparisons of services seagrasses provide.

8.) **KEY BIOLOGICAL SPECIES Measurements**. From prior animal studies (McLaughlin et al., 1983) in restored seagrass as well as long-term (7 years) studies of the animal community in seagrass (Thorhaug and Roessler, 1976), and then comparing push net samples within restored seagrass from Galveston Bay to Corpus Christi Bay, key fisheries animals were shown to be abundant. These *Penaeus and Callinectes* species plus fish juveniles and additionally any other of outstanding abundance will be measured at the various intervals of monitoring over time and among pilot sites. We particularly will focus on species important to sports fishermen or commercial fisheries (Thorhaug, A. and M.A. Roessler. 1977. Seagrass Community dynamics, Aquaculture 12 (3), 253-277; Mclaughlin et al., 1983. A Restored Seagrass Bed and Its Animal Community, Environmental Conservation 10 (3), 247-254).

9.) ENDANGERED/THREATENED SPECIES Measurements. There are several not-for-profit (Audubon, Shorebirds, etc.) and government resource manager groups (the Aransas National Refuge for Whooping Cranes) who are concentrated on the plovers, least terns, and others who gather statistic and sitings on the Whooping Cranes (including their feeding spaces, and habitat preferences), plus Texas A & M Universities concentrate on marine turtles. ESRI has in cooperation with Texas Sea Grant and Texas A & M University plus colleagues initiated a turtle siting map, including a map focusing on Matagorda Bay. This tool will be used. Also, if marine mammals have an equivalent ESRI tool, then that also will be used. We will attempt to interact with birds, marine turtles, and other ongoing counts as well as fisheries data for Matagorda Bay.

10.) SEAGRASS BLADE length & width: There will be quadrats thrown randomly into each site. 7 replicates will be extracted. If the area has less than 700 blades/m^2 then a 1-meter square quadrat will be used. If denser, then a 1/100th meter square quadrat will be measured. Blades will be collected to be measured back at our labs. Length and width of 30 or so blades/m2 will be measured. The barren of seagrass sites will be used as a control.

11.) LATERAL DISTANCE from center of planted unit. For the fall 2025 and spring 2026 and after monitoring the distance of longest lateral rhizomes in replicates will be measured with a surveyor's plastic tape measure as well as noted when areas have coalesced, which happened in multiple other projects in Texas.

Examples of how reports of monitoring measurements will be summarized. These will have mean value plus and minus around the mean.

SUMMARIES OF RESULTS TABLE: Final overview after 12 months. The essential comparative summary per site of seagrass growth, animals re-colonizing, sediment change, water clarity, depth.

Site	% sustain	Growth diameter	Height blades	Key animal	Shorebirds	Sediment	Water clarity	Depth	Light
Raspberry									
Magnolia									
Sea Drift									
Lamar bridge									
Keller Kayak									
Palacios									
Oyster									
Hog Island									
Mean									
Spatial									
Magnolia									
Sea Drift									
Mean									
Configuration									
Magnolia									
Sea Drift									
Mean									

PHYSICO-CHEMICAL RESULTS (See appendix for raw data per site per monitoring period and statistical analysis of difference between age of restoration and between sites).

Site	Salinity	Temperature	Light	Turbidity	Depth	Sediment Comp.	Sediment height	Blade Length	Success %	Species	Energetic Level
Raspberry											
Magnolia											
Sea Drift											
Lamar Bridge											
Keller Kayak											
Palacios											
Oyster											
Hog											
Mean											
Spatial											
Magnolia											
Sea drift											
Mean											
Configuration											
Magnolia											
Sea Drift											
Mean											
Total											

IV. Permits

- **GLO Permit Application**
- **Texas Parks and Wildlife Division (TPWD): letter of permission for donor material**
- **US Army Corps of Engineers: letter of permission SWG-2013**

State of Texas
Texas General Land Office
Application for State Land Use Lease
Surface Lease (SL) – Coastal

FOR GLO USE ONLY

Working File #	
Lease #	
Staff Initials	

Applicant/Official Company Name

Individual, Company, Partnership or Trust Name: Matagorda Bay Foundation

Contact (Title, First Name, Last Name, Salutation): William Balboa

Work #: 361-781-2171 Mobile #: 361-781-2171

c/o or Attn:

Mailing Address (Street, City, State, Zip):
15918 County Road 946
Brazoria, TX 77422

Email: bbalboa@ matbay.org

☑ Authorized Agent ☑ Company Contact

Individual, Company, Partnership or Trust Name: Greater Caribbean Energy and Environment Foundation

Agent/Company Contact (Title, First Name, Last Name, Salutation): Anitra Thorhaug

☑ Send contract copy to Agent/Company Contact

Work #: 305-858-0014 Mobile #: 305-490-0074

c/o or Attn:

Mailing Address (Street, City, State, Zip):
1359 SW 22nd Terrace
Miami, FL 33145

Email: athorhaug@msn.com

Corporate Applicants, Fill out the Following

Type of Business
- ☐ Person acting in own capacity
- ☐ Corporation
- ☐ Limited Liability Company (LLC)
- ☐ Limited Partnership (LP)
- ☐ Sole Proprietor
- ☐ Government
- ☐ Estate
- ☐ Trust
- ☐ Other: ____________________

Tax ID #:

State of Domicile:

If LP, Name of General Partner:

Name of President:

Name of Secretary:

Project Location

Water Body(ies): See Attached

State Tract(s): 242, 33, 133, 84, 4, 2, 77, 50, 315, 130

County(ies): Matagorda, Calhoun, Aransas

GPS Coordinates (if known): See Attached

Parcel ID (Assigned by the County Appraisal District):

Legal Description or Original Survey Name:

Project Address: These are submerged lands. They do not have addresses. Maps are attached - SEE ATTACHED APPENDIX.

Adjacent Landowners

Name:

Street Address: All sites on public lands

Name:

Street Address:

Project Description (If additional space is needed, please continue descriptions on Page 3.)

☐ Dock ☐ Pier ☐ Boat Ramp ☐ Breakwater ☐ Dredging ☑ Other (describe below)

Our goal is to test seagrass restoration success in Matagorda Bay, (success defined as creating "green", stabilized, resilient shorelines while reestablishing seagrass services: maintaining fisheries nurseries, game fish &endangered species habitat, and water clarity).

Purpose of Proposed Lease

In the past Texas has lost about 70% of its seagrass resources. Also, there have been a series of seagrass plantings which did not show success in Texas (Carangelo and Oppenheimer, 1979; Philips, 1980; Hammerstrom et al. 1993; Sheridan, 1997; Sheridan, 2004; Hammerstrom et al. 2006). These were in mitigation for various projects. However, some other projects did have high results (Thorhaug, 2001; Thorhaug et al., 2020). These techniques to have high success are needed for future building of infrastructure and shoreline resilience created by seagrass shoaling plus reconstruction of fish nurseries, for water clarity, and endangered and listed species can be regenerated in Matagorda Bay and other Texas estuarine locations. This includes bridge abutments, filled recreational areas, seawalls, navigational channels, and other activities commonly experienced in central estuaries of Texas. What will it be used fo

Description of structure(s) and the materials to be used

Tubes at the inner corners of pilot plots and for control plots. No materials left except inserted plants (315 per pilot plot: 10 plots)

Description of facilities associated with the structure

The already present parking lots of adjacent terrestrial roads are the only facilities needed for scientists to unload monitoring and planting materials to restore plugs of halodule into the pilot sites.

Method of installation, type of equipment to be used, and how it will be brought to the project site

Tasks within Phase I agencies; restoration of Halodule seagrass by trained-planting teams; Spring 2024 post-planting monitoring; monitoring Fall 2024 & early Spring 2025; final report integration as a Texas seagrass restoration plan for shoreline stability & other results; and presentations to Texas public. Considering the potential impact of intense storms, we will monitor and report after hurricanes of any intensity category. We monitor barren controls and restored sites for sediment (composition/shoreline stability, particle size, elevation), seagrass (density, extent), shoreline marsh, key fisheries groups (abundance/species), endangered-species (turtles, etc), game-fish juveniles, and shorebirds &compared with other restored sites' data. Matagorda Bay results will be published with recommendations for Texas future-scaling for CCAC's members tailored to their goals.

Describe Current Project Area

Marshes	☐ Yes	☐ No	Area	
Submerged Grasses	☑ Yes	☐ No	Area	"Barren" control, natural seagrass control
Oyster Reefs	☐ Yes	☐ No	Area	
Habitat Survey Done	☐ Yes	☐ No	Date	

Other Permits

Agency	Permit #	Date
TPWD Conditional Permit	Pending	
U.S. Army Corps of Engineers	Pending	

Amount of State Land involved: 5000 sq. ft. per pilot: total is 50,000 sq. ft. or 1.18 acre

Water Depth(s): 2-5 ft.

Project Description (continued)
Please indicate which description you are expanding on in the space provided.

Matagorda Bay has presently 1536 acres of seagrass (1.6% of Texas total), which has been ans is being degraded by development (industrial &urban pollutants, dredging navigational channels, etc.). Thousands of degraded acres in Matagorda Bay need revitalization. Matagorda Bay is the only major Texas bay never tested for seagrass restoration. Examples of shoreline erosion after degradation of seagrass are well-known especially in intense storms.
The integration of seagrass into shoreline stabilization is innovative because most managers and the public believe that shoreline stabilization is only the role of salt-marsh grass, yet without seagrass in the shallow water bayward of marshes, salt marsh grasses are more easily destroyed by storm surge. With our final project results, we will gain more knowledge in shoreline stabilization projects' constraints for seagrass restoration, useful elsewhere in Texas. Integrating our seagrass restoration knowledge plus seagrass restoration experience in other Texas bays will especially benefit future projects needing Green shoreline stabilization.
Each site in Matagorda Bay was selected from multiple candidates for the following criteria: 1) eroding shorelines; 2) proximity to publically-beneficial sites; 3) absence of known constraints on seagrass restoration (e.g. fetch, water-dynamics, water-quality, pollutants, turbidity, depth, sediment-type). Ten small trials (50ft x 100ft), will be planted using Halodule wrightii 2.25cm radius plugs, the common Matagorda seagrass in some cases with Halophila engelmanii understory.
The benefits of shoreline stability are based on our previous work at Galveston, Aransas, and Laguna Madre sites which in terms of this project will be seen as "demonstration sites". The information derived for shoreline stabilization can be used by CCAC, TDOT, SeaGrant, GLO, TFWD, TWDB, TCEQ, TSSWCB, local government, and citizens. For the first time seagrass shoreline stabilization improvement can be demonstrated to CCAC agencies, the public, and private sector throughout one bay (e.g.Matagorda) by this CMP Phase II project, which restoration increases shoaling in turn increasing shoreline stabilization especially during intense storms.

Outcomes: We anticipate at our Matagorda Bay selected-sites, we achieve enhanced shoreline stability plus seagrass benefits (enhanced fisheries' nurseries, biodiversity food webs, water clarity, &mineral cycling including carbon sequestration.

Anticipated Start Date: 05/01/2024 Expected Completion Date: 05/01/2026 Desired Term:

PROJECT PLANS AND LOCATION MAP
Attach two copies of project plans and location maps as described in the 'General Instructions for all Applicants.' Copies of plans submitted for any Army Corps of Engineers permit may be used if they meet the specifications in 'General Instructions.'

FEES AND ATTACHMENTS
A. No fees are due at this time.
B. Upon submission, include two completed copies of this application, including project maps and all applicable attachments.

NOTE: Processing of this application will not begin until it is determined to be complete. Therefore, please be sure to include all information requested either within this application or in any of the attachments.

☑ By checking this box, I certify that all information contained in this application is true and accurate, and that I have read the Instructions for Preparing Exhibits information included in this application.

Anitra Thorhaug Digitally signed by Anitra Thorhaug Date: 2023.03.05 15:25:19 -06'00' 3/5/2023

Signature of Applicant/Agent Date

Please include documentation to support authorization to sign on behalf of a Corporation, LLC, LP, LLP, or GP.

Information collected by electronic mail and by web form is subject to the Public Information Act, Chapter 552, Government Code.

INSTRUCTIONS FOR PREPARING EXHIBITS FOR THE FOLLOWING TEXAS GENERAL LAND OFFICE APPLICATIONS:

Miscellaneous Easements, Commercial Leases, Surface Leases, Sub-Surface Leases

Maps (or plats) showing the location of proposed and as-built projects on State-owned lands are required as part of the General Land Office (GLO) application process. The following instructions are to be followed when applying for new work (proposed project), reporting as-built conditions for a previously approved project, or when the activity is a Miscellaneous Easement (Right-of-way), Surface Lease, or Sub-Surface Easement on State land.

The information specified below represents minimum requirements of the GLO and additional information may be requested on a project-by-project basis to facilitate a full evaluation of the proposed activity.

The information should be submitted along with the required application form. Each map or plat must conform to the specifications contained herein. An application is not considered complete and processing of the application will not be initiated until all information requested has been submitted and GLO staff has determined that it is adequate.

Application fees and rent vary by project type. Please contact the Field Office or Permit Service Center for your area for details. You do not need to send any money at this time and will be invoiced accordingly.

NOTE: Surveys and survey plats required by other entities, Federal, State, County and/or City, are PERMISSIBLE and USABLE for GLO applications provided they meet the following requirements.

1. Each map or plat should be 8 ½" x 11".
2. A one-inch margin should be left at the top edge of each sheet for binding purposes.
3. Any shading used to identify specific areas must be reproducible by ordinary copy machines.
4. Each map or plat submitted must have a title block identifying, at a minimum:
   (a) applicant name;
   (b) applicant address;
   (c) project name;
   (d) date of preparation;
   (e) name of preparer; and
   (f) project location including county, waterbody name, and state tract number.
5. The scale for each map or plat must be clearly indicated both digitally and by graphic scale.
6. **Vicinity Maps** – **Exhibit A** for each project application must be a Vicinity Map showing the general location of the proposed work. The Vicinity Map must be produced using either a U.S.G.S. 7.5-minute Topographic Map, a Texas Department of Transportation County Road Map, or navigation chart as its base layer. The project location should be indicated by a prominent arrow on the map. An 8 ½" x 11" Xerox copy from the original Topo, county map, or navigation chart showing the project location is sufficient. It is not necessary to submit the entire Topo or county map, so long as the map is appropriately identified as to the origin of the base information (e.g. name and date of base map information used). This is most easily accomplished by copying the legend of the base map and making it part of the Vicinity Map.
7. **Project Site Map - Exhibit B** for each project application should be a Project Site Map (in Survey Plat format) which provides specific project location information. The Project Site Map should be produced at sufficient scale and detail to enable field inspectors to locate the project on the ground with minimal difficulty. Demographic features such as road numbers, stream names, railroad crossings, corporate city limits, and other prominent locative features should be included on the Project Site Map. The project location should be indicated by a prominent arrow on the map and a North arrow must be provided. Annotation may be included on the map regarding distance of the project from known points (e.g. highway intersections, road-stream crossings, etc.).
8. **Detailed Project Plan - Exhibit C** for each project application should be a Detailed Project Plan, consisting of an aerial plan-view (top view) drawing and a cross-sectional (side view) drawing of all proposed or existing structures on State-owned lands at the project site.

   Detailed Project Plans should contain, at a minimum:
   - Dimensions of all structures (existing and proposed) that will encumber State-owned lands at the project site.
   - The registration, easement, or lease numbers for any structures at the site previously authorized by the GLO (available from GLO field offices upon request).
   - Any applicable Corps of Engineers permit numbers covering the proposed work.

Page 1 – Top view drawing should contain, at a minimum:

- **a.** Location of the shoreline or banks if the project is on or adjacent to tidally influenced waters or crosses a state-owned river, stream, creek, or bayou.
- **b.** The direction of ebb and flow if in or adjacent to tidal waters, or the direction of water flow if the project crosses a river, stream, creek, or bayou.
- **c.** A North Arrow.
- **d.** The location of state tract lines (on tidally influenced lands), survey lines, or property lines, as applicable.
- **e.** The location of any marshes, submerged grass flats, oyster reefs, mud or sand flats, or other sensitive natural/cultural resources known to exist in the project area.
- **f.** The lines of mean high water and mean low water when applicable.

Page 2 – Cross-sectional drawing should contain, at a minimum:

- **a.** The bottom profile of state-owned lands.
- **b.** The lines of mean high water and mean low water when applicable.
- **c.** If the project is a pipeline, the Detailed Project Plan cross-sectional drawing must include notation as to the outside diameter (OD) of all pipelines covered by the easement, and the relationship of the pipeline(s) to any other pipeline(s) in the immediate vicinity.

Page 3 should contain, as applicable, an explanation of construction methodology, techniques, and equipment that will be used at the site.

General information of Matagorda Bay for pilot restoration of seagrass

Bay Surface Area

1,093.00km^2

River Drainage Area

109,300.00km^2

Average Daily Freshwater Inflow

150.00m^3/s

Average Bay Depth

2.00m

Average Bay Salinity

19.00

Coastal Wetlands

31.8% of bay surface at the shoreline is wetlands = 348.00km^2

Submerged Aquatic Vegetation

3% of the subtidal area is covered with SAV decreased from previous coverage of bay surface = 28.00km^2

In terms of the freshwater input to the system, water comes from a relatively large drainage basin, entering the bay from the Colorado and Lavaca Rivers, and numerous creeks and bayous, including: Tres Palacios Creek, Garcitas Creek, Placedo Creek, Big Boggy Creek, Caney Creek, Coloma Creek, Chocolate Bayou, Keller Creek and E/W Karankawa Creeks. The Matagorda Bay system contains a number of defined embayments including East Matagorda Bay, Karankawa Bay, Tres Palacios Bay/Turtle Bay and Lavaca Bay, which also encompasses Chocolate, Keller and Cox Bays (see Moseley, 1973). Oyster Lake and Powderhorn Lake are two smaller bodies of water with connections to Matagorda Bay. Another prominent feature of the system is the Colorado River, the delta of which nearly completely separates East Matagorda Bay from the rest of the system. Matagorda Bay is separated from the Gulf of Mexico by the Matagorda Peninsula, and water exchange occurs through 5 principal tidal inlets (south to north): Pass Cavallo, Matagorda Ship Channel, Greens Bayou, the Colorado River Delta Complex and Brown Cedar Cut.

