U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Coastal Texas
Protection and Restoration Study

Final Reconnaissance 905(b) Report

May 2015

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FIGURES

TABLES

Acronyms

ADCIRC - Advanced Circulation
BCR – benefit-to-cost ratio
CBBEP - Coastal Bend and Bays Estuary Program
CBRA - Coastal Barrier Resources Act
CSRM - Coastal Storm Risk Management
EFH - Essential Fish Habitat
ER - Ecosystem Restoration
EWN – Engineering With Nature
FCSA - Feasibility Cost Sharing Agreement
FEMA - Federal Emergency Management Agency
GIWW - Gulf Intracoastal Waterway
GLO – Texas General Land Office
H&H - Hydraulics and Hydrology
HFPS - Hurricane Flood Protection System
IPCC - Intergovernmental Panel on Climate Change
LOI- Letter of Intent
LNG - Liquid Natural Gas
MSA - Metropolitan Statistical Area
NNBF - natural and nature-based features
NOAA - National Oceanic and Atmospheric Administration
NRC – National Research Council
NRHP – National Register of Historic Places
NSI – National Structure Inventory
NWR – National Wildlife Refuge
PDT - Project Deliver Team
P.L. - Public Law
PMP - Project Management Plan
ppt – parts per thousand
RSLC – Relative Sea Level Change
RSLR – Relative Sea Level Rise
TPWD - Texas Parks and Wildlife Department
U.S. – United States
USACE - U.S. Army Corps of Engineers
USFWS - U.S. Fish and Wildlife Service
WMA - wildlife management areas
WRDA - Water Resources Development Act
WRRDA - Water Resources Reform and Development Act

Section 905(b) (WRDA 86) Analysis
Coastal Texas Protection and Restoration Study

1. STUDY AUTHORITY

The study is authorized under Section 4091, Water Resources Development Act (WRDA) of 2007 Public Law (P.L.) 110-114 which states:

> "Sec. 4091. Coastal Texas Ecosystem Protection and Restoration, Texas.
> (a) In General.—The Secretary shall develop a comprehensive plan to determine the feasibility of carrying out projects for flood damage reduction, hurricane and storm damage reduction, and ecosystem restoration in the coastal areas of the State of Texas.
> (b) Scope.—The comprehensive plan shall provide for the protection, conservation, and restoration of wetlands, barrier islands, shorelines, and related lands and features that protect critical resources, habitat, and infrastructure from the impacts of coastal storms, hurricanes, erosion, and subsidence.
> (c) Definition.—For purposes of this section, the term ''coastal areas in the State of Texas'' means the coastal areas of the State of Texas from the Sabine River on the east to the Rio Grande River on the west and includes tidal waters, barrier islands, marshes, coastal wetlands, rivers and streams, and adjacent areas."

2. STUDY PURPOSE

This report is a preliminary analysis to determine if there is a Federal (U.S. Army Corps of Engineers (USACE)) interest in pursuing a feasibility study related to coastal storm risk management (CSRM) and ecosystem restoration (ER) along the entire coast of Texas. Once CSRM or ER opportunities have been identified, USACE will work with local governments to determine which measures and/or projects warrant further study effort in the feasibility phase. For those potential projects, a Project Management Plan (PMP) will be developed to conduct further feasibility studies, and a Feasibility Cost Sharing Agreement (FCSA) will be coordinated with the identified non-Federal sponsors. This analysis is in accordance with the guidelines of Section 905(b) of the WRDA of 1986.

The feasibility study will identify critical data needs and recommend a comprehensive strategy for reducing coastal storm flood risk through structural and nonstructural measures that take advantage of natural features like barrier islands and storm surge storage in wetlands. Structural alternatives to be considered include improvements to existing systems (such as existing hurricane protection projects at Port Arthur, Texas City, and Freeport, and Lynchburg and seawalls at

Galveston, Palacios, Corpus Christi, North and South Padre Island), and the creation of new structural plans for hurricane storm damage reduction. ER alternatives to be considered include estuarine marsh restoration, beach and dune restoration, rookery island restoration, oyster reef restoration, and seagrass bed restoration.

3. RECOMMENDATION/FINDING OF FEDERAL INTEREST

Along the Texas coast, vital resources critical to the economic and environmental welfare of the nation are at risk from coastal storm damage. Forty percent of the nation's petrochemical industry, 25 percent of national petroleum-refining capacity, eight deep-draft ports, 750 miles of shallow-draft channels (including 400 miles of the Gulf Intracoastal Waterway (GIWW)), and critical transportation infrastructure will continue to be at risk without a comprehensive plan to protect, restore and maintain a robust coastal ecosystem and reduce the risk of storm damage to industries and businesses critical to the nation's economy and protect the health and safety of Texas coastal communities. The study area also includes critical coastal ecosystems in need of restoration, including wetlands, seagrass beds, sea turtle nesting habitat, piping plover critical habitat, and whooping crane critical habitat, as well as numerous state and Federal wildlife refuges.

This study has identified potential solutions which will provide CSRM and ER benefits, and supports initiation of a cost shared feasibility-level study effort. Because of the size of the study area and the reconnaissance phase constraints, the list of potential solutions does not represent a complete inventory of all opportunities and does not necessarily represent the most feasible and acceptable solutions. The feasibility phase will identify and screen a more complete array of alternatives.

As noted in Engineer Regulation 1105-2-100, CSRM and ER are two of the USACE high priority authorized missions. Additionally, these potential solutions could be developed in consistency with Army and budgetary polices. For coastal projects, the public ownership and use of the beach is a requirement since Federal funding is being used. Additionally, nearby adequate parking or public transportation and sufficient access points must be available for any beach area. Although no known issues with these requirements of beach ownership and public access currently exist for any alternative solution in this study, the feasibility phase will analyze the study area in depth to determine if there are any such issues in meeting these requirements. Therefore, there is Federal interest in continuation of this study into the feasibility phase.

4. STUDY AREA

4.1 General

The study area consists of the entire Texas Gulf Coast from the mouth of the Sabine River to the mouth of the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, rivers and streams and adjacent areas that make up the interrelated ecosystem along the coast of Texas. The study area encompasses 18 coastal counties along the Gulf Coast and bayfronts.

The Texas coastal zone contains several large cities at risk during storm events including the nation's fourth largest city (Houston). The coastal region is home to approximately 6.1 million people. Mineral production has a value of nearly $1 billion per year and commercial fisheries generate another $156 million. Agriculture in the less populated counties generates approximately $500 million of product per year. The value of goods exported from Texas ports in 2011 was $251 million, more than that from all other states.

The Port of Houston alone generated a statewide economic impact of $178 billion with its 25-mile-long complex of public and private facilities. The Port handled 162.4 million in foreign tonnage in 2012 and its petrochemical complex has a total daily operable refining capacity of 351,776 barrels, one of the largest in the world. The Houston Ship Channel, the 52-mile waterway under the purview of the Port of Houston Authority, is in need of significant infrastructure investment especially in the face of the latest oil and gas boom. Congestion is a constant problem for the existing century-old infrastructure. Concerns about its ability to accommodate $35 billion in new projects and expansion only highlight the economic importance of the Port of Houston and the ship channel to the area.

The Texas coast includes six barrier islands: Galveston, Follets, Matagorda, St. Joseph, Mustang, and Padre Islands. Additionally there are two barrier peninsulas, Bolivar and Matagorda. These islands and peninsulas provide the first line of defense from storm damage.

The study area has been divided into four regions loosely based on major bay systems and habitats as described in Table 4-1. These four regions mirror the regions identified in the Texas General Land Office (GLO) "The Texas Coast: Shoring up Our Future" report. An overview of the four regions is shown in Figure 4-1 with individual region maps included in Figure 4-2 through Figure 4-5.

Table 4-1 - Coastal Texas Regions for Study

Region #	Region Name	Description	Counties
1	Sabine Pass to Galveston Bay	Mouth of Sabine River at the Texas-Louisiana border to west side of Galveston Bay	Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria
2	Matagorda Bay	Entire Matagorda Bay system from the Brazoria-Matagorda County line to eastern edge of San Antonio Bay	Matagorda, Jackson, Victoria, and Calhoun
3	Corpus Christi Bay	San Antonio Bay to Baffin Bay	Aransas, Refugio, San Patricio, Nueces, and Kleberg
4	Padre Island	Southern edge of Baffin Bay to the Texas-Mexico border	Kenedy, Willacy, and Cameron

