Laguna Madre Estuary Program Environmental Strategic Plan

GLO Contract 17-184-000-9821

Final Report

Project Team:

Kim D. Jones, Lucy Camacho, Tushar Sinha, Omar Al-Qudah
Texas A&M University Kingsville
Hudson DeYoe, Augusto Sanchez Gonzalez, Jungseok Ho, Javier Guerrero
The University of Texas Rio Grande Valley

September 26, 2018

A publication funded by a Texas Coastal Management Program grant approved by the Texas Land Commissioner pursuant to National Oceanic and Atmospheric Administration Award No. NA16NOS4190174.

Executive Summary

The goal of this effort is to establish a framework of fundamental information and critical ideas to serve as a basis to assist in supporting legislation to found the 29th National Estuary Program for the Laguna Madre of the Gulf coast of Texas.

The National Estuary Program (NEP) was established by the Clean Water Act Amendments of 1987 (Section 320) to protect nationally significant estuaries threatened by development, pollution and overuse. The U.S. Environmental Protection Agency administers the NEP. The Corpus Christi Bay NEP (now the Coastal Bend Bays and Estuary Program) was among the last estuaries accepted into the program in 1992. The advantages of being in the National Estuary Program was start-up funding from the US EPA. Since the 1990s, no new estuaries have been accepted to the program although applications are still taken.

The purpose of the NEP is to combine the knowledge and talents of federal, state, and local government, citizens, industry, agriculture, academics, non-governmental organizations, and other interested parties to develop sound scientific information about an estuary to create effective management solutions to priority problems. The main product of each NEP is a Comprehensive Conservation Management Plan (CCMP) for the estuary, which is used to implement actions to protect and restore the estuary. All twenty-eight estuaries in the NEP are still functioning and have implemented their CCMPs by leveraging their base funding from EPA with funding from various sources.

The Lower Laguna Madre Estuary Program will use the NEP as a model for the development of a comprehensive plan for the enhancement of the Lower Laguna Madre. With population growth and concomitant development pressure in south Texas, the future of the Lower Laguna Madre without an estuary program is problematic. Development of a management plan for the Lower Laguna Madre will enable the region to develop local solutions to local problems.

This baseline report is organized along the lines of the NEP program focused on the three most important foundational elements to establish an NEP for the Lower Laguna Madre. The three primary Thrust Areas are: 1) the national significance of the Laguna Madre estuary system, 2) the needs and goals for a proposed LLMEP, and finally 3) the plan for the sustainability and support to operate and maintain such an NEP. It is hoped that this report can serve as a basis for the development of a CCMP for the Laguna in the future.

The important aspects of the Laguna Madre are highlighted in the report to include its unique positioning with the longest barrier island in the world, South Padre Island, its hypersalinity and resultant biota, its migratory bird habitat and being home to endangered sea turtle species. Current threats to this unique ecosystem are also outlined in the report and include stepped up oil and gas development, a plan for establishment of several new Liquified Natural Gas (LNG) terminals and processing facilities, rapid urbanization, non-point source pollution threats, and a plan for a new second access causeway from the mainland to South Padre Island which is expected to accelerate growth in the region and the Laguna Madre watershed.

The primary co-authors for Thrust Area 1: National Significance, were Hudson DeYoe, Ph.D. from UTRGV School of Earth, Environmental and Marine Sciences and Lucy Camacho, Ph.D., from TAMUK Environmental Engineering; for Thrust Area 2: Needs and Goals, were Tushar Sinha, Ph.D., from TAMUK Environmental Engineering and Jungseok Ho, Ph.D. from UTRGV Civil Engineering; and for Thrust Area 3: Likelihood for Success and Sustainability of the Program were Kim Jones, Ph.D., P.E., Director of the TAMUK Institute for Sustainable Energy and the Environment, and Augusto Sanchez Gonzalez, M.S., C.F.M. Director of Estuary, Environmental and Special Projects – Cameron County region, UTRGV Civil Engineering.

Lower Laguna Madre Estuary Program Strategic Plan

Table of Contents

2. Thrust Area 2 – LMEP Important Needs and Goals

Lower Laguna Madre Estuary Program Strategic Plan

Thrust Area 1: National Significance

1.1. Introduction

Estuaries, the transition zone between fresh and salt water, are among the most productive environments on earth. More than 80% of all fish and shrimp are dependent upon estuaries in some stage of their life cycle. Because of their great productivity, estuaries are prime commercial and recreational fishing areas for the ever-increasing human population. Estuaries are also important for other commercial activities including marine transportation, oil and gas production, and business and residential development. Recreational activities in estuaries besides fishing include ecotourism, contact water recreation and boating.

Along the Texas coast are seven major estuaries with the Laguna Madre being the largest and the southernmost. The Laguna Madre is one of only five hypersaline lagoons in the world (Javor 1989). The Laguna Madre has two parts- the Upper Laguna Madre and the Lower Laguna Madre. The Upper Laguna Madre is part of the area covered by the Coastal Bend Bays and Estuaries Program and is a component of the U.S. EPA National Estuary Program. The Lower Laguna Madre is not currently part of the National Estuary Program despite the fact that the area has experienced rapid economic and population growth in the past 30 years (Fig. 1).

The Lower Laguna Madre is home to most of the seagrass found in Texas. Due to abundant seagrass and good water quality, the lagoon has a very productive fishery and the area is renowned for its recreational fishing. South Padre Island is a popular tourist destination for a variety of reasons- it is close to Mexico, has good beaches, excellent wind sport conditions and ecotourism opportunities, as well as bay and offshore fishing. South Texas is one of the 10 best birding areas in the U.S. (USFWS 2009). The area is home to two ports- the Port of Harlingen and the Port of Brownsville. The Port of Brownsville is the largest land-owning port authority in the U.S. with 40,000 acres and is home to the largest U.S. fabricator of off-shore oil drilling platforms.

South Texas is home to 1,236,246 people (2010), representing about 4.4 % of the population of Texas. Population growth in south Texas along with rapid coastal development (both commercial and industrial) has a variety of existing and potential impacts. Eutrophication impacts can be subtle but include reduction in water quality and loss of seagrass, the backbone of the lagoon ecosystem. More people are coming to the coast to live and enjoy coastal activities which is putting more pressure on local natural resources. People come from all over Texas and the United States to enjoy the fishing which has both positive and negative impacts. The persistent and increasing stress of human use of the lagoon puts pressure on the ecosystem so it is not surprising that residents of south Texas have concerns about the future of the Lower Laguna Madre.

2016 Regional Water Plan - Population Projections for 2020-2070

State, Region and County Summary

Region	County	2020	2030	2040	2050	2060	2070
Region A Total		418,626	461,008	503,546	547,060	592,266	639,220
Region B Total		206,307	213,930	218,928	222,760	226,142	228,973
Region C Total		7,504,200	8,648,725	9,908,572	11,260,257	12,742,283	14,347,912
Region D Total		831,469	907,531	988,859	1,089,197	1,211,979	1,370,438
Region E Total		954,035	1,086,164	1,208,309	1,329,384	1,443,855	1,551,438
Region F Total		700,933	766,612	825,381	884,551	943,798	1,003,347
Region G Total		2,371,064	2,720,696	3,097,007	3,494,544	3,918,197	4,351,042
Region H Total		7,325,314	8,207,700	9,024,533	9,867,512	10,766,073	11,743,278
Region I Total		1,151,556	1,233,973	1,309,681	1,388,867	1,469,843	1,553,652
Region J Total		141,476	153,748	162,999	171,145	178,227	184,595
Region K Total		1,737,227	2,064,522	2,381,949	2,658,492	2,928,400	3,243,127
Region L Total		3,001,465	3,476,548	3,919,536	4,336,127	4,770,185	5,192,028
Region M Total		1,960,738	2,379,222	2,794,939	3,211,938	3,626,385	4,029,338
Region N Total		614,790	661,815	692,982	714,508	731,481	744,544
Region O Total		540,495	594,391	645,980	697,869	750,858	801,719
Region P Total		50,489	52,068	53,137	54,053	54,846	55,522
Texas Total		29,510,184	33,628,653	37,736,338	41,928,264	46,354,818	51,040,173

Figure 1. Population projections for Texas. Region M is south Texas. (TWDB)

1.1.1. What is a National Estuary Program?

The National Estuary Program (NEP) was established by the Clean Water Act Amendments of 1987 (Section 320) to protect nationally significant estuaries threatened by development, pollution and overuse. The U.S. Environmental Protection Agency administers the NEP. The Corpus Christi Bay NEP (now the Coastal Bend and Bays Estuary Program) was among the last estuaries accepted into the program in 1992. The advantages of being in the National Estuary Program was start-up funding from the US EPA. Since the 1990s, no new estuaries have been accepted to the program although applications are still taken.

The purpose of the NEP is to combine the knowledge and talents of federal, state, and local government, citizens, industry, agriculture, academics, non-governmental organizations, and other interested parties to develop sound scientific information about an estuary to create effective management solutions to priority problems. The main product of each NEP is a Comprehensive Conservation Management Plan (CCMP) for the estuary which is used to implement actions to protect and restore the estuary. All twenty-eight estuaries in the NEP are still functioning and have implemented their CCMPs by leveraging their base funding from EPA with funding from various sources.

The Lower Laguna Madre Estuary Program will use the NEP as a model for the development of a comprehensive plan for the enhancement of the Lower Laguna Madre. With population growth and concomitant development pressure in south Texas, the future of the Lower Laguna Madre without an estuary program is problematic. Development of a management plan for the Lower Laguna Madre will enable the region to develop local solutions to local problems.

1.1.2. Major Features of the Region

The Lower Laguna Madre Estuary Program encompasses 59 miles of Texas coastline which besides the lagoon includes Padre Island, the longest barrier island in the world, South Bay and the Bahia Grande, one of the largest marine restoration projects in the U.S. Five counties (Cameron, Willacy, Hidalgo, Kenedy, and Starr) which comprise the watershed that contributes freshwater to the Lower Laguna Madre are included in the program area (Fig. 2). One Federal Reserve, the Laguna Atascosa National Wildlife Refuge and one national park, the Padre Island National Seashore border the Lower Laguna Madre on the west and the east shorelines, respectively.

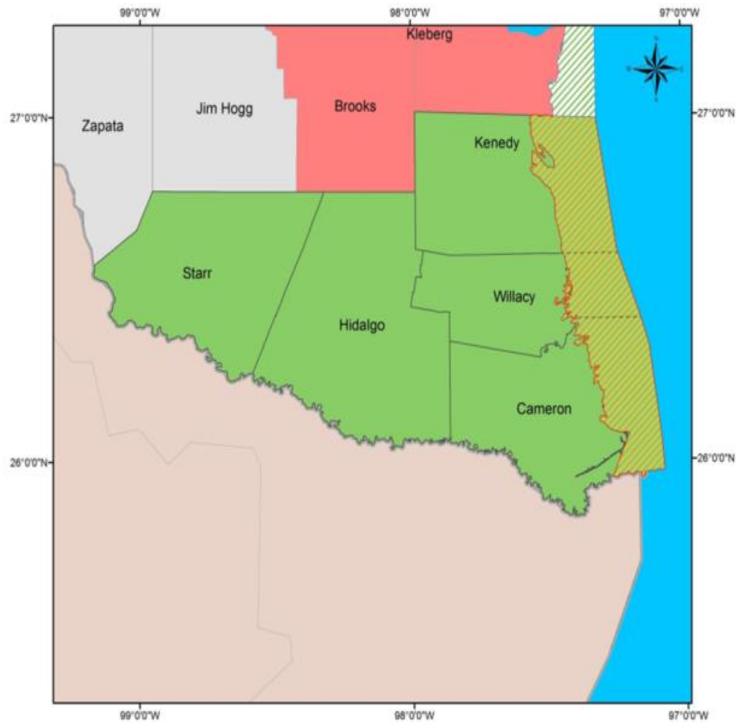

Figure 2. Geographic region of the Lower Laguna Madre Estuary Program.

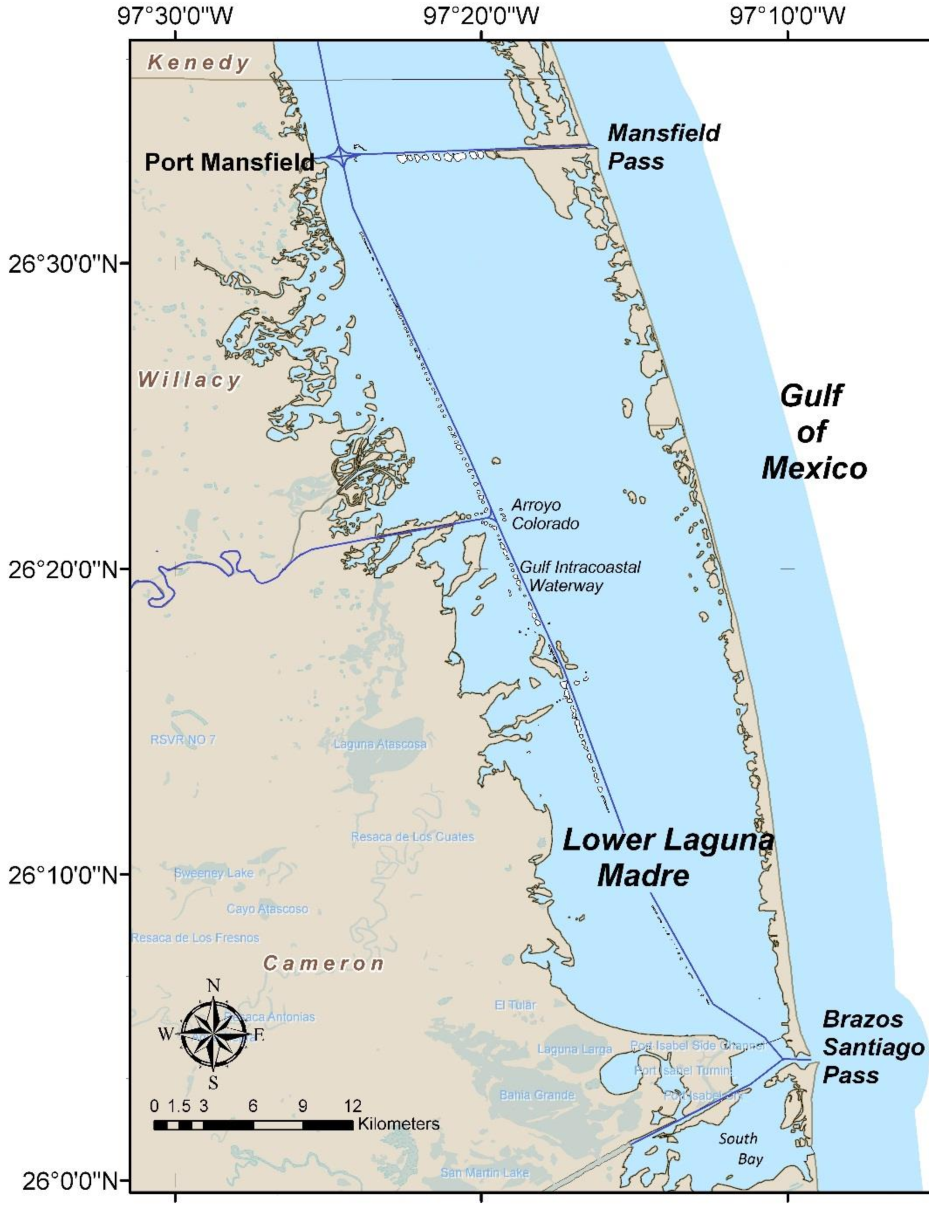

Figure 3. The Lower Laguna Madre.

1.1.3. Highlighted Features of the Lower Laguna Madre

The Laguna Madre is the largest coastal embayment along the Texas coast with a surface area of more than 1,658 km^2 at mean sea level (TDWR 1983)(Table 1). It is one of five hypersaline lagoons in the world. This shallow subtropical lagoon is bordered on the east by a barrier island, Padre Island, the longest barrier island in the world. The western shore of the lagoon consists mostly of sparsely populated and undeveloped semi-arid coastal prairie and rangeland of the Texas mainland.

Table 1. Characteristics of the Lower Laguna Madre (Tunnell and Judd, 2002).

Length	91 km (57 mi)
Average width	8 km (5 mi)
Surface area	MLW 727 km^2 (281 mi^2) MHW 1364 km^2 (527 mi^2)
Average depth	1.4 m (4.6 ft)

The lagoon has been known for its expansive seagrass meadows consisting largely of *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), and *Halodule wrightii* (shoal grass). The Laguna Madre has two basins- the upper (ULM) is separated from the lower (LLM) basin separated by a broad aeolian sand sheet which is covered by a few centimeters of water only during high water periods (Tunnell and Judd 2002). Exchange between the ULM and LLM is severely restricted and occurs via the Gulf Intracoastal Waterway (GIWW), a barge channel constructed in 1948 that cuts through the sand sheet that separates the upper and lower basins (Ward 1997).

The LLM is a shallow bar-built negative estuary. Sources of freshwater and nutrient inflow come from precipitation, direct mainland runoff, the Arroyo Colorado, the North Floodway and the City of Brownsville (Fig. 3). Brazos-Santiago Pass, located at the southern terminus of the LLM, was a natural tidal pass that was deepened for ship traffic and armored with jetties, while Port Mansfield Pass, 60 km to the north is a smaller man-made pass used for recreational boat traffic completed by 1962 (Fig. 3).

There are eight major habitats associated with the LLM- seagrass, jettied tidal inlets, oyster reefs, mangroves, salt marsh, wind-tidal flats, dredge material islands and open bay bottom. The dominant and critical habitat for the LLM is seagrass. Seagrass meadows are very productive while simultaneously providing habitat and nursery for marine animals like blue crabs, shrimp and redfish. They also improve water quality, stabilize sediment and provide a massive amount of surface area for epiphytes i.e., organisms that live on the seagrass leaves. Epiphytes are notable because they are grazed upon by a variety of small marine invertebrates that are food for other marine organisms (Tunnell and Judd 2002). Marine invertebrates and fish are common in seagrass meadows indicating the value of seagrass in maintaining the LLM ecosystem. Green turtles and loggerhead turtles were so abundant in the 1800s that they were leading marine product by weight (Hildebrand 1981). Although many birds use seagrass meadows for feeding and resting, few have been studied. One exception are redheads which make intensive use of shoalgrass during their winter stay (Cornelius 1977).

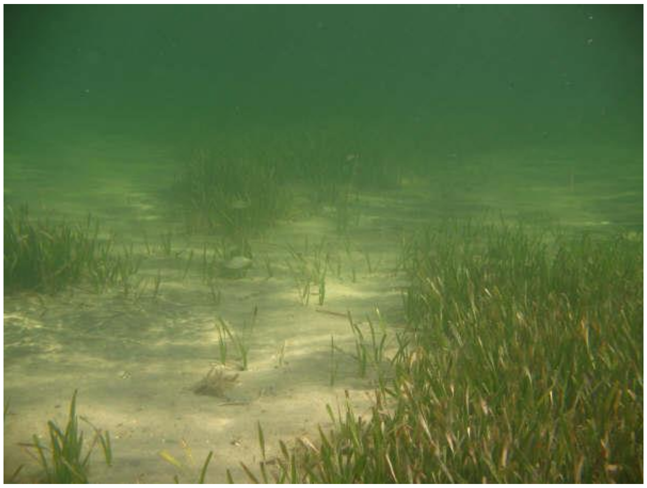

Figure 4. Turtle grass, *Thalassia testudinum.*

Open bay bottom habitat is unvegetated subtidal areas with soft sediments. Based on a 2012 survey, approximately 40% of the LLM is unvegetated bottom habitat (DeYoe and Kowalski, 2013). This is reflects seagrass loss of about 8% from 1994. This habitat strongly interacts with the overlying waters and adjacent habitats like seagrass. The benthic invertebrate community is integral to nutrient recycling for the lagoon and so thereby influences the phytoplankton community. Benthic invertebrates also play an important role as primary consumers and secondary producers so are an important part of the lagoonal food web.

Wind-tidal flats are barren-looking sand/mud flats that border the LLM (820 km^2) mostly on the eastern shore (Fig. 5). They are irregularly flooded due to a combination of astronomical tides, storm tides and wind tides. Between periods of inundation, the flats dry out. During that process salinity of the water sitting on the flats can become very high (>100) due to evaporation (unpublished data). Despite the harshness of the flats, they are very productive. Cyanobacteria mats develop on portions of the flats binding the sediments. For flats that are frequently flooded, a benthic invertebrate community develops that supports shorebirds, wading birds, crabs and fish (Withers, 1994). The flats are essential foraging habitats for wintering and migrating shorebirds and wading birds. State or federally listed endangered or threatened species including piping plovers, snowy plovers, reddish egrets, white-tailed hawks and peregrine falcons depend upon the wind-tidal flats. Tidal flat losses have been recorded for the Upper Laguna Madre between the 1950s and 1979 attributed to sea level rise (White et al. 1983). There is little information on changes in wind-tidal flat area for the LLM. Other losses are due to dredge and fill activities, mitigation projects and commercial development (Cobb 1987).

Figure 5. Wind-tidal flats south of the South Padre Island Convention Center.

There are two jettied tidal inlets for the LLM- Brazos-Santiago Pass and Port Mansfield Pass. The passes are noteworthy because they provide an artificial hard substrate (granite) habitat which is not common in the LLM or along the Gulf coast in Texas. Although the passes provide a migratory route for fish from the Gulf of Mexico to the lagoon, there is a community that has developed on the jetty rocks different from the surrounding habitats. Attached seaweeds are common along with numerous invertebrates i.e., sponges, barnacles, hydrozoans, corals, molluscs, gastropods, crabs and sea urchins. Jetty-associated fish species include sergeant-major damselfish, Atlantic spadefish, spotted jewfish, Atlantic needlefish, halfbeak, toadfish plus occasional tropical species (Alvarado 1996). Gulls and terns use the jetties for resting and feeding. Sea turtles and dolphins also use the jetties for passage and feeding areas (Shaver 1990). The jetties provide a hard substrate habitat for species that would not normally be present in the region.

Figure 6. North jetty at South Padre Island.

Oyster reefs, created largely by the eastern oyster (*Crassostrea virginica*) provide hard substrate for a wide variety of sessile (attached) organisms and protective habitat. There is little information on the organisms other than oysters that inhabit oyster reefs. The oyster population in the LLM is both physiologically and genetically different from other populations of the same species (King et al., 1994). A notable feature is that they are tolerant of hypersalinity unlike other populations of eastern oysters (Breuer 1962). Their uniqueness warrants attention.

Mangroves and salt marshes occur along the edges of the lagoon but mangroves are much more abundant (Fig. 7). The paucity of salt marsh (mostly cordgrass, *Spartina alterniflora*) is due to its inability to tolerate the hypersalinity. Mangroves in this area consists almost exclusively of the black mangrove (*Avicennia germinans*). Mangroves provide substrate and protective habitat for intertidal organisms but there is little information about the organisms that live in and use this habitat.