References

- Moseley, F.N., and B.J. Copeland. 1973. Ecology of Cox Bay, Texas, Final Report. Central Power and Light Company. Corpus Christi, TX. 165 pp.
- Ward, G.H., Jr., N. E. Armstrong, and the Matagorda Bay Project Teams. 1980. Matagorda Bay, Texas: its hydrography, ecology, and fishery resources. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. FWS/OBS-81/52.
- Armstrong, N.E. 1987. The ecology of open-bay bottoms of Texas: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.12). 104 pp.
- USEPA. 1999. Ecological condition of estuaries in the Gulf of Mexico. EPA 620-R-98-004. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, Florida. 80 pp.

Project Sites - Land maps of TGLO Texas

Site	Name	Long.	Lat.	Area	County	Waterbody	State Tract
#1	Raspberry Island - Port O’Connor	28°26’00.03"N	96°24'35.55”W	69 ft x 60 ft	Calhoun	Matagorda Bay	242
#2	Magnolia Beach	28°33'40.99"N	96°32'23.59"W	100 ft x 50 ft	Matagorda	Matagorda Bay	33
#3	Seadrift	28°24‘19.52"N	96°42'26.51"W	100 ft x 50 ft	Calhoun	Hynes Bay	133
#4	Lamar Bridge Abutment	28°08’06.05"N	97°00’28.71"W	100 ft x 50 ft	Aransas	Aransas Bay	84
#5	Port Lavaca East	28°35'49.80"N	96°36'44.45"W	100 ft x 50 ft	Matagorda	Lavaca Bay	4
#6	Port Lavaca Lighthouse Beach	28°38'20.63"N	96°36'36.28"W	100 ft x 50 ft	Matagorda	Lavaca Bay	2
#7	Keller Bay Kayak Launch	28°38'11.85"N	96°27'13.44"W	100 ft x 50 ft	Matagorda	Keller Bay	77
#8	Palacios Fish Harbor	28°41’41.67"N	96°13’59.78"W	100 ft x 50 ft	Matagorda	Tres Palacios Bay	50
#9	Oyster Lake Park	28°36‘42.15"N	96°12’54.24”W	100 ft x 50 ft	Matagorda	Matagorda Bay	315
#10	Hog Island	28°39’06.57"N	96°52'36.08"W	100 ft x 50 ft	Matagorda	East Matagorda Bay	130

Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots

(GLO Contract No. # 23-020-013-D607)

PERMITS MATAGORDA BAY SEAGRASS RESTORATION PILOTS

Bill Balboa

Executive Director

Matagorda Bay Foundation

Anitra Thorhaug

President

Greater Caribbean Energy & Environment Foundation

March, 2023

Raspberry Island off Port O'Connor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Raspberry Island off Port O'Connor
- Calhoun County, Waterbody Name - Matagorda Bay, and State tract number - 242

Raspberry Island off Port O'Connor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
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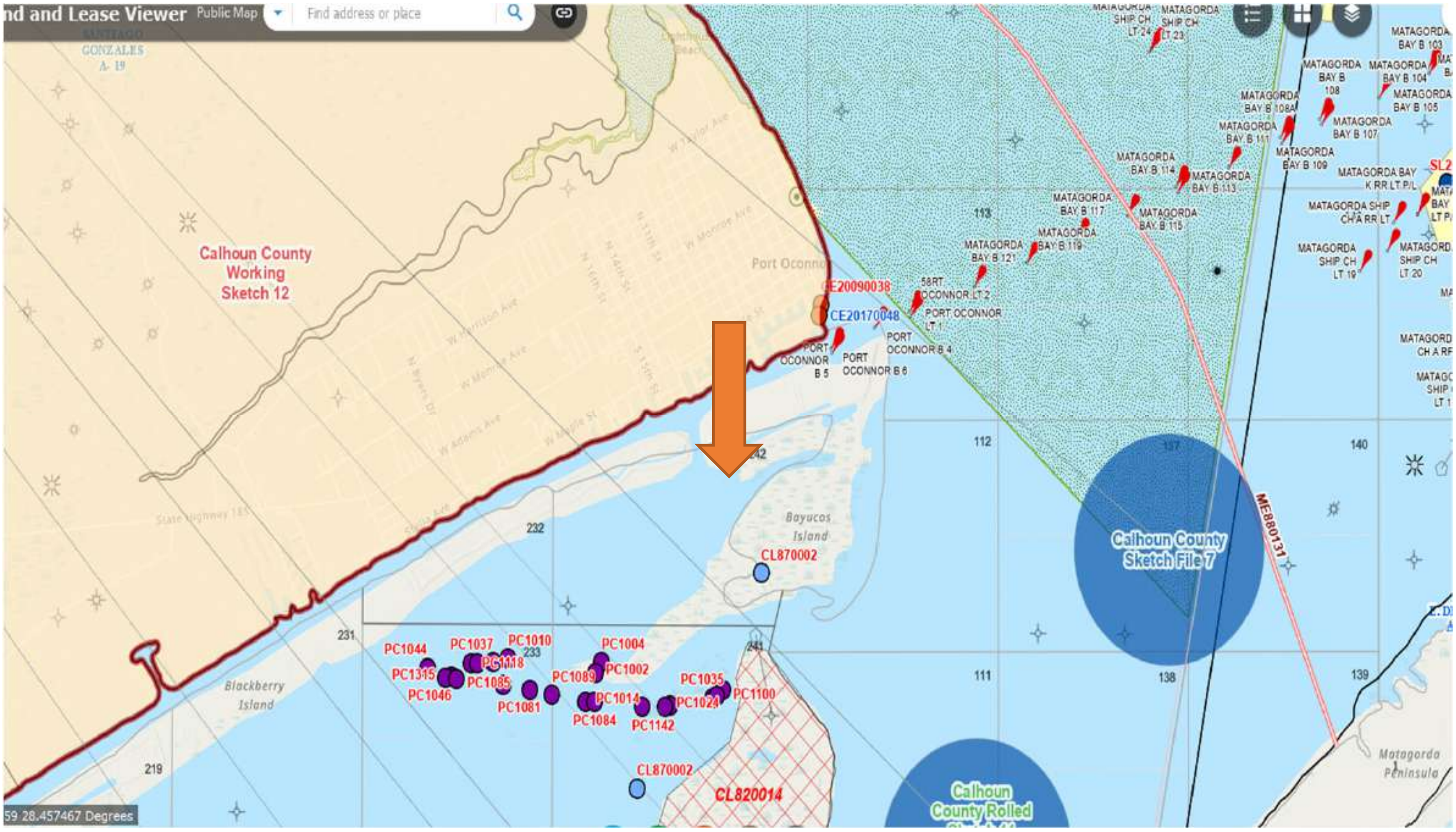
- Project Location: Raspberry Island off Port O'Connor
- Calhoun County, Waterbody Name - Matagorda Bay, and State tract number - 242

Raspberry Island off Port O'Connor



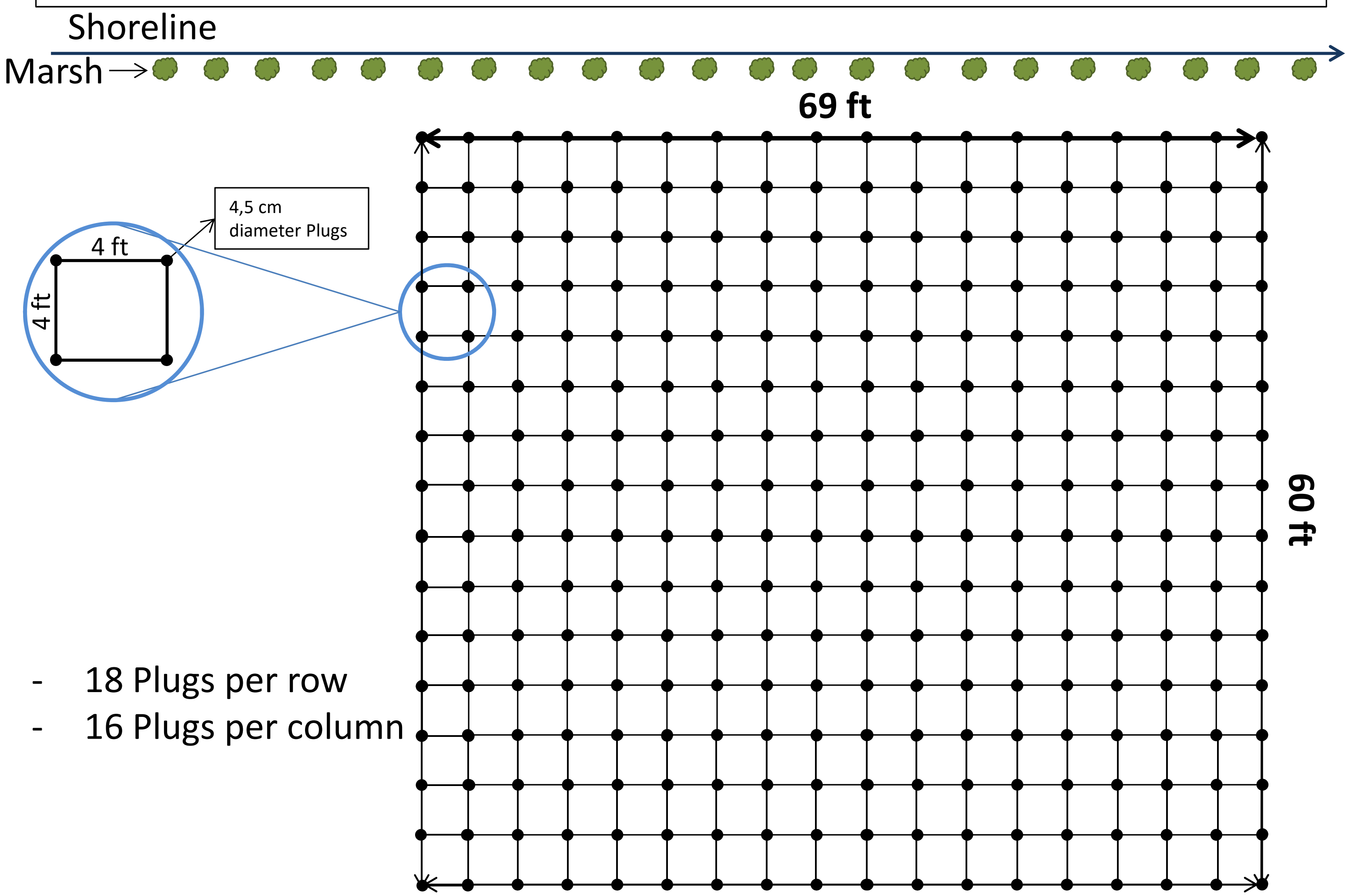
#1	Raspberry Island - Port O'Connor	28°26'0.03"N	96°24'35.55"W	69 ft x 60 ft

Raspberry Island off Port O'Connor - Plot aerial

Raspberry Island (POC)	#1	28°26'0.31"N	96°24'35.95"W	69 ft x 60 ft
	#2	28°26'0.32"N	96°24'35.16"W	
	#3	28°25'59.73"N	96°24'35.18"W	
	#4	28°25'59.71"N	96°24'35.88"W	

Raspberry Island off Port O'Connor

Set up for Matagorda Bay Seagrass Restoration Raspberry Island site will be 69 ft. by 60 ft.



- 18 Plugs per row
- 16 Plugs per column

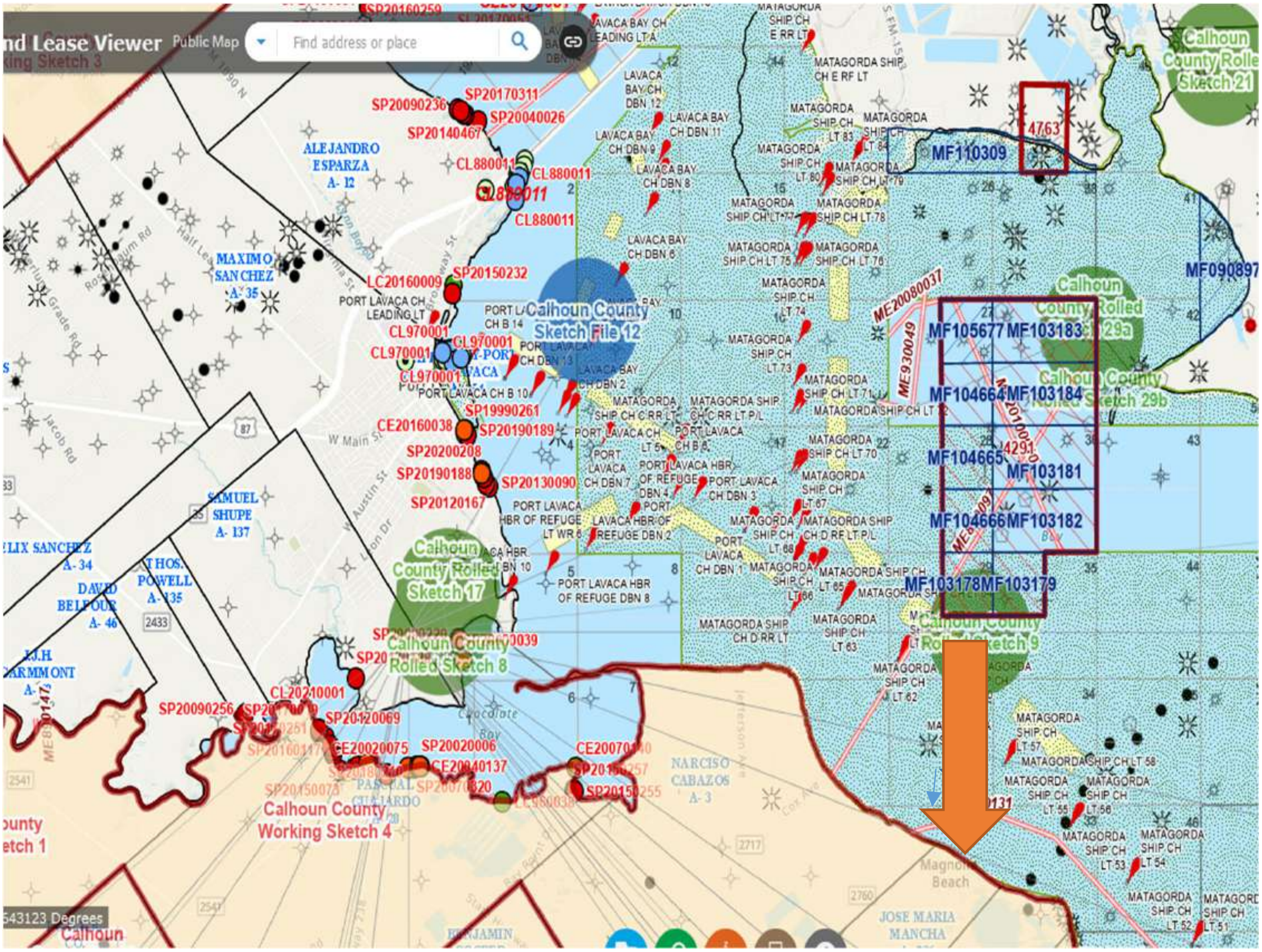
Magnolia Beach Pilot

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Magnolia beach Texas.
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 33

Magnolia Beach Pilot

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Magnolia beach Texas.
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 33