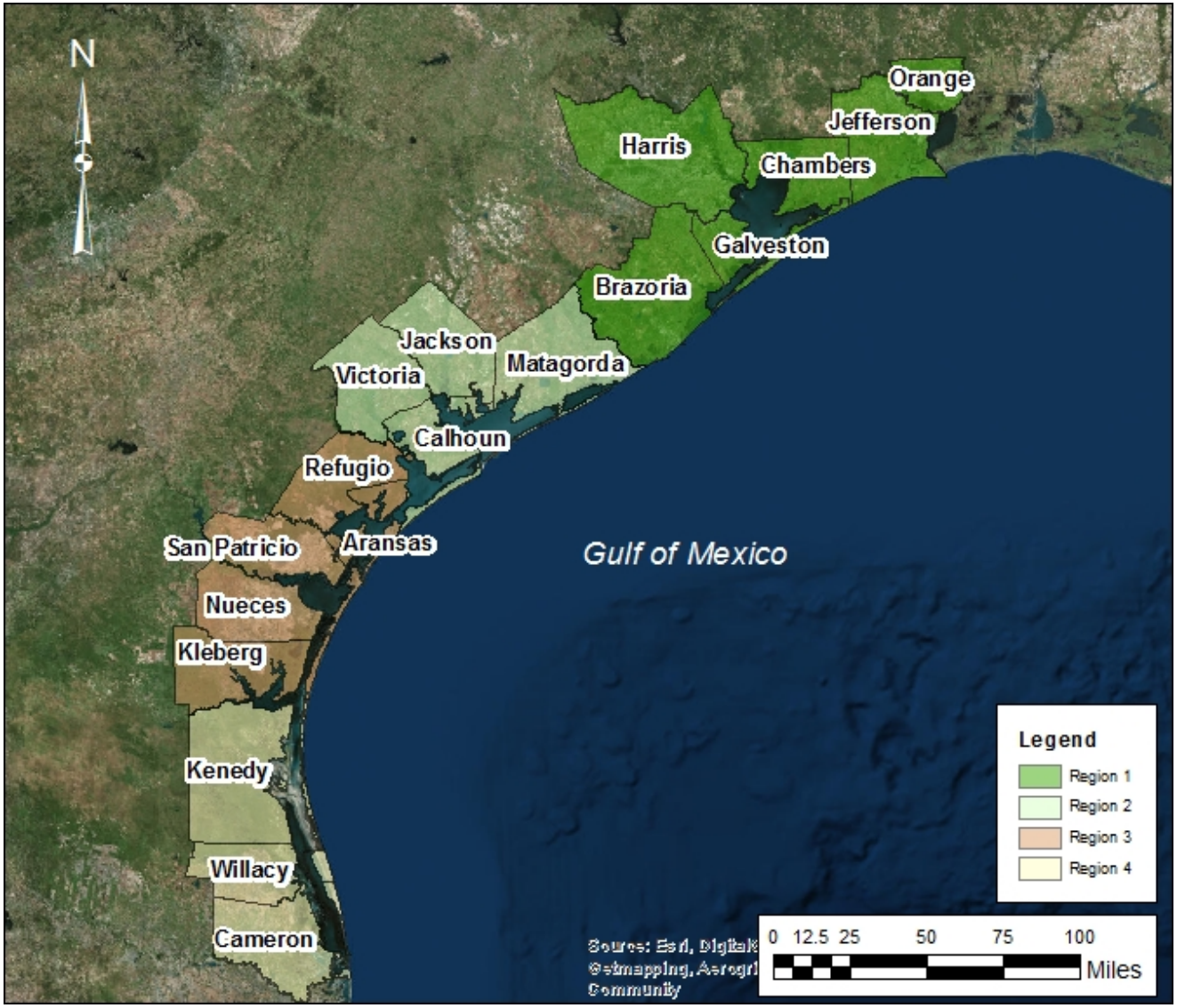

Figure 4-1 – Study Area Map

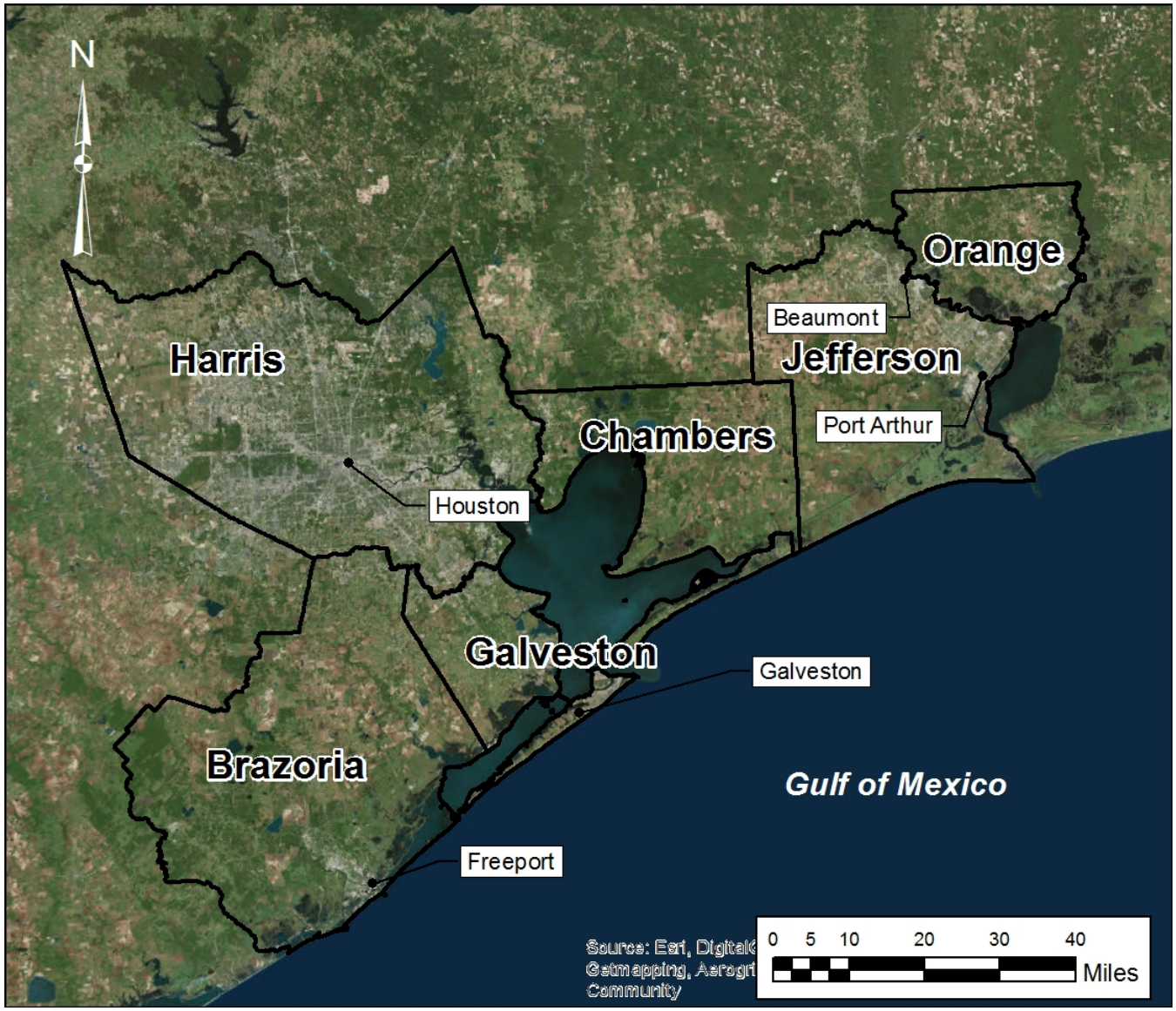

Figure 4-2 – Region 1 Area Map

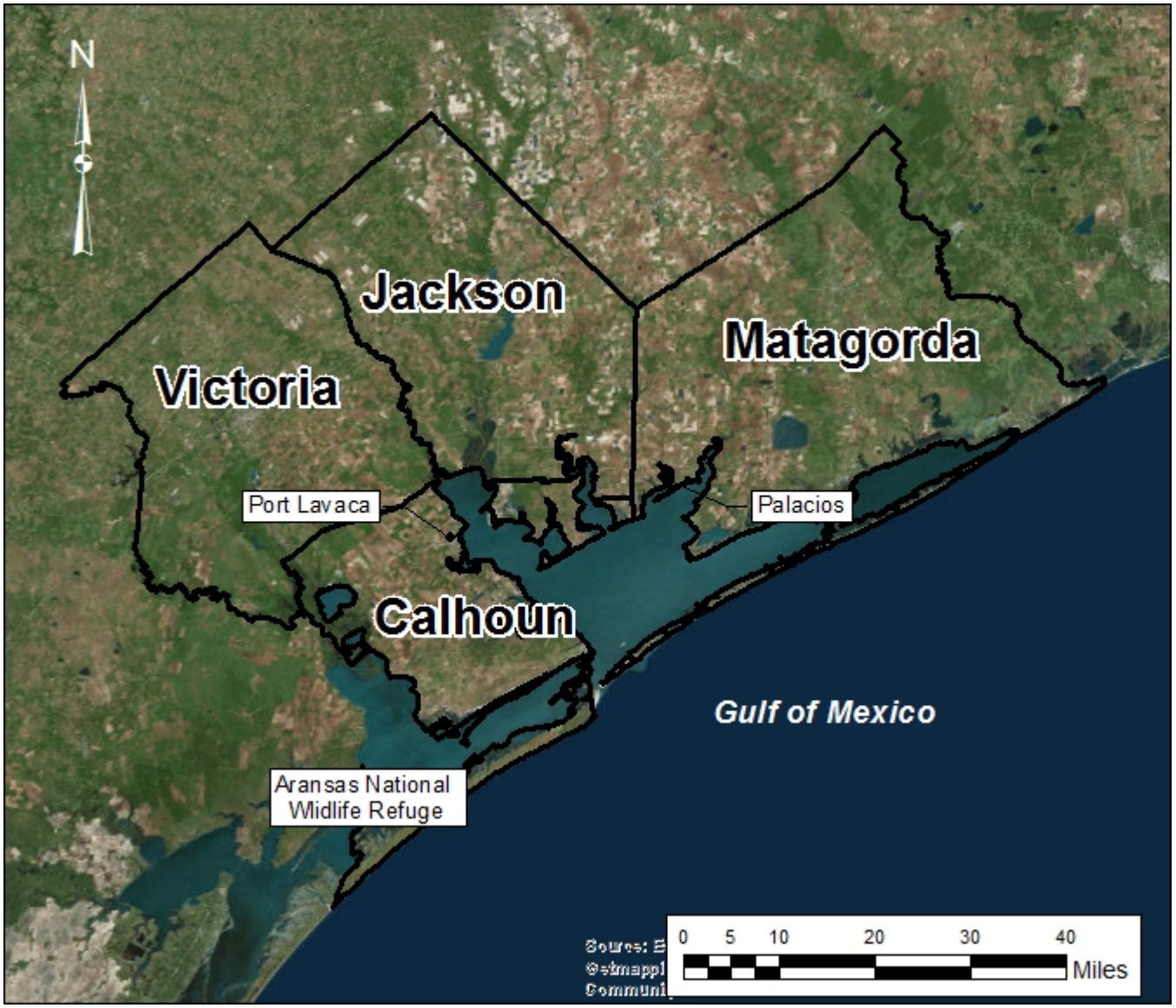

Figure 4-3 – Region 2 Area Map

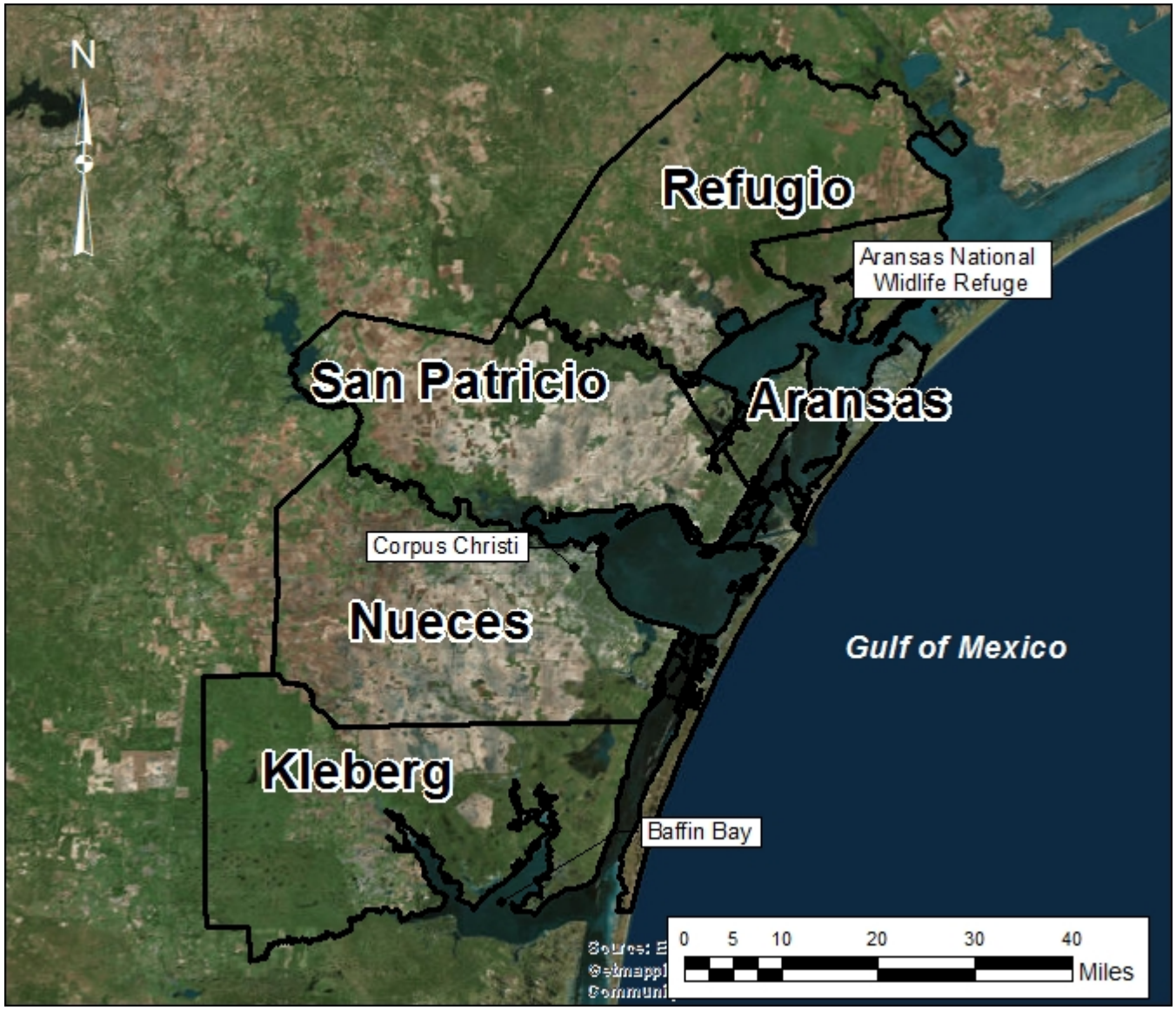

Figure 4-4 – Region 3 Area Map

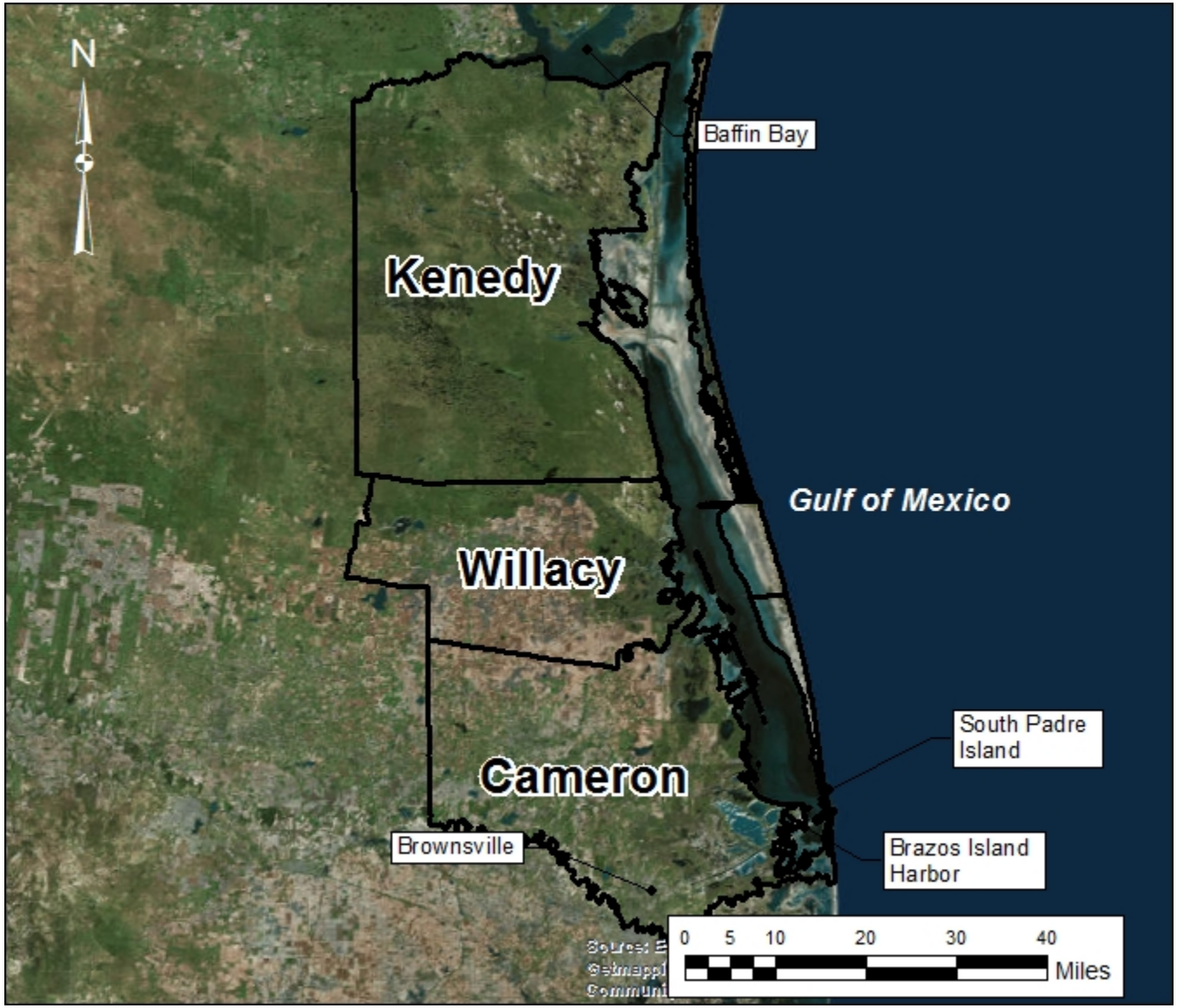

Figure 4-5 – Region 4 Area Map

4.2 Population

More than 6 million people, or approximately 24 percent of the population of Texas, now live in the 18 coastal counties. Although more than 70 percent of this population resides in or near Houston, all areas of the coast and most individual counties are experiencing population increases. The 2000 and 2010 census information are reflected in the county population data presented in Table 4-2 along with the percent change in population between this census dates.

Table 4-2 – Study Area Population

County	2000 Census	2010 Census	% Change
REGION 1			
Orange	84,966	81,837	-3.7%
Jefferson	252,051	252,273	0.1%
Chambers	26,031	35,096	34.8%
Harris	3,400,578	4,092,459	20.3%
Galveston	250,158	291,309	16.5%
Brazoria	241,767	313,166	29.5%
REGION 1 subtotal	**4,255,551**	**5,066,140**	**19.0%**
REGION 2			
Matagorda	37,957	36,702	-3.3%
Jackson	14,391	14,075	-2.2%
Victoria	84,088	86,793	3.2%
Calhoun	20,647	21,381	3.6%
REGION 2 subtotal	**157,083**	**158,951**	**1.2%**
REGION 3			
Aransas	22,497	23,158	2.9%
Refugio	7,828	7,383	-5.7%
San Patricio	67,138	64,804	-3.5%
Nueces	313,645	340,223	8.5%
Kleberg	31,549	32,061	1.6%
REGION 3 subtotal	**442,657**	**467,629**	**5.6%**
REGION 4			
Kenedy	414	416	0.5%
Willacy	20,082	22,134	10.2%
Cameron	335,227	406,220	21.2%
REGION 4 subtotal	**355,723**	**428,770**	**20.5%**
TOTAL	**5,211,014**	**6,121,490**	**17.5%**

4.3 Coastal Storms

The entire Texas coast can experience tropical cyclones in the summer and fall of each year. These storm events range from tropical depressions and storms, which result in large amounts of rain and localized flooding, to major hurricane systems with damaging winds and elevated storm surge. Along the entire Texas coast, 122 tropical storms and hurricanes have made landfall since 1851. Figure 4-6 shows the various storm paths since 1851 along the Texas coast.

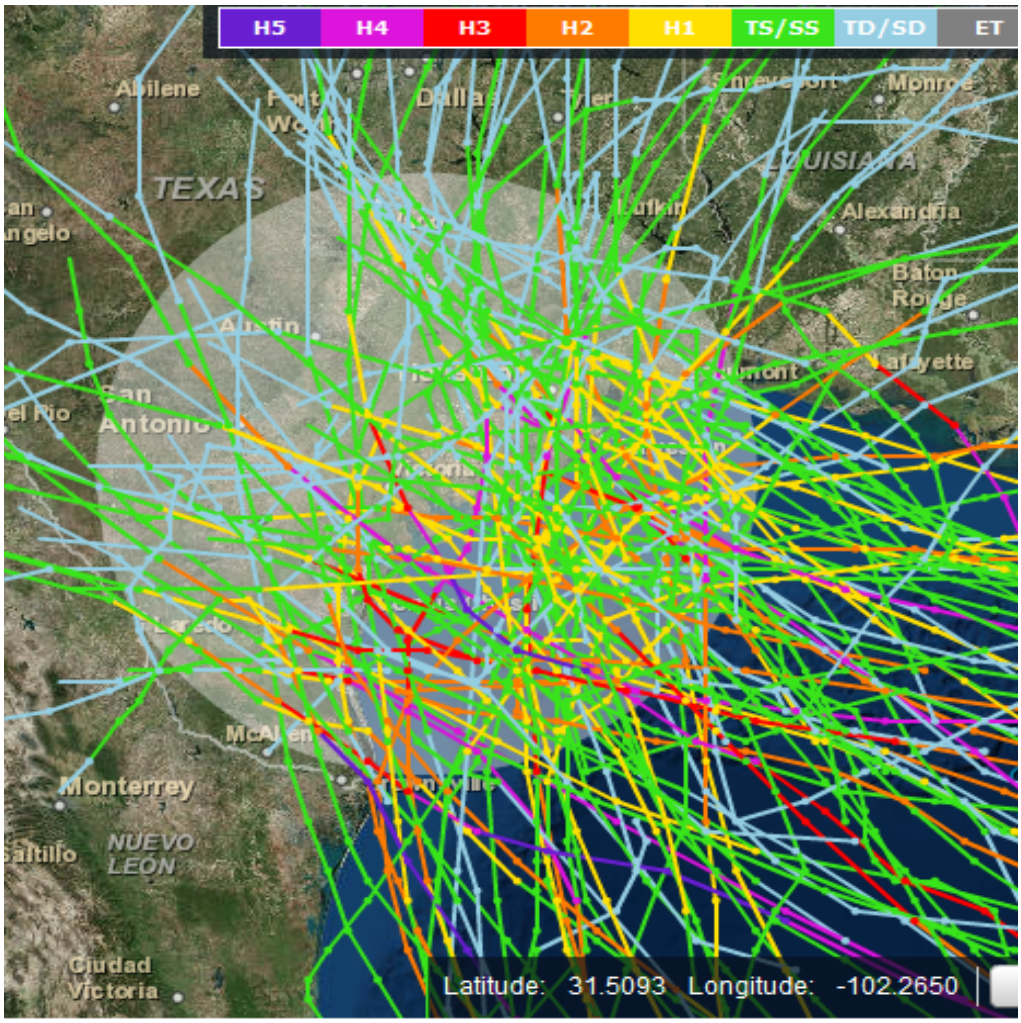

Figure 4-6 – Tropical Storm Paths since 1851

The top tropical cyclones which have impacted the Texas coast in terms of damages are listed in Table 4-3. The estimate damages included in this table are in the dollar values at the time of the storm. The Galveston 1900 Storm is included because it is considered the United States (U.S.) worst natural disaster of all time with an estimated loss of life between 8,000 and 12,000.

Table 4-3 – Top Tropical Storms by Damages Impacting Texas

Storm	Date	Landfall	Cost of Damages
Hurricane Ike	9/13/08	Galveston	$29.5 billion
Tropical Storm Allison	6/5/01	Freeport	$5 billion
Hurricane Alicia	8/18/83	Galveston	$1.8 billion
Hurricane Dolly	7/23/08	South Padre Island	$1 billion
Tropical Storm Allison	6/26/89	Freeport	$500 million
Tropical Storm Frances	9/13/98	Corpus Christi	$500 million
Hurricane Celia	8/3/70	Corpus Christi	$400 million
Tropical Storm Claudette	7/24/79	Texas-Louisiana border	$400 million
Hurricane Carla	9/11/61	Port Lavaca	$400 million
Hurricane Allen	8/9/80	Port Mansfield	$300 million
Galveston 1900 Hurricane	9/8/00	Galveston	$20 million

The total population growth along the Texas coast between 2000 and 2010 was faster than the national average growth of 9.7 percent. (The specific population growth along the Texas coast by county was previously shown in Table 4-2.) Table 4-4 shows the return period for major hurricanes along areas of the Texas coast. The Texas coast return periods for major hurricanes varies from 25 years for the Galveston Bay area to 40 years for the Refugio and Aransas Counties. The upper Texas coast is experiencing some of the greatest population growth in the study area and is the same area where major hurricanes are most frequent.

Table 4-4 – Major Storm Return Periods for Texas Coast

Region	Return Period (years)
Sabine	26
Galveston	25
Aransas	40
Corpus Christi	33
Laguna Madre	36
South Padre	30

Additionally, the majority of the Texas coast has a higher probability of experiencing major hurricane events (greater than Category 2 storms) than the lower Texas coast, or the Gulf Coast of Florida as shown in Figure 4-7.

4.4 Economy of the Study Area

The Texas coast is vital to the economy of the nation. Texas is the nation's top state for waterborne commerce with more that 500 million tons of cargo passing through Texas ports annually. Additionally, Texas is a world leader in the production of oil and petroleum products. The Texas refineries represent 25 percent of the nation's refining capacity. The shutdown of just

one Texas port can greatly impact the state and national economies. The impact of coastal storms on this vital infrastructure would be felt nationwide.

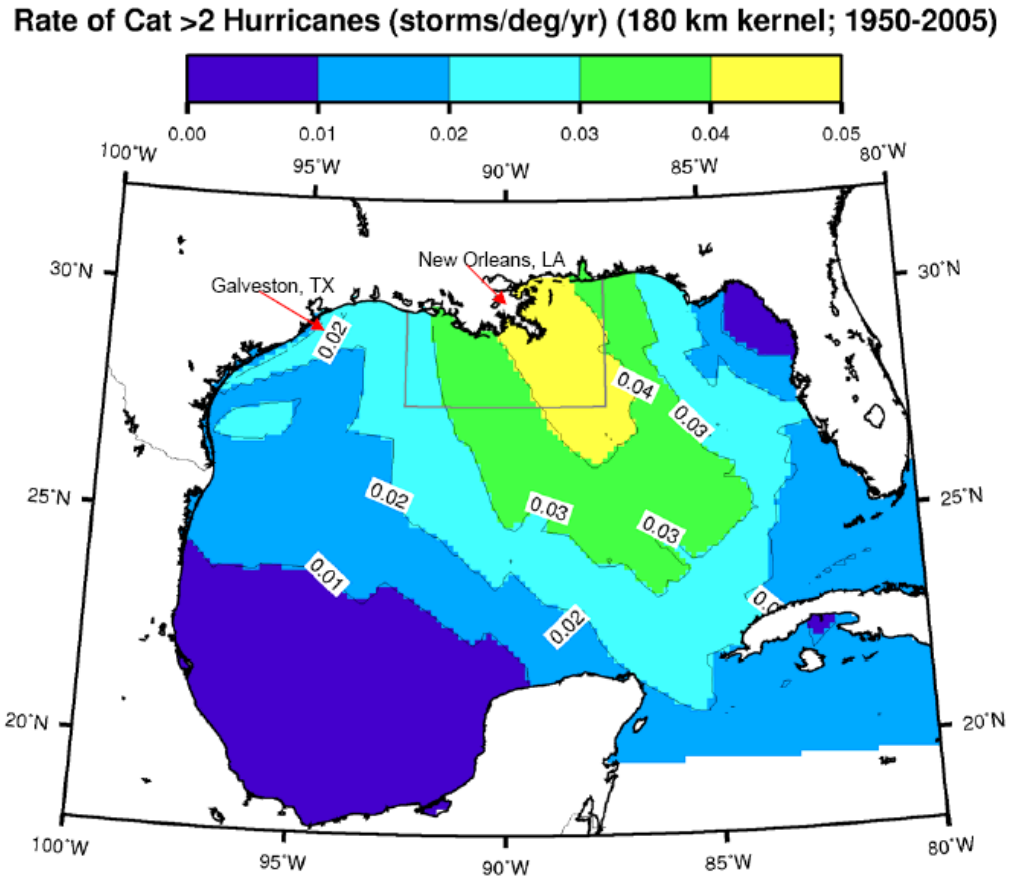

Figure 4-7 – Storm Probability in the Gulf of Mexico

4.4.1 Region 1

The Port of Houston is the second busiest in the U.S. in terms of overall tonnage (238.2 million in 2012) and handles about 70 percent of all the containerized cargo in the U.S. Gulf of Mexico. It is the busiest port in the U.S. in terms of foreign tonnage handling 162.4 million in 2012. The Port of Houston Authority operates major terminals along the Houston Ship Channel along with more than 150 companies situated along Buffalo Bayou and Galveston Bay. The port's petrochemical complex is one of the largest in the world. Total operable refining capacity for the area is 351,776 barrels per calendar day.

The Port of Beaumont, located near the mouth of the Neches River, is the fifth largest in terms of overall tonnage (78.5 million in 2012) and is the busiest military port in the U.S and second in the world. It is the headquarters of the U.S. Army's 842nd Transportation Battalion, which

specializes in port logistical activity. The area also has a total operable refining capacity of 344,600 barrels per calendar day.

The Port of Texas City is the fourth busiest port in Texas and the eleventh busiest in the U.S. handling 56.7 million in tonnage in 2012. The port also services the largest petrochemical complex in U.S. and has a total operable refining capacity of 309,000 barrels per calendar day.

The Port of Port Arthur is the fifth busiest port in Texas and the 23rd busiest in the U.S. with 30.6 million tons of cargo in 2012. Most notable is the port's total operable refining capacity of 1,115,750 barrels per calendar day, by far the largest in the nation.

Freeport is the site of the Dow Chemical Company's Texas Operations facility, which is the company's largest integrated site. The Port of Freeport handled 22 million in tonnage ranking it the 31st busiest port in the U.S. and the sixth busiest in Texas. Additionally, a $4 billion Liquid Natural Gas (LNG) project will create a world-class bi-directional import/export LNG terminal retrofitting a current facility to liquefy gas for export.

The Port of Galveston is the seventh busiest in Texas and the 47th busiest in the U.S. In addition to cargo, the port is home to the fifth largest cruise terminal in the nation. It is the year-round homeport to two Carnival Cruise Line vessels, the winter home for a Royal Caribbean vessel and also serves as a departure point for Disney and Princess Cruise Lines.

The GIWW is the portion of the Intracoastal Waterway located along the Gulf Coast of the U.S. and is the third busiest inland waterway in the U.S. It is a navigable inland waterway running 1,100 miles from Carrabelle, Florida, to Brownsville, Texas, connecting all of the ports along the Texas coast and entire Gulf Coast. The Texas portion of the GIWW, 423 miles long, was responsible for 73 million in tonnage in 2010 and handled 63 percent of its traffic. Ninety-one percent of the tonnage transported is classified as petroleum and chemical-related products. The ports in Region 1 have a combined refining capacity of approximately 2.57 million barrels per calendar day.