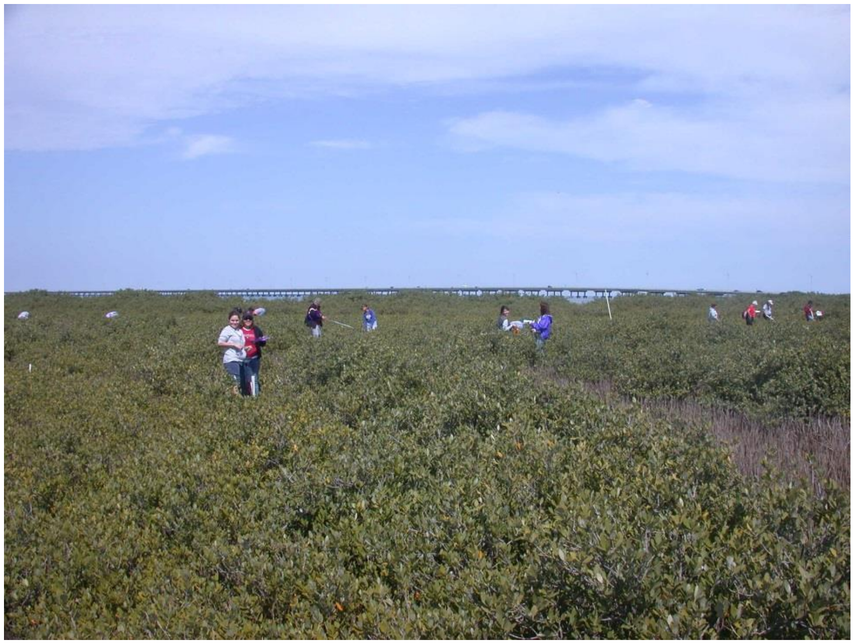

Figure 7. Black mangroves south of the Queen Isabella causeway on South Padre Island.

Biota of the LLM

Fish are an essential and economically important (recreational and commercial) component of the Lower Laguna Madre ecosystem. There are 131 fish species that have been collected in the LLM (Edwards, pers. comm.). There are five fish species of concern, threatened or endangered in the lagoon (TPWD web site). Popular recreational fish species include spotted seatrout, redfish, black drum, southern flounder, Atlantic croaker, and sheepshead. Other commercially important species that depend upon the lagoon include shrimp (brown, pink and white) and blue crabs. Oysters occur in the area but are not commercially viable. There are twenty-six species of whales and dolphins (cetaceans) noted on the south Texas coast but, the bottlenose dolphin is the most common. It as well as other cetaceans are protected species.

In south Texas, over 500 species of birds have been documented. The number of species is high due to the fact that south Texas is part of the Central Flyway for migratory bird species and a transition zone from tropical to temperate climates. There are 29 bird species that are either of concern, threatened or endangered in the project area (TPWD) including the piping plover reddish egret and brown pelican. About 77% of the North American redhead duck population overwinters at the Lower Texas coast using the LLM and coastal ponds for eating and resting (Tunnell and Judd, 2001).

There are five species of sea turtles (Atlantic hawksbill, Green, Kemp's Ridley, Leatherback, and Loggerhead sea turtles) that occur in the LLM project area. All sea turtle species are either threatened or endangered (TPWD: https://tpwd.texas.gov/gis/rtest/)

Invasive species of biota

Brown mussel (Perna perna) is a threat to indigenous shellfish in the LLM region.

Lionfish, which have no known predators (besides human), are the fastest growing coastal invasive in the region. They damage marine aquatic ecosystems by decimating life on reefs (natural and artificial). The jetties associated with Port Mansfield and Brazos-Santiago passes may be suitable habitat for Lionfish and they have been spotted on one of the Brazos-Santiago jetties (R. Kline, pers. comm.).

The area of the LLM has a rich cultural history and some of social strengths for the local population in the area stems from this legacy. Included below is just a brief listing which could be further developed into another section for a later document.

- History of the region
    - Karankawa Indians (gone by mid-1800s)
    - Spanish and Mexican heritage (Balli and ancestors)
    - Texas Republic and land management
        - Ranching (King, Kenedy, Dunn families)
        - Farming started in early 1900s
    - Passes: Brazos-Santiago (1882), Port Mansfield (1962)
    - Causeways (1st finished in 1927)
    - Padre Island National Seashore, created in 1963
    - Refuges, Laguna Atascosa NWR, created in 1946
    - Parks, Adolf Thomae Park, San Martin Lake access
- Archaeological and historical resources exist in the region from these events and population migrations

1.1.4. Economic characterization of the LLM region

The Lower Laguna Madre area of south Texas has been an important economic driver for south Texas as its commercial and sport fishing industries have grown, agricultural activities have expanded through citrus and vegetable growing, oil and gas development upstream has fostered infrastructure growth in pipelines and LNG terminals, and eco-tourism has expanded.

1.1.4.1. Leading commerce, industry and agricultural players

The Ports of Brownsville and Harlingen are busy commercial centers for the region. The oil and gasgas industry, tourism, and Rio Grande Valley growers and crop producers including citrus, sugar cane, and others are large economic drivers for growth and population increases

1.1.4.2. Imminent Projects that will Impact the LLM

Three proposed new Liquified Natural Gas (LNG) plants have been proposed near the Brownsville Ship Channel. The oil/gas industry has been expanding due to increased drilling and pipeline construction associated with the expansion of the Eagle Ford Shale gas and oil strata in South Texas. A proposed 2nd causeway for emergency evacuation and improved access to the community of South Padre Island has been proposed and planned. A new SpaceX facility is being fabricated in Cameron County. All of these new projects will stress water and land resources in the Lower Laguna Madre region.

1.2. Unique aspects of the LLM compared with other estuaries

The National Estuary Program (NEP), an EPA program, currently has 28 estuaries designated as estuaries of national significance. The estuaries are located in the Atlantic, Pacific, and Gulf coasts and also in Puerto Rico. The main purpose of the NEP is to protect and restore the water quality and ecological integrity of the estuaries of national significance. The EPA manages the NEP and provides annual funding, guidance, and technical assistance to the local NEPs. The Coastal Bend Bays & Estuary Program (CBBEP), located in the State of Texas is one of the estuary systems designated as estuary of national significance. The CBBEP joined the NEP in 1994 and since then no other estuary has been assigned the category of being of national significance. The main objective of the CBBEP is to conserve and manage the Coastal Bend Bays of South Texas (TNRCC, 1998).

There are seven major estuaries in the Texas coast. They include the Sabine-Neches Estuary (known as Sabine Lake), the Trinity-San Jacinto Estuary (known as Galveston Bay), the Colorado-Lavaca Estuary (known as Matagorda Bay system), the Guadalupe Estuary (known as the San Antonio Bay), the Mission-Aransas Estuary, the Nueces Estuary, and the Laguna Madre Estuary. The Mission-Aransas Estuary consists of the Aransas Bay and Copano Bay. The Nueces Estuary consists of the Nueces Bay, Corpus Christi Bay, and Oso Bay. The Laguna Madre Estuary consists of the Upper (including the Baffin Bay) and the Lower Laguna Madre. Minor estuaries include the Christmas Bay (located at the southwestern edge of the Galveston Bay system), Brazos River Estuary, San Bernard Estuary (The San Bernard River and Cedar Lakes complex), East Matagorda Bay, and the Rio Grande Estuary (TWDB, 2017). The major estuaries represent 2,100 square miles of sheltered water with diverse geography, resources, climate, and industry (TNRCC, 1998). The waters and lands adjacent to the Texas coast are rich on petroleum reserves, agricultural land, wildlife, fisheries resources, and recreational opportunities. They are also close to major population centers (TNRCC, 1998). All these estuaries depend on freshwater inflow to maintain a balance. However, for river estuaries water diversion, sediment deposition, or low flow conditions may result in closing the river mouth and cutting off the estuary (TWDB, 2017).

The CBBEP extends from the Gulf surf line from the eastern edge of Mesquite Bay to the Landcut south of Baffin Bay in the Upper Laguna Madre. It consists of three of the seven Texas estuaries, namely, the Aransas, the Nueces, and the Upper Laguna Madre, and is considered a transition zone between the mid- and lower-coast (TNRCC, 1998). These estuaries are flowing into the U.S. Gulf of Mexico, and are important in the provision of relevant resources to the Gulf region (TWDB, 2017). They are biologically, economically productive estuaries, and have a total open water surface area of 607,000 hectares (Texas Department Water Resources, 1981).

The Laguna Madre Estuary, which is located along the lower coast of Texas, covers an area of 280,910 acres and has an average depth of four and a half feet (TWDB, 2017). The estuary is composed of an upper and a lower estuary, which are divided by a coastal land mass known as Saltillo Flats, also referred as the Landcut (TWDB, 2017). The Saltillo Flats is a 21-mile formation of drifting sand dunes in the center of Padre Island that has almost closed the gap between the Island and the mainland, and has divided the Laguna Madre (LM) into the Upper LM and the Lower LM (Laguna Madre, 2017). The major bays within the estuary are Baffin Bay in the Upper Laguna and South Bay in the Lower Laguna. The Lower Laguna Madre is connected to the Gulf of Mexico through the Port Mansfield Channel and Brazos-Santiago Pass (TWDB, 2017). The Upper Laguna Madre extends 80 km northward from the flats to the southeast corner of Corpus Christi Bay. The Lower Laguna Madre extends 95 km southward from the flats to within 5 km of the Mexican border.(Onuf, 2006). The Laguna Madre of Texas combined with the Laguna Madre of Tamaulipas, which begins below the Rio Grande, is the biggest hypersaline bay complex on earth (Patoski, 2008).

Most of the east side of the Laguna Madre is controlled by the Padre Island National Seashore and the Nature Conservancy, and most of the west side is owned by ranches such as the King Ranch as well as the Laguna Atascosa Wildlife Refuge. At the northern and southern ends of the lagoon there is residential and marine development. Intermittent creeks that drain into Baffin Bay are home for row crop agriculture (Onuf, 2006). The conditions of the Laguna Madre have been conserved as relatively pristine due to the stewardship of the King Ranch and other large landholders in the past century and a half, which left most of the shore undeveloped. However some anthropogenic impact is still significant (Patoski, 2008).

Some of the unique aspects of the LLM include it's hypersalinity, it's international border location on migratory paths for waterfowl and other birds and other features. The LLM is one of the most favorable nesting habitats for the endangered Kemp's ridley sea turtle at South Padre Island and more southern shorelines in Tamaulipas, Mexico.

1.2.1. Hypersalinity

An estuary can be defined as a partially enclosed water body formed by the amalgamation of a river or stream and the ocean, when there is a mixing between the saltwater from the ocean and the freshwater from rivers or streams (NOAA, 2008). According to Pritchard (1967), an estuary is a partially enclosed coastal body of water which has a connection with the sea and within which seawater is measurably diluted with freshwater. Because of this connection, there is a difference in the salinity of estuarine water from estuary to estuary, which is subject to change from one estuary to the next depending on many factors (Levinton, 1995).

The major ions which govern the salinity of estuary waters include calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); and three major anions, carbonate (CO_3), sulfate (SO_4), and chloride (Cl). These ions exist in concentrations greater than 1 ppm in seawater. The mixing and transition of freshwater and saltwater in estuaries coupled with various anthropogenic activities such as oil and gas production, and mining, among others, could result in rising concentrations of these major ions in water (Simmons, 2012). This could be toxic to fish and other aquatic animals. Other activities which could increase the concentrations of these ions in estuaries include effluents from the wastewater of industries, leaching, brine disposal from desalination plants, among other activities (Ingersoll et al., 1992).

In the South Texas estuaries, salt concentrations are relatively high because they are situated in arid or semi-arid areas regions with high evaporative losses. In a semi-arid area, evaporation processes are routinely greater than precipitation recharge, leading to the high salt concentrations (Terrell et al., 1989). The high concentration of these salt ions leads to toxicity and has various ways of affecting aquatic plants. There is a possibility of the release of reactive oxygen species and oxidative degradation of plant lipids, which also has an adverse effect on the antioxidative enzymes of plants because of upsets in the anion and cation balance in estuarine waters (Shaw, 2001). Additionally, high salt concentrations in estuarine waters leads to the defoliation of the aquatic plants (Terrell et al., 1989). The optimal salinity concentrations in estuaries depends on the freshwater and saltwater values. Saltwater estuaries have a salinity range of 1-35 parts per thousand (ppt) while freshwater classified estuaries have a salinity range up to 1 ppt (Fondriest Environmental, 2013). The salinities in Gulf of Mexico estuaries range from freshly saline in Sabine Lake to hypersaline in the Laguna and Baffin Bay (Barrera et al., 1995).

The Laguna Madre estuary (LLE) is a unique hypersaline lagoon (saltier than the ocean). It is the only such water body in the nation. It is among a handful that exist worldwide. One of the contributing factor for the laguna's salinity is the shallow depth (Patoski, 2008). The water in the LLM may be saltier than in the ULM, with an average salinity of about 45 ppm, but it the important habitat of abundant snook, tarpon, jackfish, and mackerel (Patoski, 2008). Baffin Bay is a shallow bay, among the estuaries in South Texas. This Bay along with the Laguna Salda, Cayo de Grullo, and Alazan bays, cover about 129 km^2 of the estuary waters. The average depth in this bay is 2.7m. Baffin Bay also has a semi-arid climate, with an average annual rainfall of about 68cm yr^{-1}. A substantial quantity of the freshwater this Bay receives, besides runoff, is from Los Olmos Creek and the release of some permitted outfalls (Texas Water Commission 1992b). The freshwater inflow into Baffin Bay is minimal; hence the bay is subject to hypersaline conditions because evaporation of water in the Bay exceeds precipitation, and it has limited freshwater inflows, and circulation (Shormann 1992). The salinity range of the water contained in this estuary system in the drought period and summer months is ranges from an average ofabout 40 ppt to very hypersaline levels (between 60 ppt to 70 ppt) (Aryal 2001). The dominant sources of environmental threats in this Bay stems from spillage from pipelines, disposal of dredged material, and agricultural activities, and rapid urbanization.

1.2.2 Shallow depths

There are three main estuary types under the classification of water circulation category. They are salt-wedge, slightly stratified and vertically mixed (Levinson, 1999). The salt-wedge estuaries are the least mixed of all the estuaries. In salt-wedge estuaries, weak tidal currents cause a boundary to be created between the freshwater and saltwater, causing the freshwater to flow above the saltwater, out of the estuary (Molles 2002; Ross, 1995). The vertically mixed estuaries have a more dominant tidal current which allows for a nearly complete vertical mixing along the depth of the estuary and lesser salinity variation. Vertically mixed estuaries are mainly large, shallow estuaries (Ross, 1995). The partially mixed or slightly stratified estuaries exists between the vertically mixed and salt-wedge type estuaries. The salinity in this estuary type increases gradually downstream, hence, the salinity is higher at the mouth of these estuaries.

Very deep estuaries are usually slightly stratified (Xavier, 1993; Ross, 1995). The estuaries in the Gulf of Mexico are vertically mixed shallow estuaries (Bianchi et al., 1998).

Based on the geological classification, estuaries can be deltas, fjords, bar-built, coastal plains, and tectonic, among others (Xavier, 1993). Coastal plain estuaries are mainly long and narrow water bodies with many branches created by the gradual drowning of a river system which are developed when river valleys are flooded by sea levels which rise above them (NOAA, 1990). The fjord estuaries are predominantly deep, narrow, highly stratified and are formed by glacial action. Bar built estuaries are usually identified where barrier brings a gap between the ocean and the estuary. Delta estuaries are formed when ocean currents are not able to carry sediments formed at the river mouths (NOAA, 1990). The tectonic estuaries are formed when the sea fills in the vacuum caused from the cracking or folding of the earth crust (Xavier, 1993). The Gulf of Mexico estuaries combine the characteristics of the coastal plain and bar built estuaries. However, Corpus Christi Bay is a bar built estuary because it is separated from the Gulf of Mexico through the Mustang Island (Orlando et al., 1993). The Laguna Madre is fairly shallow. It has an average depth of about 2.5 feet and maximum 5 feet of depth, and covers 609 square miles (Laguna Madre, 2017).

1.2.3. Subtropical Climate

Climatic conditions in the Gulf of Mexico are known to be subtropical, with rainfall ranging from 25 to 38 inches annually. The summer in this region is usually hot and humid while the winter is mostly mild with intermittent freezing (Quenzer et al.,1998). It has been reported that the fragile state of these bays and estuaries are under serious threat, given the combination of rising temperatures, increasing populations and increasing anthropogenic activities, which poses increased pressures on these systems (Barrera et al., 1995).

1.2.4. International Border Location

The strategic location of the LLM near the international border has served to promote and extend many commercial activities along the border. One example is the shrimping industry in Port Isabel, located in the area of the LLM. This industry has served as a gateway not only to South Texas but also to northern Mexico. During the 1960s Port Isabel produced 41 million pounds of shrimps annually. This represented 65% of the state's production. An annual Shrimp Fiesta is held in the city and includes a Blessing of the Fleet. Additionally, Port Isabel is further supported by commercial fishing, tourism, and the petroleum industry (Garza, 2017).

The international border location has prompted some collaboration to protect the LLM. In 1998, the Nature Conservancy collaborated with Pronatura Noreste in Mexico to establish the Flora and Fauna Protected Area-Laguna Madre and Rio Bravo Delta, which is a 1.4 million-acre expanse of the LLM in Tamaulipas, Mexico. The area is currently governed by the National Council of Natural Protected Areas of Mexico (The NC, 2017). An additional 25,000 acres of the upper end of South Padre Island in the Laguna Madre in the U.S. has been protected by efforts of the Nature Conservancy (NC). The U.S. Fish and Wildlife Service was assigned to convert the island parcel into the South Padre Island Unit within the Laguna Atascosa National Wildlife Refuge (NC, 2017). The NC, in collaboration with the USFWS safeguarded more than 2,100 acre within the Bahia Grande Coastal Corridor in the region. This area was protected under the 2012 RESTORE Act for ecological and economic restoration of the Gulf of Mexico in the wake of the 2010 Deepwater Horizon oil spill. The preserved acreage is important to restore the tidal bay system of the Bahia Grande and would allow creating a 7,000-acree wildlife corridor to link the LM to the LRGV. The protected parcel within the Bahia Grande will also serve as a link in between protected lands on both sides of the U.S.-Mexico border. This parcel will eventually become part of the Laguna Atascosa NWR (The NC, 2017).

1.3. Similarities with other estuaries

Despite the unique aspects of the LLM, many of the risks to the health of its estuary ecosystems are similar with many other estuaries in the country.

1.3.1. Eutrophication

Eutrophication occurs when a body of water becomes overly enriched with minerals and nutrients such as nitrogen and phosphorus that induce excessive growth of plants and algae. Sources of nutrients for the Lower Laguna Madre include atmospheric deposition, precipitation, non-point source runoff and water effluent discharges directly into the LLM..

In 1992, the Texas Water Commission (now TWDB) ranked the tidal segment of the Arroyo Colorado, a distributary of the Rio Grande and the largest source of freshwater for the Lower Laguna Madre as the worst of 80 estuaries in Texas for eutrophication and the third worst in overall water quality (TNRCC, 1994). Another potentially significant freshwater source is drainage from the Brownsville watershed that enters the Brownsville ship channel through San Martin Lake and drainage ditches. Nutrient levels from this watershed are substantial (DeYoe, unpub data) but it is unclear how much of that water along with its nutrients enter the Lower Laguna Madre proper.

Excessive nutrients in ungauged inflows have been tentatively implicated in the major losses (20+ %) of LLM seagrass habitat over the last 20 years (BBEST 2013). Seagrass beds are considered to be highly susceptible to nutrient runoff due to the effects of decreased light intensity and build-up of organic matter that can cause noxious sediment conditions (Dunton et al. 2011).

1.3.2. Freshwater Inflows

Estuaries are known as shallow water bodies, characterized by the mixing of freshwater and saltwater, thereby serving as transition zones between them. The union between these two systems, in turn, produces a very valuable and productive ecosystem which is considerably important in meeting economic, recreation, transportation and commercial needs (Weber et al., 1992). The salinity gradients also help in the provision of food for aquatic life by fostering photosynthesis and ensures the stabilization of wetlands associated with the estuaries (Cross et al., 1981). An important aspect of environmental concern in estuaries is the reduced inflows of freshwater. A sufficient amount of freshwater is required to maintain the productivity of estuaries and ensure the transport of required nutrients and sediments. Therefore, the reduction in the amount of freshwater flowing into the estuary can decrease the amount required to mix with the saltwater in the estuaries, leading to very high salt concentrations. Studies have shown salt concentrations in estuaries, exceeding the allowable amount for certain organisms (Bartram 1996). The availability of freshwater is imperative for the provision of nutrients like nitrogen, phosphorus, and organic matter, required for the survival of plants and aquatic animals. These nutrients are required as food for these organisms and as such, mortality is inevitable with minimal or no supply of them by freshwater.

The Laguna Madre estuary, composed of the upper and lower segments, receives 743,000 acre-feet of freshwater inflow per year from two major contributing sources, namely the San Fernando Creek through Baffin Bay in the Upper Laguna Madre and the Arroyo Colorado in the Lower Laguna Madre. Other surrounding coastal watersheds provide additional freshwater to the estuary including the Brownsville watershed. The estuary is located within the boundaries of two Regional Water Planning Groups, including the Coastal Bend Region N and the Rio Grande Region M (TWDB, 2017).

The Rio Grande does not provide freshwater inflows to the LLM, because the River flows directly into the Gulf of Mexico (TWDB, 2011). The total freshwater inflow to the Lower Laguna Madre may include estimates of combined freshwater inflow into the estuary plus precipitation in the estuary watershed. The freshwater inflow balance consists of Combined Inflows plus Precipitation on the estuary minus Evaporation from the estuary. It has been estimated that between 1977 and 2010, the average annual diversion from the LLM represented less than 1% of combined freshwater inflows. Average annual return flows to the estuary represented about 3% of inflows. Average combined surface inflow to the LLM during this period of time was about 523,602 acre-feet per year (minimum of 234,158 acre-feet and maximum 2,726,325 acre-feet in 2010). In the determination of the total freshwater inflow balance, evaporation from the estuary as well as precipitation onto the surface of the estuary are taken into consideration TWDB, 2011). In the LLME, a negative freshwater inflow balance was observed in 30 out of 34 years, which indicates that that evaporation exceeded precipitation and combined inflow to the estuary. In this period, the average annual evaporation was about 1,554,580 acre-feet, and the average annual precipitation was 664,629 acre-feet over the surface of the LLME. The average freshwater inflow balance was then 366,348 acre-feet per year, with a minimum of -1,092,699 acre-feet and a maximum of 2,225,448 acre-feet in 2010 (TWDB, 2011).

Considering the entire Laguna Madre, a negative freshwater inflow balance has been observed in 60 out of the last 70 years, with an average deficit of about -548,652 acre-feet per year, which indicates that evaporation routinely exceeded precipitation and combined inflows to the estuary (TWDB, 2011). Given the negative ecological characteristics of the hypersaline LLME, with seawater flowing in instead of out, rates of flushing are measured in years instead of days, or months like other estuaries (positive estuaries) and therefore perturbations of the system could take years to recover (Tunnell and Judd, 2001).

1.3.3. Marine Navigation

Shipping and other maritime operations are activities of concern in estuaries. The various boating and port activities in the Corpus Christi bays has affected the bay bottoms and disrupted the habitat of life in that region (Montagna et al.,1998). Out of the entire cargo loads transported in these estuaries, over 90 percent are oil and petrochemicals (Jones et al., 1996). There have been reports of accidents between these vessels and pipelines, inadvertently leading to oil spills in estuaries. However, these vessel collisions and spills have been minimal in this bay system (Tunnell et al., 1996).

Waste and debris generated by bay users, dredging, land runoff, and offshore operations, migrates into the estuaries, negatively affecting its aesthetics, and endangering the health of organisms (Amos et al., 1997). Dredging/trawling is focused on the removal of debris and sediments from the bottom of estuarine waters to minimize the exposure of the fish and aquatic animals to these contaminants. This debris is mostly from point source pollution such as spills and industrial discharges or nonpoint source pollution from atmospheric deposition or surface runoff. Although dredging is beneficial to the estuary, it can be a problem when the spoil is not properly managed, required permits have been overlooked, and the disposal is not well planned (NOAA, 2014). Additionally, industrial and municipal discharges release toxic substances into the estuaries, which could either be deposited as sediments or taken up by aquatic organisms in the area.