Magnolia Beach Pilot

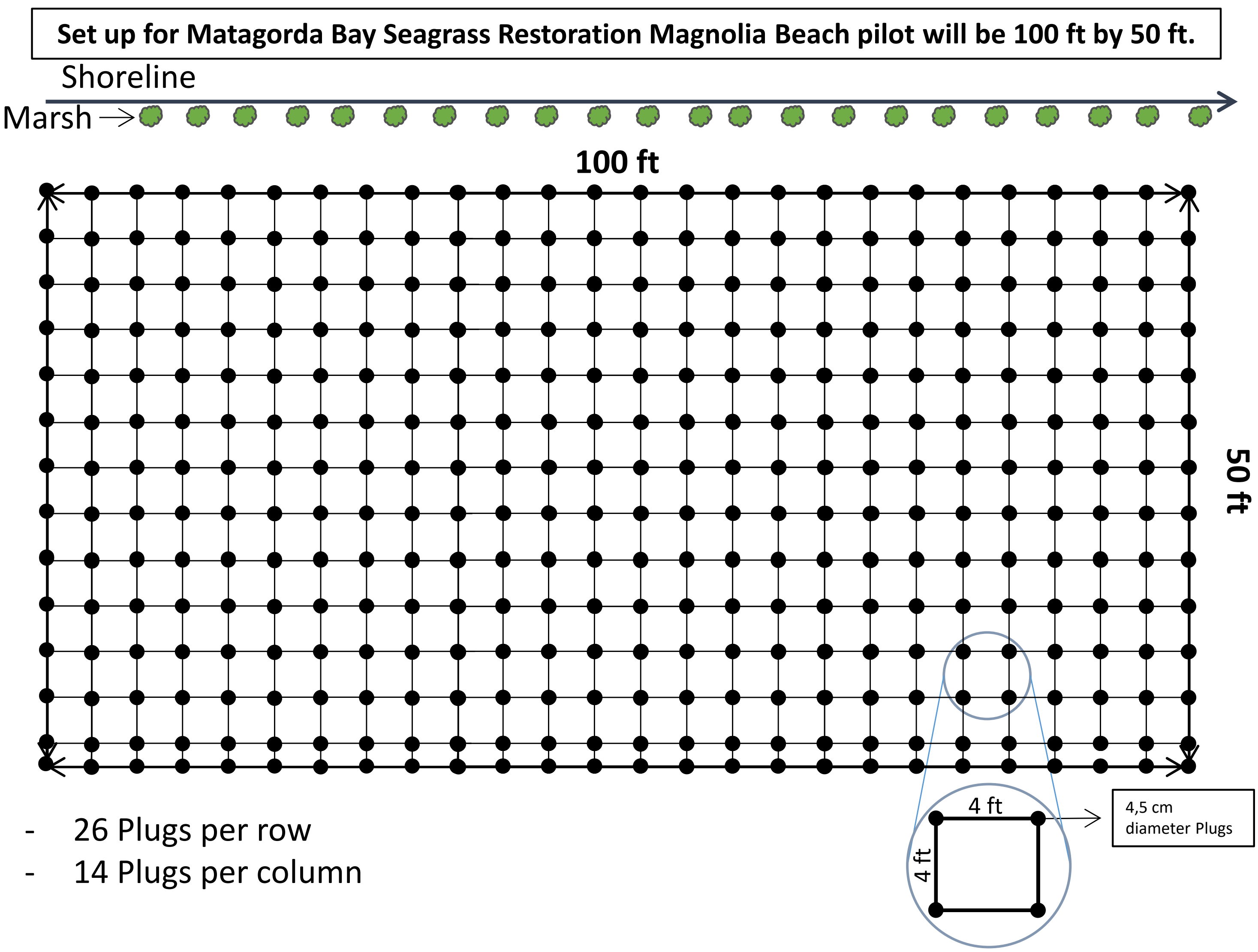


Magnolia Beach	28°33'40.99"N	96°32'23.59"W	100 ft x 50 ft

Magnolia Beach Pilot - Plot aerial

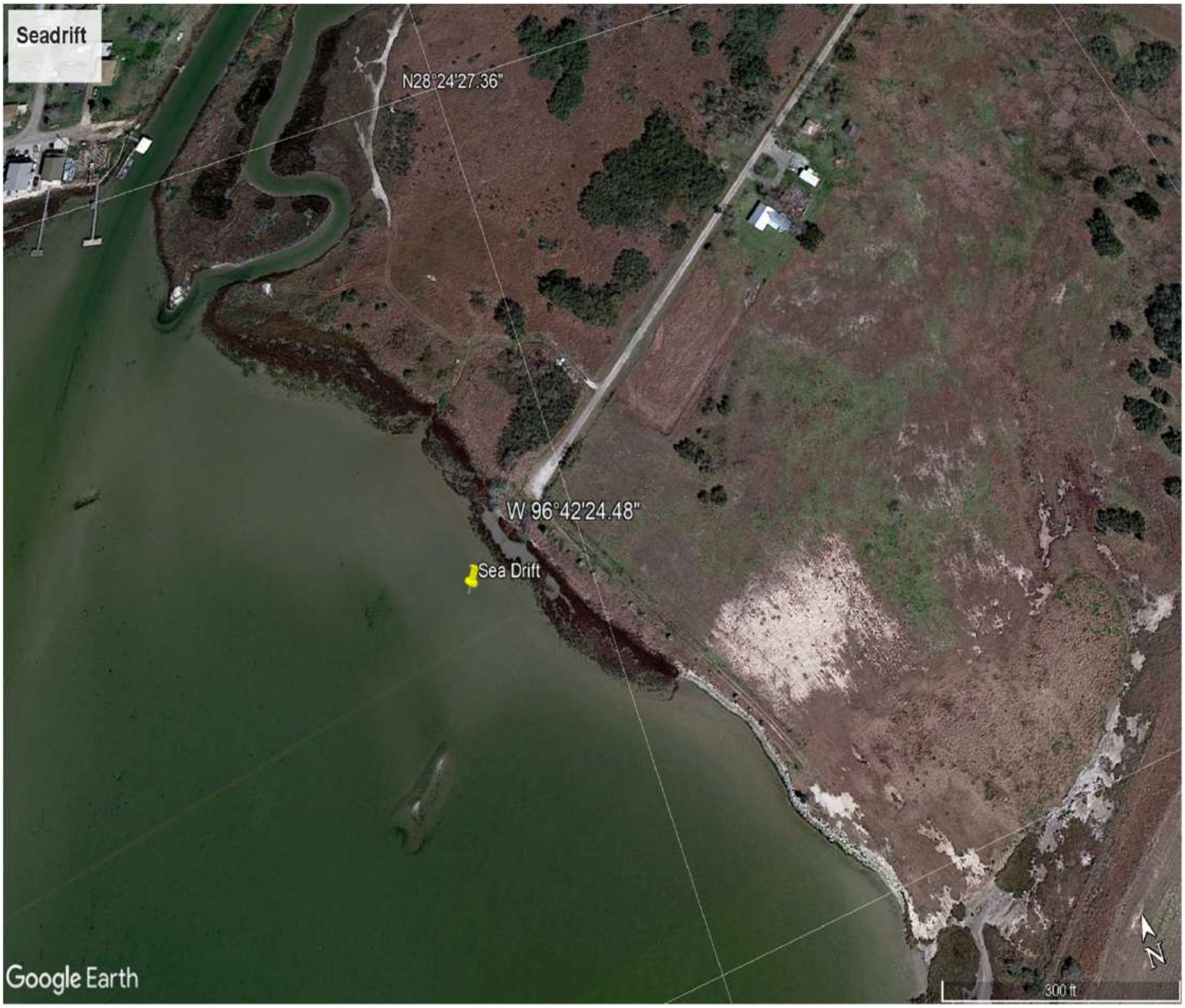
Magnolia Beach	#1	28°33'40.50"N	96°32'23.24"W	100 ft x 50 ft
	#2	28°33'40.97"N	96°32'24.26"W	
	#3	28°33'41.49"N	96°32'24.06"W	
	#4	28°33'40.96"N	96°32'23.05"W	

Magnolia Beach Pilot



- 26 Plugs per row
- 14 Plugs per column

Sea Drift



- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Seadrift.
- Calhoun County, Waterbody Name – Hynes Bay, and State tract number - 133

Sea Drift

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Seadrift.
- Calhoun County, Waterbody Name – Hynes Bay, and State tract number - 133

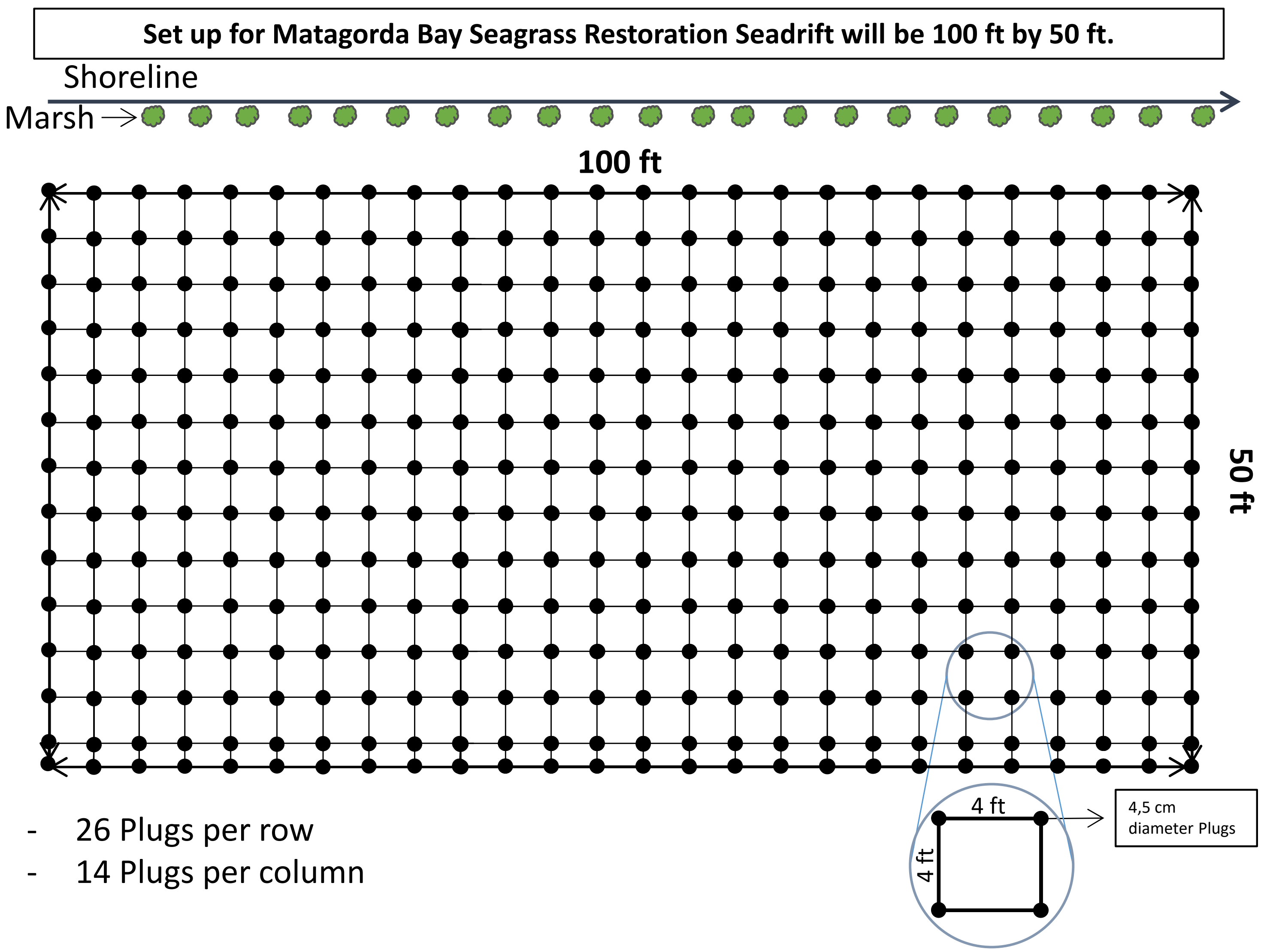
Sea Drift

Seadrift	28°24'19.52"N	96°42'26.51"W	100 ft x 50 ft

Sea Drift

Seadrift	#1	28°24‘20.13"N	96°42'26.54"W	100 ft x 50 ft
	#2	28°24‘19.27"N	96°42'26.00"W	
	#3	28°24'19.02"N	96°42'26.48"W	
	#4	28°24‘19.88"N	96°42'27.02"W	

Sea Drift



- 26 Plugs per row
- 14 Plugs per column

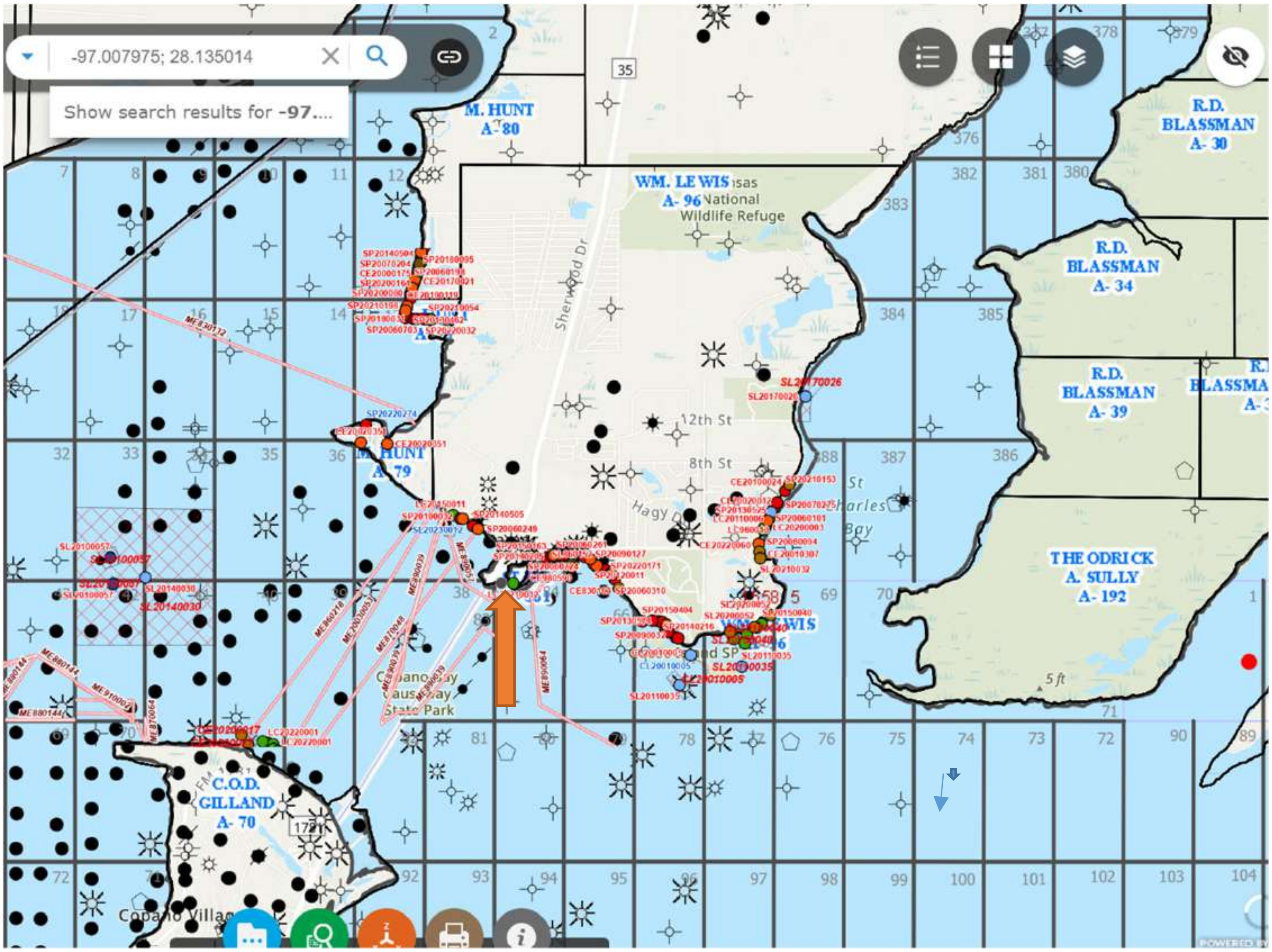
Lamar Bridge Abutment

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Lamar Bridge Abutment.
- Aransas County, Waterbody Name – Aransas Bay, and State tract number - 84

Lamar Bridge Abutment

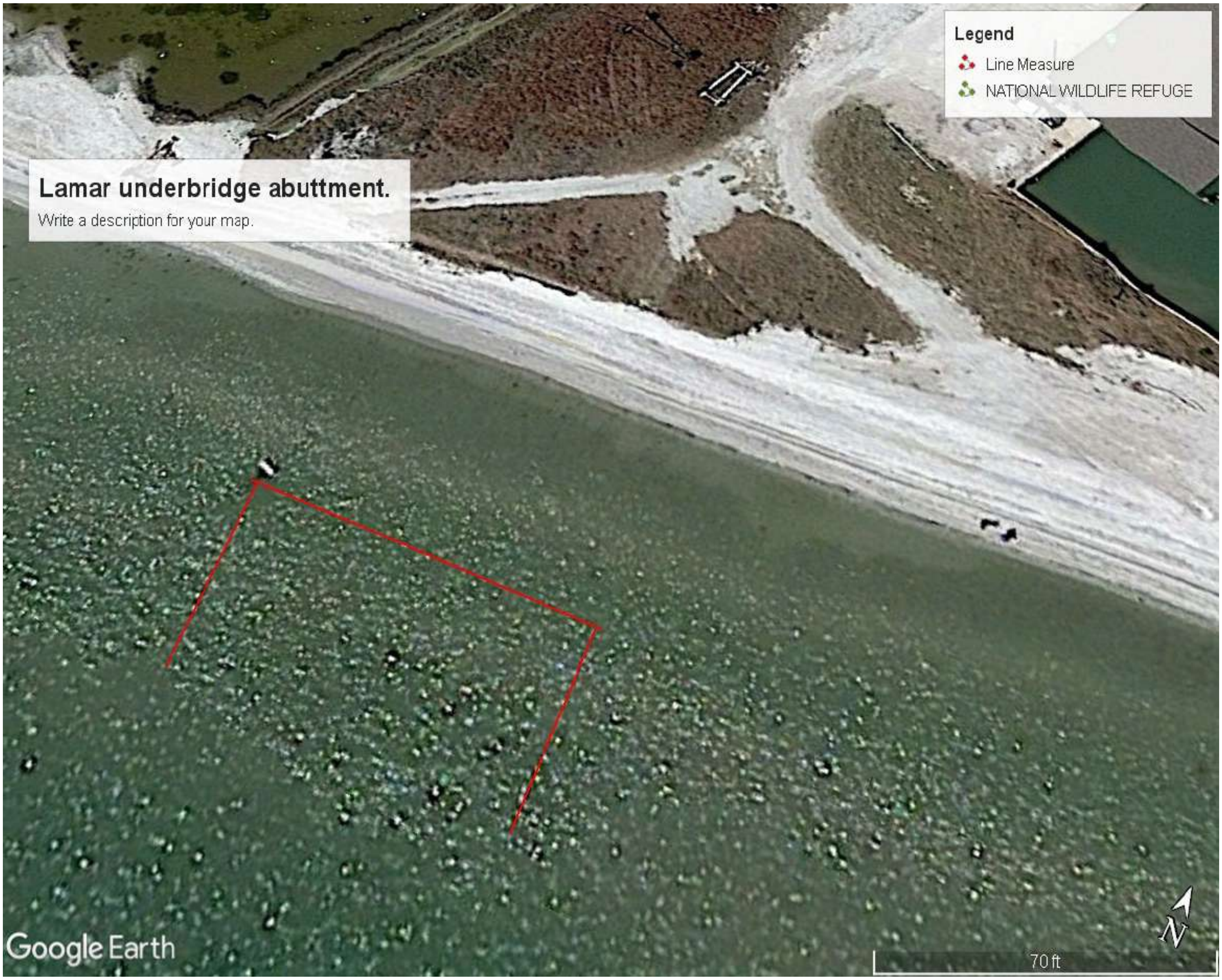
- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Lamar Bridge Abutment.
- Aransas County, Waterbody Name – Aransas Bay, and State tract number - 84