4.4.2 Region 2

The Ports of Port Lavaca and Point Comfort combined make up the 48th busiest in the U.S and the eighth busiest in Texas with 11.6 million tons of cargo and generate nearly $2 billion in annual business revenues. Victoria is the tenth busiest port in Texas and 78th in the U.S. along with being the second shallow-draft port for domestic crude petroleum. As discussed above in Region 1, the GIWW connects the ports within this region with the other ports along the Gulf Coast.

4.4.3 Region 3

The Port of Corpus Christi is the seventh busiest port in the U.S. and third busiest in Texas in terms of total tonnage with 69 million tons in 2012. The port has been dubbed "America's Wind Power Port" due to the staging capabilities of the port that have attracted a steady stream of turbine importers. The area also has a total operable refining capacity of 656,000 barrels per calendar day. As discussed above in Region 1, the GIWW connects the Port of Corpus Christi within this region with the other ports throughout Texas and the Gulf Coast.

4.4.4 Region 4

The Port of Brownsville has become the largest ship-breaking and salvage capital of the U.S. Recent contracts include the dismantling of three aircraft carriers, all three designated as "supercarriers" (the USS Constellation, the USS Forrestal, and the USS Saratoga). Five of the nation's eight ship-recycling companies are located in Brownsville. As discussed in Region 1, the GIWW connects the Port of Brownsville within this region with the other ports throughout Texas and the Gulf Coast.

4.5 Environmental Resources

The study area lies within the Gulf Prairie and Marsh ecological region, which extends along the Texas Gulf Coast from the Sabine River south to the Rio Grande (Gould et al. 1960). The prominent features of this coastal ecosystem include tidal, micro-tidal and freshwater coastal marshes; bays and lagoons which support extensive seagrass beds, tidal flats and reef complexes; barrier islands; tallgrass prairie with small digressional wetlands, and forest riparian corridors, oak mottes and coastal woodlots, and dense brush habitats. Wetland habitats provide important wintering and migration stopover habitat for migratory birds including Central and Mississippi Flyways' waterfowl, shorebirds, wading birds and marsh and waterbirds. A string of refuges and wildlife management areas (WMAs) along the coast serve as critical staging areas for waterfowl migrating to and from Mexico (Texas Parks and Wildlife Department [TPWD], 2013; U.S. Fish and Wildlife Service [USFWS], 2013).

4.5.1 Region 1

Region 1 contains the Galveston Bay area, recognized as nationally significant by Federal designation of the Galveston Bay National Estuary Program. The broad range of salinities and flat topography allows the region to support a wide spectrum of habitats, including tidal and freshwater coastal marshes; shallow bay waters which support seagrass meadows, tidal flats and reef complexes; coastal prairie with small wetland depressions; and forested riparian corridors. Extensive estuarine wetland complexes occur in the lower Sabine, Neches, Trinity, San Jacinto,

and Brazos River watersheds. Seagrass beds are present along the shallow shoreline of Upper and West Galveston Bays. Seagrass restoration efforts in recent years have resulted in a slow return of this resource to bays. Extensive oyster reef habitat occurs in the southern part of Sabine Lake and throughout the Galveston Bay complex. Areas of the Big Thicket are spread across inland areas of Region 1. Dense tree canopies, diverse habitats and varied vegetation provide ideal habitat for bald eagles, shorebirds, raptors, migrant and resident songbirds and waterfowl. Since roughly 75 percent of the bird species in North America either live in or pass through this area seasonally, the Big Thicket was designated a Globally Important Bird Area by the American Bird Conservancy in 2001 (Houston Wilderness, 2014). A barrier peninsula (Bolivar) and island (Galveston) separate Galveston Bay from the Gulf of Mexico, while the remainder of the coast in Region 1 is bounded by barrier headlands.

4.5.2 Regions 2 and 3

The central section of the Texas coast (Regions 2 and 3) is dominated by a series of bay systems and barrier islands. The discussion for these regions has been combined because the geography and significant resources are very similar. The bays in this region, from north to south, include Matagorda, San Antonio, Aransas, Copano, Corpus Christi, Nueces and Baffin Bays. All of these bay systems are protected from the Gulf by the extensive barrier systems of Matagorda and Mustang Islands. The primary exchange with the Gulf for all of these systems is through Pass Cavallo at the northern end, and through Aransas Pass near Corpus Christi Bay.

Matagorda Bay is a large estuary in Calhoun and Matagorda Counties. The Mad Island-Oyster Lake conservation area on the eastern shore contains Tamaulipan thornscrub habitat for over 300 species of songbirds, shorebirds and waterfowl. In the mid-1930s, Eastern Matagorda Bay was isolated from the rest of this system by the rapid growth of the modern delta of the Colorado River. The Colorado River was diverted into the eastern arm of Matagorda Bay in 1991 by USACE. Since the diversion, a functional deltaic marsh has developed in East Matagorda Bay at the end of the diversion cut that now forms the mouth of the river, creating habitat for many estuarine species. Widespread oyster beds once present in Matagorda Bay are now being replenished by oyster reef restoration projects. Five species of seagrasses are common within the shallow waters of the numerous bay systems.

The San Antonio, Aransas, and Copano Bays estuarine and wetlands complex provide habitat for the last wild flock of the endangered Whooping Crane (*Grus americana*) (Coastal Bend and Bays Estuary Program [CBBEP] 2014). The sustainability of wetlands within these systems is threatened by diminished freshwater inflows and hydraulic modifications, which have affected habitat quality within the historic wintering grounds for this iconic bird species. Designated Whooping Crane critical habitat, covering about 328 square miles, is located in this area.

A twelve county region extending along the coast from Aransas County to Kenedy County has been recognized as nationally significant by Federal designation of the CBBEP. Corpus Christi Bay and its smaller inland embayment, Nueces Bay, mark the center of this area and the beginning of a transition to the hotter and more arid South Texas coast. Located adjacent to the city of Corpus Christi, the bays support major estuarine and palustrine habitats including salt, brackish and fresh marsh, tidal flats, seagrass beds and mangroves. It is a shallow, well-mixed, wind driven bay system located in a semi-arid zone. Salinity may vary from nearly fresh during heavy flood events to hypersaline (> 45 parts per thousand (ppt)) during prolonged periods of low inflow. Of all Texas bays, the Nueces Bay/Delta region is the most affected by freshwater availability and has experienced substantial alteration in freshwater inflow. The State of Texas has concluded that the Nueces Bay and Delta region are in "an unsound ecological environment" due to substantial alterations in freshwater reaching the bay and delta (Nueces River and Corpus Christi and Baffin Bays and Bay Expert Science Team, 2011). The evidence for the loss of ecological soundness is the increased presence of smooth cordgrass, and the declining numbers of indicator species such as the Eastern oyster, the blue crab, and the Atlantic croaker.

Baffin Bay forms the boundary between Region 3 and 4. The land around the bay is flat and dominated by grasslands and oak savannah used primarily for agriculture and cattle ranching. Because of scarce freshwater inflow and extensive evaporation, the shallow bay has relatively high salinities. Seagrass occurs on shallow bottoms near the mouth of the bay. Unique rock formations created by relict serpulid worm reefs occur near the mouth of the bay and in the adjacent Laguna Madre. The reef and seagrasses combine to make this a popular destination for recreational fishing and famous for trophy spotted seatrout.

4.5.3 Region 4

Region 4, in the south Texas coastal zone, is dominated by the Laguna Madre - one of five hypersaline lagoons in the world. Salinity in the Lower Laguna Madre generally ranges from 31 to 37 ppt, with an average annual salinity of 33 ppt. However, salinity can vary widely depending on rainfall and freshwater inflow, ranging from extremes of as low as 2 ppt after major storms to as high as 120 ppt during extreme drought. This is higher than salinity in the western Gulf of Mexico, which ranges from 28 to 32 ppt. The Laguna is shallow, averaging approximately 4.6 feet deep, and, including the South Bay and the Bahia Grande complex, contains approximately 180,000 acres of this rare aquatic habitat. The main outlet into the Gulf of Mexico for the southern reach of the Lower Laguna Madre is Brazos Santiago Pass, through which passes the deep-draft Brazos Island Harbor (BIH) navigation channel.

Coastal, subtropical, desert, temperate, and tropical biomes converge in Cameron County, near the Rio Grande River. Thornscrub forest and brush habitat occur on upland sites like fluvial riparian zones of resacas and the Rio Grande River, and on lomas throughout the study area.

Resacas are relict oxbow lakes of the Rio Grande that provide scarce aquatic habitat in this region. Lomas are brush-covered clay dunes situated within tidal and wind-tidal flats with abrupt topographic relief reaching 30 feet above surrounding flats. Impenetrable brush with a relatively closed canopy serves as travel corridors for the federally-listed ocelot (*Leopardus pardalis*) and jaguarundi (*Herpailurus yaguarondi*). Mesquite savannahs provide good hunting areas for northern aplomado falcon, another federally-listed species.

Abundant tidal flats in this region provide important habitat for a variety of coastal wildlife from migratory waterfowl, shorebirds (like the federally-listed piping plover), wading birds, and other estuarine-dependent species like shrimp and various finfish (White et al., 1986). These flats are usually barren except for large areas colonized by blue-green algae mats called algal flats. The unique processes that result in algal flat formations only exist in several locations worldwide, including the Persian Sea, Red Sea, and eastern Mediterranean Sea (Morton and Holmes, 2009).

4.5.4 Protected Lands in the Study Area

Table 4-5 presents the protected areas by region for the study area and includes the acreage and type of habitat for each refuge.

Table 4-5 – Protected Lands in Study Area

Refuge Name	Management	Acreage	County Location		Types of habitat
Region 1 – Sabine Pass to Galveston Bay					
McFaddin National Wildlife Refuge (NWR)	National (USFWS)	58,861	Jefferson, Chambers		freshwater and intermediate marsh, Gulf shoreline dune system
J.D. Murphree WMA	State (TPWD)	24,498	Jefferson		fresh, intermediate and brackish marsh on the Chenier plain, highly diverse coastal wetlands
Texas Point NWR	National (USFWS)	8,952	Jefferson		fresh to saline marshes and some wooded uplands and prairie ridges, Gulf shoreline, Chenier plain
Lower Neches River WMA	State (TPWD)	7,998	Orange	Nelda Stark Unit	Shallow open water from degradation of a former marsh system by saltwater intrusion and subsidence
				Old River Unit	mixture of intermediate marsh and open water
				Adams Bayou Unit	coastal stream and forested bottomland
Tony Houseman WMA	State (TPWD)	3,300+	Orange		cypress-tupelo swamp
Neches River Cypress Swamp Preserve	Wetlands Mitigation Replacement of Southeast Texas (private)	541	Jefferson		cypress-tupelo swamp, emergent marsh mitigation bank

Refuge Name	Management	Acreage	County Location		Types of habitat
Blue Elbow Swamp Mitigation Bank	State (TxDOT)	2,737	Orange		cypress-tupelo swamp
Anahuac NWR	National (USFWS)	34,400	Chambers		brackish and saline marshes, coastal prairie, and coastal woodlands, Gulf shoreline
Armand Bayou Nature Center and Preserve	State (GLO/TPWD)	2,800	Harris		brackish water bayou, riparian hardwood forest, remnant coastal prairie
Atkinson Island WMA	State (TPWD)	150	Harris, Chambers		40-acre woodlot and 90 acres of brackish marsh
Candy Abshier WMA	State (TPWD)	209	Chambers		coastal prairie habitat with important coastal woodlot or oak mottes
Moody NWR	National (USFWS) perpetual non-development conservation easement	3,517	Galveston		estuarine marsh and bay shoreline
North Deer Island Sanctuary	National Audubon Society, Houston Audubon Society, private	10+	Galveston		colonial waterbird nesting island

Refuge Name	Management	Acreage	County Location		Types of habitat
	individual				
Scenic Galveston (con/t) Preserve	SCENIC GALVESTON	900	Galveston	O'Quinn I-45 Estuarial Corridor	natural, undisturbed tidal marsh, restored marsh
	State (GLO)	1,500	Galveston	Virginia Point Peninsula Preserve	coastal prairie with interspersed freshwater sloughs and ponds
Brazoria NWR	National (USFWS)	44,414	Brazoria		saltwater, freshwater and brackish wetlands, prairies, woody thickets, salt and mud flats, lakes and streams
Christmas Bay Coastal Preserve	State (GLO/TPWD)	5,700	Brazoria		prairies, extensive fresh and saline marshes
Justin Hurst WMA	State (TPWD)	440	Brazoria	Bryan Beach Unit	coastal dunes, Gulf shoreline, bay shoreline
Nannie M. Stringfellow WMA	State (TPWD)	3,664	Brazoria		coastal bottomland hardwood forest
San Bernard NWR	National (USFWS)	57,698	Brazoria, Matagorda		salt and freshwater marshes, sloughs, ponds, coastal prairies, and bottomland forest
Trinity River NWR	National (USFWS)	25,000	Chambers, Liberty		cypress-tupelo swamp, bottomland hardwood forest, wet pastures, lakes, river
Region 2 – Matagorda Bay					
Mad Island WMA	State (TPWD)	7,281	Matagorda		fresh to brackish marsh land with sparse

Refuge Name	Management	Acreage	County Location		Types of habitat
					brush and flat coastal prairie
Big Boggy NWR	National (USFWS)	4,526	Matagorda		Freshwater and saltwater marsh and uplands
Aransas NWR	National (USFWS)	114,657	Calhoun		salt, brackish and freshwater marsh, tidal flats and Gulf beaches
Welder Flats WMA	State (GLO/TPWD)	1,480	Calhoun		Submerged coastal wetlands
Guadalupe Delta WMA	State (TPWD)	7,411	Calhoun, Victoria, Refugio	Mission Lake, Hynes Bay, Guadalupe, and San Antonio Bay River Units	complex of natural and manmade wetlands, including coastal and fresh marsh and riparian habitats
Region 3 – Corpus Christi Bay					
Aransas NWR/Matagorda Island WMA	National (USFWS)	59,000	Calhoun, Aransas, Refugio		salt marsh, tidal flats, Gulf shoreline
	State (TPWD)			Matagorda Island WMA within NWR	offshore barrier island and bayside marshes
Goose Island State Park	State (TPWD)	321	Aransas		estuarine marsh, oak mottes, tidal flats
Redhead Pond	State (TPWD)	37	Nueces		freshwater wetland

Refuge Name	Management	Acreage	County Location		Types of habitat
Mustang Island State Park	State (TPWD)	3,954	Nueces		Coastal barrier island, sand dune
Region 4 – Padre Island					
Padre Island National Seashore	National Parks Service		Kleberg, Kenedy, Willacy		Coastal prairie, dune system, tidal flats, hypersaline lagoon
Laguna Atascosa NWR	National (USFWS)	21,700	Cameron, Willacy	Bahia Grande Unit	Tidally affected lagoon system, wetlands
(con't)		24,532		South Padre Island Unit	sandy beaches, dunes, tidal mud flats, brackish marsh, freshwater ponds
Boca Chica State Park	State (TPWD)	1,055	Cameron		sandy beaches and dunes
Lower Rio Grande Valley NWR	National (USFWS)	90,788	Cameron		riparian woodlands, thorn forest, resacas and mesquite savannahs

4.6 Cultural Resources

Over 6,500 cultural resources have been documented within the four regions of the study area (Table 4-6). These resources include prehistoric and historic archeological sites, historic buildings and structures, historic and archeological districts, historic markers, and cemeteries. Properties listed on the National Register of Historic Places (NRHP) include 506 sites, of which 14 are National Historic Landmarks.

Table 4-6 – Cutural Resources in the Study Area

Region	Region Name	Sites	NRHP Properties	NRHP Districts	Historical Markers	Cemeteries
1	Sabine Pass to Galveston	2,097	311	34	768	418
2	Matagorda Bay	577	117	1	229	121
3	Corpus Christi Bay	950	17	4	182	79
4	Padre Island	390	16	6	107	94
	Totals	**4,014**	**461**	**45**	**1,286**	**712**

4.6.1 Region 1

Prehistoric sites in this region are commonly found along streams and rivers and along the shorelines of the bays and Gulf Coast. These sites include campsites, dense shell middens, and cemeteries. Historic-aged resources in the region consist of farmsteads and ranches, houses, buildings, bridges, tunnels, oil industry structures, cemeteries, lighthouses, shipwrecks, and the ruins of these buildings and structures. Although historic resources can occur anywhere, these sites tend to be concentrated in small towns and urban areas, along roads, and within current and historic navigation paths. Shipwrecks may also occur in numerous locales due to the dynamic nature of the sea floor and bay bottoms and the lack of navigation improvements until the latter part of the nineteenth century.

There are several National Historic Landmarks, including the San Jacinto Battlefield, the Battleship Texas, the Tall Ship Elissa and the Spindletop Oil Field, as well as National Historic Landmark Districts, such as the Galveston Strand Historic District and the Galveston East End Historic District. There are 345 National Register Properties and 418 cemeteries within the region. Many of these historic properties are located in urban areas and are primarily historic houses, commercial and government buildings, and structures represented by the Navy Park Historic District, Houston Heights, Galveston Central Business District, Durazno Plantation, Varner-Hogg Plantation, Fort Travis, Washburn Tunnel and others. Other National Register sites and districts located throughout the area include the Apollo Mission Control Center, the

Space Environment Simulation Laboratory, the Saturn V Launch Vehicle, the Point Bolivar and Sabine Pass Lighthouses, the Beaumont Commercial District, the Jefferson Historic District, the Port Arthur-Orange Bridge, the W. H. Stark House, the Old Wallisville Townsite, Fort Anahuac, and the Chambers and Jefferson County Courthouses. The majority of these cultural resources are vulnerable to damage or destruction from hurricane storm surge.

4.6.2 Region 2

Prehistoric and historic archeological sites in the region are similar in nature and location to sites in Region 1; however, prehistoric sites are primarily located adjacent to brackish estuarine systems. Shell midden sites are especially common in the region along the shorelines and upland areas adjacent to rivers and bays and on the barrier islands. Region 2 is more rural than Region 1 and while historic sites are generally located in small urban centers, farmsteads, ranches, and plantations they can occur across the region. Shipwrecks are also common in the region and are subject to the same formation processes as in Region 1.

There are 118 historic properties recorded within the region and one of these includes the South Bridge Street Historic District in Victoria, Texas. The vast majority of the historic properties are also within the city of Victoria including the City of Victoria Pumping Plant, the Old Brownson School, Trinity Lutheran Church, and others. Outside of Victoria, historic properties include the Matagorda Island Lighthouse in Port O'Connor, the Texana Presbyterian Church in Edna, and the Hotel Blessing in Blessing.

4.6.3 Region 3

Prehistoric sites in the region are concentrated on the shorelines of Copano, Corpus Christi, and Baffin Bays, as well as along the rivers and streams that drain into these bays. Numerous sites have also been identified on the barrier islands. Both prehistoric and historic archeological sites are similar to those in Regions 1 and 2, but like in Region 2, show an increase in the number of shell middens.

There are only 21 historic properties listed in the region with many of these located in Corpus Christi and Rockport. Some notable properties include the Ragland Mercantile Company Building, the Nueces and Refugio County Courthouses, the Tarpon Inn, Fulton Mansion, and the Henrietta King High School. Historic districts include the Aransas Pass Light Station, the Broadway Bluff Improvement, and the James McGloin Homestead. Two National Historic Landmarks include the USS Lexington in Corpus Christi and the King Ranch. The King Ranch is a National Historic Landmark District that covers over two-thirds of Kleberg County.

4.6.4 Region 4

Archeological sites in the region are located primarily along the shores of the Laguna Madre, and on the barrier islands. Archeological investigations in the region have not been sufficient to clearly identify regional chronology or settlement patterns. However, prehistoric sites can be expected within fluvial terraces along streams and rivers and in upland terraces along the shorelines of the bays. Furthermore, the widespread deposition of aeolian clays has established stable clay dunes or lomas, which have a high probability for archeological sites, but are also at high risk from erosion from wind and water.

There are 22 historic properties listed within the region. Almost all of these properties are located in Brownsville or along the Rio Grande including the Cameron County Courthouse, Southern Pacific Railroad Passenger Depot, the Charles Stillman House, the Immaculate Conception Church, and La Nueva Libertad. Outside of Brownsville, properties include the Point Isabel Lighthouse in Port Isabel, the Brazos Santiago Depot at Boca Chica, and the Old Lyford High School in Lyford. There are six historic districts in the region and five of these are National Historic Landmarks. These National Historic Landmarks include Fort Brown, Palo Alto Battlefield, Palmito Ranch Battlefield, and Resaca de la Palma Battlefield, which are associated with the Mexican War and the Civil War. The King Ranch National Historic Landmark is also located in the region and occupies a large portion of Kenedy and Willacy Counties.