1.3.4. Gulf Intracoastal Waterway (GIWW)

The Gulf Intracoastal Waterway (GIWW) is a coastal canal from Brownsville, Texas, to the Okeechobee waterway at Fort Myers, Florida. The Texas Portion of the waterway is regulated by the Texas Coastal Waterway Act from 1975 (Leatherwood, 2017). In Texas the GIWW extends from Sabine Pass to the mouth of the Brownsville Ship Channel at Port Isabel, and covers 426 miles. The GIWW has been of major economic significance to Texas and the United States. It was created to meet the needs of a continuous growth of the oil and petrochemical industries along the Texas coast, which required cheap transportation of bulk material. In 1905, Congress provided an authorization to connect already existing canal segments into a continuous channel 9 feet deep and 100 feet wide from New Orleans to Galveston Bay. The canal was extended in 1941 to Corpus Christi Bay. In 1949 it was extended to the Brownsville Ship Channel and also enlarged to 12 feet deep and 125 feet wide (Leatherwood, 2017).

The GIWW provided a permanent water connection between the Upper Laguna Madre to the Lower Laguna Madre in 1949 by dredging a channel through the tidal flats. Likewise, Padre Island became two Padre islands in 1962 through the Port Mansfield Gulf Channel, also known as the East Cut or Landcut carved by the U.S. Army Corps of Engineers 8 miles east of Port

Mansfield (Patoski, 2008; USGS, 2006). The cuts together with currents produced by winds oriented toward the lagoon lowered the bay's salinity. LLM salinities rarely rise above 50 ppt after completion of the waterway (USGS, 2006). However, dredging to create the cuts and waterway caused harm to seagrass, which is the basic building block of marine life in the area (Patoski, 2008; USGS, 2006).

An Interagency Coordination Team (ICT) was created as a result of a lawsuit against the Army Corp of Engineers by the Seagrass Coalition, due to the use of harmful methods used by the Corp to dredge the Laguna Madre to maintain the GIWW. The coalition was created by the Lower Laguna Madre Foundation in 1994 to sue the agency and included state, local and private organizations. After the settlement, the ICT changed the way dredging was performed, which reduced seagrass loss (LLMF, 2017).

The GIWW serves to transport and promote the trade of goods between inland consumers through the Mississippi River system, and with international commerce through the Gulf of Mexico. A record 72 million tons of goods was carried through the canal in 1986. Mainly crude petroleum and petroleum products, along with iron and still, building materials, fertilizers, sulfur, and other bulk products are transported through the waterway. The transport of commodities along the GIWW represented in 1986 a total value of $35.5 billion and utilized a total workforce of 145,000 people. By utilizing the canal for access to the Gulf of Mexico, the commercial fishing fleet produced in 1985 a catch of 100.3 million pounds of shrimp, oyster, crabs, and fin fish, which represented a wholesale value of $176 million. The GIWW also serves as the access to the Gulf for the work boats that support hundreds of off-shore oilrigs. Extensive recreation also occurs through the GIWW. An estimate of 2.4 million boat trips originated in Texas waters in 1980, and 79% of them used the waterway (Leatherwood, 2017).

Texas is in charge of providing sites for the disposal of waste generated through regular dredging to maintain or enlarge the waterway. Disposal of waste has become a major problem since 1986 when all the original disposal sites were filled. Deep-water disposal has been proposed as an option to solve this problem with no significant impact to the environment (Leatherwood, 2017). Over the years, the Lower Laguna Madre Foundation has sought to address the impact on seagrass caused by the GIWW channel dredging, pollution from agricultural runoff, brown tide, oil and gas seismic drilling, and drainage water coming into the Laguna from a shrimp farm in the Arroyo Colorado. The need to ship gasoline by barge on the waterway was eliminated once Valero Corporation built a pipeline from their Corpus Christi refinery to the Rio Grande Valley (Patoski, 2008). Enlarging the canal to 16 feet deep by 150 feet wide had been proposed. The 1949's dimensions of the waterway (12 feet deep and 125 feet wide) were already too restrictive by the 1980s, as barges that tow longer than 1,180 feet or wider than 55 feet were not allowed to cross the waterway (Leatherwood, 2017). With the recent industrial and economic growth in the Gulf of Mexico, this may once again become an issue of concern.

Texas ranked 2nd in the nation in total waterborne tonnage transported, with 486 million tons (21%) of the total U.S. maritime freight volume on both deep-and shallow-draft waterways (TdTX, 2014). From the 78 million short tons moved in 2012, 90% were petroleum and chemical products. Additional commodities transported in 2012 included coal, primary manufactured goods, food and farm products, manufactured equipment and machinery, and waste and scrap products. Given the economic growth in the Gulf of Mexico region, the GIWW was recommended to apply to the U.S. Maritime Administration to be designated as a Marine Highway Project (TdTX, 2014). This designation, although important for economic growth and prosperity in Texas, may pose additional threats to the Laguna Madre system in general and to the LLM in particular.

1.3.5. Algal Blooms

Harmful algal blooms (HAB), also known as red tides and brown tides, are caused by the accumulation of large concentrations of microalgae, particularly dinoflagellates, which impart a red or brown color to the water (Patoski, 2008). This phenomena has been attributed to excessive nutrient levels, reduced circulation and warm temperatures. Occurrence of algal blooms in the LLM can lead to seagrass loss due to the blocking of light. The presence of some algae can be harmful to the aquatic species in the lagoon because some generate toxins that can be transferred through the food web and kill higher forms of life, including zooplankton, shellfish, fish, birds, marine mammals, and also humans that feed on them directly or indirectly. The algae toxins can bioaccumulate in shellfish, such as clams, mussels, oysters or scallops, in levels that can be lethal to the consumers. The toxins can cause paralysis, diarrhea, as well as neurotoxic and amnesic shellfish poisoning (NOAA, 2017). The presence of dinoflagellates has caused the death of millions of fish and poisoning of humans in regions of Texas and Florida. It has been reported that a single red tide event in the Gulf Coast of Florida causes a negative impact to the tourism industry, hotel/motel suppliers, commercial fisheries, and local governments for the expenses of cleaning up the beach, with an estimated cost of $20 million (NOAA, 2017).

A series of efforts have been undertaken by state and private organizations to conduct research related to HAB. The Ecology and Oceanography of Harmful Algal Bloom (ECOHAB) is developing an understanding of the population dynamics and trophic impact of harmful algal species with the purpose of using it as a basis to minimize the adverse impacts on the economy, public health, and marine ecosystems. The Monitoring and Event Response for Harmful Algal Blooms (MERHAB) (sponsored by NOAA) and Harmful Algal Program (sponsored by the Center for Sponsored Coastal Research) is working on building sustainable regional partnerships with access to real-time critical information to mitigate HAB impacts. The HAB Event Response Program supports coastal managers who have to respond to unexpected HABs events (NOAA, 2017).

The Texas brown tide was a persistent feature in the Upper Laguna Madre, particularly in Baffin Bay and Bird Island from 1990 to 1998. The brown tide occurred in the Lower Laguna Madre periodically during that period but has not been a persistent and dominating feature as it was in the Upper Laguna Madre. The unusual persistence of the brown tide is likely due to a combination of long water residence time in the ULM and features of the algae. The LLM has better exchange with the Gulf of Mexico waters and more internal circulation which may account for the relatively brief duration of the brown tide.

Data on Harmful Algal Blooms (HABs) suggests a significant increase in red tides over the last 20 years (Meridith Byrd, TPWD, Coastal Fisheries Division) for the entire Texas coast, including the LLM. The Texas Brown tide impacted the LLM in the early 1990s (Whitledge and Stockwell 1995) and other algal blooms have been regularly encountered (DeYoe, pers. observ.). These indicators put the LLM in the higher range of estuaries with increasing trends in water quality/nutrient enrichment problems. More recently, NOAA's Estuarine Eutrophication Assessment Survey Update Report (2007), essentially an "estuarine report card", stated that the condition of the LLM estuary may have generally improved over the last ten years. However, it concluded that more definitive data are needed to clarify the status of nutrient conditions, phytoplankton blooms (nuisance and HABs), and seagrass epiphyte (growth of microorganisms on leaves) and macroalgal accumulations. Observations by DeYoe (2005, pers. observ.) and Dunton et al. (unpubl. data from 2011 survey) suggest that excessive seagrass epiphyte load and drift macroalgae are a problem in some LLM locations resulting in detrimental effects on seagrass.

1.3.6. Habitat Degradation

The fast growing population in the Brownsville area of Texas have placed at risk, the native habitats of the Lower Laguna Madre as they are rapidly converted for agriculture or development. The main challenges due to habitat degradation include loss of coastal grasslands and native Tamaulipan thornscrub to invasive species, human encroachment and development, and threat of northern aplomado falcon, mottled duck, and the nation's only ocelot population and associated species (FWS, 2017). Ocelot recovery could be supported by thornscrub restoration. Similarly, Northern Aplomado Falcon recovery could be supported by grassland restoration. It has been established that in order to change this species' status from endangered to threatened, a total of 60 breeding pairs are needed. Toward this goal, 30 breeding pairs could be supported in the LLM area with grassland conservation and restoration (FWS, 2017). Restoration of hydrological diversions and development of wetlands are also needed to protect aquatic habitats in the region, including targeted colonial waterbirds, shorebirds, and waterfowl. Restored areas could provide vital food resources and forage for fishery species (FSW, 2017).

Bird nesting Habitat

Degradation of bird nesting habitat can occur when invasive species are spread and established, native vegetation is absent, and nesting sites are invaded by predators. Simultaneous restoration of native vegetation and removal of invasive species could be more efficient to restore nesting habitats. Increase of invasive species and predators have continuously increase in important sites of the LLME due to human activity. Population of predators such as coyotes, raccoons, skunks, and foxes, although native to the region, have increased and have pressure to move to areas of nesting colonies due to human activity and development. This has caused frequent failure of the colonies across the Laguna Madre. By controlling the predator population it would be possible to increase the nesting success (NAS, 2012).

The Gulf Coast Joint Venture has identified targeted birds, which include the reddish egret, migrant shorebirds, midwinter mottled ducks, wintering waterfowl, and other colonial waterbirds that use the Laguna Madre region (FWS, 2017). The Gulf Coast Joint Venture assessed seagrass needs for the waterfowl population in the Laguna Madre area. They established that the disturbance and/or lack of adjacent dietary freshwater will make 44% of existing seagrasses effectively unavailable, which will result in insufficient habitat for the waterfowl. Restoration of estuarine habitats will also improve the conditions for shrimp, blue crabs, oysters, red drum, and other marine species. Likewise, restoration and conservation of agricultural and working ranchlands can contribute to complement and support several state species, such as the northern bobwhite quail, and the white-tailed deer. Ranchlands serve as the connectivity of land, invasive species control, and water conservation efforts (FWS, 2017). Additional restoration efforts identified by the Joint Venture include enhancing the existing network of conservation lands linking the Rio Grande and the South Texas coastal ecosystem to ensure that fish and wildlife resources are sustainable; and reconnect hydrology and watershed diversions, such as the Bahia Grande, and restore wetlands and aquatic habitat for fish and other aquatic and wetland dependent species (FWS, 2017).

Seagrass

The LLM is famous for its lush seagrass beds, which accounted for approx. half of the total seagrass acreage in Texas as of 1996. However, this highly productive habitat actually decreased overall from its peak of 59,153 ha in the 1960s, to 46,558 ha in mid-1970s, and then to 46,624 ha in 1988, as documented by Quammen and Onuf (1993). Seagrass acreage and species composition changed because of dredging the Gulf Intracoastal Waterway (GIWW) and Mansfield Pass, hypersalinity amelioration, and species successional processes in a shallow high-salinity lagoon (this seems to contradict the second factor). These changes in quantity of seagrasses were accompanied by large changes in species composition, with the hypersalinity-tolerant species, shoal grass (*Halodule*), being reduced by over 60% and displaced by manatee grass (*Syringodium*) and turtle grass (*Thalassia*). An updated survey in 1998-2000 [Seagrass Status and Trends for the Laguna Madre, (Onuf 2007)] assessed the total acreage in 2000 at 46,174 ha, very similar to the 1988 level. However, Onuf (2007) concluded that the Lower Laguna Madre seagrasses were still showing effects from water clarity degradation probably from maintenance dredging on the GIWW and nutrient loading from unknown sources. Seagrass acreage has undergone further decline over the last decade, as much as 24% in the region from

Port Mansfield south to around Stover Point. Species composition has also changed significantly for this region, as indicated by almost complete loss of *Thalassia* and *Syringodium*.

The water in the lagoon was historically clear and oligotrophic because there was little freshwater inflow and associated nutrients and turbidity. Over time due to population growth in the LRGV, a Valley-wide drainage system was developed. The main drainage conduit for the LRGV is the Arroyo Colorado, whose flow is largely composed of agricultural and urban runoff and treated effluent. The Arroyo Colorado is the biggest source of freshwater to the Lower Laguna Madre. Excessive amounts of macroalgal biomass has been found in the middle reach of the LLM (DeYoe, unpub data) , which suggests nutrient over-enrichment most likely due to the Arroyo Colorado. In 2002, seagrass was added as an "Aquatic Life Use" in the Texas Surface Water Quality Standards by the TCEQ(EPA, pers comm.). One purpose of adopting seagrass as an aquatic life use is to establish a state-wide routine monitoring plan.

Dredge material beneficial reuse as islands

In the late 1940s during the excavation of the Gulf Intracoastal Waterway (GIWW) dozens of dredge materials islands were created in the Lower Laguna Madre. Over time, islands with sufficient elevation developed vegetation from herbs and cacti to small trees. Many of these islands are now used by colonial waterbirds as rookeries or breeding grounds. These islands are surrounded by shallow water providing habitat for birds feeding on fish and crustaceans. These islands have become critical for the continued survival of many colonial waterbirds.

Wind Tidal Flats

A unique feature of the LLM is its extensive wind-tidal flats covered with cyanobacterial ('blue-green algal') mats. Such wind-tidal flats, occurring in the intertidal zone, basically replace the characteristic intertidal salt marsh habitat existing on the middle and upper Texas coasts which is largely absent in the LLM. These semi-aquatic algal mat systems are well-known for their high primary production and nitrogen fixation which helps support the LLM food webs (Pulich and Rabalais1986). Wind tidal flats are an important habitat for shorebirds and wading bird species such as the piping plover, a threatened species that overwinters on the LLM wind tidal flats. Since the 1980s (White et al. 1986), the integrity of these unique intertidal areas has been degraded by heavy impacts from off-road vehicular traffic and development activities on South Padre Island.

Mangroves

Unlike the rest of the Texas coast, mangroves particularly black mangroves are an important shoreline feature of coastal south Texas. North of the LLM, salt marshes are a common feature of the intertidal zone. In the LLM, largely because of the lack of significant freshwater input and the more mild winter temperatures, black mangroves have largely replaced other vegetation in the salt marsh in the intertidal zone. Mangroves provide significant ecological services such as shoreline stabilization and habitat and nursery for birds and marine fauna.

Seeing that south Texas has most of the mangroves in Texas and the land occupied by mangroves has desirable development potential, it is worthwhile to consider enhanced conservation of mangroves in the region.

Impacts of Non-Point Pollution and the Arroyo Colorado

Limited data is available to assess impairments of the Brownsville-Resaca Watershed as well as the contributing sources of these impairments. There is a lack of available water quality data regarding the resacas, which are ancient distributary channels of the Rio Grande River. The Brownsville-Resaca Watershed is located south of the Arroyo Colorado Watershed and north of the Rio Grande Watershed. It contributes about 25% of the freshwater flow into the Lower Laguna Madre Bay. The Arroyo Colorado receives municipal, industrial, and agricultural wastewater from the Lower Rio Grande Valley. Some of the impairments of the Arroyo Colorado that can also impact the Brownsville-Resaca Watershed include high bacteria levels, low dissolved oxygen, and high nutrient concentrations (nitrogen and phosphorus compounds) in some segments of the watershed (Arroyo Colorado WPP). It has been reported that the concentration of algal biomass is three times greater near the Arroyo Colorado as compared to other areas of the LLM. The TCEQ is currently conducting a total maximum daily load (TMDL) assessment. After implementing a TMDL a reduction in nutrient-loading will benefit the LLM (Onuf, 2006).

1.4. Estuary Health Indicators

Estuary health indicators are used to provide a quantitative and qualitative identification of the ecological conditions and health problems affecting an estuary over time. The indicators are included in the Comprehensive Conservation and Management Plan (CCMP) of the National Estuary Program (NEP), and are unique to each of the 28 NSPs around the Nation (EPA, 2008). These indicators are monitored by collecting and evaluating data after the CCMP of the particular estuary program is implemented. The estuary health indicators can be used as a tool to inform environmental managers, scientists, resource managers, and the public about the conditions of the estuary. The EPA's "Indicator Development for Estuaries" provides a framework to the NEP to select appropriate indicators that are included in the Monitoring Plan of the NEP. The indicators should be linked to the issues and goals that are specific to the CCMP of the estuary program, and they should provide the basis to evaluate progress on CCMP questions. Some types of indicators include worldwide (e.g., global warming), cultural/societal (e.g., changes in human activity), economic (e.g., unemployment levels, industrial production, stock market prices), ecological (e.g., exposure of biological components to stress), environmental (e.g., human health, quality of life, ecological integrity), and programmatic parameters. Indicators from the National Coastal Conditions Reports (NCCR) I and II prepared by the EPA's National Coastal Assessment (NCA) office, which describe the ecological and environmental conditions I US coastal waters, can also be incorporated into the estuary to assist in collecting data on the overall health of the estuary (EPA 2001, 2004). Table 3 shows the main indicators (index) evaluated by the NCA office. The most common ecological indicators that are usually monitored to determine the health conditions of an estuary include water clarity, dissolved oxygen, coastal wetland loss, benthic conditions, sediment contaminants, fish tissue contaminants and eutrophic conditions (NOAA, 2004).

In general, it has been reported that estuaries and coastal ecosystems are in a perilous state (Lotze et al., 2006). Pollution, habitat degradation, climate change, nutrient loading, and food web alterations, among others, have contributed to the water quality degradation in estuaries and has impaired their ecological potency (Koch et al., 2009). The Gulf of Mexico has been reported by several studies as being in poor ecological health (NOAA, 2004). EPA (2003) called the Gulf the dirtiest coastal body of water in America. A more recent study reported the conditions of the Gulf of Mexico as being fair (EPA, 2012). Industrial and coastal development, population growth, overfishing, harmful algal blooms, and pollution are considered to be the principal factors contributing to this stage (NOAA, 2003). The National Coastal Conditions Reports (NCCR) (EPA, 2001, 2004) indicated that less than 10% of surface water penetrates to a depth of 1 meter in several areas in the Gulf of Mexico estuaries. The Environmental Monitoring and Assessment Program (EMAP) (EPA) estimated that about 4% of the bottom waters in the Gulf estuaries had hypoxic conditions. The NCCR evaluation of the Gulf of Mexico reported a score of "poor" for the benthic conditions, coastal wetland loss, sediment loss and fish tissue contamination.

The Lower Rio Grande BBEST (LRGB 2012) concluded that a sound ecological environment had existed in the Lower Laguna Madre since the late 1950s to early 1990s, but that currently, conditions are trending toward a more unsound (or disturbed) environmental condition. It was suggested that water quality issues especially warrant consideration because of the potential for causing impacts on LLM seagrass and algal populations, resulting from the direct effects of nutrient/contaminant loading and salinity regimes, and the indirect effects from nuisance phytoplankton and macroalgal blooms. Particularly, reduced water clarity and salinity reduction affecting submerged vegetation compared to 20 – 30 years ago appears problematic. These stressors may be exacerbated by the increasing trend in LLM water temperatures documented by Tolan and Fisher (2009), an indicator of potential climate change impacts. Further studies and monitoring are needed to demonstrate and quantify the connections between these water quality and water quantity (freshwater inflows) dynamics, and their role in contributing to increasing LLM ecological imbalance.

Table 3. National Coastal Assessment Indicators (EPA, 2008).

Indicator or Index	**Parameter**
Water quality	Nutrients • Nitrogen (dissolved inorganic nitrogen). • Phosphorus (dissolved inorganic phosphorus).
	Chlorophyll-*a*

	Water clarity
	Dissolved oxygen (DO)
Sediment quality	Sediment toxicity • *Ampelisca abdita* (10-day toxicity test
	Sediment contaminants • Metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn) • Organic compounds (acenaphthene, acenapthylene, anthracene, fluorene, 2-methyl naphthalene, naphthalene, phenanthrene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, pyrene, low-molecular-weight polycyclic aromatic hydrocarbon (PAH), high-molecular-weight PAH, total PAHs, 4-4'-dichlorodiphenylethylene (4-4'-DEE), total dichlorodiphenyltrichlorethane (DDT), total polychlorinated biphenyls (PCBs). • Total organic carbon (TOC)
Benthic	Benthic community diversity • Presence and abundance of pollution-tolerant species • Presence and abundance of pollution-sensitive species
Coastal Habitat	Average of the mean log-term decadal wetland loss rate (1780-1990) and the present decadal wetland loss rate (1990-2000)
Fish tissue contaminants	Metals • As, Cd, Hg, Se • Organic compounds

1.4.1. Baselines and Reference Points

The estuarine and wetland ecosystems of the LLM are "relatively sound" thus far with qualified exceptions. Its characteristic ecosystems have exhibited adaptive responses over the past 60+ years, as the lagoon has transitioned from the historical natural conditions of the late 1950s to present. Geomorphological alterations in the 1940s-50s (viz., dredging of channels and passes) have changed the lagoon environment and its characteristic species and habitats. Therefore, the current time frame for evaluation of ecological health of the LLM extends from ca 1960 to present. Conditions observed now can be considered adaptive responses to a more stable, lower-salinity environment, as a result of the absence of the extremely high salinity regimes formerly seen in the pre-1960s era (Carpelan 1967, Quammen and Onuf 1993, Onuf 2007), as well as recent evidence of climate changes (Tolan and Fisher 2009).

Several lines of evidence (seagrass prevalence and productive fishery) support that the Lower Laguna Madre Estuary environment has been "sound" from the early 1960s, but that it appears to be undergoing detrimental changes over the last 15-20 years. Measures of the status of some native species and habitats indicate that impairment of estuarine biologic and chemical processes may be occurring. As one of only 5 historically hypersaline lagoonal estuaries in the world (Tunnell 2001), this unique system is exhibiting recent symptoms of ecological disturbance that are indicative of impacts to its ecological "soundness".

1.4.2. Biological Characterization

Fish Populations

Fish are an essential and economically important (recreational and commercial) component of the Lower Laguna Madre ecosystem. There are 131 fish species that have been collected in the LLM (Edwards, pers. comm.). There are five fish species of concern, threatened or endangered (TPWD).

Long-term maintenance of normal estuarine fishery populations would appear to be possible only within the context of a generally sound estuarine environment. Texas Parks and Wildlife Department compiled a status and trends assessment based upon the 25 years of fishery samples data collected by the TPWD Coastal Fisheries Resource Monitoring Program for the LLM (J. Tolan, TPWD, pers. comm.). The results of this analysis, covering the ten species that numerically comprised > 95% of the individuals collected in all samples from 1982-2010, showed routine fluctuations in catch rates, except for blue crab (*Callinectes sapidus*). Most fisheries communities in the LLM are considered stable and intact, characteristic of the estuarine species of this subtropical area of the lower Texas coast (M. Lingo,TPWD, pers. comm.). With the exception of blue crabs and southern flounder, no significant decreases in the abundance of native species or overall changes in their trophic structure have been observed in the recent past. It is noteworthy, however, that a tropical species, gray snapper, has increased significantly in recent years in the LLM (Tolan and Fisher 2009). Additionally, some prized tropical game fish species, notably snook and tarpon, were also encountered more frequently. Documented increases in tropical fauna are thought to be related to increasing wintertime water temperatures, which have shown an upward trend from the early 1990s until 2009 (ca. 1 ºC rise over this period). Taken together, these observations would all appear to reflect a change to a warmer environment beginning to dominate the LLM (Tolan and Fisher 2009).