Lamar Bridge Abutment



Lamar Bridge Abutment	28°08’06.05"N	97°00’28.71"W	100 ft x 50 ft

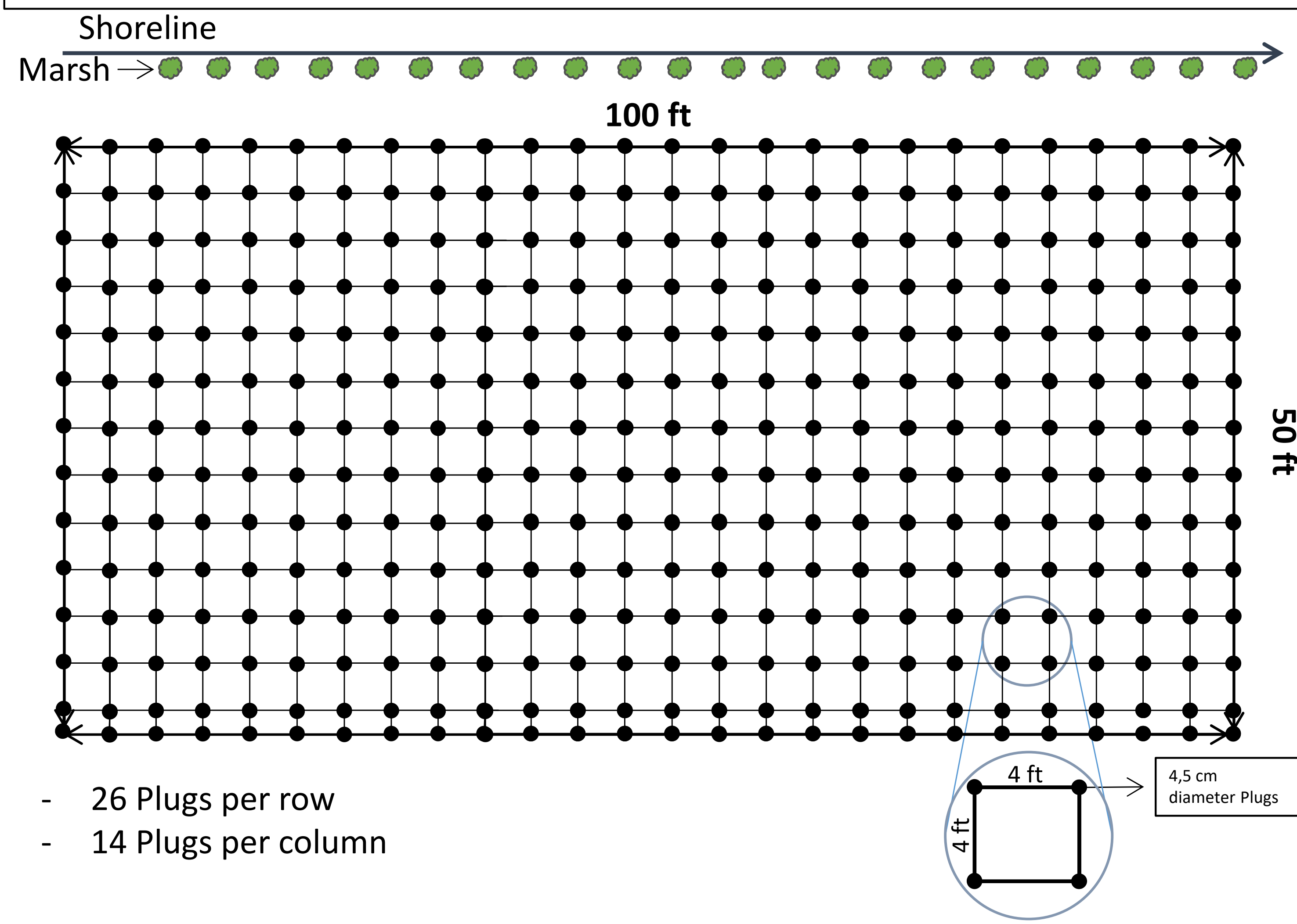
Lamar Bridge Abutment



Lamar Bridge Abutment	#1	28°08‘06.39"N	97°00’29.13"W	100 ft x 50 ft
	#2	28°08‘06.10"N	97°00’28.06"W	
	#3	28°08‘05.66"N	97°00’28.29"W	
	#4	28°08‘05.93"N	97°00’29.31"W	

Lamar Bridge Abutment

Set up for Matagorda Bay Seagrass Restoration Lamar Bridge Abutment will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

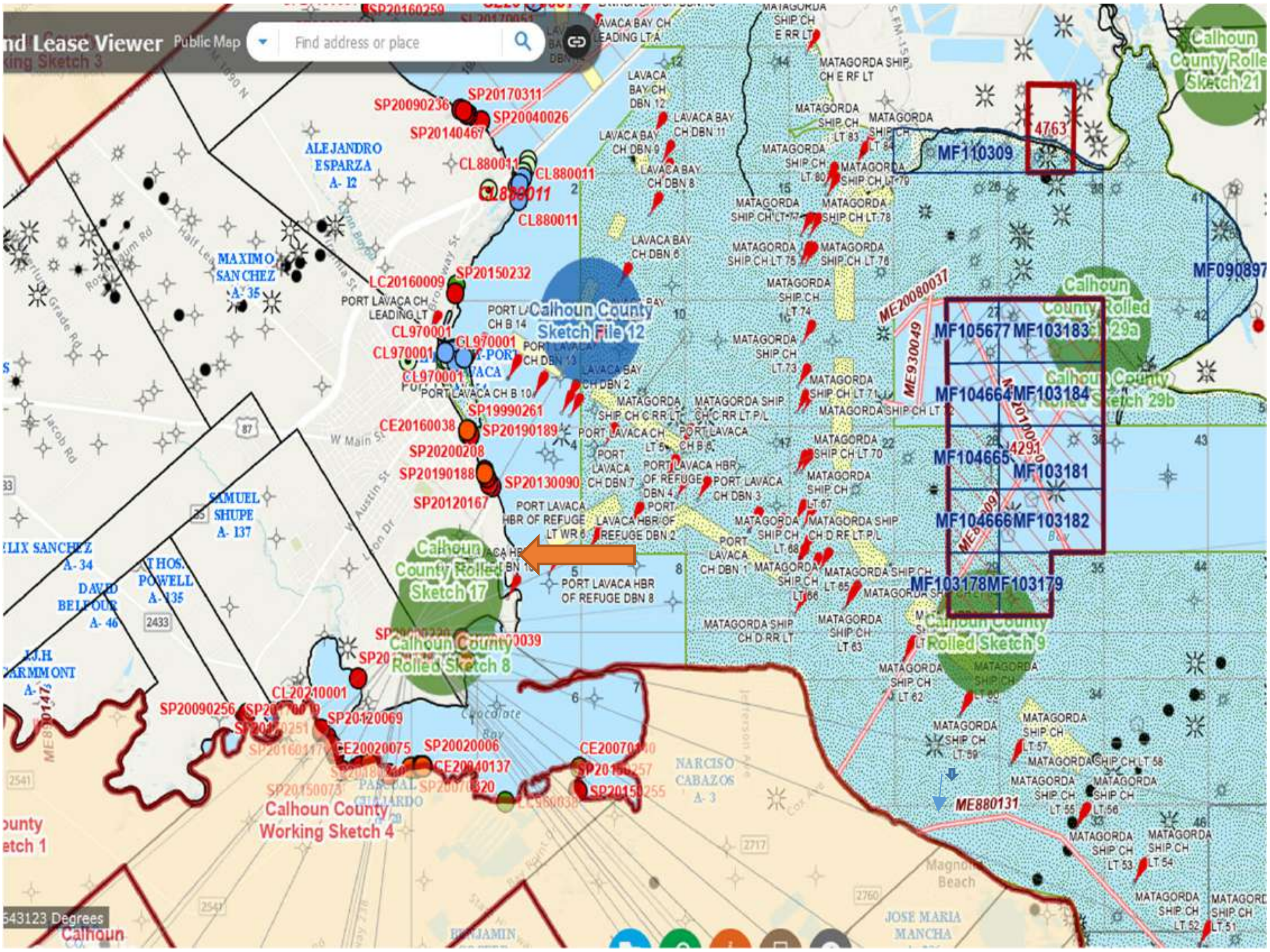
Port Lavaca East

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Port Lavaca East.
- Matagorda County, Waterbody Name – Lavaca Bay, and State tract number - 4

Port Lavaca East

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Port Lavaca East.
- Matagorda County, Waterbody Name – Lavaca Bay, and State tract number - 4

Port Lavaca East

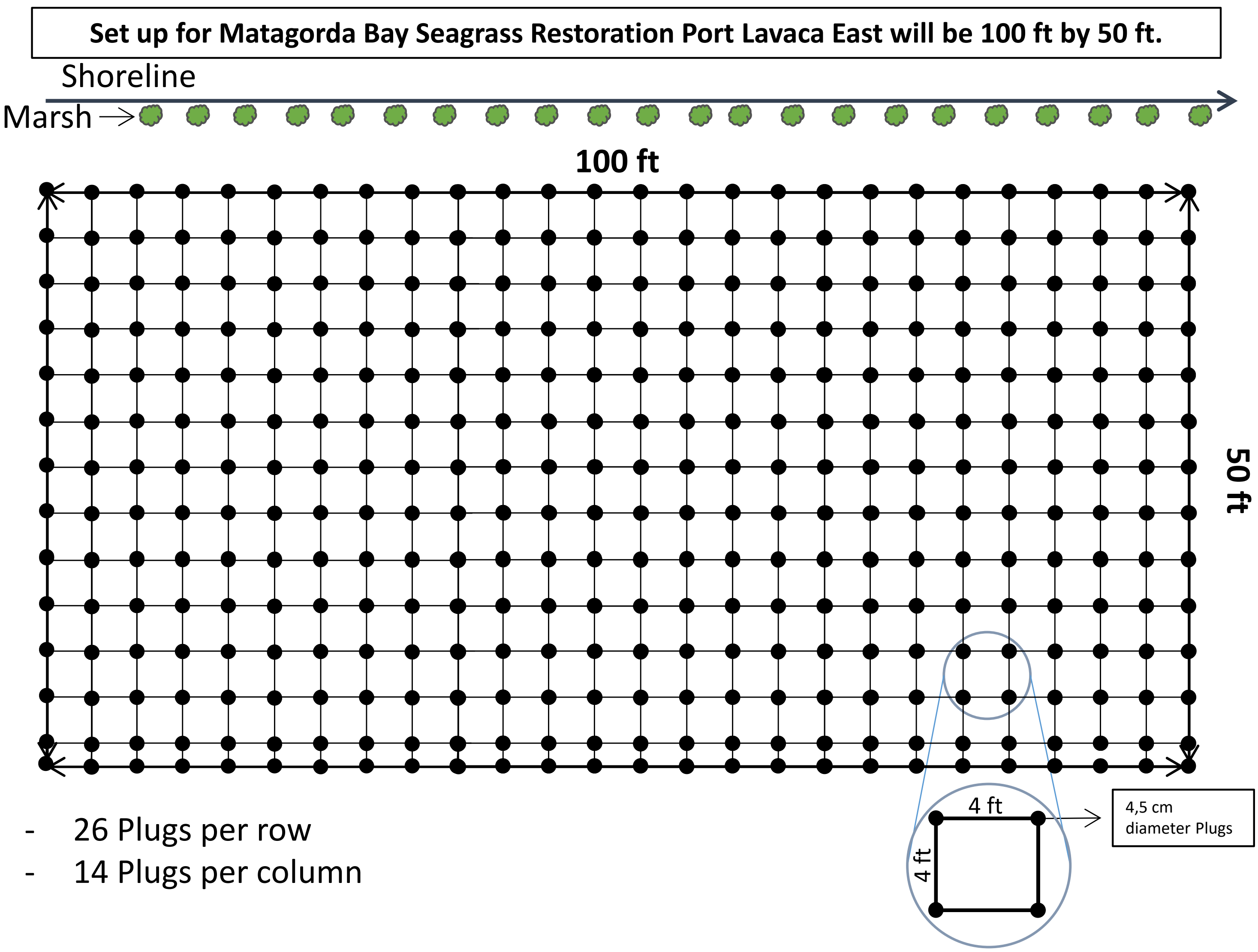


Port Lavaca East	28°35'49.80"N	96°36'44.45"W	100 ft x 50 ft

Port Lavaca East

Port Lavaca East	#1	28°35‘50.28"N	96°36’44.80"W	100 ft x 50 ft
	#2	28°35‘49.30"N	96°36’44.68"W	
	#3	28°35’49.34"N	96°36’44.12"W	
	#4	28°35‘50.36"N	96°36’44.26"W	

Port Lavaca East



- 26 Plugs per row
- 14 Plugs per column

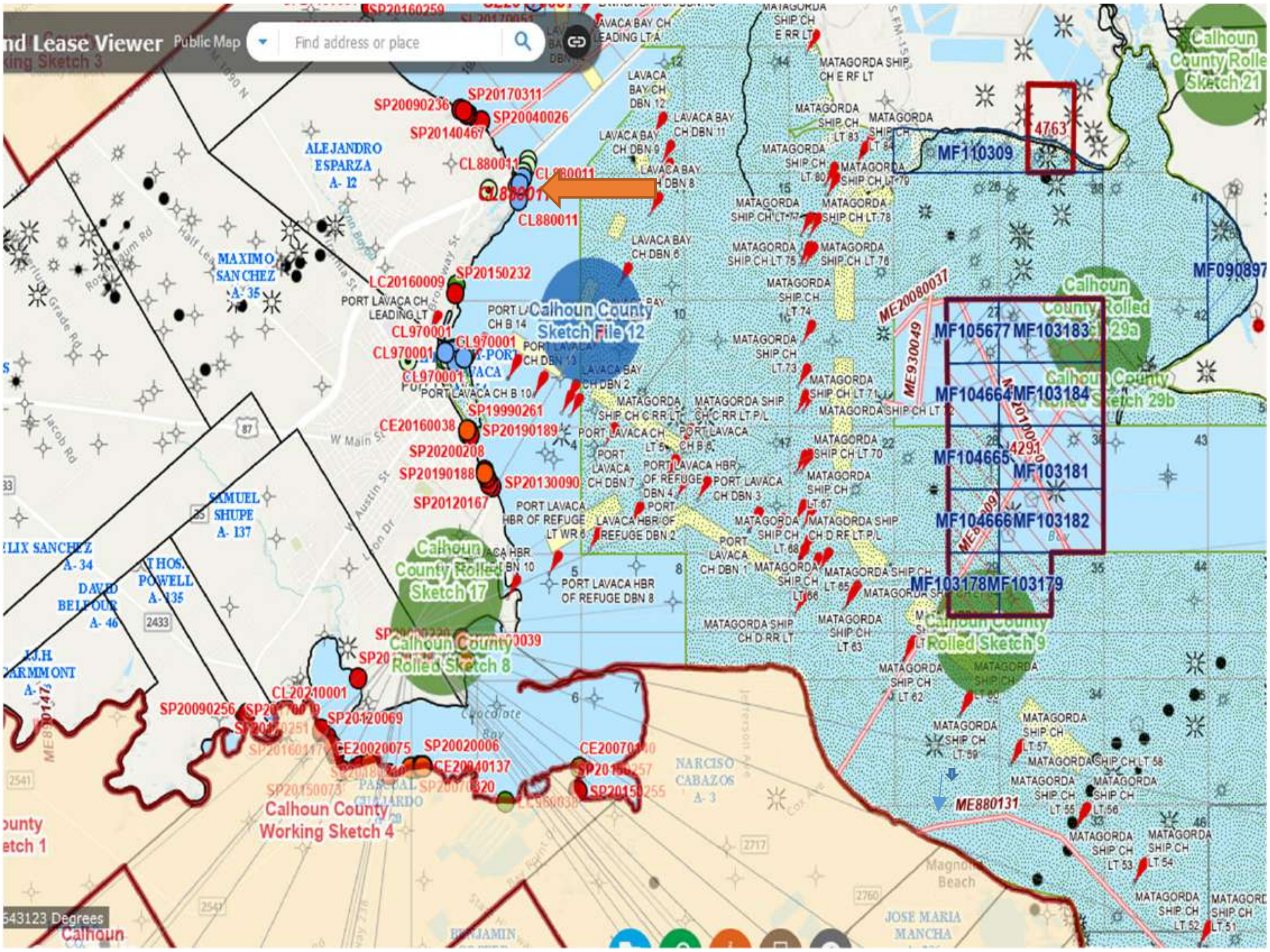
Port Lavaca Lighthouse Beach

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Port Lavaca Lighthouse Beach.
- Matagorda County, Waterbody Name – Lavaca Bay, and State tract number - 2

Port Lavaca Lighthouse Beach

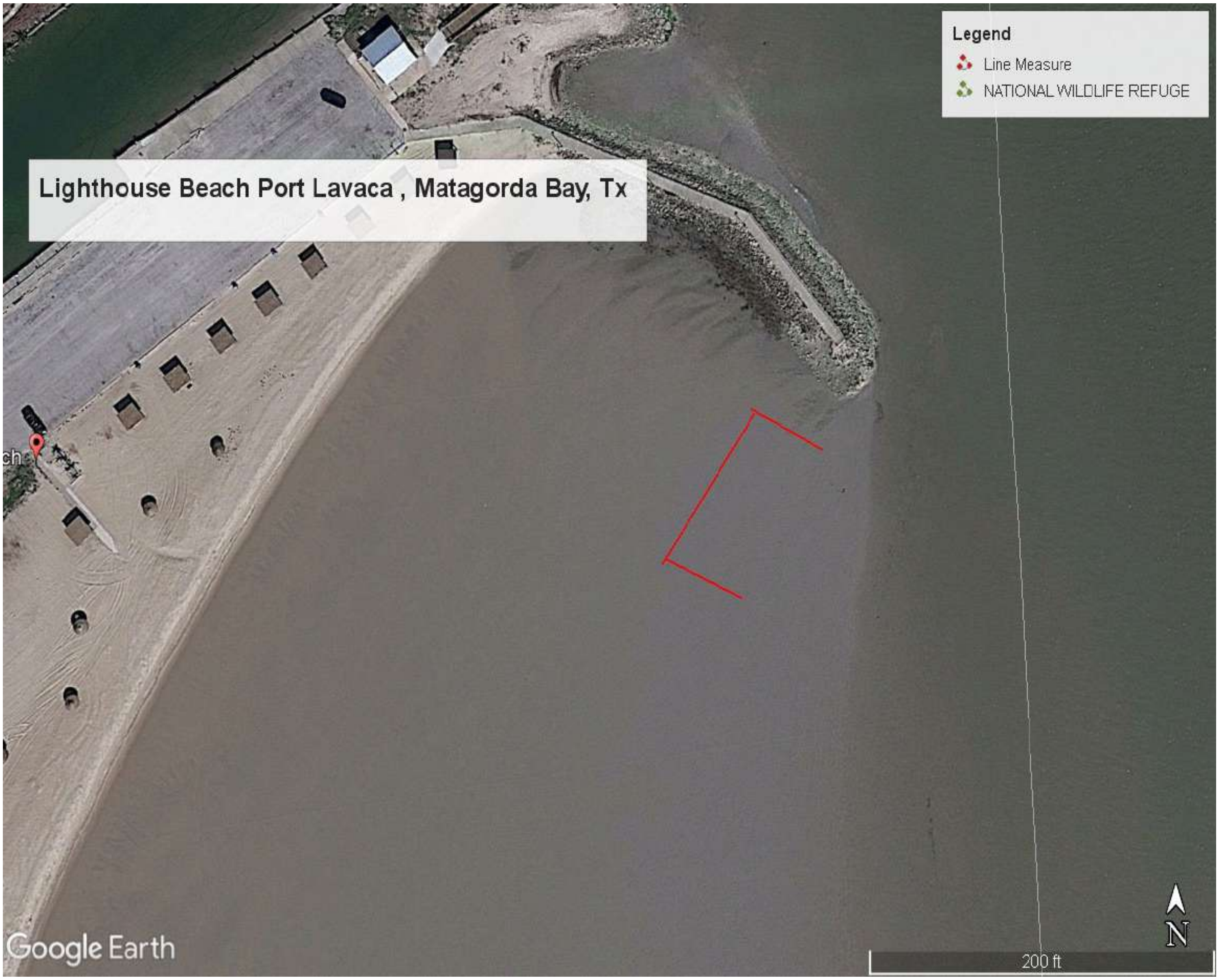
- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Port Lavaca Lighthouse Beach.
- Matagorda County, Waterbody Name – Lavaca Bay, and State tract number - 2