5. SUMMARY OF APPLICABLE PRIOR STUDIES, REPORTS AND EXISTING WATER PROJECTS

5.1 Prior and Ongoing Studies and Reports

The following studies and reports were reviewed as part of feasibility study investigations. These reports provide information on previous Federal and local evaluation of CSRM problems in the study area.

5.1.1 Texas Coastal Hurricane Study

A study was completed in March 1979, which investigated the feasibility of reducing hurricane flood damages to reaches of the Texas coast. This study divided the Texas coast into five study segments, each generally centered around a major bay system. The study areas were Sabine Lake, Galveston Bay, Matagorda Bay, Corpus Christi Bay, and the Laguna Madre. Several comprehensive and localized structural plans were determined to be economically justified but did not have local sponsorship, resulting in a recommendation for no Federal action until sufficient local interest was demonstrated.

5.1.2 Sabine Pass to Galveston Bay Feasibility Study

In 2012 a study of the upper Texas Coast which was on hold at the request of the non-Federal sponsors (Jefferson and Galveston County) was re-scoped to include a six county area (Galveston, Harris, Brazoria, Jefferson, Chambers and Orange) in Southeast Texas. This region is home to more than five million people, three of the Nation's top ten deep-draft ports, and 40 percent of the Nation's petrochemical industry. The Texas General Land Office (TXGLO) worked with the Sponsors and the additional Counties and agreed to become the new non-Federal Sponsor of the study after the re-scoping effort. The current re-scoped study began investigating CSRM and ER alternatives along the coast within the revised six county study areas. The Feasibility Cost Sharing Agreement was executed on 10 January 2013. The Project Delivery Team (PDT) determined that the scope of the project requirements is beyond the 3x3x3 guidelines. In February 2014, the project received waiver to the 3x3x3 process and was granted authority to proceed with a focused evaluation of the Sabine and Brazoria Regions for CSRM with an outcome of a recommended plan for construction to Congress. It is also completing a programmatic assessment of the six-county study area and will recommend for future study the Galveston Region for CSRM and ER opportunities for all regions. The total cost of the project is $4,400,000. Currently the project is working towards the Tentatively Selected Plan meeting and the release of a draft report to the public in the fall of 2015. The Chief's Report is scheduled for completion in September 2016.

5.2 Existing CSRM Projects

The following projects are located within the study area and were included in the development of this reconnaissance study. The condition of these existing projects is currently being studied in the Sabine Pass to Galveston Bay feasibility study, including analysis of their function and potential improvements for resiliency.

5.2.1 Port Arthur Hurricane Flood Protection System (HFPS), Texas

The existing Port Arthur and Vicinity, Texas HFPS was authorized by Flood Control Act of 1962, P. L. 87-874. Construction began in March 1966 and completed in April 1982. The system protects the Port Arthur region from coastal storm surge events coming from the Gulf of Mexico. It also protects from flooding from the Sabine River. The levee system consists of 27.8 miles of earthen embankment and 6.6 miles of floodwall. This includes 3.5 miles of coastal cantilever I-wall. There is also a wave barrier on Pleasure Island. The system was designed and constructed for a 100-year storm (1 percent annual exceedence probability) event. It is operated by Jefferson County Drainage District No. 7. In addition to residential and commercial areas in

Port Arthur, Nederland and Groves, the system protects Valero Refining, BASF/Fina, Total Petrochemicals, and the Motiva Enterprises refinery, the largest refinery in the U.S.

5.2.2 Texas City HFPS, Texas

The Texas City and Vicinity, Texas HFPS was authorized by the Flood Control Act of July 3, 1958, P.L. 85-500, substantially in accordance with recommendations of the Chief of Engineers in the House Document No. 347, 85th Congress, 2nd Session. Construction began in 1962. Authorized modifications to the project were approved in the Flood Control Act of 1968, House Document No. 187, 90th Congress, 1st Session. These authorized modifications included an extension of the levee protection system to protect the City of Hitchcock and La Marque. Construction was completed in April 1987. The Texas City HFPS is located on the southwest shore of Galveston Bay about 9 miles northwest of Galveston, Texas. The system was designed and constructed for a 100-year (1 percent annual exceedence probability) event. The levee system consists of earthen embankment and floodwalls protecting an area of approximately 36 square miles. The levee consists of 21.85 miles of earthen embankment and floodwall. There are approximately 1.32 miles of floodwall in the system, consisting of nearly 0.92 miles of I-wall (0.64 miles of Braced Cantilever I-wall and 0.28 miles of Cantilever I-wall) and 0.4 miles of T-wall. One section of earthen embankment was constructed in 1930 and enlarged in the authorized project. There is a section of levee on the northwest side of the system which was constructed by local interests in 1947 and is included as part of the system. Large petrochemical refineries are protected by the system, including the Valero Refinery and two Marathon Petroleum refineries.

5.2.3 Freeport HFPS, Texas

The overall project for hurricane flood protection for Freeport and Vicinity, Texas, was authorized by the Flood Control Act of 23 October 1962, P.L. 87-874, substantially in accordance with House Document No. 495, 87th Congress, 2nd Session. The authorization provides for construction of improvements at Freeport and Vicinity for protection against storm tides caused by tropical cyclones along the Gulf Coast of magnitudes up to and including the standard project hurricane. The Freeport and Vicinity HFPS is located in the coastal planes in southern Brazoria County, about 48 miles southwest of Galveston, Texas. The system was designed and constructed for a 100-year (1 percent annual exceedence probability) event. The Velasco Drainage District, a subdivision of the State of Texas, is the local sponsor of the Freeport and Vicinity HFPS. The system consists of approximately 43 miles of levees and wave barriers, seven pump stations and multiple gates, culverts and related appurtenances. Additionally, the line of protection includes multiple structures that also serve as control structures and docks for Dow Chemical Co., BASF, Conoco Philips, Exxon and Port Freeport. As a part of this project, USACE upgraded and incorporated existing levees into the system in

addition to extending and constructing a new levee reach northward along Oyster Creek to the high bank of Oyster Creek just east of the City of Clute. This created a comprehensive HFPS extending from the 7-mile "river system" at Brazos River mile 11, and extends to the City of Clute. Protection is provided for industrial facilities and docks, including Dow Chemical, BASF, Conoco Philips, Exxon and Port Freeport. Although the system primarily protects industrial areas, some residential areas in Freeport, Oyster Creek, Clute and Lake Jackson are also protected.

5.3 Navigation Projects in the Study Area

There are eight deep-draft navigation channels along the Texas coast, which are identified by study region in Table 5-1. These channels were considered during the development of this reconnaissance study.

Additionally there are numerous shallow-draft channels along the Texas coast including the GIWW, extending the entire length of Texas from Sabine Neches Waterway to BIH. The GIWW in Texas is a 12-foot deep by 125-foot wide channel that is protected from the Gulf of Mexico by the natural barrier islands and peninsulas. The GIWW transports cargo through the use of barges over approximately 400 miles of channel, which cross all of the Texas bay systems.

Table 5-1 – Deep-Draft Waterways by Region

Waterway Name	Depth (feet)	Width (feet)	Length (miles)	Proposed Improvements	Port and National Rank for Top 50
Region 1					
Sabine-Neches Waterway	40	400	64	48-foot depth (Water Resources Reform and Development Act [WRRDA] 2014)	Beaumont - #6 Port Arthur - #24
Galveston Harbor Channel (including entrance channel	45	800	23.9	50-foot depth (pending future study)	Galveston - #41
Houston Ship Channel	45	530	40	50-foot depth (pending future study)	Houston - #2
	36-40	300	12		
Texas City Ship Channel	45	400	6.8		Texas City - #11
Freeport Ship Channel	45	400	8.5	55-foot depth (WRRDA 2104) and 400-600-foot width by non-Federal sponsor with Federal Assumption of Maintenance	Freeport - #31
Region 2					
Matagorda Ship Channel	36	200	26	45-foot depth (pending future report)	Port Lavaca/Port Comfort - #48
Region 3					
Corpus Christi Ship Channel	45		34.1	52-foot depth, 530-foot width, additional barge lanes on both sides of the channel across Corpus Christi Bay, and extension of the La Quinta channel 1.5 miles at 39 feet	Corpus Christi - #7
Region 4					
BIH Channel	42	250	22.8	52 foot-depth (pending future report)	Port of Brownsville - #69

6. SCOPING

To identify the water resource needs throughout this extensive study area and the problems, opportunities, and planning objectives, research was conducted to collect such information from the potential stakeholders and sponsors. This collected information was used to develop potential solutions to the problems along the Texas coast and identify Federal interest in these solutions.

The Texas GLO has developed an overview of issues affecting the Texas coast, entitled "The Texas Coast: Shoring Up Our Future". This document identifies the issues of concern as wetland/habitat loss, water quality and quantity, impact to fish and wildlife, impact to marine resources, Gulf beach/dune erosion, bay shoreline erosion, flooding and storm surge, tourism/local economy, along with other less significant issues. This publication was used as a starting point in identifying problems and opportunities along the entire Texas coast.

Additionally, a series of scoping meetings were held along the upper Texas coast as a part of the Sabine Pass to Galveston Bay feasibility study. Meetings were held in Seabrook, Beaumont, Freeport, and Galveston in February and March 2012 to gather ideas for CSRM and ER opportunities in Region 1 of the study area. The information collected at these meetings is also being used in this reconnaissance study.

Separate scoping meetings were held in Palacios, Corpus Christi, and South Padre Island in August 2014 to collect similar information for the remainder of the Texas coast. These meetings requested input from the counties identified in Regions 2, 3, and 4 of the study area. An additional meeting was held in the League City to update the public in Region 1 to the activities for this reconnaissance study.

7. PROBLEMS/ OPPORTUNITIES

Significant environmental and economic impacts have been caused by the continual erosion of the Texas coastline with specific impacts to wildlife areas, wetlands, barrier islands, and residential and commercial property.

7.1 PROBLEMS

The problems in the Coastal Texas study area are:

- Population at risk – 24 percent of the state population lives within the 18 coastal counties vulnerable to impact from storms. Currently, 6.1 million people reside in these coastal counties with a projected increase of 50 percent to a total of 9.3 million residents by 2050. This area includes the fourth largest U.S. city (Houston), and other key metropolitan areas such as Beaumont/Port Arthur/Orange, Galveston/Texas City, Freeport/Surfside, Corpus Christi, and Brownsville that are severely vulnerable to life safety and economic risks from coastal storm events;
- Infrastructure is inadequate to evacuate the one million residents in hurricane evacuation zones today, and 500,000 more people are expected to move into these zones by 2035;

- Three of the nine largest oil refineries in the world, 40 percent of the nation's petrochemical industry, 25 percent of the nation's petroleum-refining capacity, and their associated infrastructure (pipelines, transportation networks, utilities) will continue to be at risk without a comprehensive plan aimed at reducing susceptibility to flood and hurricane risk. Two of the nation's petroleum strategic reserves are within the surge zone;
- Eight deep-draft seaports, 750 miles of shallow-draft channels, including approximately 400 miles of the GIWW (the nation's 3rd busiest inland waterway), and associated infrastructure will continue to be susceptible to flood and hurricane storm damages. Four of the top eleven ports in the U.S. for total tonnage (see Table 5-1) are located in the study area. Additionally, the Port of Houston is #1 in importing fuel and the Port of Beaumont is the #1 military outload port in the world. As an example of potential economic impact, it is estimated that a 30-day closure of the Houston Ship Channel would result in an economic loss of $60 billion to the nation;
- The coast of Texas includes the upper Texas coast, which is an area with a high frequency of storm impacts and economic damages (second highest area of occurrence on Gulf Coast);
- Three existing hurricane protection systems at Port Arthur, Texas City and Freeport were nearly overtopped during Hurricane Ike. These systems do not meet current design standards for resiliency and redundancy and will be increasingly at risk from storm damages due to Relative Sea Level Rise (RSLR) and climate change;
- Critical infrastructure throughout the region, including hurricane evacuation routes, nationally significant medical centers, government facilities, universities, and schools are at risk of damage from storm events;
- Environmental impacts are likely from storm damages to refineries and tank farms (e.g. release of toxic substances);
- Storm surge erosion is degrading nationally significant migratory waterfowl and fisheries habitats within the study area. Saltwater wetland losses in the Gulf of Mexico have been attributed to the effects of severe coastal storms such as Hurricanes Katrina, Rita and Ike. By comparison, a small percentage of saltwater wetland losses have been traced to discrete anthropogenic actions such as ship channels, canals and impoundments in the Gulf of Mexico region (Dahl and Stedman, 2013);
- Water shortages have resulted in increasing conflicts between municipal and industrial water supply and the ecological needs of the mid-coast estuaries, resulting in further degradation of the riverine, delta, and bay ecosystems;
- Oyster reefs have declined significantly in bay systems from Matagorda through Corpus Christi. Oyster reefs are at risk due to increasing salinities, predation and disease in

addition to the pressures of harvesting. Storm surges have adversely affected reefs by covering them with sediment;

- Sediment transport in the longshore current is being blocked by navigation channels and jetties;
- Gulf shorelines are retreating an average of 4 feet per year with some areas experiencing losses greater than 30 feet per year. This erosion is destroying nationally significant wetlands, damaging homes and commercial properties, and even destroying coastal highways;
- Erosion of bay shorelines and islands caused by wind and wakes is destroying estuarine marsh habitat and rookery islands;
- RSLR is expected to alter or displace the majority of wetlands in the next 50 to 100 years. Predicted changes in the intensity of tropical storm events, precipitation rates, and temperatures (Intergovernmental Panel on Climate Change [IPCC] 2014) will accelerate wetland impacts by increasing wave action and erosion rates, compounding the conversion of coastal marshes to open water. Sea level rise will exacerbate the height of storm surge in inland regions, potentially increasing by 2 or 3 times greater than the RSLR increment itself (Arcadis 2011);
- Critical habitat for wintering populations of the piping plover and the whooping crane may be damaged or destroyed by storm surge. Although damages may be temporary, permanent loss of shoreline and marsh can occur depending upon the storm's track and intensity and weather conditions after the storm;
- Anthropogenic hydrologic alterations have reduced riverine inflows and overland flows, or adversely altered tidal flows and circulation. In some areas, the GIWW is blocking overland flows of freshwater, and;
- Water quality is a pervasive issue throughout the coastal waters where bacteria exceed water quality standard levels in many areas, and there are also localized issues with low dissolved oxygen and contaminants.

7.2 OPPORTUNITIES

Opportunities in this study area include the following:

- Provide CSRM measures to reduce risks to public, commercial and residential property, real estate, infrastructure and life safety;
- Reduce the susceptibility of residential, commercial, and public structures and infrastructure to hurricane-induced storm damages in Texas coastal zone;
- Increase reliability of the nation's energy supply;
- Enhance public education related to coastal storm risk;

- Reduce risk for evacuation routes so they remain clear longer;
- Reduce environmental damage associated with storm damage to refinery infrastructure;
- Assist in the restoration and long-term sustainability of coastal wetlands that support important fish and wildlife resources within the study area;
- Assist in the restoration and long-term sustainability of forested wetlands that support important fish and wildlife resources within the study area;
- Assist in the restoration of barrier island environments in a manner that promotes long-term sustainability of their fish and wildlife resources;
- Assist in the improvement of water quality in coastal waters through marsh and oyster reef restoration;
- Identify potential hydrologic restoration to improve aquatic habitat;
- Maintain sediment within the system and use beneficially where feasible;
- Support programs that promote long-term erosion reduction of the Gulf Coast and limit erosion potential during future hurricane events;
- Support programs that promote long-term erosion reduction of channel shorelines and limit erosion potential during future hurricane events;
- Reduce saltwater intrusion associated with tropical systems within sensitive estuarine systems;
- Restore and protect endangered species habitat;
- Address adverse natural resource impacts of existing Federal projects, and;
- Enhance ecotourism and recreation opportunities.

7.3 FUTURE WITHOUT-PROJECT CONDITIONS

The proposed study area includes areas that have been substantially impacted in recent years by significant coastal storm events. Climate change may only exacerbate the frequency and intensity of these storms making the Texas Gulf Coast more vulnerable. As stated earlier, the Gulf Coast of Texas contains 40 percent of the nation's petrochemical industry and 25 percent of the refining capacity. Vulnerability of this valuable economic output will only continue in the future. Repeated storms will also continue to impact shipping traffic. The Gulf Coast is home to three of the ten-busiest ports in the nation including the Port Houston which is second only to the Port of South Louisiana in terms of overall tonnage. Estimates for the value of structures in the 18 counties along the Gulf Coast impacted by in the 1 percent storm event total over $68 billion and almost $130 billion for the 0.2 percent event. Hurricane Ike that struck the upper Texas coast in 2008 was the third-costliest storm in U.S. history and caused an estimated $29 billion in property damage. Impacts to an eight-county region's economy have been estimated at $142 billion over the four yearly quarters following the storm.

Significant population centers also exist along the Texas Gulf Coast exposing a substantial number of people to an increasing risk of coastal storms, including life safety risks. These areas include the Houston-Sugar Land-Baytown Metropolitan Statistical Area (MSA), the largest MSA along the U.S. Gulf Coast. Other significant population centers include McAllen-Edinburg-Mission, Corpus Christi, Brownsville-Harlingen, and Beaumont-Port Arthur MSAs. The population of the 18 counties in the study area grew by almost 18 percent between 2000 and 2010 from 5.2 to 6.1 million.

Additionally, recent repetitive storm events on the Texas coast have created vulnerable ecosystems (Williams, et al. 2009). Successive disturbance by storm surge in the future is expected to jeopardize the process by which coastal wetlands keep pace with rising sea level. It is forecast that climate change will result in an increase in the intensity of tropical storms, rising average annual temperatures, and potentially an increase in the rate of RSLR, all of which will exacerbate this trend. Gulf, bay and channel shoreline erosion will continue, exposing fresher marsh systems to saltwater stress, and continuing the conversion of marsh to open water. Marsh loss could also have devastating long-term impacts on fisheries, migrating and colonial waterfowl and wading birds. Hydrological alterations on most rivers in the coastal zone have decreased freshwater and sediment inflows and increased saltwater intrusion to coastal marshes; these impacts are expected to continue and potentially increase in the future due to the needs of a growing population and the effects of climate change. Impacts from the deep-draft navigation channels and jetty systems, as well as the shallow-draft GIWW, will continue to affect the hydrology of coastal marshes and the longshore sediment transport on the Texas coast.

8. PLANNING GOALS/OBJECTIVES

8.1 Planning Goals

The main goal of this study is to develop projects to reduce the risk to lives and property associated with coastal storms, as well as to provide ER within the study area, where feasible. ER projects will be identified that will enhance shoreline stability and improve the environment of the area, including wetland restoration efforts.

8.2 Planning Objectives

The following planning objectives for the entire Coastal Texas area for the 50-year period of analysis were used in formulation and evaluation of alternative plans for the purpose of CSRM:

1. Reduce economic damage to business, residents and infrastructure;
2. Reduce risk to human life from storm surge impacts;

3. Enhance energy security and reduce economic impacts of petrochemical supply-related interruption;
4. Reduce risks to critical infrastructure (e.g., medical centers, ship channels, schools, transportation, etc.);
5. Manage regional sediment for beneficial uses to navigation and other operations;
6. Enhance functionality of existing HFPS including evaluation of impacts due to sea level rise; and
7. Enhance and restore coastal habitat that contributes to storm surge attenuation where feasible.

Additionally, planning objectives for formulation and evaluation of plans for the purpose of ER for the 50-year period of analysis were:

1. Restore fish and wildlife habitat such as coastal wetlands, forested wetlands, bottomland forests, oyster reefs, and beaches and dunes;
2. Reduce saltwater intrusion into sensitive estuarine systems;
3. Reduce erosion to barrier island, mainland, interior bay and channel shorelines; and
4. Improve water quality in coastal bays and estuaries with restoration of marshes and oyster reefs.

9. PLANNING CONSTRAINTS

The following constraints apply to this study:

1. Minimize transfer of flood risks/induced flooding;
2. Lack of sand sources for beach nourishment/shoreline stabilization projects;
3. Alternatives must be developed within Coastal Barrier Resources Act (CBRA) guidelines;
4. Lack of authorities to affect quantity of freshwater inflows;
5. Existing upstream dams must remain in place to provide for municipal water supply storage and aquifer recharge;
6. Measures should not significantly impact resources within NWRs and WMAs;
7. Minimize impacts to Endangered Species critical habitat (e.g. sea turtles and piping plover);
8. The benefits of ER alternatives will more than offset any resulting environmental impacts, such that no fish and wildlife mitigation will be required; and
9. No use of public funds on private property without an overriding public benefit.