Birds

In south Texas, over 500 species of birds have been documented. This large number of species is due to the fact that south Texas is part of the Central Flyway for migratory bird species and a transition zone from tropical to temperate climates. There are 29 bird species that are either of concern, threatened, or endangered in the project area (TPWD). Washover passes created by the passage of storms and hurricanes in the dune structure along South Padre Island provide nesting areas for snowy plovers and roosting areas for threatened piping plovers. These washovers are part of the coastal mosaic needed by wintering piping plovers that includes Gulf beaches, such as South Padre Island, and the bayside wind-tidal flats across the dunes along the

Lower Laguna Madre. This coastal mosaic also benefits many other shorebirds including willet, dunlin, plover, sandpiper, dowitcher, sanderling, curlew, turnstone, avocet, yellowlegs, stilt, phalarope, oystercatcher, killdeer, whimbrel, and red knot (POI, 2017). There are five bird species of concern (peregrine falcon, red knot, piping plover, snowy plover and Wilson's plover) that live in or near the LLM (USFWS, 2016).

About 77% of the North American redhead duck population overwinters on the lower Texas Coast foraging in the LLM and resting and drinking in coastal fresh- or brackish water ponds (Tunnell and Judd, 2001). Redheads feed primarily on the roots and rhizomes of a seagrass (shoalgrass) so the continued presence of redheads in south Texas depends heavily on the distribution and abundance of shoalgrass. Coastal ponds are essential for redheads since they require intake of freshwater daily to avoid osmotic stress.

The reddish egret, a resident of the Texas Gulf coast and foraging habitat specialist, lives on the shores of the Lower Laguna Madre. This beautiful species had nearly disappeared in the United States by the turn of the twentieth century when their feathers were prized adornments for women's hats. Currently, their population in the LLM numbers about 2000. Reddish egrets forage only in very shallow, coastal waters and they are often found on inundated wind-tidal flats or along their periphery. During winter, reddish egrets often continue to occupy the habitat, even if water depths become too deep for them to forage. As a part of the Reddish Egret Conservation Plan (USFWS), their habits and habitats are currently being studied.

From an economic perspective, ecotourism is a substantial business in south Texas. Bird watchers come from all over the world to south Texas to see birds and butterflies. A survey conducted in off-peak ecotourism months estimated direct economic contribution from RGV nature tourism led to a total county-level economic output of $344.4 million (STNMC 2011).

Reptiles

There are five species of sea turtles (Green sea turtle, Kemp's ridley sea turtle, Loggerhead sea turtle, Hawksbill sea turtle, Leatherback sea turtle) that occur in the project area. All species are either threatened or endangered (TPWD: https://tpwd.texas.gov/gis/rtest/) so maintaining or increasing their abundance in the region should be considered a potential goal for the estuary program.

The LLM serves as a crucial developmental foraging habitat for post pelagic green sea turtles originating from Mexico, Florida, the Caribbean and the western Atlantic Ocean (Metz and Landry, 2013). Since 1991, the population of juvenile green sea turtles has exhibited exponential growth despite current threats (Metz and Landry, 2013). The project area also encompasses nesting habitat for the critically endangered Kemp's ridley sea turtle. Although Southern Texas receives a small percentage of Kemps' ridley nests, it provides 90% of research related to the species. The majority of this data is collected and analyzed under the guidance of Dr. Donna Shaver at Padre Island National Seashore.

From an economic perspective, sea turtles have substantial impact in south Texas due to the presence of Sea Turtle Inc. Sea Turtle Inc. is a 501(C)(3) located on South Padre Island dedicated to the rescue, rehabilitation, and conservation of all sea turtle species. Within their facility, the public can learn about sea turtle biology, observe turtles in rehabilitation, and contribute to sea turtle conservation. On average, STI receives 125,000 visitors per year, making it one of the largest attractions of South Padre Island.

1.4.3. Water Quality Characteristics

Water quality is generally defined by its chemical, biological, aesthetic, and physical characteristics. The presence or absence of contaminants and certain water characteristics are useful indicators of the quality of water in the estuaries (Palaniappan et al., 2010). Plants and animals living in these estuaries will react to any changes in their habitat caused by the chemical water quality and disturbances to their habitat. Pollution of water sources can take several forms and create different effects on the aquatic system. The services that estuaries can provide to benefit humans greatly depends on the overall ecosystem health. Therefore, the water quality of this ecosystem is a major requirement of the estuary's ability to support the aquatic life associated with it (Barbier et al., 2011). Water quality degradation will result in the loss of economic value, threaten the estuarine habitat, and diminish the commercial/recreational values of the estuaries.

In recent years, pollution of seawater by metals has become a major issue for aquatic life and human health in marine ecosystems. The availability of excess quantities of metals in seawater is harmful because they destabilize the ecosystem and their toxicity generates adverse biological effects on an organism's survival, activity, growth, metabolism, and reproduction (Palaniappan et al., 2010). Trace metals such as zinc, chromium, copper, cobalt, and ferrous complexes have toxic effects on aquatic species (Bartram 1996). In estuaries, there may be certain areas which have salts, nutrients, trace metals, rare earth metals and other constituents in high concentrations which can limit the use of water (Lotze et al., 2006). The immunity of the fish species is reduced when the required parameters for their safety and survival is lacking. They tend to absorb contaminants from point and nonpoint loads, thereby also placing the lives of the fish consumers at risk. Studies have revealed that the Nueces, Baffin and Copano bays have the greatest concentration of pollutants in their waters and sediments of Texas. The levels of zinc, cadmium, lead, copper and other heavy metals are the most in these bays (Ward and Armstrong, 1997; Coastal Bend Bays Plan, 1998). Reports have suggested the presence of high levels of copper and cadmium in the fish tissues of these aquatic habitats, as well as a potential increase of zinc and lead concentration in Corpus Christi and Baffin Bays (Ward and Armstrong, 1997). Outbreaks of these impairments have also been recorded in the Corpus Christi Bay and Laguna Madre bays (Murgulet et al., 2015).

According to Kennish and Fertig (2012), when trace metals and other contaminants enter estuaries from other watersheds, the estuaries behave as sinks in receiving them. The inflow of water into estuaries from several watersheds and river sources releases suspended and dissolved materials into the estuaries, likely containing trace metals (Moore, 2006). The erosion of certain rocks present in the estuary can also attribute to the presence of these metals in the estuary (Weber et al., 1992). Estuaries play a huge role in aiding the chemical speciation process of various elements and trace metals (Costa et al., 2013). In most cases, the trace metals are stored in the sediments located at the bottom of estuaries due to the series of biological and chemical process occurring within it. In some studies, the sediments are referred to as traps because they receive all the pollutants transported into the estuaries (Eugenia et al., 2004, Karthikeyan et al., 2011). Complexation, dissolution, reduction, oxidation, and precipitation, are some of the various reactions these metals experience in estuaries (Anastasi et al., 2010). There are many factors which influence the reactivity of these metals in estuaries. Some of these include the formation of the estuaries, the transport methods of the elements, the regional climate, hydrology, mixing regimes, redox conditions, the metal concentrations, the residence time of the particles, and others.

Although aquatic animals require trace quantities of some of these essential heavy metals which occur in nature, like iron, strontium, zinc, manganese, cobalt, copper, vanadium, molybdenum, and others, they all have the potential of causing harm in estuaries if they exist at concentrations exceeding stipulated limits. Metals such as antimony, lead, cadmium, chromium, arsenic are classified as metals that are not essential to aquatic organisms, therefore, if present, they can pose a threat to the environment (Connell et al., 1984, Kennish, 2012). Some of the water quality parameters play a major role in influencing the behavior of these metals in the estuarine waters. An example is the pH level of the estuarine waters. A decrease in pH level may result in the availability of more metal ions in the water and likely cause the metal and hydrogen ions in the water to compete for uptake in those sites (Connell et al., 1984). In the same manner, when there is an increase in the salt ion concentrations in the water, those cations will compete with the metals for dissociation (Connell et al., 1984).

Public health in the Nueces Bay retion has been threatened in the past due to the consumption of oysters contaminated with zinc (Ward and Armstrong, 1997). Substantial amounts of zinc have also been recorded in the sediments of the Inner Harbor, and Corpus Christi and Baffin bays, both in their water column and sediments (Ward and Armstrong, 1997). The required limit of zinc in estuarine waters for the safety of aquatic life is 76 ug/l. Elevated copper concentrations have been observed in Nueces bay (Ward and Armstrong, 1997). Studies conducted in San Francisco Bay have revealed that the presence of high levels of silver was extremely toxic to certain organisms and invertebrates (Bryan, 1971). This high silver concentrations resulted in the reduction in the productivity of the bay, minimal diversity of available species and the deterioration of the fish populations in the entire estuary (Luoma and Cloern, 1982; Smith & Flegal 1993). The recommended water quality criteria for silver is 1.8 µg/L (US EPA, 2004).

The Texas Water Quality Inventory (TWQI) and 303(d) List have reported the presence of toxic substances in Texas water bodies with concentrations that exceed the criteria required to protect aquatic life. High conditions of acidity (measured as pH) and temperature that exceeds the criteria to protect general water quality uses have also been reported. According to the TWQI and 303(d) List, a common isse determined by the water quality of water bodies in Texas include toxic contaminants and chemicals absorbed in the fish tissues which pose a threat to its consumers; the presence of total dissolved solids, sulfate, and chloride that exceeds established water quality standards; and low dissolved oxygen levels below the required level for survival of aquatic life.

Organic matter produced from industries, municipal waste, and agriculture causes an increase in biological and chemical oxygen demand. This in turn causes hypoxia, which is a major threat to aquatic habitats (Rabalais et al., 2010). Proof of the deteriorating condition of many national estuaries, is the reduction of water clarity in the estuaries due to high turbidity, substantial amounts of debris washing up on the shores, and the death of aquatic species.(Palaniappan et al., 2010).

In the past century, the increasing agricultural and urban transformations of the watersheds has been the major reason behind the water quality deterioration of ecosystems (Rabalais et al., 2009). Estuarine ecosystems are identified to be some of the most heavily used and endangered of all-natural systems globally (Lotze et. al., 2006, Worm et al., 2006). Seasonal variations in estuaries can influence the potential chemistry and salinity changes in estuaries. For example, seasonal changes oftenresult in changes to the inflow of water containing suspended material into the estuaries (WMO, 2013).

1.5. Economic Indicators

A study conducted in 1987 revealed that the Gulf of Mexico provided local economies with almost $760 million and $1.3 billion statewide for Texas (Quenzer et al.,1998). For example, the Nueces Estuary, Mission-Aransas Estuary, and Laguna Madre contribute approximately $1.87 billion annually to the Texas economy from recreational fishing activities. In corroboration with the seafood industry and nature tourism activities performed, these three systems contribute about $3.2 billion to the state economy (Nueces River and Corpus Christi and Baffin Bay Basin, and Bay Area Stakeholder Committee, 2012). Therefore, the need to maintain the health in this region is of great importance to the economic vitality of the region and the State.

By establishing the LLMEP, the economic vitality and resilience of the Lower Rio Grande Valley, Texas, and subsequently the US, can be directly and positively affected. The estuary can provide food for a growing population, shelter for boats, homes, and ports, a place to live and recreate, and an opportunity to have physical, emotional and personal wellbeing. The quality of the LLM area and access to the LLM area will positively impact the indicators of economic health of the estuary. These indicators are:

- Economic value of the LLM, which is represented by how much the use of the estuary improves the economic wellbeing of the surrounding areas and population.
  - Value used directly: Fishing, beach trips, visit to seascapes and salt marshes.
  - Value used indirectly: Estuary habitats acting as nursery for different types of fish consumed by the population; salt marshes acting as reducers of bacterial contamination of runoff; salt marshes providing clean water for swimming and surfing; intertidal vegetation, roots, and marsh soils acting as carbon dioxide extractors, and sequesters, and therefore reducers of greenhouse gases (GHG).
  - Value never used or value of existence: Willingness of some people to pay to protect the estuary and its inhabitants. The Lower Laguna Madre, one of the largest hypersaline lagoons, and undeveloped barrier island areas houses the most diverse and abundant bird population in Texas.

- Economic Impact of the LLM, which is represented by how much money, jobs, and taxes are generated by specific business activities within the estuary.
  - Marine living resources: Fisheries, seafood processing , seafood markets
  - Tourism and recreation: Amusements and recreation services, boat dealers, eating and drinking places, hotel and lodging places, recreational vehicles parks and campgrounds, scenic water tours, sporting goods retailers, aquaria
  - Marine transportation: deep sea freight transportation, marine passenger transportation, search and navigation equipment
  - New industries coming to the region
  - Employment and wage.
  - Energy production (potential)

- Economic benefit of restoration of the LLM, which is represented by public and private benefit, which could be impacted based on
  - The historic and projected degree of land loss in the estuary
  - The potential infrastructure that may be affected by coastal erosion
  - The types of costs associated with a created event of coastal erosion or mitigation
  - Infrastructure located within the sensitive areas exposed to erosion (assets in marsh and swamps areas).

1.6. Resources of National Importance

A genuine understanding of the benefits and values of these estuaries can provide enough information about what stands to be lost when these ecosystems are endangered (Koch et al., 2009). With a continuous supply of nutrients, sediments, and a salinity gradient associated with its union with saltwater from the ocean, estuaries are great sources of sustenance and habitat for a wide variety of shellfish species and other aquatic animals (Costanza et al., 1997; Barbier et al., 2011). In assigning value to estuaries, it is necessary to look at (1) their usefulness to local communities for a variety of products such as raw materials and seafood; (2) their importance as breeding habitats for aquatic life; (3) as 'coastal storm barriers' to provide coastal protection to mitigate periodic events such as tsunamis, tropical storms, and coastal floods; and (4) their tourism, recreation, education, and research benefits (Barbier et al., 2011).

There is little public awareness of the international significance of the Laguna Madre ecosystem, particularly due to its remoteness, and also because of being protected along over 70% of its shoreline by federal entities, including Padre Island National Seashore and Laguna Atascosa National Wildlife Refuge, and private lands, including the large King and Kennedy Ranches. However, overall the Laguna Madre characteristics make it unique as a natural treasure. In addition to being the most studied and most often referenced hypersaline lagoon in the world, the Laguna Madre is home to about 77% of the North American wintering population of redhead ducks; it provides shelter to many protected species, including piping and snowy plovers, reddish egrets, brown pelicans, peregrine falcons, and white-tail hawks; it provides the largest continuous expanse of suitable habitats in North America between the northern bird breeding grounds and more distant wintering grounds in South America; accounts for about 80% of all Texas seagrass beds which provides habitat to many extensive colonial water bird rookeries; it is one of the best places for recreational fishing for red drum, black drum and spotted sea trout in North America and it is the most productive Texas bay fishery; it has the most extensive wind-tidal flats and clay dunes in North America; it is home to the only strain of high-salinity-adapted oysters in North America; it has the only serpulid worm reefs in Texas; and it has the only calcium carbonate (oolite) and gypsum crystal formations in Texas. The Nature Conservancy in 1998 designated the Upper Laguna Madre as a high-priority conservation area.

Given the unique characteristics of the Laguna Madre, it is interesting to note that the Lower Laguna Madres was not included into the original designation of Estuaries of National Significance, which left unprotected a great extent of area with unique characteristics (Tunnell, 2001).

The Laguna Madre and Lower Rio Grande Valley, located in the southernmost tip of Texas, along with the U.S. border with Mexico, has some of the fastest growing communities in the U.S. This region produces important crops such as citrus, is a nexus for the international commerce with Mexico, contains several large and historic ranching operations, and is the center of natural resource-based tourism, including hunting, fishing, and natural history. The Laguna Madre is protected by Padre Island, which is the longest barrier island in the world (FWS, 2017).

1.6.1. Agriculture

Agriculture in the Lower Rio Grande Valley of Texas and the Arroyo Colorado and Lower Laguna Madre watersheds is a major economic driver for the regional economy. However, nutrients and runoff from drain fields and large scale citrus and rice growing has created significant threats to the water quality and ecosystem health of the LLM. Important implementation of agriculture best practices including fertilizer reduction programs and filter and buffer strips are described thoroughly in the Arroyo Colorado Watershed Protection Plan (ACWPP, 2017). The results of these practices are encouraging but more critical data and performance outcome evaluations are needed.

1.6.2. Tourism

The Padre Island National Seashore (PINS) is located in the LLM and represents a portion of the largest barrier beach in the United States (67.5 miles of the 130 mile long barrier island). It also includes some of the island's backwaters as the Laguna Madre. The PINS is the longest seashore in the National System. Shorter sections at each end of the island are not included in the national seashore. In those sections small county parks and commercial developments do exist. A Nueces County Park is located at the northern end of the island and a Cameron County park is maintained at the southern end. Between the two county parks and the national seashore there are areas under private or corporate ownership. The Gulf shore is considered a beachcomber's paradise (Campbell, 2017).

With one third of the entire Texas state's population concentrated in the Coastal Bend estuary region, there is an increasing threat to the recreational and commercial aquatic habitats (Brown et al., 1976). A report generated by NOAA (2004) indicated that the tourism industry in the Gulf of Mexico region, which represents $20 billion revenue, is at risk. This is caused by the devastation of coral reefs and the sinking of coastlines, which includes up to 50% of the estuaries showing signs of degradation.

1.6.2.1. Conventional Tourism

Recreational boaters with outboard propellers prompted propeller scarring in seagrass beds of the ULM, causing seagrass bed fragmentation and loss. Propeller scarring occurs when the propeller repeatedly slices into the shallow bay floor, uprooting the seagrass and permanently damaging the beds (Onuf, 2006; The NC, 20017). Both, recreational and commercial boat traffic have affected colonial nesting islands and the dense, shallow stands of seagrass beds in the lagoon (The NC, 2017).To prevent this damage, informational signs were installed at many upper Laguna Madre boat ramps by the Corpus Christi Bay National Estuary Program. Additionally, the Padre Island National Seashore designated a voluntary no-motor zone. In 2005, the State and Federal natural resource agencies (TPWD) were going to evaluate the program to decide if to continue the designation (Onuf, 2006).

The sport fishing industry in the LM is estimated in value at about $180 million/year and supports about 1, 327 jobs (POI, 2017). The Port of Isabel and Brownsville port together represent the third largest-volume shrimp port in the nation. Average annual revenue of $57 million was documented from 1990-1997 by the National Marine Fisheries Service data on offshore landings for shrimp (POI, 2017).

1.6.2.2. Ecotourism

Ecotourism is a very important revenue generating industry for the Lower Laguna Madre. Birdwatching, sea turtle observations, sport fishing, and wildlife safaris are all activities that contribute to the local economy and encourage protection and preservation of habitats and superior water quality.

1.6.3. Presence of Two Ports

There are two ports located in the Gulf of Mexico, namely the Port of Corpus Christi and the Port of Brownsville. Through the Port of Corpus Christi, the City of Corpus Christi leads the way as a net oil exporter. In 2017, the city facilitated 61% of the 478 million barrels of crude oil exports in America. The port was expected to export $5.5 billion of crude oil to U.S. trading partners. The Port of Corpus Christi is a major economic engine of Texas and the country and a major gateway to international and domestic maritime commerce. The Port is located on the western Gulf of Mexico, it is the 4th largest port in the United Sates in total tonnage, with a 36 mile, 47 foot (MLLW) deep channel. The Port has a highway network connectivity through three North American Class-1 railroads and two major interstate highways (Press release, 2017). Given the natural gas boom and pipeline development there is a need to receive the largest tankers in the world, thus the Port of Corpus Christi is also expanding its ship channel (Texas Monthly, 2017).

The port of Brownsville is a deepwater seaport in Brownsville, at the southernmost tip of Texas. The port is connected to the Gulf of Mexico by a 17-mile-long ship channel, and is the largest land-owning public port authority in the nation. It is also the only deep water seaport directly on the U.S./Mexico border. The Port of Brownsville plans to deepen the ship channel from the current 42 feet to 52 feet with the purpose of allowing larger ships to enter the Port. Increasing the size of the ships allows more cargo. Deepening the ship channel by a single inch allows a vessel to carry an extra 179 tons of cargo. This project is considered an important economic development for the Rio Grande Valley in terms of job creation (Rio Grande Guardian, 2018). The Port, together with the Rio Grande International Railway (BRG) serves as UP's intermediate switch to and from Mexico. In 2014, the port signed a strategic partnership with OmniTRAX to operate BRG and develop the GEOTRAC Industrial Hub, which has more than 1,400 acres of land suitable for light and heavy manufacturing, logistic, energy services, technology development and export/import warehousing. The Port is part of the M-10 and M-69 Marine Highway corridors, which allows transportation of cargo from the Port of Brownsville along designated marine highways, and the U.S. Intercoastal Waterway.

1.6.4. Oil and Gas Industrial Activity

Given technological innovations such as hydraulic fracturing (fracking) and horizontal drilling, petroleum and natural gas production has become the dominant fuel source worldwide. It is been estimated that global natural gas consumption will grow worldwide from 120 trillion cubic feet (Tcf) in 2012 to about 203 Tcf in 2040. The United States is the world's largest natural gas producer (TX LNG_LNG, 2017). It was reported that Texas Accounted for 24% of U.S. daily natural gas production in May 2017 (TXOGA, 2017).

The discovery of the potential productivity of the Eagle Ford Shale by Corpus Christi geologist Gregg Robertson in 2009 has created several economic activity and infrastructure changes along the Gulf coast and South Texas. One of these is the lift of a federal government wide-ranging 40-year ban on crude oil exports to allow taking advantage of the abundance of shale oil. The selection of the City of Corpus Christi to start exporting Texas oil to the rest of the world was possible since the city was close to the source and it was in good standing under federal clean-air regulations, and also because the ship traffic in the city was low enough to take on a sudden influx of new tankers, as compared to Louisiana or Houston ports. The City of Corpus Christi has become the nation's leading oil exporter. In the first quarter of 2017, it exported 316,000 barrels a day, which is equivalent to the amount of barrels exported by Beaumont, Port Arthur, and all Louisiana ports combined. Daily exports from Houston and Galveston are one tenth of exports leaving from Corpus Christi. The new port development in the City of Corpus Christi will produce between 10,000-20,000 industrial jobs with additional 30,000 jobs in retail and service sectors (Texas Monthly, 2017).

The City of Corpus Christi Harbor Bridge will be replaced over the next couple of years by the Texas Department of Transportation. The project has a cost of $800 million and the purpose is to have a bridge with a clearance of 205 feet to allow the entrance of the tallest tankers in the world to the inner harbor of the Port. The bridge will run two and a half miles end to end, and this will make it the longest cable-stayed bridge in the country.

The construction of the "Natural Gas Super-Highway" was initiated in 2017. It consists of a 650-mile long pipeline that spans from New Mexico through Texas to Corpus Christi, which is the home of the fourth largest port based on tonnage. The super-highway is expected to produce 375,000 barrels of natural gas per day. The natural gas line, which will run parallel in Texas, with a 730-mile pipeline, is expected to start operation in early 2019, and it will move about 440,000 barrels of crude oil each day from the Permian Basin Shale field to the Corpus Christi region (2017, SPI Insights). The proposed pipeline, called EPIC (Eagle Ford, Permian, Ingleside, Corpus Christi) will start shipping Permian oil, together with some from the Eagle Ford by the first quarter of 2019, and is planned to reach a capacity of 600,000 barrels that will reach the port every day (Texas Monthly, 2017). The proven reserves of the Permian Basin are 20 billion barrels of oil, 16 trillion cubic feet of natural gas, and 1.6 billion barrels of hydrocarbon gas liquids (2017 SPI Insights). The launch of the EPIC pipeline will allow

Occidental Petroleum Corporation, which is the largest producer in the Permian Basin and controls the Ingleside Energy Center, to double its production.