Port Lavaca Lighthouse Beach



Port Lavaca Lighthouse Beach	28°38'20.63"N	96°36'36.28"W	100 ft x 50 ft

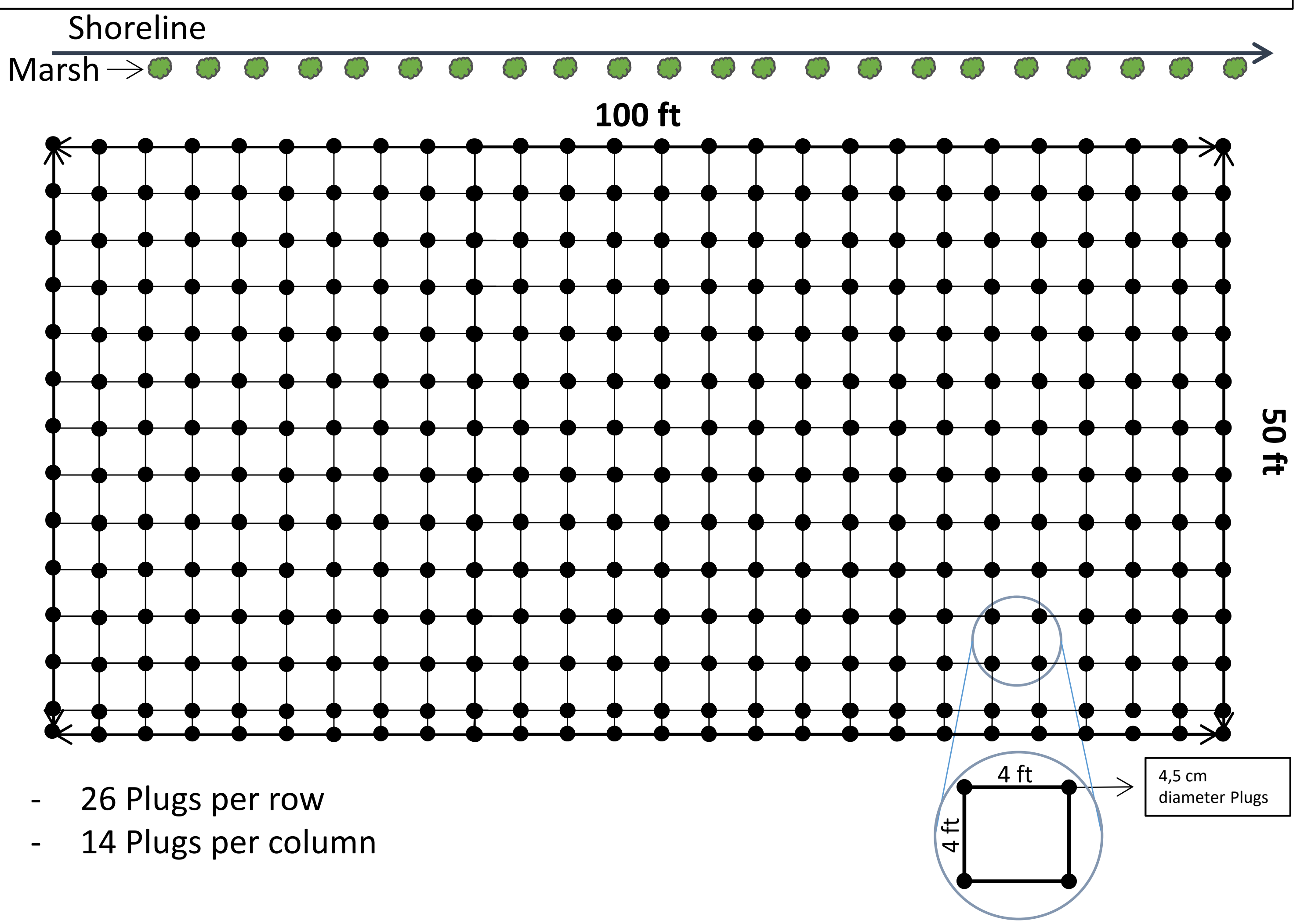
Port Lavaca Lighthouse Beach



Port Lavaca Lighthouse Beach	#1	28°38‘21.22"N	96°36’36.26"W	100 ft x 50 ft
	#2	28°38‘20.37"N	96°36’36.85"W	
	#3	28°38’20.15"N	96°36’36.34"W	
	#4	28°38‘20.95"N	96°36’35.79"W	

Port Lavaca Lighthouse Beach

Set up for Matagorda Bay Seagrass Restoration Port Lavaca Lighthouse Beach will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

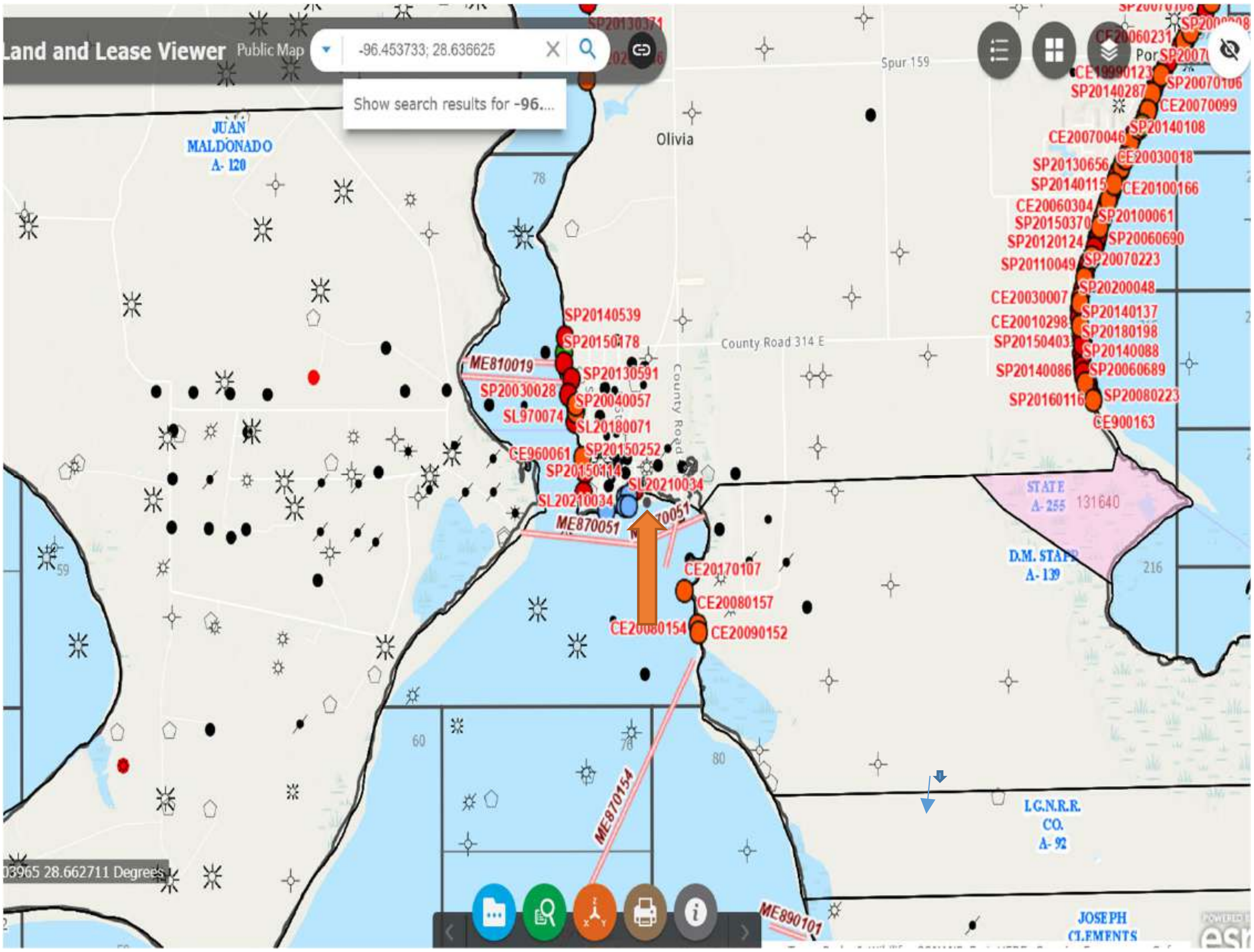
Keller Bay Kayak Launch

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Keller Bay Kayak Launch.
- Matagorda County, Waterbody Name – Keller Bay, and State tract number - 77

Keller Bay Kayak Launch

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Keller Bay Kayak Launch.
- Matagorda County, Waterbody Name – Keller Bay, and State tract number - 77

Keller Bay Kayak Launch



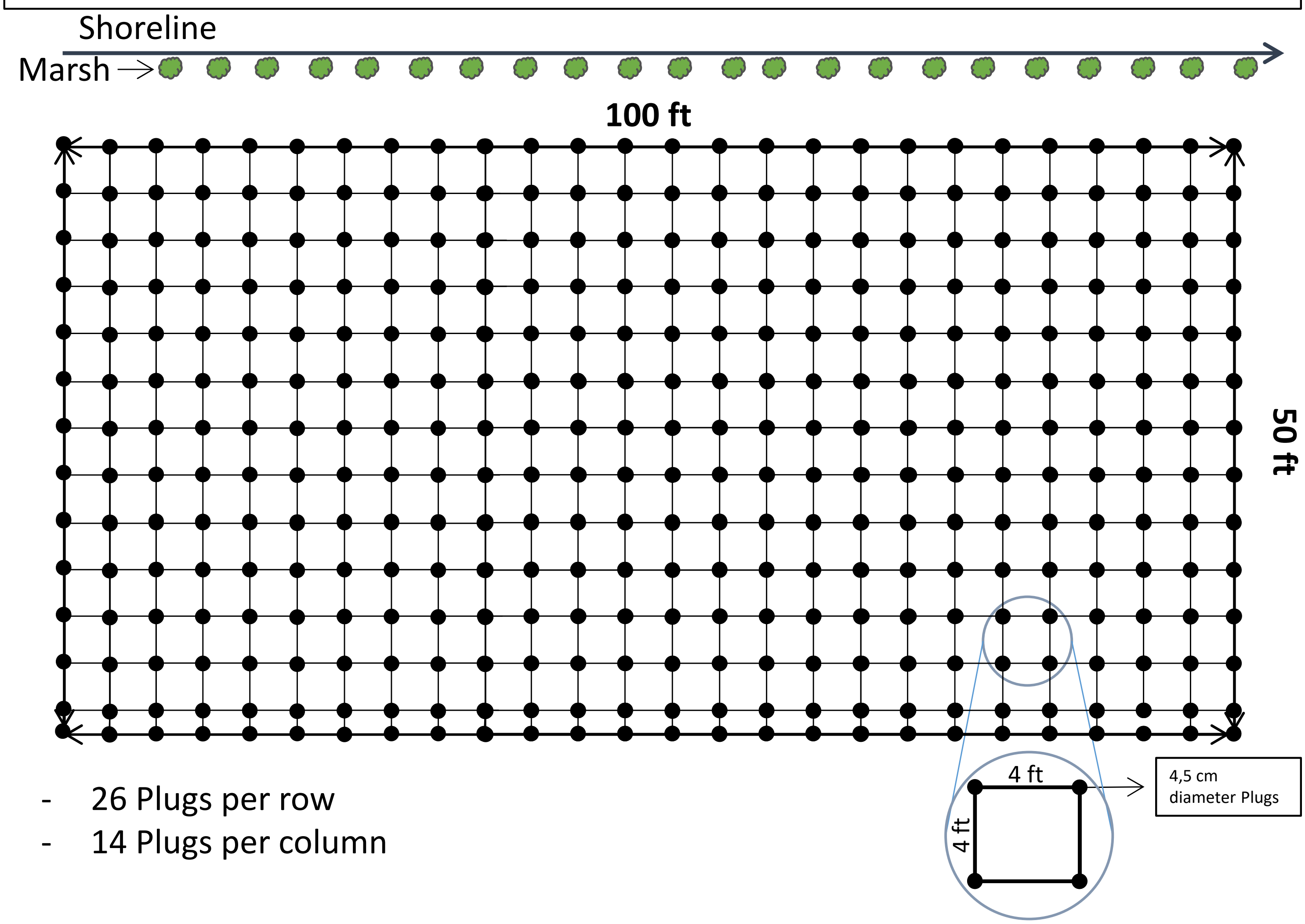
Keller Bay Kayak Launch	28°38'11.85"N	96°27'13.44"W	100 ft x 50 ft

Keller Bay Kayak Launch

Keller Bay Kayak Launch	#1	28°38‘12.13"N	96°27’14.03"W	100 ft x 50 ft
	#2	28°38‘12.13"N	96°27’12.90"W	
	#3	28°38‘11.65"N	96°27’12.89"W	
	#4	28°38‘11.65"N	96°27’13.95"W	

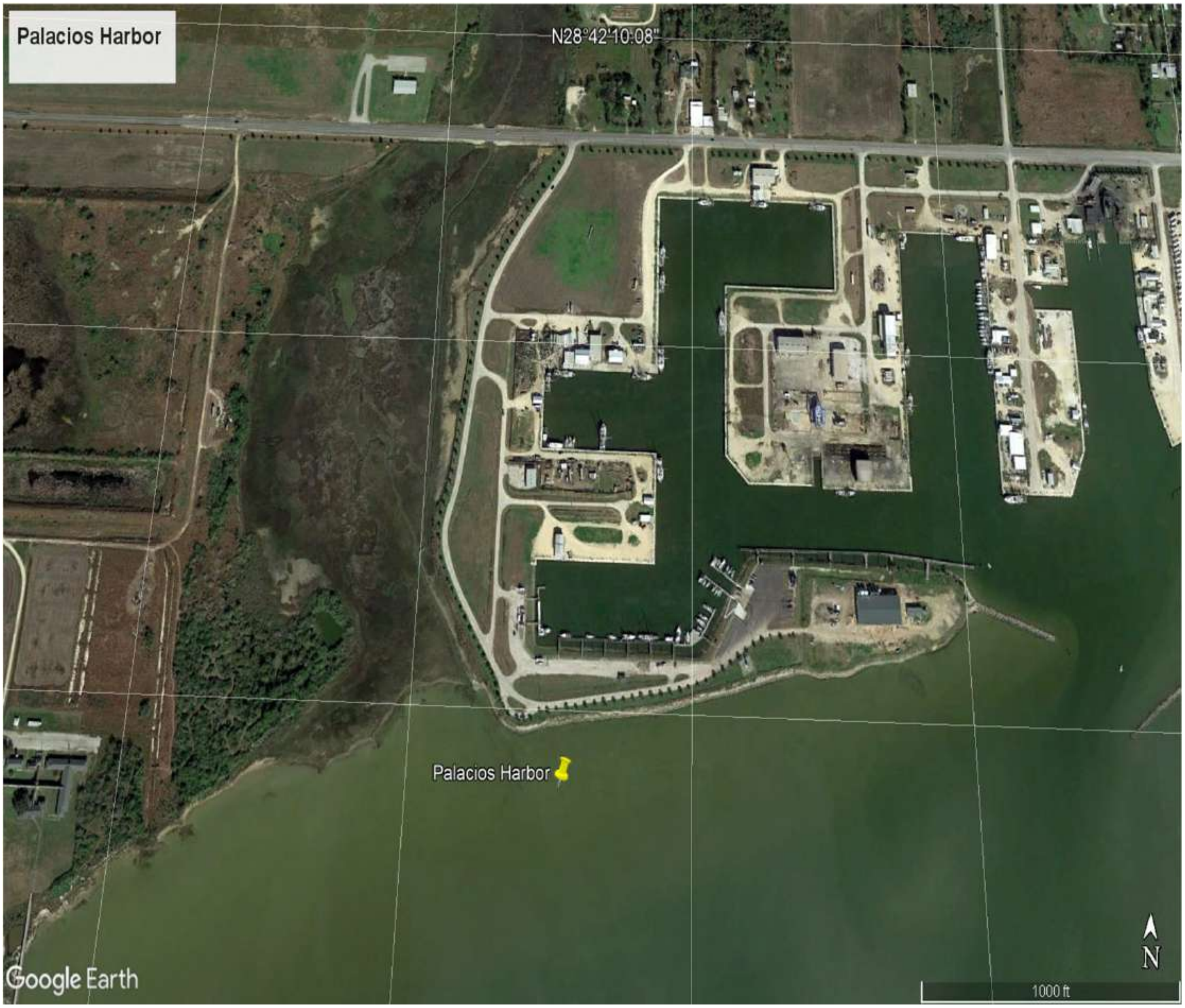
Keller Bay Kayak Launch

Set up for Matagorda Bay Seagrass Restoration Keller Bay Kayak Launch will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