10. FISH AND WILDLIFE RESOURCES CONSIDERATIONS

Over half of the coastal wetlands for the entire conterminous U.S. are in the Gulf of Mexico region. Total coastal wetlands for Texas account for 6 percent of the national total and 12 percent of the regional total (Wilson and Esslinger, 2002). The number and species of birds in this region are among the greatest anywhere in the U.S. and Canada. Over 380,000 acres of designated critical habitat for the threatened, wintering piping plover (*Charadrius melodius*) lie along the Texas coast from the Rio Grande to the Sabine River. Five species of federally-listed sea turtles (*Chelonia mydas, Lepidochelys kempii, Caretta caretta, Eretmochelys imbricata, Dermochelys coriacea*) are common in Gulf waters along the coast. Essential fish habitat (EFH) necessary for spawning, breeding, feeding, or growth to maturity of species managed by Regional Fishery Management Councils is also present along the entire Texas coast. Types of EFH prevalent in the area include wetlands, shallow vegetated waters and estuarine shell substrate.

Natural forces, which shape the system, include dominant south to southeast winds and tropical weather systems. Storm surge has had both long term positive and negative effects on the ecosystem of the region. Storm overwash deposits help shape and maintain coastal environments affected by RSLR. In some areas, storm surges result in shoreline accretion by depositing sediment on beaches and within marshes behind the shore. In other areas, storm surges have erosive effects. Far more of the Gulf shoreline in southeast Texas suffered erosion as a result of Hurricane Rita's surge than experienced accretion. Hurricane Ike caused the complete loss of a sand veneer between the low tide line and the slight dune ridge which bordered the shore from Sabine Pass to High Island, and even more importantly removed much of this ridge which once protected the freshwater wetland and coastal prairie complex in the Texas Point NWR, J.D.Murphree WMA, and McFaddin NWR (Williams et al. 2009).

The upper coast experiences substantial rainfall of over 60 inches per year, while the Rio Grande Valley area averages only 27.6 inches per year. Flooding and freshwater inflows are key systemic processes, which buffer salinity and provide nutrients and sediments to the extensive estuaries. Complex bay systems extend from the Galveston Bay system through Baffin Bay. While highly impacted by human activities, these ecosystems remain very productive for a wide variety of fish and wildlife. The bay systems in the mid-coast area (Regions 2 and 3) are complex and may involve a large outer (or primary) bay with moderate to sea-strength salinities, a secondary bay with brackish to moderate salinities, and inner (or tertiary) bays that may be brackish to freshwater.

Extensive Texas coastal wetlands, totaling more than 3.9 million acres, are a vital habitat for 75 percent of the fish and shellfish species found in the Gulf of Mexico. The marshes, prairies, and tidal flats over the entire coastal zone are a major wintering area for waterfowl of the Central Flyway, while primary routes for both the Central and Mississippi Flyways converge in the

Sabine area. On average, 1.3 to 4.5 million ducks, or 30 to 71 percent of the total flyway population winter annually on the Texas Gulf coast (Stutzenbaker and Weller 1989). This area also winters 90 percent of the snow, Canada, and greater white-fronted geese in the Central Flyway (Buller 1964). On average, 180,000 pairs of colonial-nesting waterbirds nest annually in Texas coastal habitats. Coastal forests are critically important for the nation's songbird resources as the vast majority utilize this habitat during their trans- and circum-Gulf migrations (USFWS 2008).

The study area includes critical coastal ecosystems of 3.9 million acres of wetlands, 235,000 acres of seagrass, 367 miles of sea turtle nesting habitat, 380,000 acres of piping plover critical habitat, and 328 square miles of whooping crane critical habitat, as well as 21 state and Federal wildlife refuges. Of the 367 miles of shoreline, more than 60 percent has been identified by the GLO as subject to high rates of erosion.

Most of the structural alternatives identified in this report would require fish and wildlife mitigation. These structural alternatives are discussed in more detail in Section 14.3. Structural alternatives such as a new levee/floodwall system around industries on Chocolate Bayou (B1), a new City of Galveston levee system (G2), the Galveston Bay Coastal Barrier along the Bolivar and Galveston barrier islands (G7), and a new levee/surge gate system at the Hartman Bridge on upper Galveston Bay (G8) could have substantial impacts to significant habitats, wetlands and aquatic systems. Alternatives G7 and G8 would require navigable surge gates in the deep-draft Houston/Galveston navigation channels. While these gates would be open when not functioning to stop surge, structures needed to support these gates could have serious impacts on the total amount of tidal exchange with Galveston Bay, potentially causing changes in bay and riverine circulation patterns, sediment transport, velocities and salinities, which in turn could seriously impact the nationally significant oyster reefs in the Galveston Bay complex and rare and declining estuarine marsh habitat along bay margins. The surge gate in Bolivar Roads (G7) could also result in changes to circulation and sediment changes to the Gulf of Mexico shoreline. During the feasibility study, these impacts would need to be evaluated using established Engineer Research and Design Center hydrodynamic/sediment models, certified ecosystem community models such as the Wetlands Value Assessment, or certified Habitat Evaluation Procedure habitat suitability indices (i.e. Eastern Oyster). Many of the ER and dune/beach restoration alternatives would require the adoption of conservation measures to minimize impacts to piping plover critical habitat or nesting turtle habitat. Mitigation for ER alternatives is not anticipated.

11. HISTORICAL AND CULTURAL RESOURCES CONSIDERATIONS

There are over 6,500 cultural resources recorded within the four regions. Many of these resources have national and regional significance and are either listed on or eligible for inclusion

in the NRHP. Additionally, almost all cultural resources within the four regions are at risk from hurricane storm damage to varying degrees. Those resources at highest risk are archeological sites along coastal and bay shorelines where storm surge wave action and flooding can cause severe erosion, historic buildings and structures that can be destabilized or destroyed by wave action and flooding, and submerged resources, such as shipwrecks, which can be exposed and dispersed by shifting sea floor and bay bottom during violent storm events. Indirectly, cultural resources whose owners lack sufficient money or resources to rehabilitate damaged properties could be lost entirely.

Structural and non-structural alternatives for reducing storm damage risk also pose a threat to cultural resources in the four regions as these can involve both direct and indirect impacts. Direct impacts could include damage to surface and subsurface resources from levee or wall construction and associated borrow areas, erosion from redirected storm waters into archeologically sensitive areas, and loss of historic properties resulting from buyouts. Indirect impacts could include visual impacts from obstructions such as levees and walls, increased construction/renovation in newly protected areas, and noise impacts from increased traffic in protected areas and along evacuation routes.

Although these impacts could be significant, mitigating the effects of the alternatives could be accomplished through archival research, focused intensive investigations, and cooperation with state, county, and local historical groups. The initial step in this process would be to create a detailed database of resources within areas that will be impacted by construction. This database would be created using existing Federal, state, county, and local databases and resources. The database should be supplemented with recommendations for management of known resources and recommendations for investigations of high probability areas. The next step would be to establish a programmatic management process for cultural resources, either utilizing existing agreement documents or establishing new ones. County and local historical groups should be included in the process as consulting parties in addition to the normal consultation with the State Historic Preservation Officer and relevant Tribal Preservation Officers. These agreement documents would then be used to guide any additional investigations related to selected plans. Investigations completed after alternatives have been eliminated will reduce the overall cost of compliance by focusing those investigations in specific areas. However, given the scope of the alternatives and the high probability for impacting cultural resources, the cost of evaluation and mitigation of cultural resources is likely to be high.

12. REAL ESTATE CONSIDERATIONS

Multiple real estate issues will arise because of the magnitude of this project, which will be further addressed during the feasibility phase. Potential measures will have real estate impacts throughout the 18 county study area. Estimated impacts include residential relocations and

business relocations. Estimates of the requirements associated within the above noted relocations (PL 91-646) will be applied. Condemnation actions are anticipated as well as substantial facility/utility relocations. During the feasibility phase, mitigation impacts associated with this project will also be estimated and included in the overall cost estimate for the project.

All alternative plans will be reviewed to identify real estate requirements and assess the appropriate estate required for project execution including to include any non-standard estates that may be required. An evaluation of each alternative will be made to assess ownerships involved and to determine number and kinds of utility/facility relocations affected by each alternative. Each alternative will be valued by an appraiser in order to obtain a gross estimate for real estate requirements. Any mitigation measures requiring additional real estate will be included in the analysis.

13. FORMULATING ALTERNATIVE PLANS

Plan formulation is the process of building alternative plans that meet planning objectives and develop alternatives within the planning constraints. The planning process for this study is driven by the overall objective of developing a comprehensive plan that will help manage risks associated with coastal storms within the study counties while avoiding and minimizing impacts to the area's environmental resources.

13.1 Management Measures

A management measure is a feature or activity that can be implemented at a specific geographic site to address one or more planning objectives. Alternative plans are a set of one or more management measures functioning together to address one or more planning objectives. For this study, each measure was developed addressed the planning objectives of CSDR and/or ER.

Coastal systems provide important social, economic, and ecological benefits to the nation. However, our coasts are vulnerable to the influence of a combination of factors, including storms, changing climate, geological processes, and the pressures of population growth, ongoing development and urbanization. The impacts associated with coastal flooding include storm surge inundation, waves, and erosion, as well as sea level change inundation. With sea level change, extreme water levels associated with coastal storm events increase, which increases the probabilities of occurrence for a storm producing a certain level of flooding compared to the same storm in the future. In addition to policy and programmatic efforts to reduce risk, three primary strategies were considered to address the flood risk to vulnerable coastal populations:

1. Protect - focused on structural measures to reduce risk of damages from future storm events. This strategy would likely be included in developed areas along the coast.

2. Accommodate - As sea level changes, measures can adapt based on the rate of sea level change as it occurs over time. This strategy would include improved implementation of natural and nature-based features (NNBF) consistent with this study's opportunities along with traditional nonstructural measures, such as elevation, floodproofing, and ringwalls.
3. Retreat - including the acquisition and buyouts to convert land to open space. This strategy would likely be applicable for lesser-developed areas, but, over time depending on the rate of sea level change, the strategies will likely also change.

As presented in Figure 13-1 from the recent study by the National Research Council (NRC), the foundation for building resilient communities should follow this continuous, adaptive process. The diagram approaches risk management from a community resilience perspective. It is an adaptive cycle beginning with hazard identification and risk assessment, to strategy development and implementation and then evaluation and adjustment.

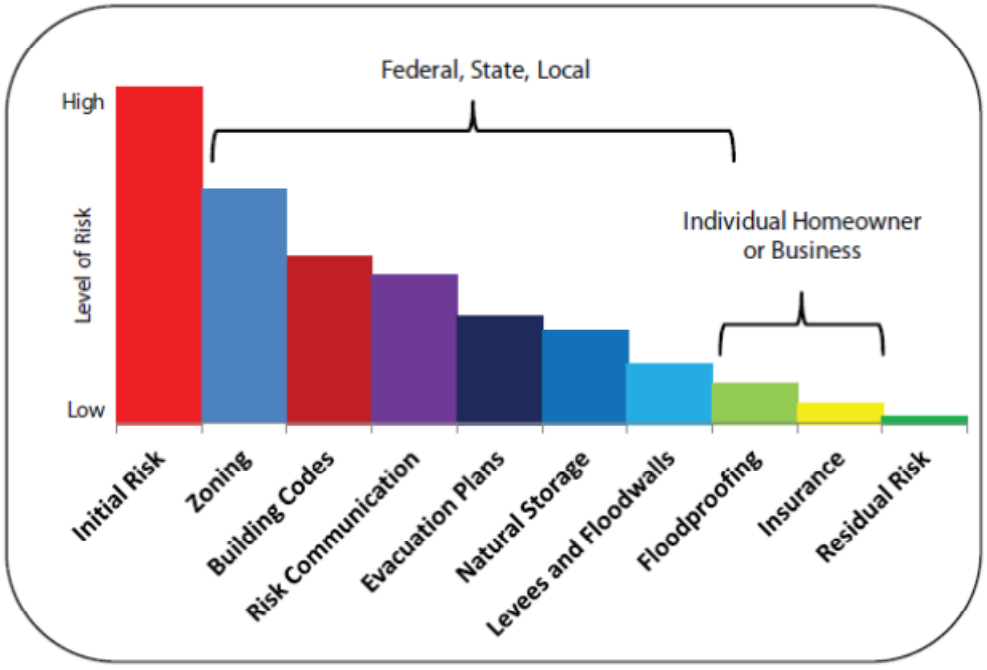

Figure 13-1 – Risk Reduction Measures.
(Source: NRC, Levees and the National Flood Insurance Program, 2013 as modified from USACE)

The bar to the left most side of the figure represents the initial risk faced by a community. Moving to the right, each bar shows the types of measures (structural and non-structural) that can be employed to reduce the initial level of risk, as well as illustrating that responsibility for various risk management measures fall into Federal, state, and local governments, as well as on the individual homeowner and business. Finally, the right-most bar illustrates that no matter what measures are employed, some residual risk always remains.

Pursuing the objective of sustainable development of water resources infrastructure poses both challenges and opportunities for the USACE. Advancing the USACE practices involves identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects.

The USACE Engineering With Nature (EWN) Program supports more sustainable practices, projects, and outcomes by working to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes (www.engineeringwithnature.org). EWN's focus on developing practical methods provides an achievable path toward an ecosystem approach to infrastructure development and operations. Consequently, EWN principles and practices can be applied across multiple USACE missions and business lines.

There are four elements critical to the success of EWN projects:

1) Improving operational efficiency;
2) Using natural systems and processes to maximize the benefits;
3) Broadening the benefits of the project – economic, environmental and social; and
4) Using collaborative processes to engage stakeholders throughout the project.

USACE has a long history of implementing some of the elements of EWN in its projects. The Coastal Texas feasibility study could thoroughly incorporate the four elements of EWN to seek a broader range of opportunities on which to apply EWN principles and practices. The use of EWN and NNBF is a method to develop solutions that are different from the traditional CSRM and ER projects and could be designed to enhance and promote resiliency and sustainability of the system and improve operational efficiency. Natural features would be designed to sustain damages during storm events with the need for repair or replacement throughout the project's life cycle while increasing resiliency of existing or proposed CSRM features. Figure 13-2 shows the various NNBFs and their benefits and performance factors.

NNBF, non-structural, and structural are terms used to describe the full array of measures that can be employed to provide increased coastal resiliency and risk reduction. An integrated, watershed-based approach that draws together a combination of measures as part of the above strategies will reduce risk and enhance coastal resilience over the long-term. A systems approach to evaluating comprehensive flood risk is necessary to evaluate the synergistic benefits of a combination of strategies, resilience and robustness of the coastal landscape, as well as to

Figure 13-2 – Natural and Nature-Based Infrastructure at a Glance

identify and communicate residual risk. Figure 13-3 depicts the coastal landscape considering the three strategies and various management measures. The framework describes the process local communities and other stakeholders could use to evaluate coastal flood risk, future vulnerability with respect to sea level rise, and the strategies and measures to manage existing vulnerabilities and increasing risk over time.

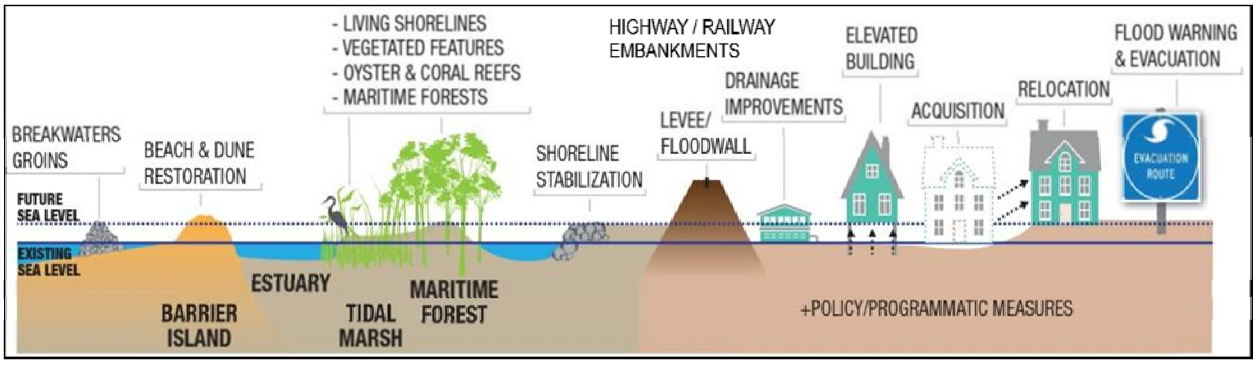

Figure 13-3 – Combination of Measures to Improve Redundancy and Resiliency

13.1.1 CSRM Measures

A suite of CSRM measures was developed by taking an integrated approach that considers combinations of the full array of available measures. All of these measures were identified as potentially effective ways to reduce the vulnerability of coastal populations and increase resilience. The CSRM measures include structural, nonstructural, NNBF, and policy/programmatic measures.

The initial array of measures was developed with public, local government and agency input gathered during the four Sabine Pass to Galveston Bay study scoping meetings held in 2012 in Region 1 (Sabine, Galveston, and Brazoria) and four additional meetings held in 2014 in each Texas coastal region established for this study.

Potential structural, NNBF and nonstructural measures considered in this study were:

- Structural (road raising, levees, surge gates, floodwalls, breakwaters, hardening of infrastructure, etc.)
- NNBF (dunes and beaches, salt marsh, oyster reef, barrier islands)
- Nonstructural (buyouts, structure raising, flood warning systems, floodplain management, regional sediment management, etc.)

These nonstructural, NNBF features and structural measures were considered as part of the study analysis and were developed to address study objectives previously presented in Section 8.

These measures can be combined with other measures, nonstructural or structural, to form possible alternatives that could be evaluated in this study process and carried on into the feasibility phase. The alternatives identified for each region are presented in Section 14 below.

13.1.2 ER Management Measures

ER measures were developed that would restore or protect significant coastal habitats, improve water quality, or protect or create habitat for endangered species and fishery resources. In many cases, these measures would also contribute to the reduction of storm surge impacts to economic and natural resources in the region. The ER measures include:

- Marsh restoration
- Dune restoration and beach nourishment
- Gulf shoreline ridge restoration
- GIWW island restoration
- Shoreline erosion control structures (breakwaters/groins)
- Freshwater hydrologic restoration structures (siphons)
- Creation of oyster reef
- Restoration of rookery islands

14. ARRAY OF ALTERNATIVES

14.1 Economic Basis for CSRM Alternatives

14.1.1 Structure Values

In order to identify the potential for economic damages in the study area for the eighteen counties along the Texas coast, flood zones representing the 1 percent (100-year) and 0.2 percent (500-year) annual exceedence probability delineations from Federal Emergency Management Agency (FEMA) digital Q3 Flood data were loaded into ArcMap for each of the eighteen counties. This flood data was intersected with a shapefile consisting of structure data obtained from the National Structure Inventory (NSI) within SimSuite, a web-based, interactive and customizable application built by USACE's Readiness Support Center. The NSI is built from FEMA's HAZUS database and the National Land Cover Land Use database with all structure values classified as residential, industrial, commercial, and public. The estimates for structure value for the 1 and 0.2 percent annual exceedence probability events are listed in Table 14-1 by county and grouped by region. The estimated value of structures in the 1 percent exceedence event is $68.439 billion and the value for the 0.2 percent annual exceedence probability event is $129.649 billion.