One of the regions that is greatly benefiting from the economic growth due to natural gas is the Rio Grande Region in the Lower Rio Grande Valley, South Texas. The Rio Grande LNG project, one of the currently 7 LNG export projects under construction or planned in the state of Texas, is planning to have an investment of up to $20 billion in an LNG liquefaction plant and purification facility that are being constructed in Cameron County, in the Lower Rio Grande Valley (TX LNG_LNG, 2017). The project has a total capacity of 27 Million tons per annum (MTA), and will generate more than 3,000 permanent jobs in the Cameron County. The purpose is to promote the hiring of more than 80% of the workforce from the local region and additional hiring from the surrounding counties. The project will also contribute $137 million in tax revenue to Cameron County. The total Texas economic benefits due to the Rio Grande LNG project are projected to be $23.1 billion. In addition to creating high paying jobs, the Rio Grande LNG project will also promote Science, Technology, Engineering, and Math (STEM) education (TX LNG_LNG, 2017). The importance of the Eagle Ford Shale, located near Cameron County, can be understood by considering that one single day of natural gas production in the play could meet the natural gas needs of over 230,000 U.S. homes for one month (TXOGA, 2017).

Exelon's Annova LNG project, at the Port of Brownsville in the Lower Rio Grande Valley, Texas, is expected to have a total capacity of 6.95 MTA and create 675 jobs during construction and 165 permanent jobs during operation. Project approval was expected to occur in March 2018, and is expected to provide a positive economic impact to Cameron County. The most important contribution of the Annova LNG project to the County will be an increase in the average salary of workers. The current average wage per job is just over $30,000, with per capita income around $25,000, and according the latest census information, just over 34% of the population lives at or below the poverty line. The Annova LNG project is projected produce skilled worker opportunities with an average salary of $70,000 with benefits that will represent $110,000 in total compensation. The facility will also generate over $34 million in annual tax revenues (TX LNG-LNG, 2017). The Annova LNG project will help to accelerate commerce in the LRGV and keep the Port of Brownsville connected to very important points of the global market. Being located in an international port, the project will help enhance the connectivity of Texas and the U.S. to the world (TX LNG-LNG, 2017).

An LNG terminal in the Rio Grande, which is being constructed in Cameron County, Texas, is projected to contribute about $326 million per year to the county's gross production. The construction of the Rio Grande LNG terminal was initiated in 2017, and is projected to initiate operations in 2020. A Rio Grande Bravo Pipeline will also be ready by 2020 and will be used to transport natural gas from the Eagle Ford Shale region (TX LNG-LNG, 2017).

The Rio Grande and the Annova LNG projects will provide economic stimulus and diversification to the Lower Rio Grande Valley and surrounding area in Texas (TX LNG-LNG, 2017; SABJ, 2015). Even though these projects will utilize the Brownsville ship channel in Cameron County, the counties of Starr, Hidalgo, and Willacy will also have benefit from construction and operation of the LNG export facilities. Due to the proximity of the LRGV to Northern Mexico, these investments will also impact the Mexican border state of Tamaulipas (SABJ, 2015).

The Tax revenue from these projects will booster additional infrastructure, education and service development in Texas. The additional five projects that are being developed in other regions in Texas are the Golden Pass LNG, Freeport LNG, Port Arthur LNG, and Cheniere's Corpus Christi LNG project.

1.6.5. Living resources of the LLM

In the project area, there are nine principal estuarine habitats: open bays, hard substrates (i.e., jetties), oyster reefs, seagrass meadows, mangroves, coastal marshes, tidal flats, barrier islands, and Gulf beaches. Additional near coastal terrestrial habitats include coastal prairies, lomas, and ranchland. All these habitats provide home to more than 3,200 species of plants and animals.

The high number of unique species occurring within south Texas are in part due to the southern location of the region being quite different than the rest of Texas and being on the border between tropical and temperate climate zones.

Among nongame species in South Texas using this diverse assemblage of habitats there are a number of federally listed threatened and endangered species which include: birds like brown pelican, whooping crane, bald eagle, northern aplomado falcon, piping plover, least tern (inland breeding populations).

An endangered bird species that depends heavily on South Texas coastal habitats for its survival is the piping plover. This species is a small, stocky, sand-colored plover with orange legs that occupies Texas beaches, bays and lagoons during the non-breeding season which runs from July through May. They spend most of its time foraging and resting on wind tidal flats along the edge of the lagoon and retreat to the gulf beaches during high tides. Major threats to the species in Texas are disturbances and development along the beaches and wind tidal flats as well as chemical spills from the petroleum and other industries with diccharges within the lagoon and the Gulf of Mexico.

1.6.6. Economic Growth

In general, the Gulf of Mexico is growing much faster in all measures than the northern regions.

- 62.8% of the Central Gulf in Texas represent estuary regions.
- 31.1% of the Texas economy is located in the Central Gulf.
- 3.4% of the US economy was represented by the Central Gulf in Texas in 2004.

The Lower Laguna Madre estuaries will be impacted by the population and economic growth of one of the metro areas that are close to the estuaries, including the McAllen-Edinburg-Mission metro area. The forecast for population growth in Hidalgo County, Texas, is about 2.2% for 2018. This region will see the highest growth in South Texas, followed by Webb County. By 2018, the economic activity in the McAllen-Edinburg-Mission metro area will experience an annual GDP growth rate of 3.0% (the Mission Chamber of Commerce reported a GDP of 3.85%) due to the strong investment interest from large retailers like Dave & Busters, Dick's Sporting Good, and others. This metro area became the 5th largest Texas metropolitan statistical area in 2015, and it is expected to be the 8th fastest growing metro area in Texas (Contreras, 2017; MCC, 2017). It will also add 31,300 jobs over the next five years (MCC, 2017).

The City of Corpus Christi will experience 2.1% of economic activity growth in the near future, while the Brownsville-Harlingen areas will have an economic growth of 1.9% and will benefit from investments in the region from UTRGV, and SpaceX among others (Contreras, 2017).

According to the Mission Chamber of Commerce (MCC, 2017), the steady population growth in the McAllen-Edinburg-Mission metro area has prompted a high business expansion. The following economic activities will become a reality in this metro area in 2019 (MCC, 2017):

- Opening of Texas A&M College Station in McAllen. Programs to be included are engineering, technology, biomedical sciences, agriculture, and lab sciences;
- Expansion of La Plaza Mall with an additional fifty stores that will add an additional 245,000-square-feet to the retail site;
- Opening of the Bert Ogden Arena in Edinburg. This will be the largest arena in the Rio Grande Valley, with 8,500 seats. The Arena will be a venue for sports, entertainment, and shows;
- Opening of the HEB Park, with a 9,700 seat soccer stadium and outdoor activities;
- Opening of SpaceX, which will bring in engineering jobs and opportunities for local students attending the region's colleges and universities;
- Increase the depth of the port channels of the Port of Brownsville, which will make the port one of the deepest ports in the Gulf of Mexico. This will make it competitive with other national ports;
- Establish a $114 million-dollar manufacturing plant in Brownsville from the Italian SATA group that will help creating over 300 jobs over a ten-year period;
- Continue improvement of the UTRGV and associated medical school that will create economic development opportunities.

Lower Laguna Madre Estuary Program Strategic Plan
Thrust Area 2: Important Needs and Goals

2.1 Overview of Program Needs and Goals

The Laguna Madre accounts for about 25% of the coastal region of Texas and is a shallow hypersaline lagoon, which is located in the western coast of the Gulf of Mexico. The Lower Laguna Madre ranges from 3 to 12 km in width and extends 95 km southward from the seldom-flooded sand and mudflats to within 5 km from the US-Mexico border (USGS, 2006). The Lower Laguna Madre (LLM) supports diverse species of fishes and invertebrates that are economically valuable to the region (Tunnell et al, 1996; Robinson et al., 1997). Most of the Laguna Madre's bottom is covered by seagrasses (Onuf 1994; 1996), which are critical to the health of the Laguna. There has been a decline in seagrasses in the LLM since 1967 (Sheridan, 2003).

The goal of this chapter is to identify critical issues and concerns in the LLM estuary region that are important not only to promote conservation and sustainability of natural resources as well as ecosystems but also for economic development of the region. The critical issues and needs are identified through participation of local, state, and federal governments as well as interested entities (e.g. non-profit organizations and educational institutes). The critical issues and needs identified in this study will be used to develop a comprehensive conservation management plan (CCMP) to address those issues. The LLM Estuary strategic plan will help the stakeholders move forward for statewide and national recognition and potentially seek new funding opportunities for addressing critical issues in the region.

This chapter first describes local and regional resources (Section 2.2) that are of importance followed by issues and critical needs (Section 2.3). Finally, Section 2.5 describes a list of key stakeholders, potential international partners/entities as well as local, state and federal governments/agencies that could play a major role in development and implementation of the CCMP for the LLM Estuary Program. The LLM has several unique natural resources and features that are of importance to the local and regional scales as described in Thrust Area 1, which are further described along with needs and goals in the following paragraphs.

2.2. Local/Regional Resources of Importance

2.2.1. Multi-billion dollar trade corridor in the Rio Grande Valley across US and Mexico border: The LLM Estuary region is unique due to the multi-billion dollar trade volumes that cross the US-Mexico border. In 2015, Texas traded approximately 176.5 billion dollars of goods and servicess with Mexico, which is more than three times higher than its second largest trading partner – China (Texas Department of Transportation – TXDOT report, 2017). In particular, the largest trading commodity between Texas and Mexico border was comprised of machinery and electrical products, worth 39.2 billion dollars in 2015 (TXDOT, 2017).

2.2.2. Port of Brownsville – Deep Water Sea Port for trade: The Port of Brownsville is a deepwater seaport, located at the southernmost tip of Texas. It provides employment with about 44,000 related jobs and about $3 billion economic activity in the state (http://www.portofbrownsville.com/). It is the second largest foreign trading zone in the US and it is the largest land-owning public authority in the country.

2.2.3. Jobs and Employment: The population of Rio Grande Valley is about 1.5 million. McAllen's Metropolitan Statistical Area (MSA) was ranked #1 in the US for long-term job growth in 2012 (US Bureau of Labor Statistics, 2012). McAllen ranked #2 in Texas in per capita retail sales (https://assets.recenter.tamu.edu/documents/mktresearch/RGV_NAI_ECONOMIC_REPORT_2015.pdf). The labor force in the Rio Grande Valley grew from 314K to 462K between 1995 and 2010 while the unemployment rate decreased from 18.4% to 11.6%.

2.2.4. Habitat for a wide variety of fish and wildlife species: The LLM serves are a key habitat for wide variety of fishes such as Speckled Trout, Sand Trout, Whiting, Red Drum (Redfish), Black Drum, Tarpon, and Mangrove Snapper. In deep water, the fishes of South Padre Island and Port Mansfield, include typical catches of Red Snapper, Kingfish, Tuna, Amberjack, Shark, Grouper, and wide variety of deep water species (http://www.wintertexaninfo.com/fishing.html). The Laguna Madre also serves as habitat for reddish egrets, western sandpipers, midwinter mottled ducks, wintering redheads and pintails and other colonial waterbirds (https://www.fws.gov/southeast/gulf-restoration/next-steps/focal-area/laguna-madre-and-lower-rio-grande-valley/). The Laguna Madre is also home to federally endangered species such as Northen Aplomado Falcon, Ocelot (which is only found in Cameron and Willacy counties nationwide) and the Gulf Coast Jaguarundi.

2.2.5. Nature parks and wildlife refuges: The Santa Ana National Wildlife Refuge and Laguna Atascosa Wildlife Refuge are located in the Rio Grande Valley. The Santa Ana Wildlife Refuge is located along the banks of Rio Grande River in Hidalgo County. It serves as habitat to 397 bird species and more than 300 butterfly species. The Laguna Atascosa National Wildlife Refuge is the largest protected area of natural habitat in the

Lower Rio Grande Valley and is located in Cameron County. This refuge serves as a habitat for nine endangered and threatened species including Northen Aplomado Falcon, Texas Ocelot, Gulf Coast Jaguarundi, and rare wild cats (Texas Parks & Wildlife, 2003).

2.2.6. World Birding Centers (eco-tourism) and pathway for migratory birds: There are nine different locations of World Bird Centers in the Rio Grande Valley. These centers are home to more than 500 species of birds including several tropical bird species that are uniquely found in the South Texas. The Lower Rio Grande Valley is a major bird corridor, which is at the convergence of Central and Mississippi major flyways. These world birding centers also provide educational and outreach field trip to students from Pre-K to 12 grades (https://tpwmagazine.com/archive/2016/may/ed_1_birds/).

2.2.7. Butterfly watching center: The National Butterfly Center is located in Mission, TX, and is home to over 200 different species of butterfly. The educational center at Butterfly watching center supports field trips for grades Pre-K to 12 for providing education and learning activities (National Butterfly Center, https://www.nationalbutterflycenter.org/).

2.2.8. Commercial Fishing/Shrimping: The Laguna Madre commercial fishing industry accounts for 25% of all finfish caught in Texas bay systems. Based on 1993-1995 average data, the Laguna Madre estuary is the second biggest commercial fishing employment source along the Texas Gulf Coast (Jones and Tanyeri-Abur, 2001). A prolific shrimp industry is one of the major economic benefitss of the Lower Laguna Madre. Port Isabel averaged a catch of 3,600,000 tons of shrimp annually, which accounted for 65% of the entire shrimp production of Texas. However, the estuary's environmental protection is being threatened from recent developments of the Lower Laguna Madre, e.g., energy industry and shoreline development. (https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/97483188b.pdf)

2.2.9. Citrus and Aloe Vera industries: The Valley's citrus industry was established early in the 20th century, and is comprised of almost 27,000 acres across a three-County area in the Valley which produces more than 14 million cartons of citrus product each year valued at over $100 million dollars. (https://texascitrusindustry.com/). The A*loe Vera industry* took root in the Valley's booming agribusiness so readily that the state's commercial aloe growers have no close competitors. The medicinal qualities of aloe vera propelled it into a reliable fixture of Lower Rio Grande Valley agriculture and made the region a worldwide center of activity for the aloe industry (http://www.texascooppower.com/texas-stories/nature-outdoors/lyford-county-aloe-the-valleys-versatile-crop). Aloe was grown on 3,000 to 4,000 acres in the Valley before and prompted growers to locate additional fields in Mexico. Although significant expansion is not expected, the local aloe vera industry is robust and developed according to the Texas Agricultural Experimental Station office in Weslaco.

2.2.10. Water based recreational industry: The LLM has several popular water based recreation destinations. The Laguna Madre Estuary was ranked as the second largest destination in terms of travel expenditures and employment in over the six major estuaries of Texas (Jones and Tanyeri-Abur, 2001). The LLM is one of the few places in Texas where travelers are able to find decent snorkeling from the beach. It was rated by Scuba Diving magazine as one of the top 100 snorkeling sites in 2010. The beach jetties provide homes to many types of fish normally found on reefs, including wrasse, trumpetfish and triggerfish. (http://traveltips.usatoday.com/snorkeling-texas-111200.html) Retrieved December 7, 2017.

2.2.11. Ramaderos: mid-Delta Thorn Forest community: The Ramaderos biotic community sits at the western edge of the refuge. This arid landscape is cut by deep arroyos and small tributaries that extend for miles from the Rio Grande. Wildlife travels unimpeded down the humid corridors of lush riparian vegetation, particularly during times of drought and extreme heat. The biota of these natural drainage channels is a result of higher moisture and deeper soils. A tree typically foraged upon by white-tailed deer and cattle, the seemingly unobtrusive guayacan, has a root system that plant ecologists speculate may endure for almost 1,000 years. (https://www.fws.gov/refuge/Lower_Rio_Grande_Valley/wildlife_habitat.html)

2.2.12. Sabal Palm Sanctuary: The Sabal Palm Sanctuary is a 557-acre (225-hectare) nature reserve and bird sanctuary located in the delta of the Rio Grande Valley in Cameron County near Brownsville, Texas. It is noted for being one of the last locations in the Rio Grande Valley with a profuse grove of sabal palms, an edible-heart-bearing palm much prized by pre-Hispanic inhabitants and noted by early explorers. As a relatively habitat-rich remnant of this Valley, it is a prized birdwatching and butterfly watching location for persons interested in the ecology of the Valley and adjacent states of northern Mexico. (https://en.wikipedia.org/wiki/Sabal_Palm_Sanctuary)

2.2.13. Loma system surrounded by Borrichia flats and dunes: Based on Texas Parks & Wildlife, Borrichia frutescens (sea ox-eye daisy) is the clear aspect dominant of these irregularly flooded sites. These flats become very extensive from Corpus Christi Bay, southward including the Lower Laguna Madre. These marshes occupy relatively low-lying, coastal situations on level landforms influenced by tidal fluctuations. Some sites are only influenced by storm tides, or tides resulting from extreme wind events. The composition of these marshes is primarily influenced by the frequency and duration of tidal inundation. (https://tpwd.texas.gov/landwater/land/programs/landscape-ecology/ems/emst/herbaceous-wetlands/texas-coast-salt-and-brackish-tidal-marsh)

2.2.14. Pothole coastal prairie, salty prairie, sand-sheet grasslands: The South Texas Sand Sheet, also known as the Coastal Sand Plains and the Llano Mesteño, occupies more than two million acres at the southern tip of the state, just north of the Lower Rio Grande Valley. The region is defined by a sheet of eolian sand blown inland from the shoreline of the Gulf of Mexico during Holocene times, a sheet that covers most of Kennedy and Brooks counties as well as the northern tips of Willacy, Hidalgo and Starr counties. The Laguna Madre separates the Sand Sheet from modern barrier islands along the Gulf of Mexico, but there is no clear boundary between the Sand Sheet and the Flour Bluff Peninsula, a Pleistocene barrier island situated west of the Laguna Madre in southern Nueces County. The flora of the South Texas Sand Sheet includes about 54 taxa that are endemic to the state of Texas. Among those, fourteen are essentially endemic to the Sand Sheet proper. (http://w3.biosci.utexas.edu/prc/DigFlora/WRC/Carr-SandSheet.html).

2.3. Issues and Ecological and Natural Resource Specific Needs of the LLM

2.3.1. **Identify existing data and gaps**

There have been few studies in the Lower Laguna Madre Estuary to characterize and model water quality indicators, which underscores the need to collect baseline conditions such as water quality parameters, drainage maps, detailed topography, endangered bird and wildlife species, wetlands mapping, and air quality measurements. This section describes the status of existing data and the need for further data collection and improved modeling studies.

2.3.1.1. Water quality data collection and modeling: There have been limited studies on water quality characterization or modeling in the Lower Laguna Madre Estuary region. Schoenbaechler and Guthrie (2011) implemented TxBLEND to simulate water circulation and salinity transport within the LLM estuary system. The study found that the TxBLEND model was able to capture long term trends in salinity gradients throughout the Laguna Madre Estuary but it failed to capture the short term high frequency variability in salinity. It was proposed that the development of 3-D hydrodynamic models will help to increase the capability and predictability of the TxBLEND model in capturing salinity changes. The US Department of Interior (DOI, 1998) conducted a short-term discharge measurement study for 3 days during June 19-22, 1997 at five sites in the LLM near Port Isabel for calibrating an Estuarine Hydrodynamic and Conservative Transport Computer Model. The study found that the net inflow to LLM from South Bay during three tidal cycles over a three-day period was probably the result of wind-driven flows but more data needs to be collected for model calibration and validation (Texas Water Development Board, http://www.twdb.texas.gov/surfacewater/bays/models/index.asp)..

Collect data on detailed topography: Given the flat topography of the LLM region, there is a need to collect detailed elevation data. One of the challenges highlighted in the Arroyo Colorado Watershed Protection Plan Update (TWRI, 2017) is the need to collect high resolution DEM data to update the stream network in the LLM region. It is important to measure the streamflow volume and timings correctly for developing hydrologic models for the region. Lack of detailed stream network and flat topography underscores the need to collect high resolution DEM data and validate other elevations dataset such as LIDAR and USGS DEM data. The mapping of irrigation and drainage networks, the identification of existing coastal management and adaption programs and enhanced wetlands delineation and mapping are all needed activities.

2.3.1.2. Identify threatened and endangered bird/wildlife species: As described earlier, the Laguna Madre is home to more than nine federally endangered bird and wildlife species such as Northen Aplomado Falcon, Ocelot, Gulf Coast Jaguarundi and rare wild cats. More data is needed to monitor and estimate the baseline conditions of species richness and biodiversity, including the reintroduced species in the region. (https://www.fws.gov/uploadedFiles/Public%20Review%20Draft%20EA%20Sept%202014%20(1).pdf).

2.3.1.3. Mapping Sea Grass: Given the historic abundance of sea grass in Lower Laguna Madre and its role in determining the ecosystem health of the Laguna (Onuf 1994; 1996), it is critical to map sea grass distribution in the region.

2.3.1.4. Monitor air and water quality due to existing and upcoming industrial growth (LNG, Space X): The Lower Rio Grande Valley (LRGV) is undergoing rapid industrial growth. The construction and operation of Liquefied Natural Gas (LNG) and Space X in the LRGV will result in economic growth in Cameron County and communities in South Texas. The LNG project as well as Space X launch will inject several billions of dollars towards boosting local economy of the entire region. Baseline data needs to be collected on water quality and air quality to determine impacts of rapid urbanization and industry growth on human health and the environment (https://www.brownsvilleherald.com/news/lng/).

2.3.2 Significant Regional Issues

2.3.2.1. Habitat conservation and restoration (threatened and endangered species): Restoration is broadly defined as the act, process, or result of returning a degraded or former habitat to a healthy, self-sustaining condition that resembles as closely as possible its pre-disturbed state. Examples of restoration include removing material from a filled wetland, increasing tidal flow to a restricted wetland, re-establishing natural river flow, enhancing degraded seafloor habitats, treating runoff to improve water quality, cleaning up contaminated habitats, and managing invasive species. Many projects involve multiple types of restoration and focus on improving the health of whole ecosystems. In the Lower Rio Grande Valley since 1995, more than 3.2 million seedlings have been planted on over 9,600 acres for the benefit of endangered ocelots and other native wildlife. In addition, it is important to better understand the connections between species abundance and the water availability in riparian ecosystems (https://www.fws.gov/refuges/refugeupdate/MayJun_2014%20HTML/steadily_connecting.html).

2.3.2.2. Seagrass conservation and protection: The most common approach to conserving seagrass ecosystems is to reduce common threats to them (e.g. pollution, damage by boats), for example through new regulations or incentives. Restoring seagrass ecosystems can include harvesting and transplanting seagrass plants and subsequent management and monitoring of restored sites. In particular, there has been a decline in seagrasses in the LLM since 1967 (Sheridan, 2003), and therefore, it is important to understand the factors that affect sea grass distributions in the region (https://pubs.usgs.gov/sir/2006/5287/pdf/LagunaMadre.pdf).