Palacios Harbor

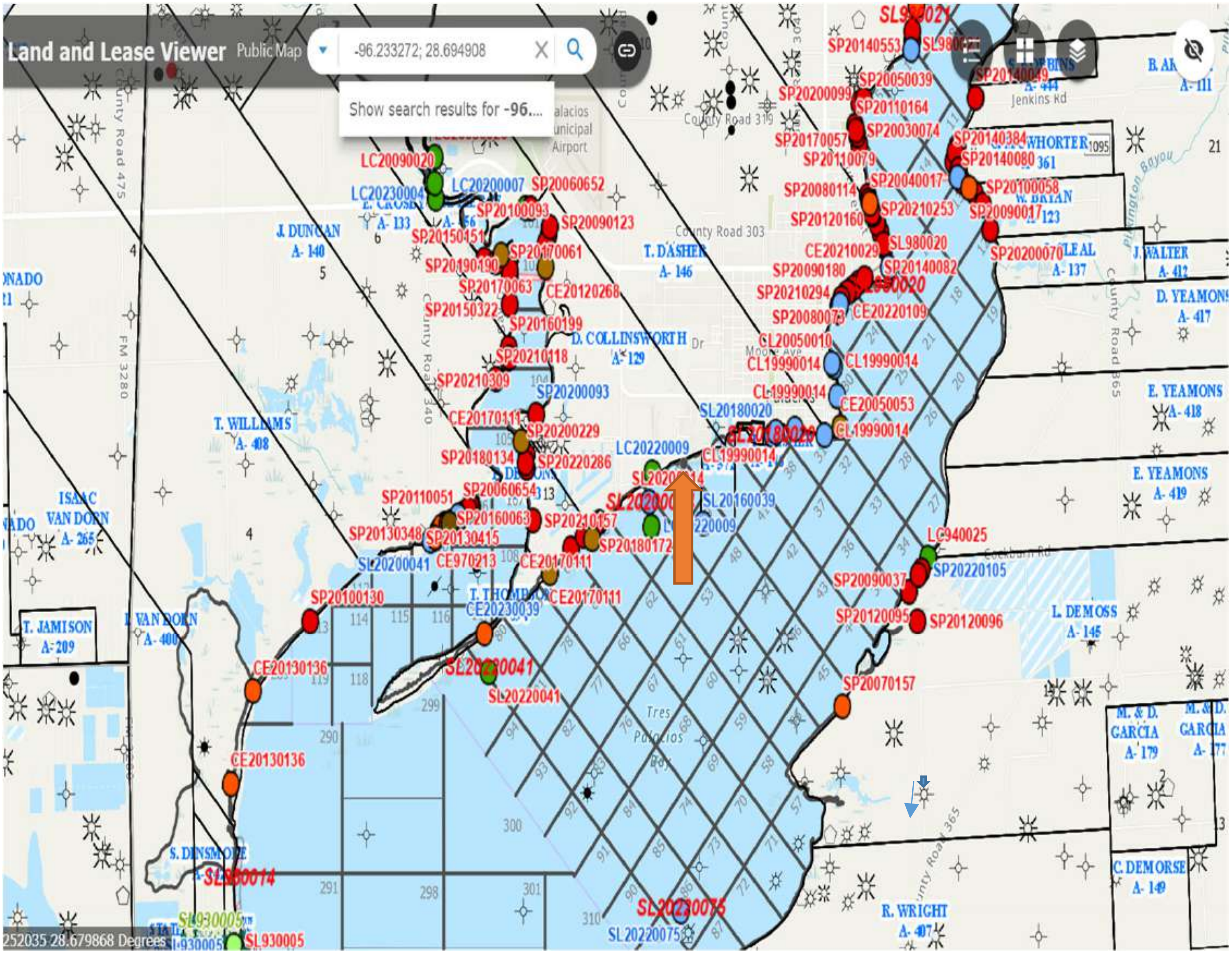


- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Palacios Harbor.
- Matagorda County, Waterbody Name – Tres Palacios Bay, and State tract number - 50

Palacios Harbor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Palacios Harbor.
- Matagorda County, Waterbody Name – Tres Palacios Bay, and State tract number - 50

Palacios Harbor



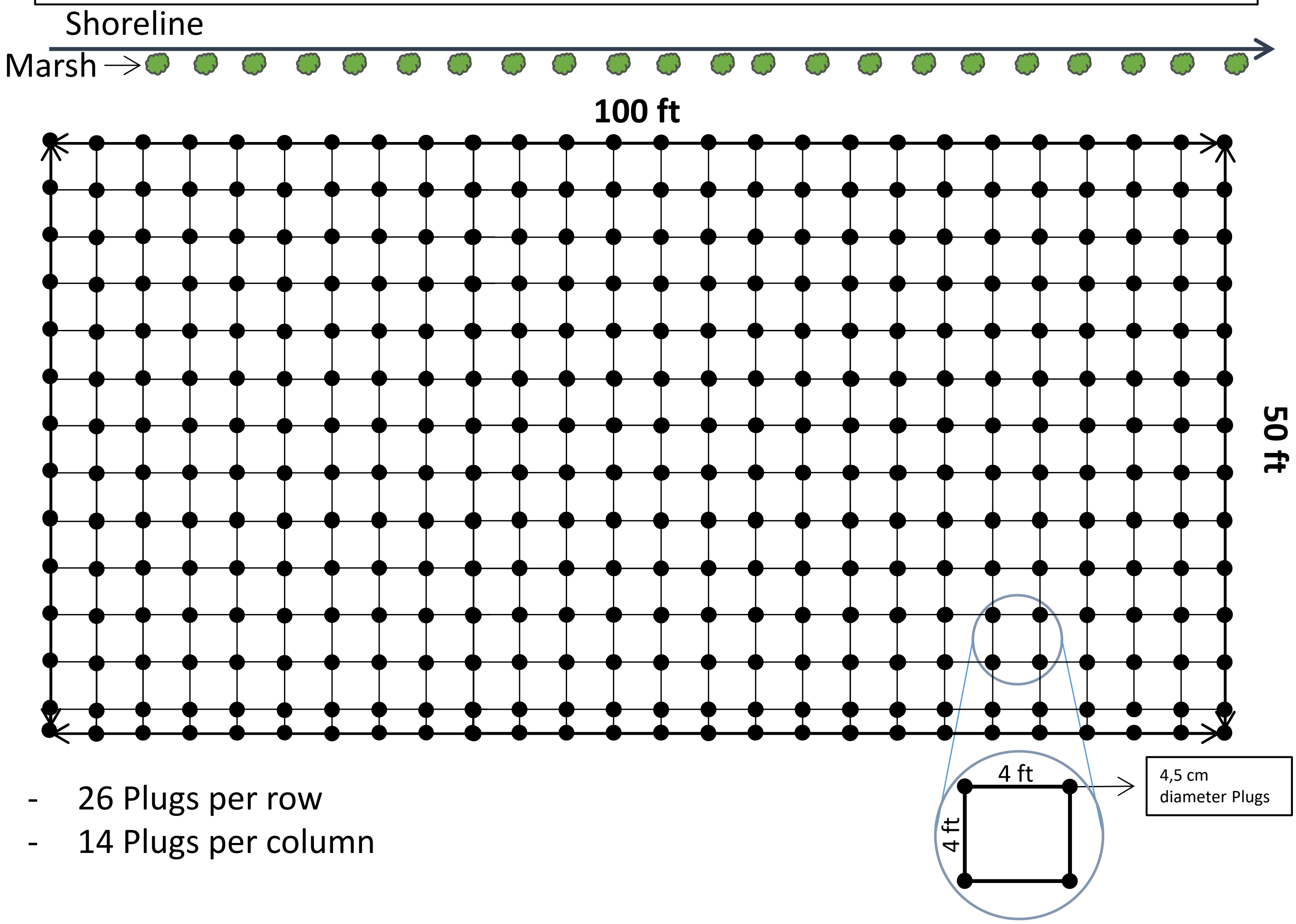
Palacios Harbor	28°41’41.67"N	96°13’59.78"W	100 ft x 50 ft

Palacios Harbor

Palacios Harbor	#1	28°41'41.80"N	96°14'00.45"W	100 ft x 50 ft
	#2	28°41'42.07"N	96°13'59.37"W	
	#3	28°41'41.60"N	96°13'59.20"W	
	#4	28°41'41.34"N	96°14'00.23"W	

Palacios Harbor

Set up for Matagorda Bay Seagrass Restoration Palacios Harbor will be 100 ft by 50 ft.



- 26 Plugs per row
- 14 Plugs per column

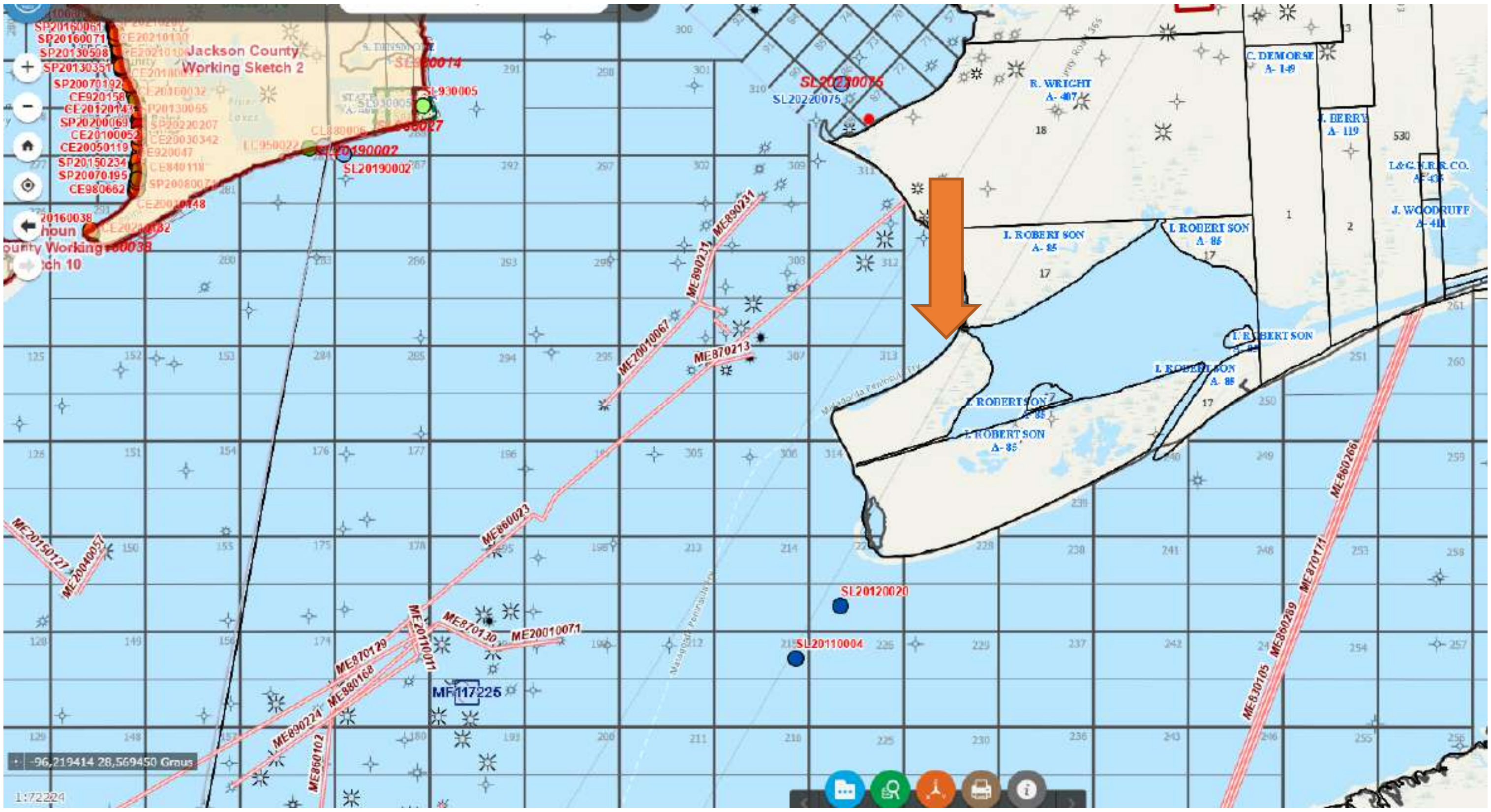
Oyster Lake Park

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Oyster Reef Park
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 315

Oyster Lake Park

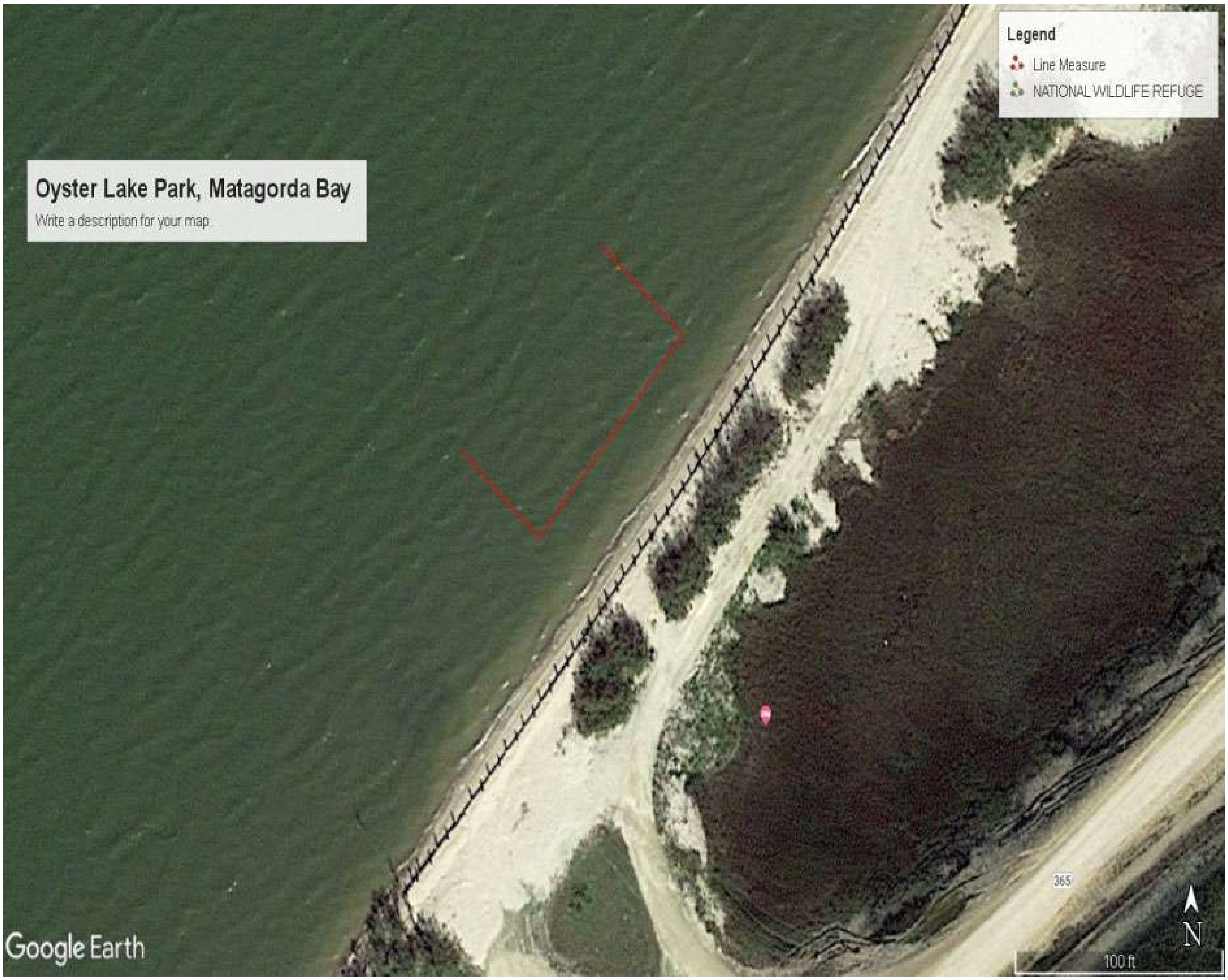
- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Oyster Reef Park
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 315

Oyster Lake Park



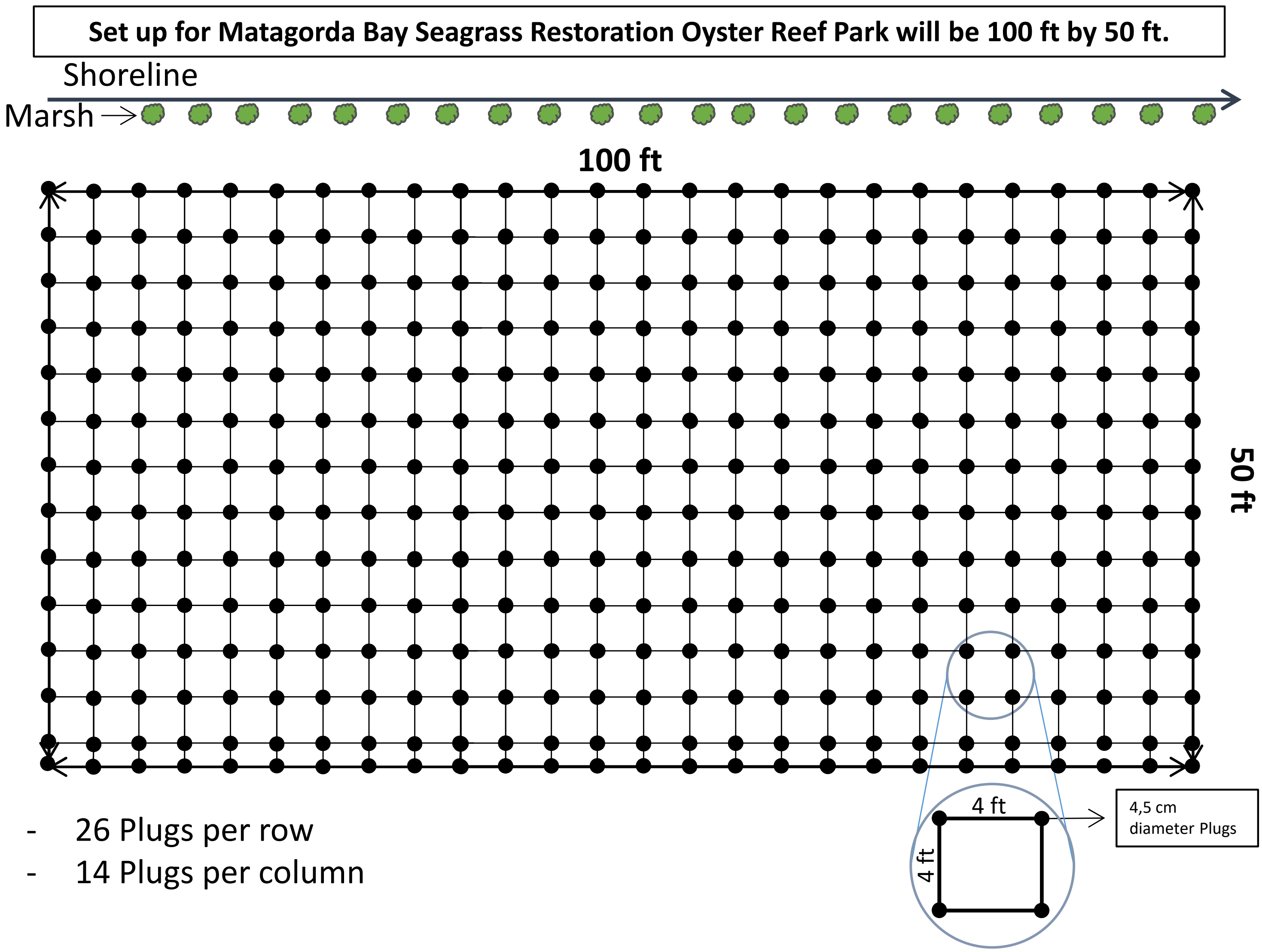
Oyster Lake Park	28°36'42.15"N	96°12'54.24"W	100 ft x 50 ft