Table 14-1 – Structure Value for 1 percent (100-year) and 0.2 percent (500-year) Annual Exceedence Storm Events

County	Damage Category	100-Year	500-Year
Region 1			
Orange	Commercial	$415,658,000	$855,927,000
	Industrial	$136,543,000	$235,520,000
	Public	$42,667,000	$76,642,000
	Residential	$1,392,435,000	$3,413,925,000
	County Total	***$1,987,302,000***	***$4,582,014,000***
Jefferson	Commercial	$399,959,000	$1,970,530,000
	Industrial	$114,749,000	$294,082,000
	Public	$83,447,000	$248,802,000
	Residential	$1,544,687,000	$7,567,031,000
	County Total	***$2,142,841,000***	***$10,080,445,000***
Chambers	Commercial	$152,730,000	$217,985,000
	Industrial	$126,812,000	$145,473,000
	Public	$6,122,000	$6,602,000
	Residential	$491,741,000	$746,633,000
	County Total	***$777,405,000***	***$1,116,693,000***
Harris	Commercial	$6,828,963,000	$15,027,271,000
	Industrial	$2,486,217,000	$4,255,563,000
	Public	$957,496,000	$1,488,804,000
	Residential	$23,804,208,000	$48,141,732,000
	County Total	***$34,076,884,000***	***$68,913,370,000***
Galveston	Commercial	$2,120,961,000	$3,643,216,000
	Industrial	$773,575,000	$1,003,628,000
	Public	$227,008,000	$301,697,000
	Residential	$9,375,221,000	$16,018,762,000
	County Total	***$12,496,764,000***	***$20,967,303,000***
Brazoria	Commercial	$914,541,000	$1,306,542,000
	Industrial	$285,930,000	$423,444,000
	Public	$84,800,000	$117,632,000
	Residential	$4,524,187,000	$6,027,413,000
	County Total	***$5,809,458,000***	***$7,875,031,000***
Region 1 Subtotal		**$57,290,654,000**	**$113,534,856,000**
Region 2			
Matagorda	Commercial	$209,823,000	$260,419,000
	Industrial	$23,700,000	$36,791,000
	Public	$24,574,000	$28,616,000
	Residential	$1,078,635,000	$1,360,703,000
	County Total	***$1,336,732,000***	***$1,686,528,000***
Jackson	Commercial	$65,548,000	$97,360,000
	Industrial	$18,823,000	$20,757,000
	Public	$5,747,000	$11,342,000
	Residential	$226,635,000	$344,727,000
	County Total	***$316,753,000***	***$474,185,000***

County	Damage Category	100-Year	500-Year
Victoria	Commercial	$151,159,000	$196,817,000
	Industrial	$17,694,000	$20,421,000
	Public	$6,641,000	$6,641,000
	Residential	$604,739,000	$746,403,000
	County Total	***$780,233,000***	***$970,282,000***
Calhoun	Commercial	$123,447,000	$173,675,000
	Industrial	$49,700,000	$68,499,000
	Public	$9,588,000	$9,588,000
	Residential	$455,285,000	$658,668,000
	County Total	***$638,021,000***	***$910,431,000***
Region 2 Subtotal		**$3,071,739,000**	**$4,041,426,000**
Region 3			
Aransas	Commercial	$109,931,000	$234,931,000
	Industrial	$10,657,000	$22,147,000
	Public	$76,811,000	$91,566,000
	Residential	$646,127,000	$1,224,633,000
	County Total	***$843,526,000***	***$1,573,277,000***
Refugio	Commercial	$8,652,000	$13,426,000
	Industrial	$1,404,000	$1,802,000
	Residential	$23,243,000	$43,023,000
	County Total	***$33,298,000***	***$58,250,000***
San Patricio	Commercial	$123,964,000	$160,182,000
	Industrial	$126,153,000	$132,072,000
	Public	$22,903,000	$26,222,000
	Residential	$666,902,000	$1,088,754,000
	County Total	***$939,921,000***	***$1,407,230,000***
Nueces	Commercial	$463,949,000	$620,355,000
	Industrial	$127,007,000	$147,906,000
	Public	$88,787,000	$93,141,000
	Residential	$2,197,839,000	$2,825,353,000
	County Total	***$2,877,582,000***	***$3,686,755,000***
Kleberg	Commercial	$63,309,000	$82,692,000
	Industrial	$5,797,000	$6,722,000
	Public	$3,686,000	$8,452,000
	Residential	$217,287,000	$260,418,000
	County Total	***$290,079,000***	***$358,284,000***
Region 3 Subtotal		**$4,984,406,000**	**$7,083,796,000**
Region 4			
Kenedy	Commercial	$182,000	$182,000
	Industrial	$4,270,000	$4,270,000
	Residential	$4,742,000	$5,168,000
	County Total	***$9,194,000***	***$9,620,000***
Willacy	Commercial	$66,463,000	$67,221,000
	Industrial	$26,548,000	$26,915,000
	Public	$5,219,000	$12,149,000
	Residential	$502,329,000	$511,014,000
	County Total	***$600,558,000***	***$617,298,000***

County	Damage Category	100-Year	500-Year
Cameron	Commercial	$502,159,000	$839,481,000
	Industrial	$90,136,000	$344,658,000
	Public	$94,856,000	$158,382,000
	Residential	$1,795,494,000	$3,019,501,000
	County Total	***$2,482,645,000***	***$4,362,022,000***
Region 4 Subtotal		**$3,092,397,000**	**$4,988,940,000**
Grand Total		**$68,439,196,000**	**$129,649,018,000**

14.1.2 Population and Housing Units

Table 14-2 depicts estimates for population and housing units for those 2010 Census blocks that intersect the 1 percent (100-year) and 0.2 percent (500-year) delineations from the FEMA digital Q3 Flood data. Compared to the overall eighteen-county population along the coast, 27 percent of the population lives in the 100-year floodplain while 56 percent live in the 500-year floodplain.

Additionally, Figure 14-1 shows the index for social vulnerability to environmental hazards (SoVI®) of populations within the study area as compared to the nation as a whole. This information was developed by the Hazard & Vulnerability Research Institute and shows the uneven capacity for preparedness and response and where resources might be used most effectively to reduce the pre-existing vulnerability. SoVI® also is useful as an indicator in determining the difference in recovery from disasters for various populations of residents.

The index synthesizes 30 socioeconomic variables, which the research literature suggests contribute to reduction in a community's ability to prepare for, respond to, and recover from hazards. SoVI® data sources include primarily those from the U.S. Census Bureau. Seven significant components explain 72 percent of the variance in the data. These components include race and class, wealth, elderly residents, Hispanic ethnicity, special needs individuals (including nursing home residents), Native American ethnicity, and service industry employment.

This index indicates that Region 1 has a low social vulnerability when compared within the nation. Regions 2, 3, and 4 indicate a high or medium – high SoVI® when compared within the U.S. Region 4 is especially vulnerable due to the high rates of poverty.

14.1.3 Shoreline Restoration Measures

Several shoreline protection and restoration measures such as beach nourishment and dune restoration could be analyzed for potential economic benefits derived from CSRM and/or increases in recreational use. CSRM can be accomplished by analyzing how projects can reduce

Table 14-2 – Population and Housing Units for the 100- and 500-Year Flood Events

	100-Year		500-Year	
County	**Housing Units**	**Population**	**Housing Units**	**Population**
Orange	21,005	49,341	43,004	99,676
Jefferson	21,496	52,001	67,027	164,230
Chambers	7,345	18,828	13,956	36,560
Harris	390,710	1,009,754	847,782	2,183,885
Galveston	63,592	119,149	113,709	239,122
Brazoria	51,627	132,770	82,951	218,968
Region 1 Subtotal	**555,775**	**1,381,843**	**1,168,429**	**2,942,441**
Matagorda	9,429	15,809	13,793	25,462
Jackson	3,976	7,860	6,538	12,662
Victoria	12,090	29,081	20,716	49,794
Calhoun	6,055	8,706	11,327	17,967
Region 2 Subtotal	**31,550**	**61,456**	**52,374**	**105,885**
Aransas	6,604	6,974	13,861	16,833
Refugio	579	1,050	1,385	2,711
San Patricio	7,848	18,202	14,547	34,447
Nueces	29,147	59,998	52,216	110,695
Kleberg	4,179	9,453	6,652	14,876
Region 3 Subtotal	**48,357**	**95,677**	**88,661**	**179,562**
Kenedy	154	246	161	269
Willacy	4,588	11,786	4,736	11,866
Cameron	49,058	123,800	78,379	208,723
Region 4 Subtotal	**53,800**	**135,832**	**83,276**	**220,858**
Grand Total	**689,482**	**1,674,808**	**1,392,740**	**3,448,746**

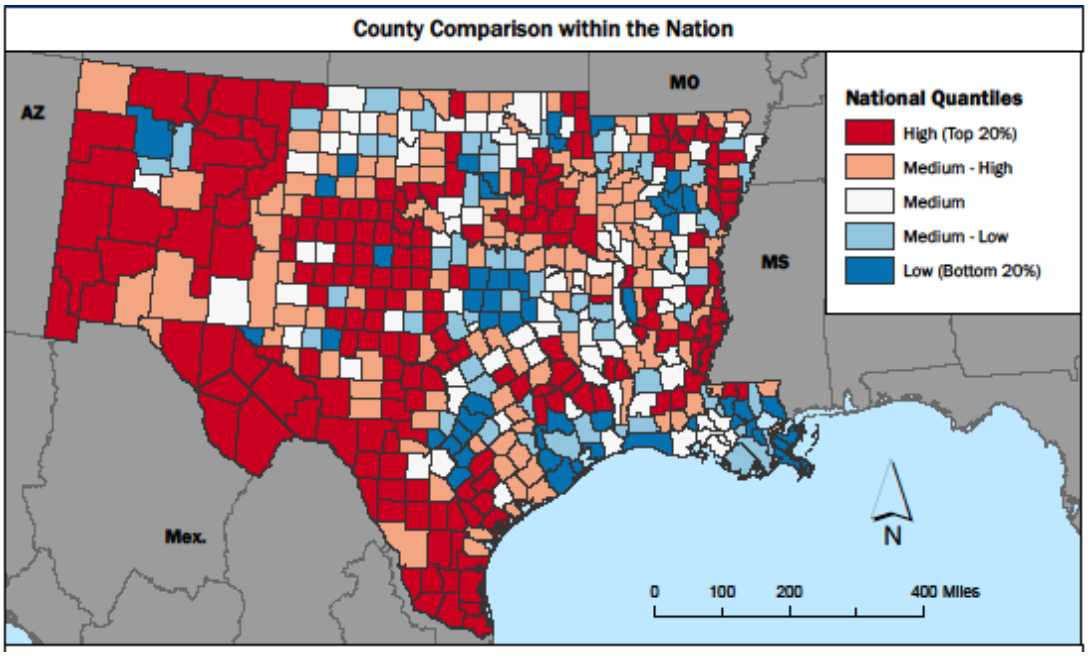

Figure 14-1 – Social Vulnerability to Environmental Hazards
Source Hazards & Vulnerability Research Institute Based on U.S. Census 2010 and American Community Survey, 2006-2010

erosion, inundation, and wave impacts. Such measures can reduce the annual damages to structures and property by placing beach fill on the beach, underwater, or as dunes. These dune and beach nourishment measures can also attract additional recreational users thereby adding to storm reduction benefits to create economically viable alternatives by optimizing benefits relative to costs. The USACE-certified tool for analyzing these benefits during the feasibility phase would be Beach-fx which evaluates the physical performance and economic benefits and costs of shore restoration projects. The following alternatives have the potential to generate both CSRM benefits: B3 (Brazoria County Dune/Beach Restoration, G5 and G6 (Galveston County Dune/Beach Restoration, M1 (Matagorda County Sargent Dune/Beach Restoration, CA1 and CA2 (Calhoun County Indianola and Port O'Connor Beach Restoration), NA1 and NA2 (Nueces County North Padre Island and Corpus Christi Dune/Beach Restoration), and CM1 and CM 5 (Cameron County Adolph Thomae Jr Park Shoreline Restoration and South Padre Island Dune/Beach Restoration).

14.2 Measures Developed

14.2.1 Region 1 Measures

From the ongoing Sabine Pass to Galveston Bay feasibility study, potential projects for the Sabine area were identified and included new Gulf CSRM measures and ER measures such as beach nourishment, dune restoration, Chenier ridge restoration, sediment management, shoreline armoring, and submerged nearshore breakwaters. Additionally, inland structural barriers, reconstruction of existing and construction of new regional hurricane protection systems, local surge risk reduction measures systems, raising roads as surge or overwash protection barriers, GIWW erosion protection, marsh restoration, and salinity/water control structures were included in this area.

Similar potential projects for the Galveston area were developed to include various restoration measures such as beach nourishment, dune restoration, beach ridge restoration, sediment management, shoreline armoring, and submerged nearshore segmented breakwaters, as well as Gulf and inland structural barriers, reconstruction of existing and construction of new regional hurricane protection systems, local surge risk reduction measures systems, raising roads as surge or overwash protection barriers, GIWW erosion protection, and marsh restoration. Specific targets include but are not limited to the shoreline west of Rollover Pass and near Fort Travis. Additional potential projects include development of a comprehensive regional sediment management plan for the Galveston Bay system and Gulf shoreline. Viability of Gulf shoreline projects is dependent on the sponsor's ability to acquire easements and compliance with CBRA.

Potential projects for the Brazoria area included various Gulf CSRM and restoration measures such as beach nourishment, dune restoration, sediment management, shoreline armoring and

submerged nearshore breakwaters. Specific targets include Quintana/Bryan Beach, Surfside Beach, and Follets Island. Additionally, structural measures similar to those listed above for the Sabine area will be included for the Brazoria area.

Some costs for these projects developed for the Region 1 measures included Operations and Maintenance (O&M) costs over a 50-year period of analysis. Others were taken directly from proponent's studies of potential problems and do not include O&M costs.

14.2.2 Region 2 Measures

Potential projects for the Matagorda Bay area were developed to include various restoration measures such as beach nourishment, dune restoration, beach ridge restoration, sediment management, and shoreline armoring, as well as Gulf and inland structural barriers, GIWW erosion protection, and marsh restoration. Aquatic ecosystem impacts associated with future changes in water supply and water quality in the mid-coast estuaries could also be evaluated under a future feasibility study under this authorization. Such a study could identify potential hydrologic modification to enhance circulation and tidal exchange, for example. Additional potential projects include development of a comprehensive regional sediment management plan for the Matagorda Bay system and Gulf shoreline. Some costs for these projects were developed using the unit costs from the Region 1 measures, which included O&M costs over a 50-year period of analysis. Others were taken directly from proponent's studies of potential problems and do not include O&M costs.

14.2.3 Region 3 Measures

Potential projects for the Corpus Christi Bay area were developed to include various restoration measures such as beach nourishment, dune restoration, beach ridge restoration, sediment management, and shoreline armoring, as well as Gulf and inland structural barriers, GIWW erosion protection, and marsh restoration. Aquatic ecosystem impacts associated with future changes in water supply and water quality in the mid-coast estuaries could also be evaluated under a future feasibility study under this authorization. Such a study could identify potential hydrologic modification to enhance circulation and tidal exchange, for example. Additional potential projects include development of a comprehensive regional sediment management plan for the Corpus Christi Bay system and Gulf shoreline. Some costs for these projects were developed using the unit costs from the Region 1 measures, which included O&M costs over a 50-year period of analysis. Others were taken directly from proponent's studies of potential problems and do not include O&M costs.

14.2.4 Region 4 Measures

Potential projects for the Laguna Madre/ Padre Island area were developed to include various restoration measures such as beach nourishment, dune restoration, beach ridge restoration, and sediment management, as well as GIWW erosion protection, marsh restoration, water quality management. Some costs for these projects were developed using the unit costs from the Region 1 measures, which included O&M costs over a 50-year period of analysis. Others were taken directly from proponent's studies of potential problems and do not include O&M costs.

14.3 Alternative Analysis

14.3.1 Region 1 Alternatives

The early analysis for the Sabine Pass to Galveston Bay study resulted in a screening-level initial array of alternatives with initial implementation costs, economic benefits, and environmental benefits. This information was gathered from ongoing studies for the existing Freeport and Vicinity Hurricane Flood Protection project and a county-wide CSRM for the Orange area. Additionally, information was collected on other measures, including the Galveston Bay Coastal Barrier, and the Surge Gate and Barrier at the Hartman Bridge. Information on these alternatives is based on conference presentations or other publicly available information.

The economic benefits are the difference between without-project damages that would occur under the existing condition, and residual damages that would occur with a given measure in place. The extent of potential storm surge impacts were mapped using existing Advanced Circulation (ADCIRC) modeling (100-year storm event) recently completed by FEMA under the Flood Plain Map Modernization effort. Future with- and without-project damages to structures, contents, and vehicles were calculated using the Hydrologic Engineering Center – Flood Impact Analysis software package which analyzes consequences for a given flood event, in this case, a 1 percent (100-year) annual exceedence probability.

Environmental benefits for structural measures providing risk reduction from a 100-year storm event were calculated using the acreages of wetlands impacted as identified by the ADCIRC modeling. Acreages for wetland benefits were calculated using GIS shape files based on the future with-project flood depth grids. The shape files were used to clip wetland acreage from the 2012 National Wetlands Inventory dataset. Some measures are intended to improve the resiliency of barrier islands and floodplains by preserving and/or restoring marsh or preventing marsh erosion. The effectiveness of these areas in attenuating storm surge could not be modeled with the 100-year storm event. Therefore, the acres of marsh restoration were based on the acres of marsh or barrier islands that would be restored. Other measures would raise roadways on barrier islands and headlands by about 6 feet. These barriers would have minimal risk reduction effect against a 100-year storm, but they would have a significant effect as a first line of defense

for storms of lower magnitude such as 10-, 20-, 30-year events. The higher roadbeds would prevent scouring and salinity insults to fresher wetland environments over a large area inland from the roadway. Hydraulics and Hydrology (H&H) modeling was not conducted to determine areas that would benefit by measures for the smaller but more frequent storm events. The wetland acre benefits for these measures assume that the raised highways would protect the marshes inland up to the vicinity of the GIWW.

Table 14-3 presents a summary of the cost, economic benefits and environmental impacts for some of the potential alternatives. The ongoing Sabine Pass to Galveston Bay feasibility study is focusing on the CSRM alternatives in the Sabine and Freeport areas (Alternatives B2, J1, and J2) so there would be no need for inclusion of those particular areas in the future Coastal Texas study. However, the other alternatives, including the CSRM for Galveston County, as well as ER for the entire region, are not being addressed in the ongoing feasibility study and could be included in the Coastal Texas study. Additionally, no estimate was developed for the environmental impacts for a release of hazardous materials from this facility if it is impacted by a storm. This information is not readily available and would have to be developed in any future feasibility-level study to more accurately reflect the value and impact of protection of these facilities. As demonstrated in Table 14-3 all of these alternatives support a continued study of the Galveston Bay area into feasibility. No benefit-to-cost ratios (BCRs) are included for these alternatives.

14.3.2 Region 2 Alternatives

Several CSRM and ER alternatives have been identified for this region. Costs of the plans have been developed using a cost per linear foot or cost per acre of marsh restoration from the Sabine Pass to Galveston Bay study or costs taken directly from other proponent's studies. Table 14-4 presents the alternatives, their costs, and benefits. No BCRs were available for these alternatives.

For the CSRM, Alternative M1 consists of an 8-mile long beach restoration project to protect the GIWW. Erosion is expected to breach the existing Sargent Beach erosion protection project and beach face that protects navigation on GIWW within 50 years and would impact residential developments in the area. Alternative CA1 would protect the City of Indianola, Port O'Connor, Palo Alto, and the Port Lavaca bayfront while CA2 would protect residences and a park facility in Port O'Connor. Economic benefits could not be easily calculated for these specific projects. However, economic values within the surge zones previously presented in Table 14-1 indicate that there are over $3 billion of property in the region located within the 1 percent annual exceedence probability zone that could benefit from protection.