2.3.2.3. Managing invasive species: an “invasive species” is defined as a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Measures to prevent invasive plant spread start with ensuring vehicles and equipment are clean of invasive plants and seed. Soil disturbances should be minimized in all construction and maintenance activities, along with a promotion of the establishment of health plant community. The movement of of weed- infested soil or gravel should be limited. Groups should use certified weed-free seed mixes or vegetation in disturbed areas to provide competition for new infestations. Stakeholders and growers should contain neighboring infestations and restrict movement of invasive plants from adjacent lands, while protectingareas that are not infested. Invasive species cause many problems in wildlife habitat by choking out native species, absorbing necessary water and/or competing for resources. Guinea and other grasses, for example, form a thick mass at soil level that other plants seeds cannot germinate. Non-native plants also can create a monoculture, in which those plants take over and prevent biological diversity. Some of the most problematic plants include guinea grass, buffelgrass, Brazilian pepper, hydrilla and water hyacinth. One such example is in Resacas, where invasive animal species such as nutria, nilgai antelope and feral hogs can cause damage to habitats. In particular, nutria are notorious for destroying wetland vegetation and plugging up drainage areas, and feral hogs are prone to tearing up soil (http://www.brownsvilleherald.com/news/local/non-native-species-invade-valley/article_e5b294c0-2b52-54c4-a613-3acb23879ebb.html).

2.3.2.4. Dune protection and conservation: Sand dunes are a natural barrier to destructive forces of wind and waves; they are also the least expensive and most efficient defense against storm surge flooding and beach erosion. Dunes absorb the impact of storm surge and high waves, preventing or delaying intrusion of waters into inland areas. Inland areas become more vulnerable to hurricanes and tropical storms when the dune line is weakened. Protecting dunes helps prevent loss of life and property during storms and safeguards the sand supply that slows shoreline erosion. Disturbance of the foredunes by vehicles, pedestrians, construction work, or grazing animals can promote wind erosion. If unchecked, this erosion can lead to almost complete removal of dunes, depleting the supply of sand available for exchange during storms. Sometimes entire dunes are bulldozed to level a construction site or to lay pipelines. In these cases, damage is not limited to the immediate site. Dunes adjacent to the site are also exposed to wind erosion (http://www.glo.texas.gov/coast/coastal-management/forms/files/dune-protection-manual-gpb.pdf).

.

2.3.2.5. Erosion control and beach nourishment: During erosion, loose rock, soil, and sand particles are moved from one location to another by either wind, water or other natural agents. Estimates of erosion and sedimentation rates are useful to land and water resource planners as a guide for land-conservation measures in areas where such measures are needed most. They can be used by planners of water-resources impoundments, and by those interested in the transport and deposition of pollutants. Texas has some of the highest coastal erosion rates in the country; 64 percent of the Texas coast is eroding at an average rate of about 6 feet per year, with some locations losing more than 30 feet per year. As a whole, the Texas coast average erosion rate is 4.1 feet per year. When the Texas coast erodes, property values decrease and homes and businesses are lost. Tourism suffers and local economies feel the impacts as well as the farming and fishing industries. Without healthy beaches, dunes, and wetlands to protect the coast, there is a day-to-day erosion and the impact of major storms like Hurricane Ike are far more severe. For instance, Rookery Island has been experiencing severe soil erosion issues (http://www.glo.texas.gov/coast/coastal-management/forms/files/cepra-report-2017.pdf).

2.3.2.6. Preserve nature and walking trail interconnections: The Rio Grande Valley equips many walking/hiking trails over wildlife refuges that are run by the U.S. Fish and Wildlife Service: Laguna Atascosa National Wildlife Refuge (97,000 acres), Lower Rio Grande Valley National Wildlife Refuge (40,000 acres), and Santa Ana National Wildlife Refuge (2,000 acres). These walking trail interconnections protect and preserve the natural environment, and provide visitors with opportunities to interact with their natural surroundings and the creatures living within them (https://www.fws.gov/refuge/Lower_Rio_Grande_Valley/visit/wildlife_watching_areas.html).

2.3.2.7. Restore and protect coastal and marine resources as well as habitats: Due to the Deepwater Horizon Oil spill, coastal and marine resources as well as natural habitats for wildlife and aquatic species have been severely impacted. Therefore, it is critical to estimate the impacts of Deepwater Horizon oil spill on these resources and restore the natural resources and habitats especially in Gulf coast areas such as the LLM (https://www.britannica.com/event/Deepwater-Horizon-oil-spill-of-2010).

2.3.3. Environmental and Natural Resources Needs and Issues

2.3.3.1. Wetlands restoration and modeling potential wetlands restoration sites: Wetland restoration reestablishes or repairs the hydrology, plants and soils of a former or degraded wetland that has been drained, farmed or otherwise modified. The goal is to closely approximate the original wetland's natural condition, resulting in multiple environmental benefits. Some environmental benefits are the improvement of surface and groundwater quality by collecting and filtering sediment, nutrients, pesticides and bacteria in runoff. Wetlands can reduce soil erosion and downstream flooding, provide food and shelter for many species and enable the recovery of native plant communities (https://training.fema.gov/hiedu/docs/fmc/chapter%208%20-%20floodplain%20natural%20resources%20and%20functions.pdf).

2.3.3.2. Effects of Sea Level Rise (SLR) and changes in climate on freshwater inflows: Sea level rise due to a warming climate has three principal causes: 1) a warming ocean caused water in the seas to expand, 2) a warmer climate causes an increase in terrestrial glacial melt water, and 3) the increase in global temperature results in increased levels of melting floating icebergs and ice breakups. Since these events are occurring, a prudent group of stakeholders leading the proposed LMEP will make plans to both mitigate and adapt for this increase in sea level rise. Planners and managers in the region are already developing innovative erosion control plans, and new projects such as Cameron County's Isla Blanca Park upgrades and restoration, which is moving several pavilion structures further inland and protecting them with stronger more resilient native plant dunes. Freshwater inflows will also be affected as increased levels of salt water intrusion should be expected.

2.3.3.3. Impacts of urbanization (e.g. agriculture to urban) on water quality: Urbanization is the increase in the proportion of people living in towns and cities versus rural environments. In order to build the buildings, trees and vegetation are removed. This has an effect on the watershed and drainage systems with increased storm runoff and erosion because there is less vegetation to slow water as it runs down hills. This means there will be more sediment in washed into streams (https://water.usgs.gov/edu/urbaneffects.html)..

2.3.3.4. Stormwater management to reduce urban runoff/flooding and improve water quality: The LRGV Stormwater Task Force (SWTF) is a co-operative group of 20 cities and municipalities and organizations dedicated to more effective stormwater management, pollution reduction and water quality improvement in the region. This organization has pledged support for and resource assistance to help implement the LLMEP. An important focus of the LRGV SWTF has been the promotion and implementation of Green Infrastructure (GI) or Low Impact Development (LID) approached to mitigate storm water pollution. The synergy between the collaborative efforts of the SWTF and the LMEP to improve regional water quality in and around the LLM should be encouraged and supported.

2.3.3.5. Point and non-point pollutant loadings: Encisco et al. (2014) studied the impact of residue management and sub-surface drainage on non-point source pollution in the Arroyo Colorado Watershed and found that residual management in six agricultural fields reduced the quantity of TSS, ortho-Phosphate (PO_4) and Phosphorus levels in irrigation runoff in the Arroyo Colorado. Encisco et al. (2014) also suggested the need to collect more water quality data to provide strong evidence to make water quality management decisions. Moltz et al. (2011) found that process-based models are valuable in determining the locations of critical areas to develop and implement cost-effective non-point source pollution prevention programs for large watersheds such as the Rio Grande Basin (Camie et al. 2012).Another water quality concern is low DO and poor water quality in the North and South Ponds due to sewage water effluents and stormwater runoff in the 40-acre site at World Birding Center (Edinburg, 2017). Membrane treatment systems are promising technologies to help control the spread of the cryptosporidium parasite in the Arroyo Colorado basin (http://lrgvdc.org/downloads/water/ArroyoWPP_Draft_01-20-17.pdf).

2.3.3.6. Enhance coastal resilience under extreme events: Coastal resilience means improving the ability of a community to "bounce back" after hazardous events such as hurricanes, coastal storms, and flooding rather than simply reacting to impacts. Weather and climate disasters events across the United States cause the deaths of people and billions of dollars in damage. In 2012 there were 11 weather and climate disasters that that caused 377 deaths and over 110 billion in damages (NOAA NCEI, 2018).

2.3.3.7. Hurricane mitigation: Hurricane storm surge is an abnormal rise in sea level that destroys coastal land due to the extensive erosion caused by the rapid flow circulation of a hurricane, as well as overland floods caused by the abnormal rise in the ocean. This is a definite threat to the Rio Grande/Río Bravo Estuary border region including the Lower Laguna Madre (LLM), since it plays a significant role in the United State Gulf Intracoastal Waterway by providing tourist attraction and habitats for marine life. Improved prediction of storm tide zones will give vital information on a disaster prevention and emergency management, since coastal flooding is primarily a result of storm surge, wind-driven ocean waves, and tidal influence in the low-lying coastal areas. Countywide emergency management e.g., Cameron and Willacy Counties, needs to be enhanced for the region (http://www.co.cameron.tx.us/document_center/Approved_Cameron_County_HMAP_Ready_for_Web_Page.pdf).
(http://www.twdb.texas.gov/conservation/municipal/plans/index.asp).

2.3.3.8. Poor drainage in colonias and flooding issues:
Colonias are unplanned small residential communities without most utility services. The drainage and flood control aspects of these small communities are of concern, and excessive runoff from these colonias can create water impairment threats to the LLM. Improved management for drainage and wastewater treatment in the regional colonias is an important need for the LLM watershed.

2.3.3.9. Drought prediction and mitigation for enhancing resiliency: A drought contingency plan is a strategy or combination of strategies for monitoring the progression of a drought and preparing a response to potential water supply shortages resulting from severe droughts or other water supply emergencies. The last big drought the Valley region was back in early 2013 and rainfall had not returned to moderate conditions until fall of 2014. As of October 2017, TWDB released a water condition report which stated that the lower Rio Grande Valley and northeast Texas will remain under moderate drought conditions which have expanded slightly. When drought conditions exist, entities implement drought contingency plans and drought management strategies. Entities implementing water restrictions plans are required to notify the Texas Commission on Environmental Quality. With the implementation of drought contingency plans, entities can develop more resilience for future occurrences (http://www.twdb.texas.gov/conservation/municipal/plans/index.asp).

2.3.3.10. Algal blooms in waterways and drainage ditches: Algal blooms in waterways and ponds and streams are primarily caused by excessive nutrient runoff from non-point source pollution (NPS) which further leads to eutrophication and subsequently low dissolved oxygen levels. One of the primarily impairments in the Arroyo Colorado Watershed is low dissolved oxygen along with bacteria. Thus, non-point source pollution prevention and mitigation in both rural and urban and agricultural operations must be a priority for consideration by the CCMP of the proposed LLM Estuary Program.

2.3.3.11. Bank erosion control of resacas: Resacas or regional ox-bow ponds and lakes in the LLM watershed, are critical structures for flood control and management. These structures must be protected and sometimes reinforced through various methods including hard and soft (vegetative) management and installation approaches because of their important role in flood control and the management of nutrients and sediment.

2.3.3.12. Desalination and management of brine disposal: Given the rapid growth in population and industries in the region, the demand of freshwater resources is going to increase significantly based on several TWDB water resources planning group reports. Desalination can offer alternative sources of water that can promote further growth and development in the region. Some of the ongoing challenges in sea water desalination are higher costs and proper disposal of brine generated during the desalination process. To overcome these issues, there is a need to develop cost-effective technologies that can lower the costs of desalination and find alternative and cheaper methods to safely dispose of the brine in the Bahia Grande area or others in the LLM region (http://www.twdb.texas.gov/innovativewater/desal/index.asp).

2.3.3.13. Water conservation and flood control: Water conservation and reuse programs will be an important focus for the CCMP as the fresh water inflows become more needed in the future to achieve more balanced ecosystems in the LLM. Irrigation Districts and Drainage Districts are working towards improved water management through canal and channel maintenance activities and conservation approaches. Stormwater capture and reuse is becoming more prevalent in areas in California and some of those ideas and methods may be transferable to the south Texas region. Innovative flood control optimization for severe events should take into consideration drainage planning, outflow bottlenecks, storage and unique regional features such as the Brownsville Resaca system.

2.3.3.14. Wind farms and their effects on wildlife and hydrology: A wind farm is a group of wind turbines in a location used to produce electricity by harvesting the power of the wind. A large wind farm can contain hundreds of wind turbines spread out over hundreds of miles. Modern turbines have a solid tower so birds cannot rest or nest on them. The presence of large wind turbines may cause birds to avoid a site, thus losing a foraging resource and requiring birds to expend extra energy to fly around in order to avoid a collision. The risk of collision not only threatens individual birds but also amplifies existing threats to their populations. Offshore wind farms have been found to divert migration routes of sea ducks from those routes traditionally followed. When constructing wind turbine farms, turbine foundations, access tracks, and borrow pits must be built which may lead to additional sediment or chemical pollution to water supplies (https://www.boem.gov/ESPIS/5/5305.pdf).

2.3.3.15. Surface water – groundwater (GW) interactions and effects GW pumping: Many studies show that the leakage of surface water to recharge groundwater and vice versa could varies significantly at various spatial and temporal scales (Sophocleous 2002; Winter et al., 2002, Green et al., 2001). Aquifers containing contaminants can discharge into surface waters, leading to the contamination of these surface water bodies. Similarly, surface water bodies can transmit water (and perhaps contaminants) to groundwater. Therefore, it is important to estimate and analyze surface water – groundwater interactions using modeling and data acquisition. When considering the dependence of ecosystem health on salinity regimes in south Texas, focus should not only be directed to surface water inflows and high evaporation rates, but also to groundwater discharges and other anthropogenic sources of salinization (Bighash and Murgulet, 2015). Additionally, excessive groundwater pumping in coastal areas of the LLM Estuary system can result in salt water intrusion issues in freshwater resources. Therefore, integrated surface water – GW modeling studies are much needed to better understand and manage freshwater resources in the region (https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1856&context=usdaarsfacpub) (http://www.glo.texas.gov/coastal-grants/_documents/grant-project/15-047-evaluating-groundwater.pdf).

2.3.3.16. Monitoring of air and water quality due to rapid industrial growth: Due to the construction and operation of new LNG facilities and Space X in the LRGV, the region will experience rapid economic growth. However, it is also important that such economic development take place in a thoughtful manner such that the environment is not severely impacted. Therefore, it is critical to monitor air and water quality in the

LLM region to estimate and mitigate the potential impacts of rapid industrial growth on the environment and ecosystem services. Accordingly, creative and effective mitigation and restoration projects should be promoted to balance the economic growth by minimizing the impact to the environmental and human health.

2.4 Economic Development Needs and Issues

2.4.1 Need to promote eco-tourism: Ecotourism is tourism directed toward notable features of the natural environment in order to support conservation efforts and observe wildlife in their natural habitat. Ecotourism is important since it builds environmental and cultural awareness while providing a direct financial benefit for conservation. It also raises sensitivity to a host region's political, environmental and social culture. Some local places that promote eco-tourism include the Bentsen- Rio Grande Valley State Park; in this park one can bird watch and observe nature. Another popular place for ecotourism is the Dolphin Research and Sea Life Nature Center where the tourists are able to experience sea life while exploring different attractions. Another example is agro-ecotourism via the Hiltop Gardens in Port Mansfield near the Hidalgo County border. Farmer communities can benefit from Ranch tours to promote ecotourism, which can also add economic value to stakeholders in the region (https://www.brownsvilleherald.com/news/lng/, https://www.spibirding.com/your-visit, https://chambermaster.blob.core.windows.net/userfiles/UserFiles/chambers/1294/CMS/convert/www.valleychamber.com/files/3164.pdf).

.

2.4.2. Need for smart economic development and infrastructure: In the Lower Rio Grande Valley, several new LNG projects and the Space X launch will add multi-billions of dollars to the local economy. However, smart economic development strategies need to be developed so that corresponding mitigation and restoration projects can be optimized to balance the impacts to the environment and human health. Many small and mid-sized cities around the United States are struggling because their economies were built largely on a single economic sector that has changed significantly. Instead of seeking major employers to replace these lost jobs, several cities are trying a different method to overcome these challenges. One of those methods is the stimulation of smart economic development. There are three core components for a smart growth economic development strategy which include supporting businesses, workers, and quality of life. Supporting and expanding existing businesses and attracting new businesses contribute to economic development in several key ways, including helping businesses create jobs, encouraging entrepreneurship, enhancing fiscal sustainability by expanding and diversifying the tax base, and improving quality of life with new services and amenities. Workforce development is important for ensuring that residents can successfully compete for employment opportunities and that all residents have the opportunity to benefit from the local economic prosperity. A variety of factors can improve quality of life, such as a thriving downtown or commercial district with neighborhood-serving shops and restaurants; green and open spaces; a variety of transportation choices, including options for walking, biking, driving, and public transit; artistic, cultural, and community resources such as museums, public art, community centers, religious institutions, and other community gathering spaces; and medical, technical, and academic institutions. Aesthetic improvements might include green infrastructure such as trees and other vegetation that help to improve the pedestrian environment while absorbing rainwater and improving water and air quality.

Another important consideration of economic development is to estimate effects of second causeway on South Padre Island, Port Isabel and the surrounding areas. Fig 8. Shows the reasonable alternatives for South Padre Island 2nd access causeway under consideration by the Cameron County.

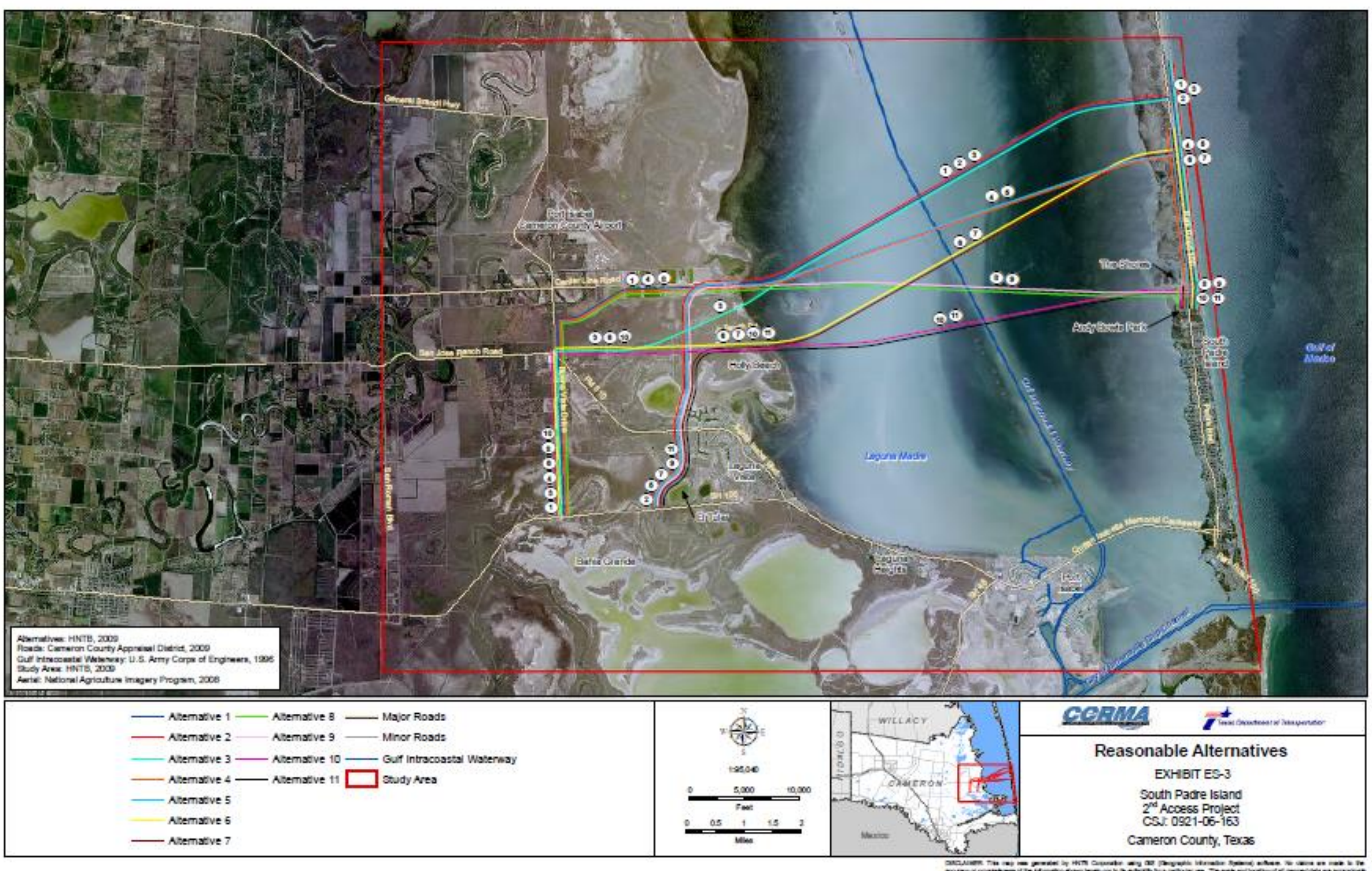

Fig 8. Reasonable alternatives for South Padre Island 2nd Access Project

(source: Cameron County).

Another example of infrastructure on economic growth is demolition and repair of Rio Hondo Bridge: The Bridge, built in 1953, spans the Arroyo Colorado River allowing access to the Port of Harlingen and is one of only two lift-span bridges in Texas. The long-running shutdown due to the bridge renovation construction has been an serous transportation issue, although allowing barge traffic access to the Port of Harlingen upstream. TxDOT, the project manager expects the iconic span will re-open to traffic in December 2018 (https://valleycentral.com/news/local/txdot-rio-hondo-bridge-to-open-friday).

.

2.4.3. Need to quantify economic values of wildlife conservation and protection: Given the importance of wildlife and habitats in the LLM region, which serve as home to several unique and threatened species of birds and animals, it is important to continue to assess the economic benefits for wildlife conservation and protection. Several National Nature Reserves, World Birding Centers and natural habitats and wetlands in the LLM Estuary region need to be protected and the cost benefit analyses need to be performed in terms of incorporating eco-tourism, recreation activities and restoration projects (https://www.researchgate.net/publication/11393617_The_value_of_wildlife).

2.5 Policy, Management and Planning Needs and Issues

2.5.1. Need for updating emergency management plans and evacuation routes: Effective emergency management plans and open evacuation routes during severe events are priorities for the local municipalities and stakeholder for the LLM. Thus these plans will have to be considered and implemented in conjunction any long range plans and strategies for LLM estuary program development. Other regional plans including but not limited to solid waste management plans, erosion control plans, flood mitigation plans and stormwater management plans should also be considered while developing the CCMP.

2.5.2. Ship channel maintenance: The Port of Brownsville and its ship channel are becoming leaders and trend-setters in its environment protection, economic development, and social/scientific problem solving and challenges. The Port of Brownsville and ship channel is the only deep-water port located on the U.S. and Mexico border at the southernmost tip of Texas at the westernmost terminus of a 17-

mile long ship channel that flows into the Gulf of Mexico at the Brazos Santiago Pass. The Brownsville Ship Channel was recently authorized to deepen channel to 52 feet by approval under the Water Resources and Development Act 2016, which supports the Brazos Island Harbor Channel Improvement project proposed by the U.S. Army Corps of Engineers. In addition, multiple Liquefied Natural Gas (LNG) facilities are proposed to be located near the Bahia Grande Wetland, a restored wetland beginning in 2005 by rerouting the Laguna Madre through a pilot channel from the ship channel. About 1,850 acres of land are proposed to be used for the LNG sites and about 22 % of the ship channel shoreline. The wetland serves as an important nursery and habitat for a wide variety of fish and shellfish and the restoration project received the National Wetlands Conservation award in 2007. It is obvious that the positive and negative impacts of the new development plan in this coastal/port area are serious issues for regional economic development and environment protection to be considered by the proposed LLM EP (https://www.portofbrownsville.com/).