Oyster Lake Park - Aerial photo with pilot drawing



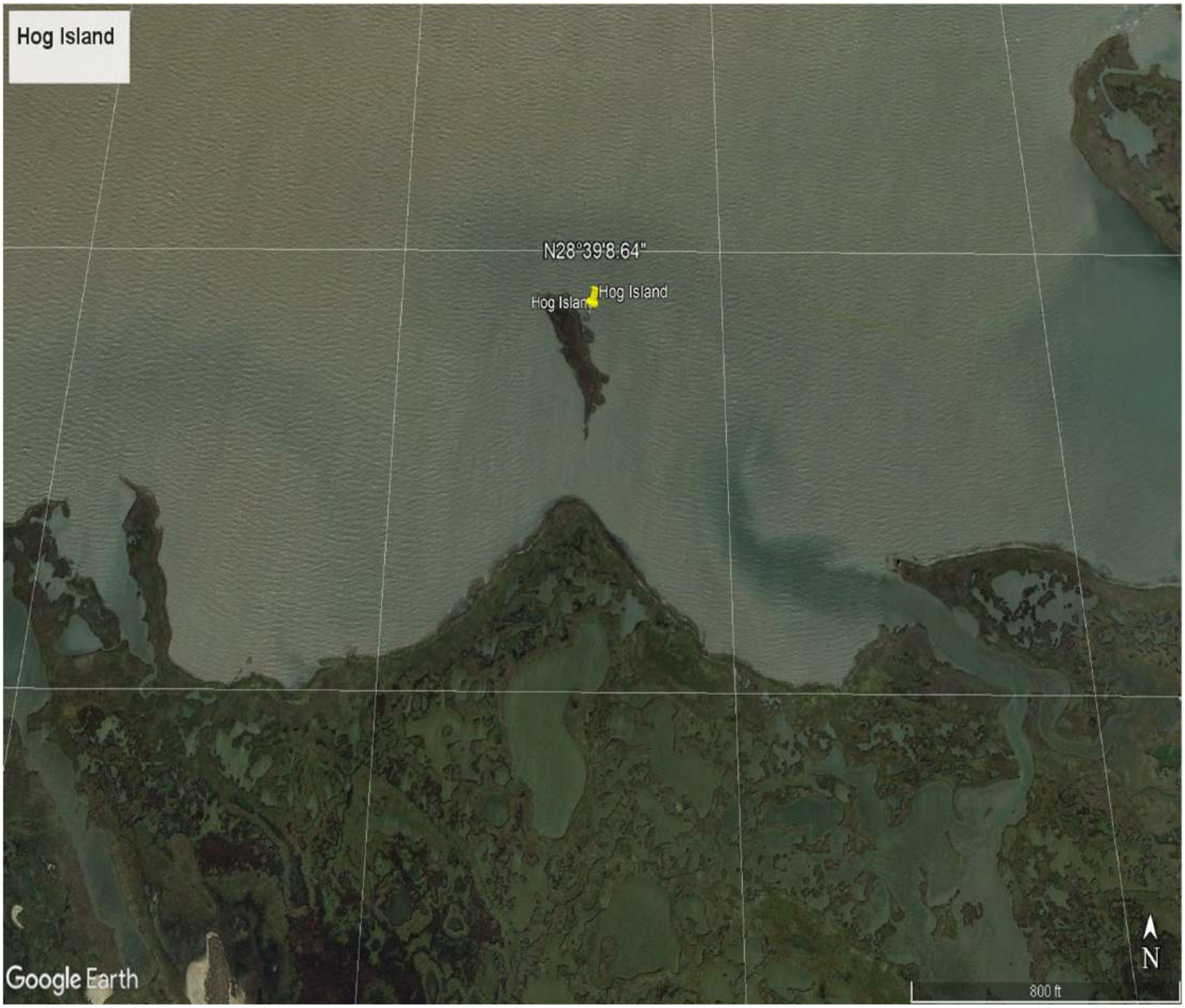
Oyster Lake Park	#1	28°36'41.60"N	96°12'54.42"W	100 ft x 50 ft
	#2	28°36'42.36"N	96°12'53.71"W	
	#3	28°36'42.65"N	96°12'54.17"W	
	#4	28°36'41.88"N	96°12'54.89"W	

Oyster Reef Park



- 26 Plugs per row
- 14 Plugs per column

Hog Island



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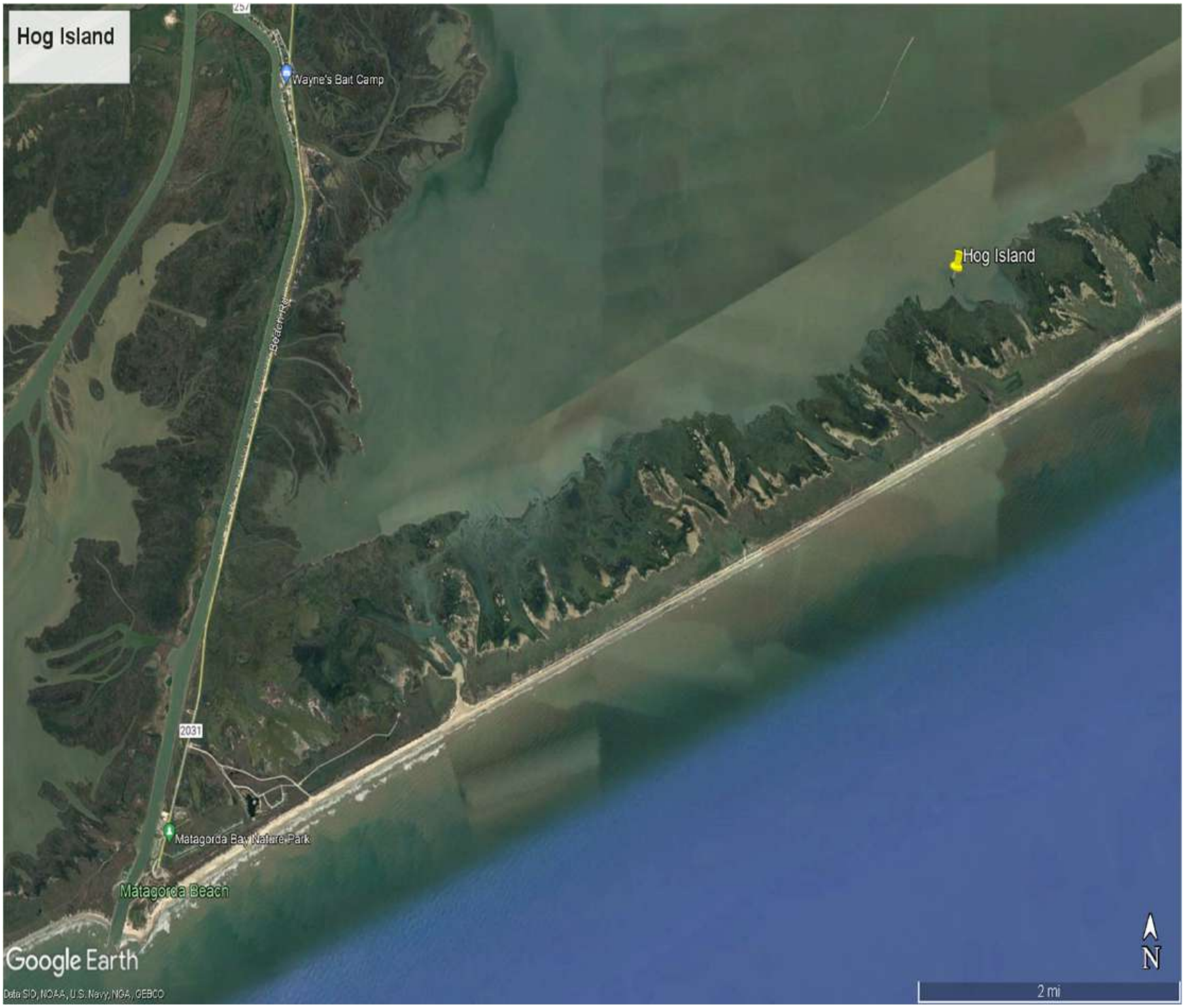
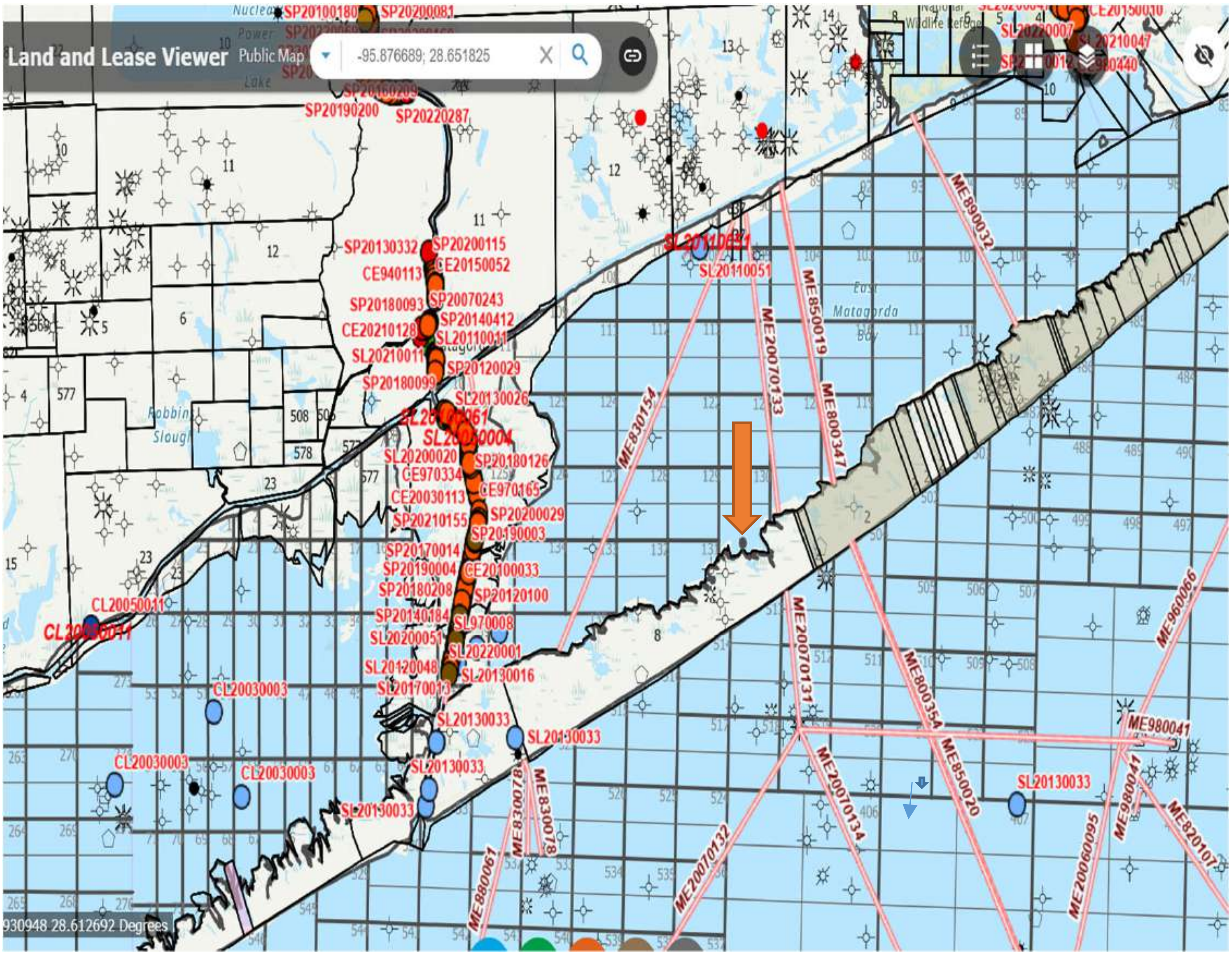
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Hog Island .
- Matagorda County, Waterbody Name – East Matagorda Bay, and State tract number - 130

Hog Island



- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Hog Island .
- Matagorda County, Waterbody Name – East Matagorda Bay, and State tract number - 130

Hog Island

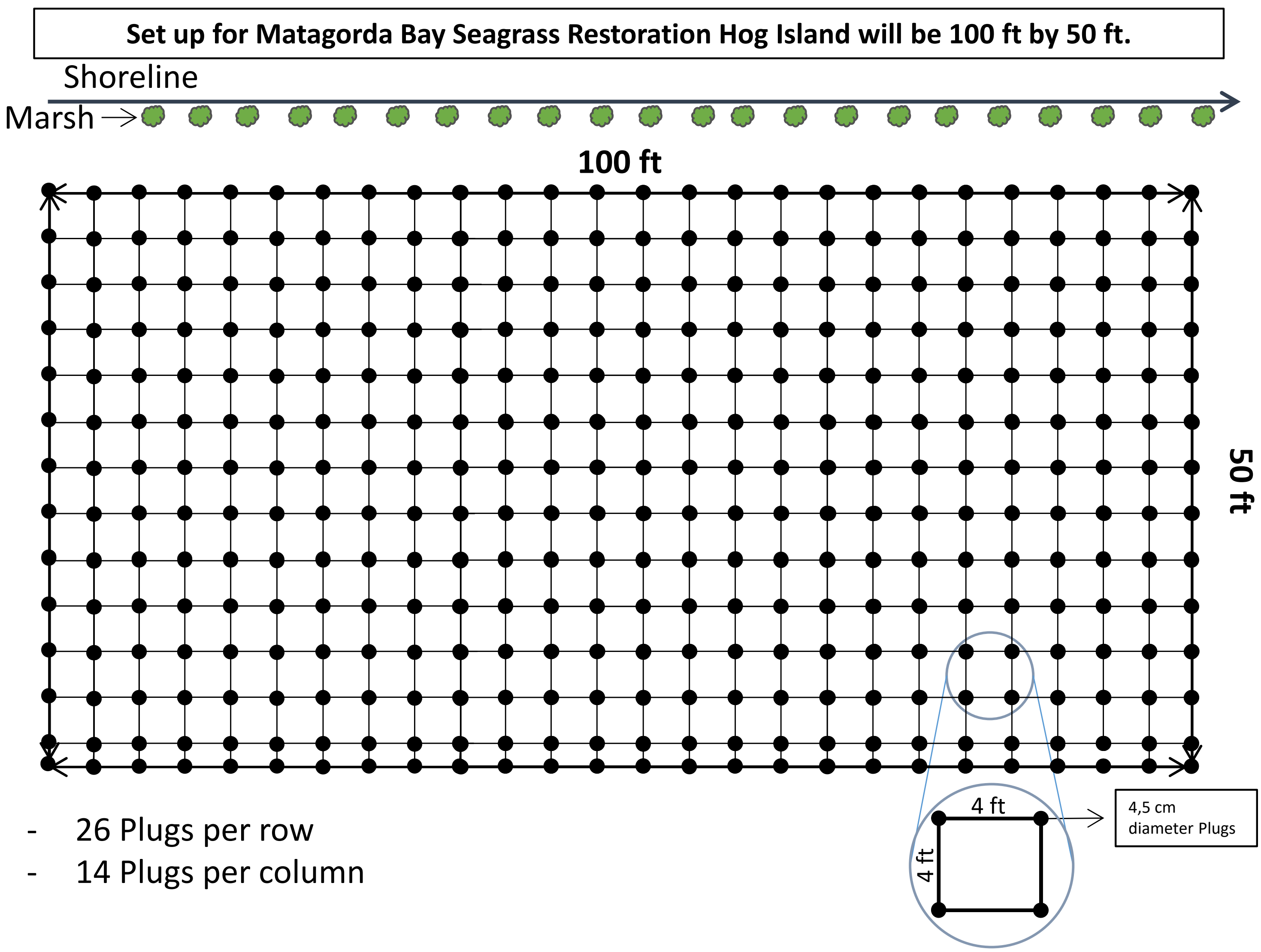


Hog Island	28°39’06.57"N	96°52'36.08"W	100 ft x 50 ft

Hog Island

Hog Island	#1	28°39’06.98"N	95°52’36.52"W	100 ft x 50 ft
	#2	28°39’06.05"N	96°52’36.14"W	
	#3	28°39’06.25"N	96°52’35.63"W	
	#4	28°39’07.19"N	96°52’36.01"W	

Hog Island



- 26 Plugs per row
- 14 Plugs per column

DEPARTMENT OF THE ARMY
U. S. ARMY CORPS OF ENGINEERS, GALVESTON DISTRICT
2000 FORT POINT ROAD
GALVESTON, TEXAS 77550

March 15, 2024

Compliance Branch

SUBJECT: **SWG-2013-00364**; The Matagorda Bay Foundation and Great Caribbean Energy and Environment Foundation, No Permit Required, Seagrass Planting, Eight Sites in Matagorda, Calhoun, and Aransas, Counties, Texas

Ms. Anitra Thorhaug
Great Caribbean Energy and Environment Foundation
4709 Austin Street
Houston, Texas 77004

Dear Ms. Thorhaug:

This letter is in response to your request, dated January 27, 2024, requesting a no permit required letter for planting seagrass. The eight project sites are located in Matagorda, Calhoun, and Aransas Counties, Texas (maps enclosed).

The Corps of Engineers has the regulatory responsibility over two federal laws, Section 10 of the Rivers and Harbors Act (Section 10) which regulates work and/or structures in/or affecting navigable waters of the United States (U.S.) and Section 404 of the Clean Water Act (Section 404) which regulates the discharge of dredged and/or fill material into waters of the U.S., including navigable waters. Based on our desk review, the proposed plan submitted states that approximately 3,130 plugs of seagrass will be planted at eight sites, specifically, Raspberry Island, Magnolia Beach, Seadrift, Lamar Bridge Abutment, Keller Bay Kayak Launch, Palacios Fish Harbor, Oyster Lake Park, and Hog Island. The proposed plan is not a regulated activity subject to Section 404 or Section 10, provided that there is no discharge of dredged and/or fill material in waters of the United States or work and/or structures placed in a water of the United States. Therefore, the proposed seagrass planting does not require a Department of the Army permit. This No Permit Required letter does not address geographic jurisdiction for the project sites.