Table 14-3 – Region 1 Sabine Pass to Galveston Bay Alternatives

Alternative Number	Alternative Name	Alternative Description	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* (acres)
		CSRM Alternatives			
B1	Brazoria Co - CSRM Levee at Chocolate Bayou	Levee system	472,997,000	5,109,000	125
B2	Brazoria Co - Freeport and Vicinity, Texas Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	123,784,000	2,195,837,000	0
B3	Brazoria Co CSRM Dune/Beach Restoration	Dune/beach (6.3 mi)	661,282,000		635
G1	Galveston Co - Closing Rollover Pass	Fill channel (0.25 mi)	6,873,000		42
G2	Galveston Co - CSRM Ring Levee -City of Galveston	Levee System	556,116,000	3,296,295,000	300
G3	Galveston Co - Raising Road (SH 146) for Low Level Surge Risk Reduction	Road raising (17 mi)	563,080,000	3,073,296,000	2,900
G4	Galveston Co - Texas City, Texas Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	36,985,000	2,139,338,620	0
G5	Galveston Co Beach/Dune Restoration	Dune/beach (43.8 mi)	2,862,653,000		950
G6	Galveston Seawall Dune-Beach Restoration	Dune/beach (7 mi)	453,368,000		235
G7	Galveston Region - Galveston Bay Coastal Barrier	Levee system (52 mi) & navigation gate	6,232,500,000	14,042,424,000	121,000
G8	Galveston Region - Surge Gate and Barrier at Hartman Bridge	Levee system (5 mi) & navigation gate	801,842,000	3,054,181,000	3,200
J1	Jefferson Co Port Arthur and Vicinity Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	64,148,000	4,446,704,000	0
J2	Sabine Region CSRM Levees	Levee system	1,743,500,000	1,535,553,000	7,400
		ER Alternatives			
B4	Brazoria Co - Bastrop Bay Shoreline Protection	Shoreline protection (0.9 mi)	20,420,000	-	40
B6	Brazoria Co GIWW Breakwaters	Breakwaters (3.3 mi)	219,877,000	-	1,110
B7	Brazoria Co GIWW Island Restoration	Island Restoration (131 acres)	18,202,000	-	215
C1	Chambers Co Shoreline Restoration	Shoreline protection (22 mi)	137,121,000	-	600
G9	Galveston Co (Bolivar) Marsh Restoration	Marsh creation (1995 ac)	62,608,000		1,955
G10	Galveston Co (Island) Marsh Restoration	Marsh creation (2466 ac)	99,436,000		2,466

Alternative Number	Alternative Name	Alternative Description	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* (acres)
G11	Galveston Co (West Bay) Marsh Restoration	Marsh creation (6002 ac)	144,369,000		6,002
G12	Galveston Co GIWW Breakwaters	Breakwaters (27.5 mi)	185,188,000		1,089
G13	Galveston Co GIWW Island Restoration	Island restoration (393 ac)	23,818,000		393
J3	Jefferson Co - GIWW Breakwaters	Breakwaters (1.9 mi)	181,509,000	-	761
J4	Jefferson Co - GIWW Island Restoration	Island restoration (42 ac)	3,542,000	-	64
J5	Jefferson Co - Marsh Restoration	Marsh creation (9304 ac)	145,729,000	-	9,304
J7	Jefferson Co Restore Beach Ridge	Ridge restoration (33.8 mi)	33,027,000	-	20,200
J8	Jefferson Co Hydrologic Restoration of Salt Bayou	Siphons	11,711,000	83,752,000	65,500
O1	Orange Co - GIWW Breakwaters	Breakwaters (3.3 mi)	20,480,000	-	50
O2	Orange Co - GIWW Island Restoration	Island restoration (131 ac)	10,215,000	-	131

*Environmental Benefits calculated as number of wetland acres protected by measure

Table 14-4 – Region 2 Matagorda Bay Alternatives

Alternative Number	Alternative Name	Alternative Description	Total Cost ($)	Environmental Benefits* (acres)
CSRM Alternatives				
M1	Matagorda Co Dune/Beach Restoration – Sargent Beach	Dune/Beach Restoration (8 mi)	861,851,000	4,250
M2	Matagorda Co - Mouth of Colorado to 3-Mile Cut Beach Restoration	3 Gulf shoreline groins & beach nourishment (3 mi)	25,657,000	182
CA1	Calhoun Co Dune/Beach Restoration - Indianola Beach	Beach Restoration (0.5 mi)	67,990,000	
CA2	Calhoun Co Dune/Beach Restoration - Port O'Connor King Fisher Beach	Beach Restoration (0.7 mi)	61,287,000	
ER Alternatives				
CA3	Calhoun Co. – Matagorda Island Restoration	hydrologic restoration	19,200,000	150
CA4	Calhoun Co - Redfish Lake on Carancahua Bay	Breakwaters (3 mi)	130,218,000	300
CA5	Calhoun County – Keller Bay	Breakwaters (3 mi)	$18,100,000	4,100
CA6	Calhoun Co – Chester Island in Matagorda Bay	Rookery island restoration (30 acres) and breakwaters	$17,000,000	30
M3	Matagorda Co. – Matagorda Bay - Half Moon Oyster Reef Restoration	Oyster reef (75 ac)	9,600,000	75
M4	Matagorda Co - Dressing Point Island - Rookery Restoration	Restore island (25 ac)	4,988,000	25
M5	Matagorda Co. - hydrologic modification	hydrologic restoration		

The ER alternatives include beach restoration, oyster reef and bird rookery island restoration, increase of circulation within marsh areas, as well as construction of protective breakwaters. Each of these alternatives would protect or restore essential habitat.

14.3.3 Region 3 Alternatives

Several CSRM and ER alternatives have been identified for this region. Costs of the plans have been developed using a cost per linear foot or cost per acre of marsh restoration from the Sabine Pass to Galveston Bay study or costs taken directly from other proponent's studies. **Error! Reference source not found.** presents the alternatives, their costs, and benefits. No BCRs were available for these alternatives.

For the CSRM, Alternative N1 consists of an 0.8-mile long beach restoration project to protect several hotel properties while Alternative N2 would protect Corpus Christi Beach. Economic benefits could not be easily calculated for these specific projects. However, economic values within the surge zones previously presented in

Table 14-5 – Region 3 Corpus Christi Bay Alternatives

Alternative Number	Alternative Name	Alternative Description	Total Cost ($)	Environmental Benefits* (acres)
CSRM Alternatives				
N1	Nueces Co - North Padre Island dune/beach restoration	Dune/beach restoration (0.8 mi)	76,627,000	4,250
N2	Nueces Co - Corpus Christi Beach	Beach restoration (0.5 mi)	50,780,000	29
ER Alternatives				
A1	Calhoun Co. - Copano Bay Oyster Reef Restoration	Oyster reef (150 ac)	19,200,000	1,955
N3	Nueces Co - Nueces Delta Shore protection	Breakwaters (3.5 mi)	21,100,000	140
N4	Nueces Co - Shamrock Island Restoration	Breakwaters (2.0 mi)	2,500,000	270
N5	Nueces Co. - hydrologic modification	hydrologic restoration		
R1	Refugio Co - Aransas River Delta Marsh Restoration	Marsh creation (375 acres)	33,407,000	375
R2	Guadalupe River Delta Preservation and hydrologic restoration	Breakwaters (1.3 mi)	59,258,000	6,800
SP1	San Patricio Co -Redfish Bay Marsh Restoration	Breakwaters (4.6 mi)	27,940,000	2,500

Table 14-1 indicate that there are almost $2.9 billion of property located within the 1 percent annual exceedence probability zone in Nueces County that could benefit from these protection alternatives.

The ER alternatives include construction of protective breakwaters in several locations to prevent future erosion of habitat. These proposed breakwaters would be located just off of the Nueces Delta edge, around rookery islands in Corpus Christi Bay, around the Guadalupe River Delta, and in Redfish Bay. Additional alternatives included oyster reef restoration in Copano Bay and marsh restoration in the Aransas River Delta. Each of these alternatives would protect or restore essential habitat, including the critical habitat of the endangered whooping crane (Guadalupe River Delta).

14.3.4 Region 4 Alternatives.

Several CSRM and ER alternatives have been identified for this region. Costs of the plans have been developed using a cost per linear foot or cost per acre of marsh restoration from the Sabine Pass to Galveston Bay study or costs taken directly from other proponent's studies. Table 14-6 presents the alternatives, their costs, and benefits. Economic benefits for the South Padre Island Beach Restoration were available from a prior USACE study effort and is included in the table.

Table 14-6 – Region 4 Laguna Madre Alternatives

Alternative Number	Alternative Name	Alternative Description	Total Cost ($)	Economic Benefits ($)	Environmental Benefits* (acres)
		CSRM Alternatives			
CM1	Cameron Co - Shoreline Protection-Adolph Thomae Jr. Park	Bulkhead (0.3 mi)	1,092,000		3
CM5	South Padre Island Beach Restoration	Periodic Beach Renourishment on South Padre Island over 50 years	83,000,000	874,120,000	
		ER Alternatives			
CM2	Cameron Co - Bahia Grande Hydrologic Restoration	Widening/deepening pilot channel (0.5 mi)	1,750,000		15,000
CM3	Cameron Co - Bird and Heron Islands Restoration	Breakwaters (0.8 mi), mangrove restoration	6,110,000		20
CM4	Cameron Co - Three Islands Restoration	Island restoration (330 acres)	65,835,000		330
W1	Willacy Co - Mansfield Island Restoration	Breakwaters (0.3 mi)	12,966,000		35

For the CSRM, Alternative CM1 consists of a shoreline protection alternative in Adolph Thomae Jr. County Park on the Arroyo Colorado channel to complete bank stabilization in order to protect the county park. This would also protect property in Laguna Atascosa NWR. Park facilities and infrastructure are in critical danger of being lost due to vessel traffic, flooding and storm surges. Continual impact caused by these actions could compromise recreational opportunities for this area and for thousands of visitors.

Alternative CM5 includes costs and benefits developed in a prior USACE study effort and would provide beach renourishment to the beach of South Padre Island, which have been experiencing a recent average erosion rate of 18 feet per year. This area is periodically renourished during maintenance dredging of the BIH entrance channel, which provides material suitable for use on the beach. The material is either placed in a nearshore feeder berm that is located within the depth of closure of the shoreline or directly on the eroding beaches, depending on whether the City of South Padre Island is able to pay the incremental cost to place the material directly onto the beach. Placement in the feeder berm, which is considered the least cost disposal plan, allows nearshore transport to move some of the material onto the beach. This incremental cost has been about $2 to $3 million per dredging cycle and occurs about every 1.5 years. This renourishment effort is limited by the quantity of suitable maintenance material available per cycle resulting in limited reaches of shoreline being nourished. Despite this regular maintenance material renourishment effort, the beach continues to erode. Identification of alternative sand sources may allow for the entire shoreline to be renourished and become more stable. There are 567 structures that are projected to be affected by erosion over a 10-year period of analysis that was

used in the previous study with a total replacement value of $150 million. Left unimpeded, erosion will cause loss of structures and land over time.

The ER alternatives include restoration of islands in Cameron and Willacy Counties along with protective breakwaters for these islands and restoration of hydrologic flows into the Laguna Madre.

14.4 Federal Interest of CSRM Alternatives

The CSRM alternatives identified in this study would reduce the risk of coastal storm damage to industries and businesses critical to the nation's economy and protect the health and safety of Texas communities. Specifically, reevaluation of the existing levee systems in the Freeport, Texas City, and Jefferson County HFPS to provide resiliency and improvements to increase the level of protection provided, as well as the consideration of new levee systems would reduce coastal storm flooding and provide additional life and safety benefits to the areas within the levee system. Dune and beach restoration focused in developed areas along the entire Texas coast would provide a buffer to lessen impacts of coastal storms. Road raising, levees, and navigation surge gates could be combined in such a way to decrease the storm surge effects within Galveston Bay and provide CSRM benefits to the development along Galveston Island, the west side of Galveston Bay, as well as the Houston Ship Channel infrastructure in the northern part of the bay. In developing these CSRM alternatives, consideration will be given to the beneficial use of dredged material from the nearby navigation projects (both deep-draft and shallow-draft). Use of dredged material as a resource could benefit future channel improvement projects as well as O&M placement needs and could result in cost savings to both the CSRM projects and navigation projects.

All of the benefits expected with these alternatives are covered in the USACE high priority CSRM mission and could be developed in such a way as to be consistent with Army and budget policies. Continued study at the feasibility level would further develop the array of alternatives with economics and BCRs to determine the alternatives or groups of alternatives which would best provide CSRM benefits.

14.5 Federal Interest of ER Alternatives

The national significance of ecological resources that would be addressed by this study must be established in order to confirm a Federal interest in continuing to evaluate ER alternatives in the feasibility phase. Federal interest in potential ER alternatives in the study area has been identified by the recognition of significance from national and regional perspectives. Potential measures that could be pursued include those which restore sediment and raise marsh elevations, protect marsh shorelines from erosion, restore wetland hydrology, preserve habitat for Endangered Species Act threatened and endangered species such as the endangered whooping crane, piping

plover, and green, hawksbill, loggerhead, Kemp's ridley, and loggerhead sea turtles. The following information on the significance of resources addressed is presented to support the significance determination and to establish a Federal interest.

These measures would preserve special aquatic sites recognized as nationally significant by the Clean Water Act, as well as preserving exceptionally scarce and declining estuarine intertidal and emergent marsh as determined by the latest USFWS/National Oceanic and Atmospheric Administration (NOAA) status and trends report (Dahl and Stedman, 2013). Based on this study, estuarine marsh is more vulnerable and increasingly more scarce than wetlands in general. There was a 35 percent increase in the rate of decline of saltwater wetlands over the period between 1998 and 2004. The increased loss rate is attributed to accelerated losses in the Gulf of Mexico region, where the estimated rate of saltwater wetland loss more than doubled between 2004 and 2009. These losses account for 99 percent of all saltwater wetland losses to open water over that time period.

Beach and dune restoration would reduce risk of storm damages, would protect similar estuarine marsh habitats that are located just inland from the beaches, and would preserve and/or increase critical habitat for threatened, wintering populations of the piping plover. Restoration of bird rookery islands, as well as all of the other measures discussed above, would benefit areas identified as a Habitat of Major Concern under the North American Waterfowl Management Plan, as well as many species identified as Birds of Conservation Concern. Most would also help to restore or preserve shallow waters designated as EFH under the Magnuson-Stevens Conservation and Management Act.

Restoration of oyster reef provide restore estuarine shell substrate, another type of EFH recognized as nationally significant. Oyster reef is declining nationally, with most remaining reef located on the Gulf Coast in Texas and Florida. Worldwide, it has been estimated that 85 percent of oyster reefs have been lost (Beck et al. 2011). The oyster reef restoration projects would contribute to NOAA's National Shellfish Initiative, which is working nationally to protect and restore oyster populations. Seagrass beds are another special aquatic site recognized as nationally significant by the Clean Water Act and the Magnuson-Stevens Conservation and Management Act; they are considered vegetated shallow water EFH.

Regional and local support of these measures is demonstrated by numerous ER plans, including but not limited to: the Galveston Bay Plan of the Galveston Bay Estuary Program; the Coastal Bend Bays Plan of the CBBEP; the Gulf Coast Joint Venture: Chenier Plain Initiative, Texas Mid-Coast Initiative, and Laguna Madre Initiative, Habitat Conservation and Coastal Public Access Plan for the San Antonio Bay System, Salt Bayou Watershed Restoration Plan, and the Bahia Grande Restoration Plan. Criteria for institutional, public and technical recognition developed for each of the ER measures are presented in Appendix A. Federal interest in

potential ER alternatives in the study area has been established and further evaluation of ER alternatives is recommended for the feasibility phase.

14.6 Potential Sponsors for Alternatives

A single non-Federal sponsor is not likely to be identified for the Coastal Texas feasibility phase due to the extensive study area and the broadly varying project purposes. However, Table 14-7 matches the list of the alternatives by region previously identified in this report with potential sponsors who may be interested in that specific project. Additionally, these potential sponsors were matched to the alternatives in matrix form in Table 14-8 to more easily identify the alternatives of interest to a specific sponsor.

Matagorda County, Cameron County, Jefferson County, and the Cities of South Padre Island and Galveston have expressed an interest in being a non-Federal sponsor for the future study in their respective regions and have provided letters of intent stating such. GLO has also provided a letter of intent (LOI) expressing an interest in serving as a non-Federal sponsor along with these regional partners. Appendix B includes copies of each LOI received for the future Coastal Texas feasibility study. The City of Corpus Christi Nueces County, and Texas Department of Transportation have also expressed an interest in being a non-Federal sponsor for future projects, although no LOIs have been submitted to date.

Table 14-7 – Alternatives Matched to Potential Sponsors

Region	Alternative Number	Project Purpose	Alternative Name	Alternative Description	Potential Sponsor
1	B1	CSRM	Brazoria Co - CSDRM Levee at Chocolate Bayou	Levee system	GLO, Brazoria County, Brazoria County Conservation & Reclamation District 3
1	B2	CSRM	Brazoria Co - Freeport and Vicinity, Texas Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	GLO, Brazoria County, City of Freeport, Velasco Drainage District
1	B3	CSRM	Brazoria Co - CSDRM Dune/Beach Restoration	Dune/beach (6.3 mi)	GLO, Brazoria County, City of Surfside, TPWD
1	G1	CSRM	Galveston Co - Closing Rollover Pass	Fill channel (0.25 mi)	GLO, Galveston County, TxDOT
1	G2	CSRM	Galveston Co - CSDRM Levee -City of Galveston	Levee System	GLO, Galveston County, City of Galveston
1	G3	CSRM	Galveston Co - Raising Road (SH 146) for Low Level Surge Protection	Road raising (17 mi)	GLO, Galveston County, Harris County
1	G4	CSRM	Galveston Co - Texas City, Texas Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	GLO, Galveston County, City of Texas City
1	G5	CSRM	Galveston Co - Beach/Dune Restoration	Dune/beach (43.8 mi)	GLO, Galveston County
1	G6	CSRM	Galveston Seawall Dune-Beach Restoration	Dune/beach (7 mi)	GLO, Galveston County, City of Galveston
1	G7	CSRM	Galveston Region - Galveston Bay Coastal Barrier	Levee system (52 mi) & navigation gate	GLO, Galveston County, City of Galveston, Harris County, City of Houston
1	G8	CSRM	Galveston Region - Surge Gate and CSDRM Levee at Hartman Bridge	Levee system (5 mi) & navigation gate	GLO, Harris County, City of Houston, Port of Houston Authority
1	J1	CSRM	Jefferson Co - Port Arthur and Vicinity Hurricane Flood Protection Project Reevaluation	Reevaluate levee system	GLO, Jefferson County, Jefferson County Drainage District 7
1	J2	CSRM	Sabine Region CSDRM Levees	Levee system	GLO, Orange County, Jefferson County, Jefferson County Drainage District 7
1	B4	ER	Brazoria Co - Bastrop Bay Shoreline Protection	Shoreline protection (0.9 mi)	GLO, Brazoria County, Ducks Unlimited
1	B6	ER	Brazoria Co - GIWW Breakwaters	Breakwaters (3.3 mi)	GLO, Brazoria County, TxDOT, Ducks Unlimited
1	B7	ER	Brazoria Co - GIWW Island Restoration	Island Restoration (131 acres)	GLO, Brazoria County, TxDOT
1	C1	ER	Chambers Co - Shoreline Restoration	Shoreline protection (22 mi)	GLO, Chambers County, Galveston Bay Estuary Program, Galveston Bay Foundation
1	G9	ER	Galveston Co (Bolivar) - Marsh Restoration	Marsh creation (1995 ac)	GLO, Galveston County, TxDOT, Galveston Bay Estuary Program, Galveston Bay Foundation
1	G10	ER	Galveston Co (Island) - Marsh Restoration	Marsh creation (2466 ac)	GLO, Galveston County, Galveston Bay Estuary Program, Galveston Bay Foundation
1	G11	ER	Galveston Co (West Bay) - Marsh Restoration	Marsh creation (6002 ac)	GLO, Galveston County, TxDOT, Galveston Bay Estuary Program, Galveston Bay Foundation, The Nature Conservancy
1	G12	ER	Galveston Co - GIWW Breakwaters	Breakwaters (27.5 mi)	GLO, Galveston County, TxDOT, Ducks Unlimited
1	G13	ER	Galveston Co - GIWW Island Restoration	Island restoration (393 ac)	GLO, Galveston County, TxDOT
1	J3	ER	Jefferson Co - GIWW Breakwaters	Breakwaters (1.9 mi)	GLO, Jefferson County, TxDOT, Ducks Unlimited
1	J4	ER	Jefferson Co - GIWW Island Restoration	Island restoration (42 ac)	GLO, Jefferson County, TxDOT
1	J5	ER	Jefferson Co - Marsh Restoration	Marsh creation (9304 ac)	GLO, Jefferson County, Ducks Unlimited
1	J7	ER	Jefferson Co - Restore Beach Ridge	Ridge restoration (33.8 mi)	GLO, Jefferson County, Ducks Unlimited
1	J8	ER	Jefferson Co - Hydrologic Restoration of Salt Bayou	Siphons	GLO, Jefferson County, TxDOT, Ducks Unlimited
1	O1	ER	Orange Co - GIWW Breakwaters	Breakwaters (3.3 mi)	GLO, Orange County, TxDOT, TPWD
1	O2	ER	Orange Co - GIWW Island Restoration	Island restoration (131 ac)	GLO, Orange County, TxDOT
2	M1	CSRM	Matagorda Co - Dune/Beach Restoration – Sargent Beach	Dune/Beach Restoration (8 mi)	GLO, Matagorda County, TxDOT
2	M2	CSRM	Matagorda Co - Mouth of Colorado to 3-Mile Cut Beach Restoration	3 Gulf shoreline groins & beach nourishment (3 mi)	GLO, Matagorda County
2	CA1	CSRM	Calhoun Co - Dune/Beach Restoration -Indianola Beach	Beach Restoration (0.5 mi)	GLO, Calhoun County
2	CA2	CSRM	Calhoun Co - Dune/Beach Restoration - Port O'Connor King Fisher Beach	Beach Restoration (0.7 mi)	GLO, Calhoun County