2.5.3. Oil spills and illegal waste dumping: Due to oil spills such as the Deepwater Horizon spill in 2010, it is critical to develop an inventory of "shovel-ready" significant mitigation and restoration projects for the regional environment. In particular, strategies for restoration of natural habitats and wildlife need to be promoted in response to oil spills. Similarly, illegal waste dumping could be minimized by improved monitoring, data collection, and an enhancement of awareness in the local society and by thorough enforcement of regulations. There is a need to minimize illegal dumping of wastes and spills in the Arroyo Colorado basin, remote areas, canals and resacas throughout the LLM watershed. With the advent of new oil and gas activity, this need becomes critical to prevent and mitigate potentially severe impacts (https://www.britannica.com/event/Deepwater-Horizon-oil-spill-of-2010).

2.5.4. Purple Pipe effluent management (for parks, water features, others): Upcoming reclaimed water reuse "purple pipe" projects across the LRGV may decrease flows in the Arroyo Colorado and increase pollutant concentrations, if not managed properly (City of Mission, 2017).

2.5.5. Public health issues and transmission of diseases: The semi-arid tropical climate of South Texas can support transmission of various diseases transmitted by vectors such as Zika virus and others. The LLM EP group must be prepared to work with municipalities and agencies to improve ecosystem health and help mitigate vector transmission of disease where appropriate.

Lower Laguna Madre Estuary Program Strategic Plan

Thrust Area 3: Likelihood of Success and Sustainability of the LM Estuary Program

3.1 Overview

Texas A&M University – Kingsville (TAMU-K), the University of Texas – Rio Grande Valley (UT-RGV) and Cameron County have formed a partnership to develop a Strategic Plan to establish a National Estuary Program (NEP) in the Lower Laguna Madre (LLM) watershed. The Strategic Plan (the Plan) includes tools, techniques and information to assist coastal and LLM watershed communities better understand water quality, ecosystem health and resilience vulnerabilities in their region. The Plan will be utilized by decision-makers and municipal leaders to promote community resilience, disseminate information and establish integrated local water quality and ecosystem management plans for their respective communities and jurisdictions.

The draft Strategic Plan consists of three (3) Topic Thrusts that have been divided into subtopics and further divided into specific issues of interest. Each Thrust Topic has a project team manager assigned to coordinate research assignments, workshops and meetings, and reporting. Each subtopic issue of interest represents a research assignment. TAMUK and UT-RGV researchers, staff and students were assigned specific research assignments that included literature reviews, identifying and gathering existing pertinent information, reporting data gaps, identification of additional stakeholders, and a final assessment of the scope of work for the NEP process. Any additional issues of interest identified during the collaborative workshop and planning period and not listed on the original list will be added to the scope of work, if time allows. The findings of each Topic Thrust were assessed and Critical Issues under each Topic Thrust identified. The Critical Issues are presented with a priority level, resolution goals, objectives, action items and potential projects. Each potential project includes a narrative, a principal investigator or owner, a cost estimate, a scope of work, and expected outcomes. The project types were listed and categorized as planning, design, construction, real estate purchase, mitigation, startup and expected completion date, required funding, existing resources and schedules, research, outreach or management. Other categories were added, as warranted, during the grant period.

The resulting Strategic Plan now consists of three Topic Thrusts under the headings: 1) National significance designation, 2) Important needs and goals for an LLM Estuary Program, and 3) Critical resource identification and planning for the implementation and sustainability of an LLM NEP. Each Topic Thrust was subdivided into subtopics and further divided into specific areas of interest. Each area of interest was assessed and Critical Issues for that Topic Thrust were identified. Each Critical Issue consisted of a Goal, Objective, and Action Items. The Strategic Plan also includes a section in which Critical Issue Action items were identified as potential projects.

3.2 Significance of engagement of local, regional, state and federal stakeholders

The likelihood of success or sustainability of the proposed Laguna Madre Estuary Program will be based on the support and commitment of the regional and local stakeholders to achieve the goals of the Program, including the achievement of a healthy coastal ecosystem. Federal and state agency collaboration will be important and influential, but the leadership and long term success will be most strongly dependent on the regional municipal and local communities and citizens.

As a starting point for establishment of the LMEP, Cameron County, Texas, passed a resolution of commitment providing resources and fiscal support for a Laguna Madre Estuary Program planner and coordinator on April 9, 2015. A copy of this Resolution is provided in Appendix A which provides resources for the position to coordinate and help organize Estuary Program activities and planning.

In 2017, the Texas General Land Office provided additional support through a grant from the CMP Cycle 21 Program to develop a Strategic Plan to organize and plan to establish and implement an Estuary Program for the region. The Texas General Land Office CMP Cycle 21 funds have been used to help develop the Plan. The project has identified pertinent data sources and compiled information on critical issues related to estuarine, coastal, agricultural, industrial, recreational and inland resources in the LLM through workshops and meetings. The project also helped assess the findings, examine and prioritize critical area issues, ascertain the economic impact of the issue through cost analysis and the development of objectives and action items to initiate the process. Additionally, the project located data gaps and expanded the collaborative team to include area stakeholders (e.g. landowners, agricultural organizations, non-profit groups, NGOs, and other local governments) also during the workshop series. A list of workshops that were completed with stakeholder groups, and workshop locations and dates is presented as a Table in Appendix B.

Important aspects of this Plan will include the steps outlined for correspondence and linkage to the U.S. EPA National Estuary Program focused on the guidelines, significance, needs and sustainability planning in a manner consistent with relevant guidance documents.

Public support for the Laguna Madre Estuary Program is essential and will be brought about through education programs, outreach, watershed protection planning group collaboration, higher education institutions in the region, and the Lower Rio Grande Valley Stormwater Task

Force consisting of over 20 municipalities, cities, counties, irrigation districts, drainage districts and agencies.

Over the long term, a Comprehensive Conservation & Management Plan (CCMP) will be needed for the Estuary Program and the U.S.EPA National Estuary Program Guidance document (EPA 842-B-92-002) should be followed for this process. This guidance document includes information to develop an effective Conference Management Membership, a Characterization Summary, Base Program Analyses, Action Plans, Finance Plans and Implementation Strategies, a Monitoring Program Plan, a Federal Consistency Report, a Public Participation Summary and a Summary of the Response to Public Comments. Afterwards, more steps toward Estuary Program establishment include more public review, the Governor's concurrence, CZM consistency review, and the EPA Administrator's approval.

Important considerations for inclusion into the proposed Estuary Program for the Laguna Madre include two major new development scenarios for South Padre Island and the region - the proposed Second Access Causeway to the northern part of the Island, and extensive proposed Liquified Natural Gas (LNG) terminal and pipeline construction near the Brownsville Ship Channel. The proposed Second Access Causeway is needed for more effective emergency evacuation and preparedness for the regions citizens, but the expected increase in property values and added tax revenue will create increased development pressures and stressors on Laguna Madre ecosystems and water quality. At least three proposed LNG processing facilities and terminals including Rio Grande LNG, Texas LNG, and NextDecade LNG have begun to file proposals with FERC for approval to begin permitting and construction near the Ship Channel. The construction of these facilities will have significant potential impact on shoreline erosion, sediment runoff and transport, wetlands and native habitat, and water quality. The proposed Estuary Program will be needed to help stakeholders address these issues and develop mitigation and adaptation strategies. The LNG operators have been invited to collaborate and help optimize topics of concern to be faced by the proposed LMEP.

New and existing watershed protection plans (WPP) for the region will be important participants in the membership of the new LMEP. The Arroyo Colorado WPP has been approved by TCEQ and U.S.EPA for implementation in 2017, and the Brownsville Ship Channel Ressaca WPP is under development by TCEQ and faculty and students from the University of Texas Rio Grande Valley. These important Plans will need to be coordinated and critical issues coalesced with the objectives and goals of the LMEP.

The Arroyo Colorado flows through Hidalgo, Cameron and Willacy Counties in the Lower Rio Grande Valley of Texas into the Laguna Madre (Figure 1). As a result of low dissolved oxygen levels, the tidal segment of the Arroyo Colorado (2201), does not currently meet the aquatic life use designated by the State of Texas and described in the Water Quality Standards. This has been the case for every 303(d) list prepared by the state since 1996. There have also been concerns for high nutrient levels in this river as documented on every 305(b) assessment prepared by the state since 1998. In order to meet the dissolved oxygen criteria (24-hour average of 4.0 mg/L and minimum of 3.0 mg/L) at least 90% of the time between the critical period of March through October, the Texas Commission on Environmental Quality (TCEQ) (2003) estimates a 90% reduction in nitrogen, phosphorous, oxygen demanding substances and sediment will be necessary.

The Arroyo Colorado Watershed Protection Plan (WPP) is a valuable building block and platform for the LMEP. In response to impairment in this watershed, a local effort was initiated to develop a WPP to improve conditions in the Arroyo Colorado. Working with the TCEQ, the Texas State Soil and Water Conservation Board (TSSWCB), and other agencies, a local steering committee has devised and begun to implement strategies to increase dissolved oxygen in the Arroyo and improve its environmental condition.

The consensus-based, local effort began in July 2003 with the formation of the Arroyo Colorado Watershed Partnership. The Arroyo Colorado Watershed Partnership Steering Committee, consisting of local stakeholders and agency representatives, and workgroups provided direction for the Arroyo Colorado Watershed Partnership in development of the Arroyo Colorado WPP. Texas Sea Grant College Program and the AgriLife Extension Service facilitated and coordinated the development of the WPP through funding provided by TCEQ through a Clean Water Act (CWA) Section 319(h) grant. The WPP included five major components: Wastewater Infrastructure; Agricultural Issues; Habitat Restoration; Further Study and Monitoring/ Refinement of TMDL Analysis; and Outreach and Education. The five workgroups developed recommendations for each of their components including action items that will improve water quality. As a result of their efforts, the "Watershed Protection Plan for the Arroyo Colorado, Phase I" was developed and released in 2007.

3.2.1. The LRGV TPDES Stormwater Task Force

In 2002, facilitated by Texas A&M University –Kingsville (TAMUK), a coalition of then seventeen (now up to twenty in 2017) LRGV local governments joined to form the LRGV TPDES Stormwater Task Force (LSWTF) in a joint effort to develop a proactive regional approach to comply with the TPDES Phase II MS4 rules. TAMUK and the LSWTF developed a regional stormwater management plan (SWMP) adopted by the membership. The SWMP includes BMPs that are required as part of the seven (7) MCMs of the State's TPDES program. It is important to note that LID concepts are not mandated in the State of Texas and are not part of the region's TPDES MS4 programs.

The LTSTF project idea evolved from a 2002 local stormwater brainstorming round table held in La Feria, Texas. Several preliminary meetings continued at various cities until the coalition was formally organized. Local government officials and qualified professionals representing various communities in the LRGV region attended these meetings. The group agreed to develop a way to achieve a regional SWMP to comply with the TPDES regulations. The group formalized the organization by contractually empowering TAMUK to facilitate the group and by developing a system of by-laws that included election of board members.

The LTSTF uses a unique, collaborative regional approach to involve various levels of government, including the TCEQ and the EPA, in developing cost-effective solutions that will achieve compliance with the TPDES rules. The LTSTF project embodies the spirit of the mutually beneficial relationships between local governments and embellishes this relationship with academia and regulators. The overall impact of this organization has yet to be fully realized.

The primary goal of the LTSTF project in 2002 was to develop and implement a regional SWMP to comply with Phase II regulations. In 2006, the LTSTF modified its mission to include NPS pollution quality management approaches to address broader water quality and watershed issues, particularly those associated with the ACWPP. The LTSTF project has already enjoyed side benefits of increased communication and cooperation, and created a collaborative process for discussing water quality issues in the LRGV's four-county region. In addition, this collaboration has enabled the participating communities and TAMUK to successfully secure many grant funding opportunities since its inception. The LTSTF membership is detailed in Appendix A.

In 2003, LTSTF participants began entering into local government interlocal agreements with TAMUK, which outlined the desire to address stormwater quality issues on a regional basis and named TAMUK as its facilitator. In executing these interlocal agreements, emphasis was placed on developing programs that study existing successful programs, addressing community goals, providing technical assistance and training, and promoting regional approaches.

In addition to the municipalities listed in Appendix A, the following organizations and individuals have been involved in LTSTF project planning and training: the cities of Laredo, Corpus Christi and San Antonio, the Arroyo Colorado Watershed Protection Partnership, TCEQ Water Quality Division and Small Business Group, EPA Region 6 Stormwater Division and Border 2012 Group, South Texas Environmental Institute, Texas Department of Transportation, Texas Sea Grant, Lower Rio Grande Valley Development Council (LRGVDC) and University of Texas-Pan American.

TAMUK and UTRGV are providing facilitation and management assistance for the LTSTF project, initiating this effort through a National Science Foundation (NSF) grant and from annual membership fees collected from the membership municipalities. The funds provide resources for staff to facilitate the group's efforts in formulating LTSTF project goals and developing LTSTF programs. Funds are also used to host workshops, expert panel discussions, conferences, seminars and training sessions.

In October of 2006 during a Task Force meeting held in Mission, TX, the organization formed several committees: ordinance, grant, scholarship, outreach, training, housekeeping, and construction. TAMUK has been working closely with the committees in implementing the SWMPs.

The new stormwater paradigm presents many questions to local governments in the LRGV. What is a stormwater management program, what will it cost, who will fund the program, is it needed, and how much will it cost? The LTSTF regional LID program is a key part of a successful regional storm water program. But, regulators and academia do not have a firm grasp of the costs associated with developing and implementing an LID program in a semi-arid region, like South Texas. Although the average citizen often takes for granted the services municipalities provide, the stormwater services are nonetheless expected. The region now requires that municipalities provide a stormwater runoff pollution protection service. This new paradigm requires the development of infrastructure and funding strategies to support providing this service.

Storm Water Quality is Now a Municipal Responsibility**.** This is not the first time municipalities have been confronted with environmental water quality regulations that affect the manner that cities allocate funds. Total Maximum Daily Load (TMDL) regulations recently started developing new performance measures for local governments, and LRGV communities have become very familiar with the Arroyo Colorado TMDL studies. Based on these studies, the drafters of the Arroyo Colorado Watershed Protection Plan (ACWPP) concluded that urban NPS pollution runoff is contributing to the impairment of the Arroyo Colorado. Thus, the timing of the LID program could not have been better. Local governments typically tend to procrastinate when it comes to addressing non-mandated environmental issues, usually because of lack of resources and lack of expertise and understanding rather than due to a non-proactive attitude. Still, finding funds to implement an LID program is a huge responsibility for any municipality. Cost effectiveness and revenue potential will be major considerations for our local governments when developing this LID concept (APWA, 2000).

3.2.2. A Regional Approach to Stormwater Management

Cities are no strangers to the concept of regionalization, and sharing the costs to comply with environmental mandates was received favorably. During LTSTF meetings it was evident that the primary role of local governments in NPS pollution management is to address local problems and needs, and at the same time comply with state and federal regulations in the most cost-effective manner. Creating a regional task force responsible for assisting cities with storm water management was viewed as a proactive idea because the collaboration promotes cooperation and dissemination of ideas. A coordinated, regionalized program can also produce economies of scale, resulting in significant cost benefits. For example, in a similar effort in Kentucky, a stormwater district that oversees thirty-three (33) municipal storm water systems conducted a study that compared the cost of developing a SWMP on a municipality-by-municipality basis with the cost associated with a regional effort. The study showed a cost two (2) to five (5) times more if each municipality prepared its own SMWP versus having a regional entity oversee the task (Woolpert, 1998). Moreover, a regional entity, with a facilitator like TAMUK, can objectively address the cause of a stormwater concern rather than just the symptoms of the problem, which often happens in the regions like the LRGV where political boundaries drive decision-making and funding allocation.

Regionalization also means that developers, engineers, and others will be less likely to violate stormwater-related policies if they know that a well-managed regional entity, rather than a small municipality, is responsible for the programs. Moreover, regionalization minimizes varying interpretations of the regulations and thus provides for consistent policies from city to city. LRGV municipalities recognize that NPS pollution management must become a top priority, but they demand innovative and cost-effective programs. The LTSTF realizes that an innovative funding approach for NPS pollution management will save money. This type of sustainable planning and local support will be transferred to the proposed LMEP even though the LMEP will be a voluntary participatory program.

3.3 Ongoing synergies and efforts to manage regional water quality and ecosystem health

The cost effectiveness of a regional approach to manage non-point source pollution is well established. The community leaders of the LTSTF membership determined that the most cost effective and efficient approach for addressing local storm water management issues was to develop and implement a regional task force approach under the guidance of a single entity. This approach has been formalized through the development and execution of Interlocal Agreements between TAMUK and the LTSTF members. Although, the LRGV region has not conducted a study to determine the cost effectiveness of a regional program, TAMUK found that the Kentucky study (Woolpert, 1998) supported the need for a regional approach to address NPDES Phase II rules. This document provides the details of a program that was developed for thirty-three (33) cities and three counties to comply with the federal Storm Water Phase II regulations. Estimates calculated by this study suggest that, by using a regional approach, the communities could achieve a cost savings of between 30 % to 70 % over the next five years. Similarly, in his report *Estimating Costs for Phase II Stormwater Management Program* (2000), Andrew Reese documents that a regional approach can reduce the costs of developing brochures, ordinances, billboards, web sites, and bulk PR materials.

In the LRGV, the communities share similar demographics and similar environmental concerns. Most residents live in low- or fixed-income households and cannot afford to pay fees to support the environmental-related requirements. Thus, there is a strong case for any type of collaboration that would keep costs down. In the LRGV, each community is contiguous to other communities, with some cities bordered by four (4) other cities. Thus, the LRGV appears as one urbanized metropolitan region. Although all these communities experience similar NPS pollution problems, none had in place a NPS pollution program or ordinance. Since the creation of the LTSTF, stormwater tasks were generally viewed as “add-on” responsibilities for departments and staff that have other primary responsibilities. To varying degrees, with the exception of McAllen and Brownsville, the communities had existing staff (such as sanitary sewer, code enforcement, or road department personnel) handling stormwater operations, maintenance, regulation and enforcement. None of the communities could maintain a person, much less a department, to handle stormwater administration planning, design, and engineering; water quality planning and monitoring; and capital improvements and expenditures. The regional approach taken by the LTSTF allows the LRGV communities to share these responsibilities, which results in a much more cost-effective program for addressing NPS pollution issues.

A significant outreach component of the LSWTF has been the sponsorship of the Annual Water Quality Conference at South Padre Island, Texas, for over 20 years. Several key symposia and presentations have been focused on the proposed Laguna Madre Estuary Program in 2016 and 2017.

3.3.1. Implementation of the Arroyo Colorado Watershed Protection Plan

The implementation of the Arroyo Colorado WPP is a priority for the TECQ Nonpoint Source (NPS) Pollution Program, and this partnership will address and implement a number of Storm Water Management and Education & Outreach elements identified in the plan. As stated in the land use section of the Arroyo Colorado WPP, “The Arroyo Colorado Watershed Partnership seeks to develop, promote and achieve sound land use practices that protect and preserve watershed resources, maintain water quality and minimize pollutants entering the Arroyo Colorado.” One of the goals of the Arroyo Colorado WPP is to increase awareness of and promote development options that incorporate elements of Smart Growth and LID. LID is an approach to land development or re-development that works with nature to manage storm water as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats storm water as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, cisterns, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and is a key component of the EPA’s national program to address urban NPS pollution. This can be achieved using onsite measures such as vegetated swales, rain gardens, green roofs, porous pavement and larger-scale practices such as retention ponds.

This project has several components that are related to the planning and updating of the Watershed Protection Plan including an important continuation of LID monitoring for bioretention facilities, rain gardens and swales and pervious pavements. Several new LID installations in the Watershed are currently generating important high quality data on reduction in runoff flows and runoff pollutant concentrations. These data are essential in the load reduction estimation needed for simplified cost-benefit analysis to provide the Valley planners, city managers, and county officials with the needed support information to bolster local ordinances and integrate LID into regional and local planning activities. Other components include street sweeping data collection and characterization for input in to watershed modeling and planning, training for LID project operation and maintenance, and cyber-infrastructure for the Arroyo Colorado interactive map and data management.

The Lower Rio Grande Valley continues to be one of the fastest-growing areas in the United States. With urbanization ever increasing within the Lower Rio Grande Region, the remaining public lands in this region will face ever increasing pressure to accommodate off site rainwater discharges from encroaching developments, subdivisions and planned communities. Incorporating successful BMPs into facility infrastructures and amenities at the refuge and/or public lands will optimize benefits from on-site rainfall. Likewise, incorporating successful BMPs will improve facility infrastructures and amenities to reduce the negative impact from contaminated off-site runoff.

3.3.2. GI/LID Program in the LRGV

The main objective of the Lower Rio Grande Valley's (LRGV's) LID program has been to develop numerous LID projects throughout the region and attempt to institutionalize this concept into municipal planning, storm water infrastructure design, and private sector development.

Each member of the Task Force has developed plans for at least one or several LID project themes in their jurisdictions. Several of these LID projects have been built as part of this program and TAMUK has used faculty, staff and graduate students to fulfill the role of obtaining data from these projects, develop findings for evaluation of the effectiveness of these BMPs in the LRGV region and provided outreach and reporting to the partners on these findings. The project team has been providing recommendations on use of these LID concepts, planning strategies and cost analyses. It is important to mention that institutionalizing LID strategies in the LRGV requires a substantial effort by the local governments and other stakeholders to convince the local community to incorporate LID concepts into everyday life, traditional development, and storm water management strategies. This program monitors existing and new LID features and programs to generate and collect data and information to support load reduction estimation and watershed planning forecasts from a variety of activities.

Texas A&M Kingsville and the LRGV TPDES Stormwater Task Force and UTRGV have been working with their partners to promote acquisition of data that will be used to evaluate water quality and load reductions within the region, to determine NPS pollution treatment potential, to provide an economic analysis, to support watershed modeling goals and to evaluate the overall effectiveness of the LID applications within the affected regions of the LRGV. Several of the characteristic LID demonstration projects are being contrasted and compared to each other within the boundaries of the site specific project, and/or will be contrasted and compared to LID projects and their site specific characteristics and applications in neighboring geographical regions or jurisdictions. The LID projects are being modeled through the use of flow reduction matching and calibration and validation using software such as WinSLAMM or equivalent to predict LID performance and load reductions for unique LRGV LID practices. The results can be used by modelers and planners for scale up and broader watershed application. New designs for optimal pervious pavements and other variants have been developed with Alamo, Mission, San Juan and at parking areas near UTRGV including using local materials, various types and volumes of underground storage and retention, and new water treatment techniques for optimal uptake and filtration and removal of nutrients.

In addition to monitoring operations at Alamo, Mission and San Juan, a new installation of bioswales with local biofiltration materials has already been constructed and prepared for testing and is ready to collect water quality data for utilization and evaluation in other LID models and applications throughout the Watershed. At UTRGV four bioswale parking lots are located in the vicinity of each other as shown in Figure 1 below. Table 1 lists the bioswale materials and the parking lot drainage area to be tested in this study. These materials were selected based on previous laboratory modeling study results conducted by Ho and Hernandez (2013). In previous sampling, it was determined that pumice material demonstrated superior stormwater volume reduction and solids removal capacity, while manufactured medium sand also showed proven performance in solids filtration with a more affordable price. The team will sample the first flush of stormwater at the inlet of the each bioswale system. The sample represents untreated raw stormwater runoff. The group will also sample the treated stormwater at the effluent end of the four bioswale systems. Through these analyses, parameters can be generated for input and initialization of some bioswale subroutines in the WinSLAMM model for prediction and inputs into designs and watershed scale modeling.