Areas of Federal Interests (federal projects, and/or work areas) may be located within this proposed project area. Any activities in these federal interest areas would also be subject to federal regulations under the authority of Section 14 of the Rivers and Harbors Act (aka Section 408). Section 408 makes it unlawful for anyone to alter in any manner, in whole or in part, any work (ship channel, flood control channels, seawalls, bulkhead, jetty, piers, etc.) built by the United States unless it is authorized by the Corps of Engineers (i.e., Navigation and Operations Division).

If you have any questions concerning this matter, please reference file number **SWG-2013-00364** and contact me at the letterhead address, by telephone at 409-766-6322, or via email at Diana.L.Ray@usace.army.mil. To assist us in improving our service to you, please complete the survey found at https://regulatory.ops.usace.army.mil/customer-service- survey and/or if you would prefer a hard copy of the survey form, please let us know, and one will be mailed to you.

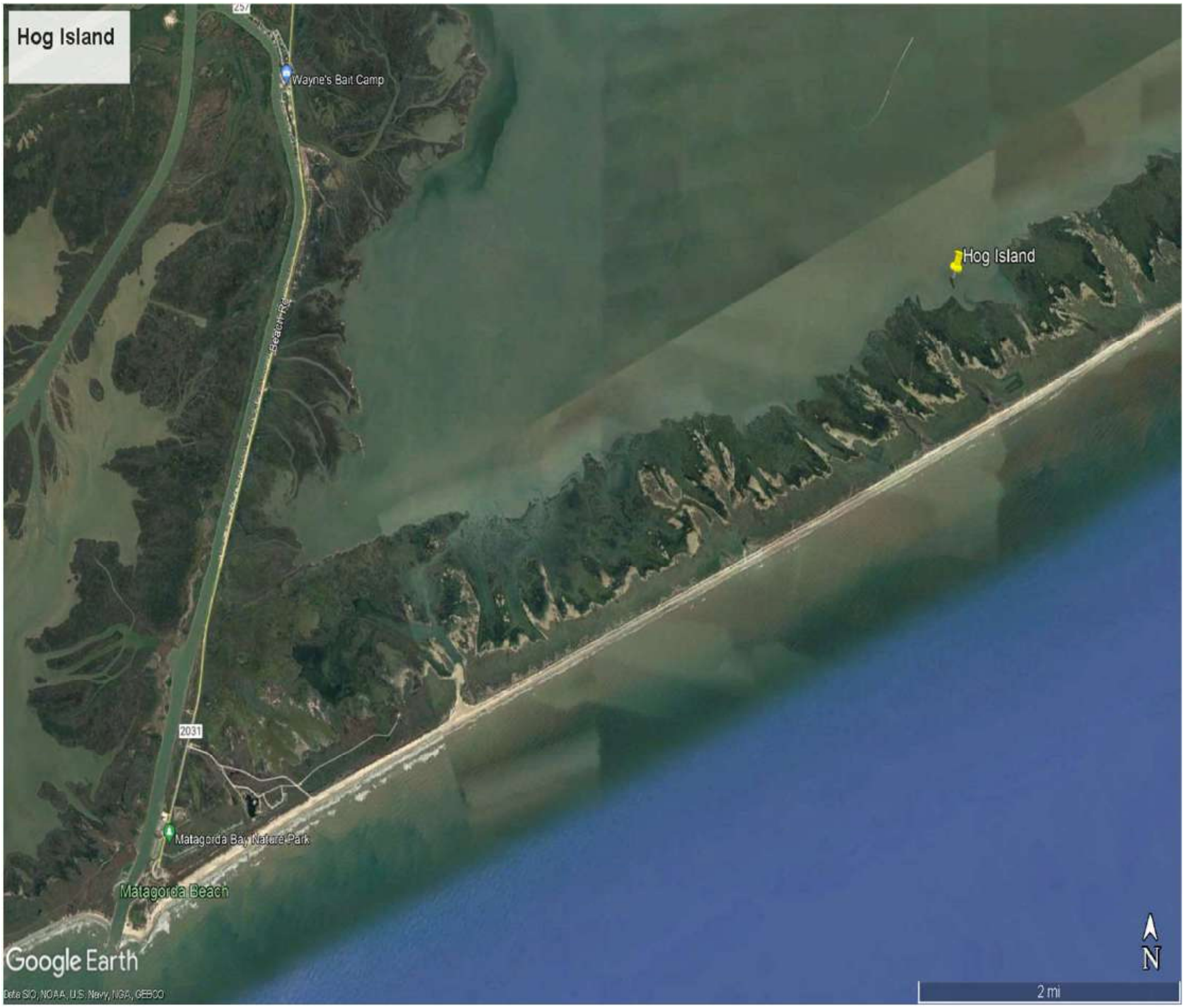
Sincerely,

Lynne Ray
Project Manager
Compliance Branch

Enclosures

RECEIVED 27JAN2024

Hog Island



- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Hog Island .
- Matagorda County, Waterbody Name – East Matagorda Bay, and State tract number - 130

RECEIVED 27JAN2024

Oyster Lake Park

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Oyster Reef Park
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 315

RECEIVED 27JAN2024

Palacios Harbor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Palacios Harbor.
- Matagorda County, Waterbody Name – Tres Palacios Bay, and State tract number - 50

RECEIVED 27JAN2024

Keller Bay Kayak Launch

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Keller Bay Kayak Launch.
- Matagorda County, Waterbody Name – Keller Bay, and State tract number - 77

RECEIVED 27JAN2024

Lamar Bridge Abutment

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Lamar Bridge Abutment.
- Aransas County, Waterbody Name – Aransas Bay, and State tract number - 84

RECEIVED 27JAN2024

Sea Drift

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **January, 2023**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Seadrift.
- Calhoun County, Waterbody Name – Hynes Bay, and State tract number - 133

RECEIVED 27JAN2024

Magnolia Beach Pilot

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607)**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Magnolia beach Texas.
- Matagorda County, Waterbody Name - Matagorda Bay, and State tract number - 33

RECEIVED 27JAN2024

Raspberry Island off Port O'Connor

- Applicant Name: **The Matagorda Bay Foundation & Greater Caribbean Energy and Environment Foundation**
- Applicant Address: **4709 Austin St., Houston, Texas 77004**
- Project Name; **Matagorda Bay Shoreline Resilience: Restoring Seagrass Pilots (GLO Contract No. # 23-020-013-D607**
- Date of Preparation: **December, 2022**
- Name of Preparer: **Anitra Thorhaug**
- Project Location: Raspberry Island off Port O'Connor
- Calhoun County, Waterbody Name - Matagorda Bay, and State tract number - 242

March 14, 2024

Anitra Thorhaug
1359 SW 22 Terrace
Miami, FL 33145

Dear Dr. Thorhaug,

This letter is in response to your inquiry about introducing seagrass into public waters of the state for Phase II of the Matagorda Bay Seagrass Restoration Pilot Study that is slated to receive a funding award from the Coastal Management Program administered by the Texas General Land Office. Texas Parks and Wildlife Department (TPWD) regulates the introduction and stocking of fish, shellfish, and aquatic plants into the public water of the state (Parks and Wildlife Code §12.015, 12.019, 66.015). Under title 31 of the Texas Administrative Code, section 57.252 requires a permit for the introduction of fish, shellfish, and aquatic plants into public waters.

Permits for the introduction of fish, shellfish, or aquatic plants into public waters are typically issued for a six-week period with extensions of up to one year at the discretion of the program director of the Environmental Resources Program. Because your request for a consultation was submitted over one year prior to your first planned introduction, we cannot provide approval for this permit until May 2024. However, we recognize that you have requested a letter confirming the ability to receive an introduction permit for grant submission purposes.

Upon review of your application materials, we have determined that this permit may be eligible for issuance provided that 1) the application is submitted with the same introduction locations and species closer to the time of the introduction, and 2) the rules governing introduction permits do not change prior to May 2024. This preliminary approval is dependent upon the stipulation that, at the time of introduction, the sites identified as "Donor" and "Recipient" remain the same as in the provided table (attachment A). In addition, at the time of introduction, the methodology of collecting 4.5 square inch plugs at one plug per 9 square feet intervals shall remain the same (see attachment A for full methodology).

We appreciate your careful review of the conditions of the permit and your efforts to meet all applicable requirements. If you need further information or have any questions, please contact the Aquatic Introduction Permit Coordinator, Margaret Wheat-Walsh, 361-431-6003 ext. 833.

I appreciate your efforts to cooperate and fulfill the requirements of this law.

Sincerely,

TEXAS PARKS & WILDLIFE

Life's better outside.®

Jacqueline Robinson

Jackie Robinson
Lower Coast Team Lead
Ecosystem Resources Assessment
1409 Waldron Rd
Corpus Christi, TX 78414

EC:JR:MWW

Attachment A

DONOR SITES of "Matagorda Bay Seagrass Restoration Pilot study" Phase II.

From Matagorda Bay Foundation.

Anitra Thorhaug, William Balboa co-Principles of Phase I and Phase II.

The proposed sites for testing restoration success in Matagorda Bay will be transplantation of plugs of *Halodule wrightii* including in some sites the naturally-occurring understory of *Halophila engelmanii*. There will be 4.5 sq inches diameter plugs taken at one per plug per 9 sq ft intervals about 314 per site, making 0.0239 acre total for the project taken to create 1.3 acres when all survive. This long-term coverage could be far more acreage.

Site	Amount Donor	Season April-June2025	Site Donor	Site Donor	Site Recipient	Site Recipient	Potential Final acreage	Configur-ation recipient
Raspberry	110 sq ft	April to June	28 26 40.65N	96 24 07.60W	28°26' 00.03"N	96°24' 35.55"W	6250 sq ft	Rows
Alternative donor		April to June	28 27 45.63N	96 24 57.50W	same	same	--------	Rows
Magnolia	110 sq ft	April to JUne	28 27 45.63N	96 24 57.50W	28°33' 40.99"N	96°32' 23.59"W	6250 sq ft	rows
Magnolia	70 sq ft	April to June	28 27 45.63N	96 24 57.50W	same	same		Various Circle, star, arrow
Sea Drift	110 sq ft	April to June	28 24 13.53N	96 42 25.32W	28°24' 19.52"N	96°42' 26.51"W	6250 sq ft	Rows
Sea Drift	70 sq ft	April to June	28 24 13.53N	96 42 25.32W	same	same		Various circle

								star arrow
Lamar bridge abuttment	110 sq ft	April to June	28 08 19.65N	96 58 39.95W	28°08’ 06.05"N	97°00’ 28.71"W	6250 sq ft	Rows
Keller	110 sq ft	April to June	28 27 45.63N	96 24 57.50W	28°38' 11.85"N	96°27' 13.44"W	6250 sq ft	rows
Palacios	110 sq ft	April to JUne	28 41 39.51N	96 13 55.44W	28°41’ 41.67"N	96°13’ 59.78"W	6250 sq ft	rows
Oyster	110 sq ft	April to June	28 36 52.54N	96 12 43.21W	28°36‘ 42.15"N	96°12’ 54.24”W	6250 sq ft	rows
Hog	110 sq ft	April to June	28 42 03.09N	95 55 28.56W	28°39’ 06.57"N	96°52' 36.08"W	6250 sq ft	Rows
Total from donor sties	**1020 sq ft**	**Or 0.0239 acre**						
Total to 8 Recipient sites	1020 sq ft.	Or 0.0239 acre						

Application for Permit to Introduce Fish, Shellfish or Aquatic Plants into Public Waters

(No Fee Required)

For assistance completing this form, please call 512-389-4742 or email IFpermits@tpwd.texas.gov.

NOTE: This application will not be considered unless fully completed and must be received by the Department at least 30 days before the proposed introduction. Consultation with local or regional fisheries biologists before application submission is required for aquatic resource relocations and recommended for all applicants. If you have not yet consulted the local biologist, please call or email the permits office for their contact information.

1. **APPLICANT INFORMATION:**
Effective September 1, 2015, Texas Parks & Wildlife is required to collect Social Security numbers for the purpose of child support enforcement under the Texas Family Code, Section 231.302 and Federal Statute 42 U.S.C. §666. Missing or incomplete information may delay application processing time.

Name: Matagorda Bay Foundation, A.Thorhaug, Ph.d Social Security #: ______

Address: 1359 SW 22 Terrace, Miami, Fl 33145
Street City State Zip

Email: bbalboa@ matbay.org Primary Phone: (305) 490 - 0074

Would you like to help us reduce paper by choosing to receive your permit by email? ▣ Yes ☐ No

2. **PUBLIC WATER WHERE ORGANISMS WILL BE INTRODUCED** (address or GPS coordinates):
Matagorda Bay (6 sites list appended), San Antonio Bay (1 site);Aransas Bay (1 site)

3. **EXPECTED DATE OF INTRODUCTION:** 05 / ____ / 2025 (MM / DD / YYYY)
For relocations or plantings—what is the expected end date of the activity? 11 / ____ / 2025

4. **WHAT IS THE PURPOSE OF THIS INTRODUCTION?**

☐ Fish Stocking ☐ Planting ☐ Aquatic Resource Relocation ▣ Research

☐ Other – Please Describe: investigating factors of successfulseagrass restoration Mat. Bay

5. **SPECIES TO BE INTRODUCED** (for aquatic resource relocations, please skip this question):

Common Name	Scientific Name	Number	Size
1) Shoal grass	Halodule wrightii		
2) star grass	Halophila engelmanii (part of above Hw)		
3)			
4)			

5. SPECIES TO BE INTRODUCED (continued):

Common Name	Scientific Name	Number	Size
5)			
6)			
7)			
8)			

6. SOURCE OF ORGANISMS: appended areas in DONOR AREAS

7. COMMENTS: Need to have documentation of portential of this permit prior to 3/15/2024 for final Phase I report to TGLO , NOAA. There needs to be a potential decision this will be permitted.

8. AFFIDAVIT:

I certify that
(1) all the information provided above is accurate and complete and
(2) that I have received and read the rules pertaining to Introduction of Fish, Shellfish, or Aquatic Plants (31 TAC Ch. 57C: http://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=5&ti=31&pt=2&ch=57&sch=C&rl=Y).

I understand that under Texas Penal Code §37.10, it is a felony to make a false statement on this form.

Anitra Thorhaug
Signature of Applicant

1 / 5 / 2024
Date

Please return completed application to:
Permit Coordinator, Inland Fisheries
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744

To help our office process your request more efficiently, you may email completed applications to IFpermits@tpwd.texas.gov or fax to: 512-389-4405

Texas Parks and Wildlife Department maintains the information collected through this form. With few exceptions, you are entitled to be informed about the information we collect. Under Sections 552.021 and 552.023 of the Texas Government Code, you are also entitled to receive and review the information. Under Section 559.004, you are also entitled to have this information corrected.

VI. Table of Texas CCAC agencies interested in various aspects of Seagrass Restoration Pilot sites in Matagorda Bay. Background on Coastal Coordination Advisory Committee interest in CMP 23-020-013-D607

The needs of Texas Coastal committee within the Matagorda Bay pilot Seagrass investigation

Organization	Lead Member	Responsbile Party CCAC	Goals	Shoreline Stability/Resilience	Habitat for Fisheries Nurseries	Endangered Species	Mineral Recycling	Water Clarity	Food Web	Seagrass Restorarion Plan	Seagrass Restorarion Info	Best Practices	Need for Video about Seagrass	Need for Inhouse Info	Need for their Public	Need Training Consultants
TGLO				x	x	x	x	x	x	x	x	x	x	x	x	
TPWF	Robin Reichers	Robin, Evan		x	xx	xx	x	x	xx	x	x	xx	xx	x	x	
Seagrant	Pam Plotkin	Pam Plotkin, Natalie Wilderman		x	x	xxx	x	x	x	xx	xx	xx	xx	x	x	
TDOT	Doug Booher			xxx	x	x	x	x	x	x	x	x	xx	x	xx	xxx
TCWQ	Steven Schar	Steven, Margaret		x	x	x	x	xxx	x	x	x	x	xx	x	x	
Watershed Soil/H2O Conservatio	Brian Koch	Margaret		x	x	x	x	xx	x	x	x	x				
Agriculture Dept.	Rob Ziehr	Bob		x	x											
Railroad Commission	Leslie Savage			x	x	x	x	x		x			x			
Surface H2O Resources																
Local Citizen Repr.	--	--														

VII. Links to seagrass videos for Coastal Coordinating Advisory Committee (CCAC) members to use for public outreach

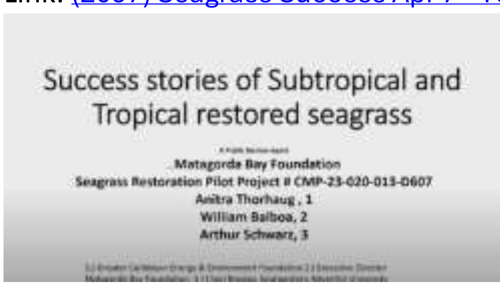
- **Public Outreach video about services of seagrass to the Texas public.**
- **Public Outreach video about success of Seagrass Restoration in Texas and elsewhere in subtropics and tropics.**
- **Public Outreach and to consultants to Texas government on "Restoration of Seagrass in Texas"**

Links to seagrass videos

Links to seagrass videos for Coastal Coordinating Advisory Committee (CCAC) members to use for public outreach (to be used by the websites of each agency needing outreach of seagrass to their publics). One of the videos to be used for consultant firms of CCAC members when they are required by permits to restore seagrass.

I. Public Outreach Video about services of seagrass to the Texas public.
"What Texans like about seagrass in their coastal bays"
Link: [video1320155073 (youtube.com)]

II. Public Outreach video about success of Seagrass Restoration in Texas and elsewhere in subtropics and tropics.
"Success stories of subtropical and tropical restored seagrass"
Link: [(2097) Seagrass Success Apr 7 - YouTube]



III. Public Outreach and to consultants to Texas government on "Restoration of Seagrass in Texas"
"Process of seagrass restoration for Texas"
Link: [(2097) Restoration April7 - YouTube]