Region	Alternative Number	Project Purpose	Alternative Name	Alternative Description	Potential Sponsor
2	CA3	ER	Calhoun Co. – Matagorda Island Restoration	hydrologic restoration	GLO, Calhoun County, Coastal Bend & Bays Estuary Program
2	CA4	ER	Calhoun Co - Redfish Lake on Carancahua Bay	Breakwaters (3 mi) and Marsh Restoration (190 acres)	GLO, Calhoun County, The Nature Conservancy
2	CA5	ER	Calhoun Co – Keller Bay Restoration	Breakwaters (3 mi)	GLO, Calhoun County
2	CA6	ER	Calhoun Co – Chester Island Restoration	Breakwaters (0.9 mi) and island restoration (30 acres)	GLO, Calhoun County, Audubon Society, San Antonio Bay Foundation, Port of Calhoun
2	M3	ER	Matagorda Co. – Matagorda Bay - Half Moon Oyster Reef Restoration	Oyster reef (75 ac)	GLO, Matagorda County, The Nature Conservancy
2	M4	ER	Matagorda Co - Dressing Point Island - Rookery Restoration	Restore island (25 ac)	GLO, Matagorda County, The Nature Conservancy, Audubon Society
2	M5	ER	Matagorda Co - hydrologic modification	hydrologic restoration	General Lane Office, Matagorda County, Calhoun County, Lower Colorado River Authority, San Antonio Bay Foundation
3	N1	CSRM	Nueces Co - North Padre Island dune/beach restoration	Dune/beach restoration (0.8 mi)	GLO, Nueces County
3	N2	CSRM	Nueces Co - Corpus Christi Beach	Beach restoration (0.5 mi)	GLO, Nueces County, City of Corpus Christi
3	A1	ER	Aransas Co. - Copano Bay Oyster Reef Restoration	Oyster reef (150 ac)	GLO, Aransas County, The Nature Conservancy
3	N3	ER	Nueces Co - Nueces Delta Shore protection	Breakwaters (3.5 mi)	GLO, Nueces County, Coastal Bend & Bays Estuary Program
3	N4	ER	Nueces Co - Shamrock Island Restoration	Breakwaters (2.0 mi)	GLO, Nueces County, The Nature Conservancy, Audubon Society
3	N5	ER	Nueces Co - hydrologic modification	hydrologic restoration	GLO, Nueces County, City of Corpus Christi
3	R1	ER	Refugio Co - Aransas River Delta Marsh Restoration	Marsh creation (375 acres)	GLO, Refugio County
3	R2	ER	Refugio Co - Guadalupe River delta preservation and hydrologic restoration	Breakwaters (1.3 mi) and closing of Traylor's Cut	GLO, Refugio County, International Crane Foundation, San Antonio Bay Partnership, The Nature Conservancy, Guadalupe-Blanco River Authority, Texas Parks and Wildlife Department
3	SP1	ER	San Patricio Co -Redfish Bay Marsh Restoration	Breakwaters (4.6 mi)	GLO, San Patricio County, Texas Parks & Wildlife Department
4	CM1	CSRM	Cameron Co - Shoreline Protection-Adolph Thomae Jr. Park	Bulkhead (0.3 mi)	GLO, Cameron County
4	CM5	CSRM	South Padre Island Beach Restoration	Periodic Beach Renourishment on South Padre Island over 50 years	GLO, City of South Padre Island, Cameron County
4	CM2	ER	Cameron Co - Bahia Grande Hydrologic Restoration	Widening/deepening pilot channel (0.5 mi)	GLO, Cameron County, Brownsville Navigation District
4	CM3	ER	Cameron Co - Bird and Heron Islands Restoration	Breakwaters (0.8 mi), mangrove restoration	GLO, Cameron County, Brownsville Navigation District
4	CM4	ER	Cameron Co - Three Islands Restoration	Island restoration (330 acres)	GLO, Cameron County, The Nature Conservancy, Audubon Society
4	W1	ER	Willacy Co - Mansfield Island Restoration	Breakwaters (0.3 mi)	GLO, Willacy County, The Nature Conservancy, Audubon Society

Table 14-8 – Potential Sponsor Matrix

Region 1																													
Potential Sponsor	**CSDRM Alt.**													**ER Alt.**															
	B1	B2	B3	G1	G2	G3	G4	G5	G6	G7	G8	J1	J2	B4	B6	B7	C1	G9	G10	G11	G12	G13	J3	J4	J5	J7	J8	O1	O2
Brazoria County	X	X	X											X	X	X													
Brazoria County Conservation & Reclamation District 3	X																												
Chambers County																	X												
Ducks Unlimited														X	X						X				X	X	X		
Freeport, City of		X																											
Galveston, City of					X				X	X																			
Galveston Bay Estuary Program																	X	X	X	X									
Galveston Bay Foundation																	X	X	X	X									
Galveston County				X	X	X	X	X	X	X								X	X	X	X	X							
Harris County						X				X	X																		
Houston, City of										X	X																		
Jefferson County												X	X										X	X	X	X	X		
Jefferson County Drainage District 7												X	X																
The Nature Conservancy																				X									
Orange County													X															X	X
Port of Houston Authority											X																		
Surfside, City of			X																										
Texas City, City of							X																						
Texas Department of Transportation				X											X	X		X		X	X	X	X	X			X	X	X
Texas GLO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Texas Parks & Wildlife Department			X																									X	
Velasco Drainage District		X																											

Table 14-8 – Potential Sponsor Matrix (cont.)

	Region 2 - 4																								
	Region 2													Region 3							Region 4				
Potential Sponsor	**CSRM Alt.**		**ER Alt.**									**CSRM Alt.**		**ER Alt.**							**CSRM Alt.**		**ER Alt.**			
	M1	M2	CA1	CA2	CA3	CA4	CA5	CA6	M3	M4	M5	N1	N2	A1	N3	N4	N5	R1	R2	SP1	CM	CM5	CM2	CM3	CM4	W1
Audubon Society								X		X						X									X	X
Brownsville Navigation District																							X	X		
Aransas County														X												
Calhoun County			X	X	X	X	X	X			X															
Cameron County																					X	X	X	X	X	
Coastal Bend & Bays Estuary Program					X										X	X										
Corpus Christi, City of													X				X									
Guadalupe-Blanco River Authority																			X							
International Crane Foundation																			X							
Lower Colorado River Authority											X															
Matagorda County	X	X							X	X	X															
The Nature Conservancy						X			X	X				X											X	X
Nueces County												X	X		X	X	X									
Port of Calhoun								X																		
Refugio County																		X	X							
San Antonio Bay Foundation								X			X															
San Antonio Bay Partnership																			X							
San Patricio County																				X						
South Padre Island, City of																						X				
Texas Department of Transportation	X																									
Texas GLO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Texas Parks & Wildlife Department																			X	X						
Willacy County																										X

15. KEY FEASIBILITY STUDY ASSUMPTIONS AND ASSOCIATED UNCERTAINTIES

More detailed key feasibility study assumptions will be developed during the feasibility phase. Some key assumptions for the study of a barrier system such as that considered in the Galveston Bay area have been developed and are listed below. The feasibility study costs are a gross estimate for each discipline which was developed using the SMART Planning and 3x3x3 rule from WRRDA 2014. The PMP for the feasibility phase will be developed to more accurately identify the scope and cost of the future study.

The key uncertainties for the feasibility phase are:

- H&H Modeling – the modeling effort will adequately capture hydraulics, hydrology, water quality, and sediment transport processes for the existing conditions and proposed alternatives over the period of analysis. Reduced, screening level analyses may be employed where the risk of doing so is acceptable;
- The environmental impact analysis of CSRM alternatives would evaluate potential impacts to estuarine aquatic systems as well as direct impacts of construction;
- RSLR - While the future rate of RSLR in the study area is uncertain, it must be considered in project planning. RSLR consists of two components: global (eustatic) sea level rise and local subsidence. The uncertainty in the rates of eustatic sea level rise is evident in the variability of the different modeled rates given for the NRC (NRC, 1987) projections and the 2007 IPCC. A similar degree of uncertainty exists with the rate of local subsidence; and
- Use of technical data developed by others - The PDT would maximize use of technical data developed by local stakeholders. For example, in the Galveston region, planning efforts have begun at multiple research entities, including Texas A&M University at Galveston and the Severe Storm Prediction, Education and Evacuation from Disasters Center. Additionally, the Gulf Coast Community Protection and Recovery District has begun an effort to collect existing technical data within the study area using a $3.9 million grant from GLO to develop order of magnitude economic benefit and cost data for projects throughout Region 1. The scope of work for the feasibility study would leverage information from all of these ongoing studies. If the data and technical outputs from these ongoing studies are to USACE's standard, this information could be used to decrease the cost of the feasibility effort.

Consideration of these key uncertainties will inform development of the PMP with the risks being captured in the study risk register developed by the PDT.

16. FUTURE PROJECT IMPLEMENTATION

The Coastal Texas study area covers the entire Texas coast with its varied and numerous problems and opportunities. The four distinct regions which are covered in this study were divided based on major bay systems and habitats. A potential feasibility study for both CSRM and ER opportunities has been identified within these four regions and are discussed by region below. This comprehensive feasibility study will be performed through partnering with a number of non-Federal sponsors, some of which are focused on a specific area while others have a more comprehensive interest in the entire coast. The non-Federal sponsors who have submitted a LOI (included in Appendix B) stating their willingness to work with USACE to develop the scope and enter into a FCSA agreement for the comprehensive Coastal Texas Feasibility Study include:

- GLO (coastwide)
- City of Galveston (Region 1)
- Matagorda County (Region 2)
- Cameron County (Region 4)
- City of South Padre Island (Region 4)

In future implementation of the Coastal Texas feasibility phase, a systematic approach to the Galveston Bay area should be developed because of the ongoing study of the improvements to the Houston Ship Channel (HSC). This approach would tie all of the existing and future projects for the HSC and Coastal Texas together in order to share the dredged material resources for project implementation. The Coastal Texas and HSC future feasibility studies could be formulated as to design Coastal Texas projects which utilize material from the HSC project, as well as future channel maintenance. This connection between the studies has the potential to lessen the placement needs for the HSC while providing a nearby material source for the various ER and CSRM project features such as marsh restoration, beach and dune renourishment, barrier island creation, levee construction, etc. within the entire Galveston Bay system. This systematic cross-project formulation could greatly improve operational efficiencies with the costs for the blended features being segregated for allocation to the appropriate authorities.

Although other studies are not being conducted concurrently, there may be similar opportunities to leverage dredged materials from three other authorized channel deepening projects (Sabine-Neches Waterway, Freeport Harbor, and Corpus Christi Ship Channel) and one with an approved Chief's Report (Brazos Island Harbor). Additionally, material from maintenance or future improvements to the GIWW could present similar opportunities. Material from these proposed projects could be incorporated as sources for alternatives in future Coastal Texas feasibility studies.

The future Coastal Texas Protection and Restoration Feasibility Study will also provide regionally based strategies and measures that may offer additional mitigation options for USACE Regulatory permit applicants to consider provided they are consistent with the requirements of the Mitigation Rule (33 CFR 332).

Additionally, an interim result of the comprehensive feasibility study of the entire coast of Texas could be the identification of the problems, needs, and opportunities in the study area to be used as a "Master Plan" for the State of Texas in future planning efforts. These interim results will provide:

- Early external communication to advance dialogue on shared vision values among Coastal Texas constituents/agencies to inform the way forward, and
- Early rollouts of general authority actions for pursuit with non-Federal sponsors to begin realizing benefits.

Because of the extensive study area and the complication of studying some of the problems which were already identified in Region 1 during the Sabine Pass to Galveston Bay feasibility study, it is expected that the Coastal Texas feasibility study would greatly exceed the $3 million, 3-year study effort that is now standard for USACE studies. Below is a discussion on each region's component to the study and the estimated costs for that component. Discussion of the comprehensive feasibility study cost is included in Section 17.

16.1 Region 1

In the Coastal Texas Region 1 portion of the future feasibility study, the alternatives included CSRM projects in the Galveston area and ER for the entire region. The Sabine Pass to Galveston Bay Feasibility Study previously identified and prioritized the potential projects within this region (with current focus on CSRM projects in the Sabine and Freeport areas). During the 3x3x3 exemption process for this ongoing feasibility study, the costs to complete the study in focused areas and at various risk levels were identified. All remaining CSRM alternatives in the Galveston area are considered a high priority for any future study due to the impact of a coastal storm to this region. However, the cost needed to properly study these Galveston CSRM alternatives at a feasibility level is expected to be significantly more than the recommended $3 million cost limit. The future feasibility study of the Galveston area was deferred from consideration in the ongoing Sabine Pass to Galveston Bay Feasibility Study to allow further progress on analyses, data collection, and models currently under development by others in the Galveston region. Leveraging these ongoing efforts would help to lower the cost of a USACE feasibility study. Therefore, the future Coastal Texas study would consider all CSRM and ER alternatives in the Galveston Bay area identified but not evaluated in the Sabine Pass to Galveston Bay Feasibility Study.

Barrier alternatives in the Galveston Bay area include extremely large and complex structures that are very challenging to construct, operate, maintain, and adapt. If future conditions are realized outside the range of the expected uncertainties, very costly and time-consuming modifications or replacements would be required. Additionally, CSRM benefits may not be realized as quickly as similar benefits for competing alternatives if implementation of these complex barriers takes longer than that for these competing alternatives. This delayed implementation could result in people and property suffering unnecessary risk exposure. A strategy utilizing multiple lines of defense should be considered in the feasibility phase rather than focusing on only structural options for CSRM in this area.

The GIWW shoreline protection for the entire Region 1 (Jefferson, Galveston, and Brazoria Counties) was considered the highest ER priority due to the degradation of the existing marsh and shoreline. The study of ER opportunities for Jefferson County has begun in a separate feasibility study in which scope for the study and development of the FCSA is already underway. Therefore, the ER opportunities for Jefferson County are assumed to be addressed in this separate effort. Only ER opportunities for Galveston and Brazoria Counties will be considered in the Coastal Texas feasibility study.

The City of Galveston has provided a LOI expressing interest in partnering with other sponsors to address problems and opportunities in the Houston/Galveston area. GLO has also provided a LOI expressing an interest in being a partner with the regional sponsors.

16.2 Region 2

In Region 2, Matagorda County has agreed to be a sponsor and provided a LOI for any CSRM or ER studies. The highest priority of the CSRM alternatives for future study would be a focus on shoreline restoration in Matagorda County (M1 and M2). Oyster reef restoration (CA3 and M3) would be the ER focus of future study. Additional sponsors may be needed to support further study of the Calhoun County CSRM and ER opportunities. It is expected that the study effort for the Region 2 component of the study could be completed for a maximum of $3 million in about 3 years.

16.3 Region 3

In Region 3, the recommended CSRM focus for future study would be the Nueces County North Padre Island (N1) and other CSRM measures that could be identified within this area. For ER, Alternatives for marsh restoration (R1) and hydrologic restoration (R2) would help protect critical habitat of the whooping crane in the Aransas River Delta and the Guadalupe River Delta. Nueces County and the City of Corpus Christi may have an interest in becoming a non-Federal

sponsor for the Region 3 portion of the future feasibility study but have yet to provide LOIs. GLO may choose to partner on this region's study focus but may not support the same projects that the local interests prefer. Therefore, additional sponsors may be needed to support further study of some of these CSRM and ER opportunities. It is expected that the study effort for the Region 3 component of the study could be completed for a maximum of $3 million in about 3 years.

16.4 Region 4

In Region 4, the highest priority CSRM alternative for future study would be the South Padre Island beach restoration (CM5) while for ER, alternatives which restore hydrologic circulation and bird islands in the Bahia Grande (CM2, CM3) would be the focus. Cameron County and the City of South Padre Island have provided LOIs for sponsorship of a Region 4 portion of the future Coastal Texas feasibility study. It is expected that the study effort for the Region 4 component of the study could be completed for a maximum of $3 million in about 3 years.

17. FEASIBILITY PHASE COST ESTIMATE AND SCHEDULE

According to USACE SMART Planning and the 3x3x3 rule, the feasibility phase for the development of a comprehensive Coastal Texas study would be expected to be completed in 3 years at a cost of $3 million. Considering the coastwide comprehensive requirement of the study authority (WRDA 2007, Sec 4091), completion of such a complicated study over such a broad area is not likely to meet the current regulations and guidelines for USACE feasibility studies. If the study was limited to the 3x3x3 standard, it would be a programmatic effort to identify the problems, needs, and opportunities with no actionable recommendation for construction. Therefore, an exemption package for Congressional notification is expected prior to the execution of the FCSA. The exemption package will be scoped starting from WRRDA 2014, Sec 1001 requirements on SMART Planning in useful increments and for increasing levels of detail linked to the risk register, explaining how risks are progressively bought down to demonstrate a supportable investment decision for recommendation. Existing information, subject matter expertise, parametric tools, and enterprise resources will be used in building the exemption package. The cost share for the Coastal Texas feasibility study will be 50 percent Federal and 50 percent non-Federal.

As discussed previously, it is expected that the costs to complete feasibility-level analyses in Regions 2, 3, and 4 would be about $3 million each. A representative $3 million study cost for each portion is presented by discipline in Table 17-1. More detailed costs will be provided for each regional component in the Coastal Texas Feasibility Study's PMP and potentially adjusted following vertical team alignment.

Table 17-1 – Region 2, 3, or 4
Feasibility Phase Cost Breakdown

Discipline	**Cost ($)**
Project Management	425,000
Planning	425,000
Environmental	450,000
Economics	350,000
Real Estate	150,000
Geotechnical	350,000
Hydraulics & Hydrology	350,000
Cost Engineering	150,000
General Engineering	350,000
TOTAL	**3,000,000**

For Region 1, it is expected that the complexity of the analyses needed to adequately compare an alternative such as a coastal barrier system along the Bolivar Peninsula and Galveston Island shorelines to comparable protection from an inland barrier system resulting in selection of an NED plan would require much larger study costs than those $3 million study costs in Regions 2, 3, and 4. During the ongoing Sabine Pass to Galveston Bay feasibility study, a rough estimate of study costs which focused on the Houston/Galveston CSRM measures was developed for a medium risk effort. This cost totaled approximately $10 million. Table 17-2 presents a breakdown of this $10 million cost by discipline. More detailed costs will be provided in the PMP and potentially adjusted following vertical team alignment.

Table 17-2 – Region 1 Feasibility Phase Cost Breakdown

Discipline	**Cost ($)**
Project Management	600,000
Planning	900,000
Environmental	900,000
Economics	600,000
Real Estate	600,000
Geotechnical	2,600,000
Hydraulics & Hydrology	2,100,000
Cost Engineering	500,000
General Engineering	1,400,000
Work-In-Kind	300,000
TOTAL	**10,500,000**

The combined cost of the comprehensive Coastal Texas feasibility study is presented in Table 17-3. As stated previously, these costs are estimates that will be further refined during the preparation of the exemption package and PMP.

Table 17-3 – Coastal Texas Comprehensive Feasibility Phase Cost Breakdown

Discipline	**Cost ($)**				
	Region 1	**Region 2**	**Region 3**	**Region 4**	**Total**
Project Management	600,000	425,000	425,000	425,000	1,875,000
Planning	900,000	425,000	425,000	425,000	2,175,000
Environmental	900,000	450,000	450,000	450,000	2,250,000
Economics	600,000	350,000	350,000	350,000	1,650,000
Real Estate	600,000	150,000	150,000	150,000	1,050,000
Geotechnical	2,600,000	350,000	350,000	350,000	3,650,000
Hydraulics & Hydrology	2,100,000	350,000	350,000	350,000	3,150,000
Cost Engineering	500,000	150,000	150,000	150,000	950,000
General Engineering	1,400,000	350,000	350,000	350,000	2,450,000
Work-In-Kind	300,000				300,000
Independent External Peer Review	500,000*				500,000
TOTAL	**11,000,000**	**3,000,000**	**3,000,000**	**3,000,000**	**20,000,000**

*IEPR will cover entire study area and has not been broken out by region.

18. LETTERS OF INTENT

Potential non-Federal sponsors willing to pursue a feasibility study described in the Section 905(b) analysis and share in its cost have been identified. LOIs have been received from Jefferson County (separate study underway), Matagorda County, Cameron County, the City of South Padre Island, the City of Galveston, and GLO with the potential for additional sponsors to be identified during the scoping process for the future studies. At that time, the FCSA will be drafted and executed and the feasibility phase can begin.

19 MAY 2015
Date

Richard P. Pannell
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