An LID BMP Operation & Maintenance and Training Program (A&M Kingsville & the LRGV TPDES Stormwater Task Force & UTRGV) has already been established for the region. In recent years, A&M Kingsville, in partnership with the members of the Lower Rio Grande Valley TPDES Stormwater Task Force has facilitated the development of six (6) constructed wetlands, 11 pervious pavements, 2 green roofs, 1 green wall, 5 bioswales, 2 rain gardens and 6 rainwater harvesting systems in the LRGV regions with the support of the Section 319 program and other grant programs. The implementation and optimization of regional BMPs is a key strategy for improving water quality in the Arroyo Colorado Watershed Protection Plan. These BMPs are spread out throughout the region to treat and detain stormwater runoff, to improve water quality, to facilitate education, and monitoring in a variety of locations and situations to help optimize the BMPs within the LRGV and its unique coastal, agricultural, urban and semi-arid geographical regions.

In order to facilitate effective operations, maintenance, and long term management for these BMPs, Texas A&M Kingsville and its partners plan to employ a Stormwater BMP professional to monitor the ecosystem health, make recommendations, provide professional training, and educate the public and elected officials on the importance of these BMPs and LID in improving water quality. This program will provide continuity, provide knowledge retention within the stakeholder's organization, and emphasize continuing education to the BMPs upkeep. A&M Kingsville and the Task Force will develop a job description. An office will be provided in the R^3TEC at A&M Kingsville, Citrus Center in Alamo, Texas. R^3TEC staff will be available to provide overhead, office support, support for training programs and environmental education, and administration, monitoring, and evaluation of the program. The program coordinator will also be able to provide additional expertise on native vegetation and wildlife, natural systems, and Valley-wide education and outreach. Water quality monitoring equipment has been purchased for several sites and will be used for training.

Routine maintenance and monitoring would be the primary responsibilities for the Program Coordinator. Regular quarterly monitoring will include a submittal of a written report of needed maintenance and operation issues that need to be addressed along with specific management and maintenance recommendations A BMP Management Plan will be developed for each BMP, based on site-specific goals and objectives, including recommendations for vegetation and equipment (pipes, fittings) maintenance, erosion control, short-circuiting of wetlands and addressing clogging issues of the permeable pavement.

A goal of this task is to ensure continuity in operations, maintenance and management of all of the various BMPs in the LRGV region. The Program Coordinator will provide professional training for city staff, outreach and environmental education for the public to garner support for other LID initiatives, and information for elected officials to promote the use of LID BMPs and change outdated codes that restrict their use. A professional training manual will be developed and produced in English and Spanish to address operation and maintenance issues of each of the BMPs. Quarterly professional training workshops, for up to 15 participants each, will incorporate the training manual and other handouts. For the greatest effect, the workshops will be marketed not just to Task Force members, but also to smaller municipal governments and other entities and individuals dealing with BMP maintenance issues in the Arroyo Colorado Watershed.

3.3.3. Engagement of public officials and local leadership

Engaging and empowering public and elected officials will promote and assure buy in to projects associated with water conservation, stormwater management, non-point source pollution reduction, and the wide-spread use of LID measures. The Program Coordinator along with R^3TEC staff and volunteers, will develop, promote, and conduct popular environmental water quality topics at the various BMP sites for schools and public groups. A minimum of 5 presentations per year will be held for up to 15 participants per presentation. LID signage will be placed at each BMP site for additional outreach.

The main objective of the Lower Rio Grande Valley's (LRGV's) LID program has been to develop numerous LID projects throughout the region and attempt to institutionalize this concept into municipal planning, storm water infrastructure design, and private sector development.

Each member of the Task Force has developed plans for at least one or several LID project themes in their jurisdictions. Several of these LID projects have been built as part of this program and TAMUK has used faculty, staff and graduate students to fulfill the role of obtaining data from these projects, develop findings for evaluation of the effectiveness of these BMPs in the LRGV region and provided outreach and reporting to the partners on these findings. The project team has been providing recommendations on use of these LID concepts, planning strategies and cost analyses. It is important to mention that institutionalizing LID strategies in the LRGV requires a substantial effort by the local governments and other stakeholders to convince the local community to incorporate LID concepts into everyday life, traditional development, and storm water management strategies. This project proposes to monitor existing and new LID features and programs to generate and collect data and information to support load reduction estimation and watershed planning forecasts from a variety of activities.

Cameron County's leadership with the Coastal Cities Task Force is another example of engagement of public officials and leaders into the promotion of Green Infrastructure and a commitment to the improvement to regional water quality.

3.3.4. Regional LID BMP interactive mapping, cyberinfrastructure and data management currently ongoing at A&M Kingsville and UTRGV

Previous project work under the NPS program at A&M Kingsville has built and established a web based interactive map highlighting important Valley wide BMPs and their georeferenced locations. This map and its associated support data structures have been adopted and housed by A&M Kingsville and the LRGV Stormwater Task Force and UTRGV. The new LMEP may choose to expand the BMP inventory and its informational platforms using the map, additional servers and cyberinfrastructure to make the system even more user friendly and complete. A decision support tool of high functionality and integration with watershed modeling tools is the long range goal. A minimum of 20 LID and/or conventional urban BMPs (different from those previously surveyed) have already been mapped. The Program could develop and ground truth GPS locations for identified BMPs and input descriptions and parameters (size/dimensions, soil type/condition, tributary areas, site specific parameters) for modeling into a database similar to MS Access or other and link to interactive map; provide to key personnel, stakeholders and partners.

3.3.5. Cameron County resource commitment and support for the LMEP

Cameron County is an important leader for implementation of the proposed LMEP.The Cameron County Parks and Recreation Department has proposed a $40M long range plan for Park expansion, environmental protection and enhancement. This plan includes important enhancements of strategic South Padre Island areas including Isla Blanca Park, Atwood Park and other sections of shorelines and coastal sections that border the Laguna Madre. The restoration of the Bahia Grande wetlands and bay areas has been a priority for the County and the region.

Resources from the Texas General Land Office, Texas Commission on Environmental Quality, the Texas Water Development Board, Texas Parks and Wildlife and Restore Act programs should be sought to complement, augment and implement the coalescing of these important regional programs through the establishment of the proposed LMEP.

The political alignment and support for the LMEP is well established through the leadership provided by Cameron County along with that of Texas A&M University Kingsville and the University of Texas Rio Grande Valley. The passage of the Cameron County resolution providing resources for a coordinator position for the LMEP, along with resources from the U.S. EPA Region 6 for coordination of an initial workshop, and that of TGLO for strategic planning in the Cycle 21 CMP program have all demonstrated the commitment of the region and its partners. Other support is being provided by commitment from additional partners such as the LRGV Stormwater Task Force made up of 20 cities and organizations, the Cameron County Coastal Cities Task Force, the LRGV Regional Mobility Authority, the LRGV Economic Development Council, and Willacy and Hidalgo Counties.

Partnerships with other regional institutions of higher education such as South Texas College (STC) in McAllen and the Harlingen Texas State Technical College (TSTC) have been established.

The LRGV Environmental Network (now called the LRGV Sustainability Network) at UTRGV has assisted in laying the groundwork for the establishment of a national estuary program for the Lower Laguna Madre. The progress and success of both efforts have been complementary. In the last workshop of the Network (May 2016), Ray Allen, the director of the Coastal Bend Bays & Estuaries Program presented an overview of their program and how a similar program could benefit the region. Participants for the Network workshop (30+) have overlapped considerably with the entities engaged in the Estuary Program meetings.

NGOs engaged include the regional section of the Sierra Club, the LRGV Audubon Society, and the LRGV Master Naturalists groups.

A long range plan for the establishment of support for the LMEP as a qualitied non-profit 501 (c) (3) should be a goal for the management conference.

3.4 Summary of Likelihood of Success and Sustainability of the Program

In summary, the local and regional support for the sustainability of the proposed LMEP is well established.

The strategic plan for the LMEP will serve to help coalesce and integrate key items from the new and existing watershed protection plans, regional stormwater management plans, solid waste management plans, erosion control plans, and other critical guidance policies and protocols for the region. This plan can be formulated through three phases or stages as follows:

I. Gather information, critical data, and guidance documents from regional ecosystem and water quality based plans already promulgated in the region including the Arroyo Colorado Watershed Protection Plan, the Lower Laguna Madre/Brownsville Ship Channel Watershed Protection Plan, the Cameron County Erosion Control Plan, the

Rio Grande, Rio Grande Estuary and Lower Laguna Madre Basin and Bay effort and others.

II. Establish a publicly available regional data repository and cyberinfrastructure for the planned Laguna Madre Estuary Program for ecological information and data warehousing and processing, quality assurance, and dissemination through program education and outreach activities.

III. Develop updates to existing plans and develop new, coordinated and coalesced planning guidelines, recommendations for policies, ecological and water quality for the new Program.

IV. Continue and expand public education and communication effort to keep the stakeholders engaged in the process.

These established partnerships have already been developed and implemented by the current Cameron County Laguna Madre Program Estuary Program Coordinator. Additional resources have been sought through external grant applications to the General Land Office and the TCEQ, and U.S. EPA. The U.S. EPA Region 6 provided a start up grant to conduct an important beginning workshop and symposium in San Benito, Texas in 2016, to help establish collective efforts and highlight the potential benefits to the region and the estuaries. The Texas General Land Office (GLO) provided resources through the CMP Cycle 21 program to bring the planners and scientists together to develop this initial strategic plan.

Strong support for the Program has been documented and personnel support and resources provided by the 20 cities, municipalities, and irrigation and drainage districts in the Lower Rio Grande Valley TPDES Stormwater Task Force (currently celebrating its 20th year anniversary), and the communities in the Cameron County Coastal Cities Task Force. Regional university partners have been participating in the planning and implementation of the Program since 2015 including Texas A&M University Kingsville, the University of Texas Rio Grande Valley, South Texas College in McAllen, Texas State Technical College (TSTC) in Harlingen, while also working with regional public school districts such as McAllen and Pharr-San Juan and others.

Finally, public support for the LMEP includes the regional non-governmental organizations (NGOs), other municipalities, and private organizations (such as the Sierra Club, the LRGV Audubon Society, the LRGV Master Naturalists and the Nature Conservancy) have expressed broad support for the LMEP. Another important contributor has been the Lower Rio Grande Valley Ecological Network housed at the University of Texas Rio Grande Valley in Edinburg, TX. Citizen Scientist's water quality monitoring programs have been included along with the outreach and education activities of the LRGV Stormwater Task Force, and the watershed protection plans.

The Texas A&M University Citrus Center has been a locus for agriculture planning and innovative programs for ranchers and growers in the region since 1945. Through the engagement of Texas A&M University Kingsville, this important connection to the regional farmers and growers of the significant agricultural community in the watershed has been secured.

The Texas State Soil and Water Conservation Board has been an important guiding agency for the most water efficient and sustainable practices and will continue to contribute through participation with the LMEP.

3.5 The way forward for the LMEP

With a strong network of federal, state and local partners as described in the previous section, the LMEP is actively seeking full engagement of other enterprises such as public utilities boards, incoming energy companies (LNG and windfarms) along with SpaceX and the ancillary industries accompanying them. Expanding the stakeholder network is one of many important steps for the continuity and sustainability of the LMEP that will include the coalescing of important aspects and parameters from existing watershed protection programs and other guidance documents. Increasing applications for federal, state and regional funding/resources, leveraged funding through foundations and private resources similar to that achieved by the Galveston Estuary Program are also key elements for the development and sustainability of this Estuary Program.

A beginning set of Specific Action Items is listed in Tables 3.1 through 3.5 of this Chapter starting with many of the needs identified in Thrust Area 2 of this document.

New applications for resources will target improved characterization, modeling and forecasting of the most sustainable and protective strategies to preserve the quality of the LM and incorporate key development milestones such as the Second Access Causeway to SPI and LNG pipeline and processing facilities along the Brownsville Ship Channel.

Cameron County will continue to provide resources for the LMEP coordinator position and coordinate efforts with existing agencies and the Cameron County Coastal Cities Task Force. The Institute for Sustainable Energy and the Environment at Texas A&M University Kingsville and the University of Texas Rio Grande Valley Civil Engineering water cluster and College of Science group (School of Earth, Environmental and Marine Sciences) will continue to provide support and resources for the LMEP through faculty release time and graduate students.

More resources will be sought and established for the LMEP environmental informatics infrastructure, web-based training and data warehousing, quality assurance and education and outreach activities. Key focus items will be the LM living resources and protection needs identified in Thrust Area 2, and important restoration projects such as the Bahia Grande restoration and the Cameron County Parks Long Range Plan and others.

The proposed organizational structure for the LMEP will closely follow those of the successful Coastal Bend Bays and Estuaries Program in Corpus Christi and Galveston Bay Estuary Program. However, some special partnerships will be recognized in this structure to emphasize the needs of some special status members such as regional landowners, growers, oil and gas developers, the Regional Mobility Authorities, and others.

See Appendix B for an itemized listing of the strategic stakeholders and groups envisioned for the success of the LMEP.

The Monitoring Strategy for the LMEP will include measurable parameters to evaluate success, a strong outreach and communication plan and roles and contributions for partners and collaborators and agency supporters.

The principal goals for the Laguna Madre Estuary Program will encompass the broad goals as itemized in the U.S. EPA National Estuaries Program goals for Comprehensive Conservation and Management Plans (CCMPs). These goals include a focus on restoring water quality, restoring and conserving habitat, replenishing and protecting living coastal and marine resources, enhancing community resilience, and restoring and revitalizing the Gulf economy,

To summarize some of the most critical issues to be addressed by the LMEP are the following as a starting point for the Management Committee to start initiatives for the Program.

- Limited freshwater inflows need characterization and protection including the reduction of non-point source pollution with green infrastructure and innovative techniques
- Loss of wetlands (seagrass and mangroves) and critical habitat needs to be addressed
- Rapid oil and gas development for the emerging liquified natural gas (LNG) industry needs evaluation and mitigation
- Dredging of channels and spoil beneficial reuse is needed
- Impacts of algal blooms (red tides and brown tides) need mitigation
- Degradation of water quality in the estuaries and tributaries needs to be reversed
- Sea turtle habitat protection and restoration must be a priority
- Determining and mitigating cumulative impacts of new development and the maintenance and impacts of drainage and irrigation districts should be addressed
- Protect and enhance birding habitat for red egret, redhead duck, piping plover, and other shorebirds
- The impacts of sea level rise and climate change on the Laguna Madre must be assessed and planned for mitigation and adaptation
- The balance between ecological protection and economic growth must be carefully considered and measured with innovative trend analyses for the Laguna Madre.

A short list of action items is summarized below (more complete listings are in Tables 3.1 through 3.5)

- Coalesce and implement the LMEP Management Conference and establish the organizational structure, participants, operating guidelines, advisory boards and sources of funding
- Finalize and implement the LMEP Strategic Plan

- Develop and adopt a Comprehensive Conservation and Management Plan (CCMP) for the Lower Laguna Madre Estuary Program

Formalize priorities for short-range projects:

- Establish informational databases, mapping tools, policies and cyber infrastructure for the LMEP
- Continue to enhance the Bahia Grande restoration project
- Assess status and trends of living resources
- Develop and implement coastal dune protection policies, County Erosion Control Plans, and enhance vulnerable dune ecosystems
- Complete the characterization of flows and sub-basins in and around the North Floodway and northern segments of the Arroyo Colorado watershed
- Develop and implement training programs for managers and technical personnel to optimize and maintain constructed wetlands

Formalize priorities for longer-term projects:

- Geospatial modeling and optimization of BMP placement and designs for specific sub-basins in the region
- Complete the data acquisition and modeling of water quality for the Lower Laguna Madre for predictive studies and mitigation evaluations
- Continue characterization and modeling of seagrass, water quality, habitat quality and ecosystem assessment
- Model and mitigate the impact of long-term development projects such as the Second Access Causeway to SPI, and LNG and pipeline infrastructure near the Brownsville Ship Channel

Finance Strategy for LMEP sustainability

To successfully leverage federal seed money into substantial sums, the LMEPs has develop this finance plans to obtain a variety of federal, state, local, and private funding. As stated above, the LMEP has identified the most critical issues (program priorities), the funding strategies, implementation status and sources of funding to address the mentioned issues are listed on the table below:

Funding strategy	**Status**	**Source(s)**
Annual Appeal	Under Consideration	General Public
Special Appeal	Under Consideration	Special Interest Groups

Grant and Partnership	Implemented	EPA, TCEQ, TWDB, TSWWCB, NOAA, TPWD, TxGLO, etc.
License Plate Program	Under Consideration	Registered Vehicles in the State of Texas
Supplemental Environmental Project	In the process of approval	TCEQ through fines and penalties
Hotel Occupancy Tax	Under Consideration	Out-of-town Visitors
Interlocal Agreements	Implemented	Local governments/stakeholders

Thus far a strong stakeholder partnership is established with strategic alliances, the above financing options identified (some of the currently under implementation) and that seed money has been allocated to the conference (GLO CMP grant and Cameron County Interlocal Agreement to establish the program). It is the LMEP purpose to generate a "snowball effect" by demonstrating environmental results that will be disseminated across the stakeholders in the watershed that will help to increase the LMEP's portfolio of success stories to entice existing and potential contributors to invest in the Program.

Table 3.1 Lower Laguna Madre Estuary Program planned action items for restoring water quality.

Critical issue. Restore Water Quality	
Objective	**Action Item**
Coalesce and quality assure LM water quality data and information from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for LM water quality assured data and information
Acquire more quality assured water quality data and information in and around LM critically impaired areas to improve water quality modeling and understanding of impairments and their resolution	Develop sources of support for additional water quality sampling and data acquisition near discharge outlets and for critically impaired areas of the LM
Identify and address WQ data gaps; establish basis for Comprehensive Conservation and Management Plan (CCMP)	Develop proposals to collect WQ data to address data gaps

Reduce the impacts of desalination concentrate disposal into water bodies in the LM watersheds	Implement new methods and technologies to more effectively treat the concentrate produced by the RO treatment of brackish water at the Southmost Regional Water Authority (SRWA) Regional Desalination Plant
Improve desalination economics and reduce impacts recover minerals from RO concentrate	Evaluate and implement new physico-electro-chemical processes to recover minerals with marketable value, such as calcium sulfate, and sodium chloride, from RO concentrate produced at the SRWA desalination plant
Identify sites and sub-watersheds with water quality concerns and/or impairments	Use modeling to characterize sub-watersheds and identify additional sites for water quality data collection
Assess surface water and groundwater availability and develop water management strategies to enhance water availability for human and ecosystem needs (e.g. freshwater inflows)	Use multiple hydrologic models to estimate water availability, improve water management (e.g. storing excess water during floods as detention ponds or in underground reservoirs (e.g. Aquifer Storage Recovery)

Critical Areas: Outfalls and impaired areas on the Arroyo Colorado, Brownsville Ship Channel, Bahia Grande, San Martin Lake, IBWC Floodway, Hidalgo Main Drain, Raymondville Drain, drainage canals and regional detention facilities	
Goal: Increase water quality to EPA's minimum standards.	
Potential Funding Sources: CWA 319, GLO CMP, CIAP, Border 2020, RESTORE Act, EPA GOMP, local and national non-profit foundations	
Implementation Strategies	
Participation	Recommended Strategies
Local Utility Companies	Work with local utility companies to improve desalination management practices.
Municipalities	Work with municipalities to establish routine monitoring of storm drain outfalls and promote implementation of green infrastructure.
Drainage Districts	Work with drainage districts to establish routine monitoring of drainage canals and ditches during peak irrigation season
Stormwater Taskforce	Develop monitoring plan and stormwater monitoring demonstration project to establish stormwater pollution load database. Assist cities with establishing their own monitoring program

Local Universities	Develop sub-watershed models and decision making tools for municipalities that help to estimate the impact new development or redevelopment will have in stormwater pollutant loading to the Lowe Laguna Madre.

Table 3.2 Lower Laguna Madre Estuary Program planned action items for restoring and preserving habitat.

Critical issue. Restore and Preserve Habitat	
Objective	**Action Item**
Coalesce and quality assure seagrass quality and productivity data and information from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for seagrass quality assured data and information
Acquire more quality assured seagrass data and information in and around LM FWI sources and mixing zones to improve ecosystem modeling and linkage to water quality impairments and their resolution	Develop sources of support for additional seagrass assessment and remote sensing data acquisition near FWI sources and around critically impaired areas of the LM
Coalesce and quality assure ecosystem inventories and trends for ecosystem resources and data and information from various sources	Develop proposals and resources to establish quality assured data and information to support the significant inventories and trends in current ecosystem health and protection for the LM
Coalesce and quality assured freshwater intrusion data and stormwater control information for the LLM	Develop proposals and resources to assess data gaps of the LLM freshwater intrusions and to build a systematic LLM watershed wide flood control model
Coalesce and quality assure tidal flats and mangrove quality and productivity data and information from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for tidal flats and mangrove quality assured data and information

Develop sea- turtle friendly Dune Mitigation and beach nourishment practices, protocols and technical guidance.	Expand the scope and engagement of agencies and NGO, such as Sea Turtle Inc., to provide input in the dune mitigation projects and dune protection committee.

Critical Areas: Tidal Flats, fresh water outfalls into the LLM, FWI mixing zones	
Goal: Protect And Enhance habitat in the LMEP watershed	
Potential Funding Sources: GLO CMP, CIAP, RESTORE Act, EPA GOMP local and national non-profit foundations	
Implementation Strategies	
Participation	Recommended Strategies
NGOs	Work with NGOs to include their expertice in better practices development
Local Universities	Develop monitoring networks for FIW mixing areas and its impact on seagrass health.

Table 3.3 Lower Laguna Madre Estuary Program planned action items for replenishing and protecting living coastal and marine resources.

Critical issue. Replenishing And Protecting Living Coastal And Marine Resources	
Objective	**Action Item**
Coalesce and quality assure vegetation assessment data and information for coastal dunes from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for LM water quality assured data and information
Acquire more quality assured vegetation assessment data and information in and around LLM critically impaired areas to improve ecosystem modeling and dune resilience to erosion and coastal storm surges	Develop sources of support for additional dune vegetation sampling and data acquisition near areas of accelerated dune erosion and sparse vegetation, including remote sensing monitoring tools and coastal hydrodynamic models
Coalesce and quality assure living resources assessment data and information for the LLM	Develop proposals to assess the status, trends and data gaps of LLM living resources
Address data gaps of LLM living resources	Develop proposals to acquire new data to address critical living resources data gaps.
Critical Areas: Entire Lower Laguna Madre	
Goal: protect existing living coastal resource to the levers before major anthropogenic impact	
Potential Funding Sources: GLO CMP, CIAP, RESTORE Act, EPA GOMP, TPWD, USFW, local and national non-profit foundations	

Table 3.4 Lower Laguna Madre Estuary Program planned action items for enhancing community resilience.

Critical issue. Enhancing Community Resilience	
Objective	**Action Item**
Coalesce erosion control data and response plans and information from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for quality assured erosion data and information
Acquire more quality assured coastal erosion data and information in and around areas of exceptionally high erosion and vegetation damage to improve erosion control response modeling and propose new approaches and methods of protection	Develop sources of support for additional erosion measurements and data acquisition near infrastructure and critically impaired areas of the LM
Enhance resiliency during droughts and floods	Use hydrologic modeling to forecast droughts and floods. Use real-time hydrologic forecasting information to update drought contingency plans.
Acquire more quality assured coastal economic data and information for the LM to assess impacts of catastrophic weather events	Develop sources of support for additional economic data acquisition to help decision makers plan for appropriate mitigation of tropical storms
Critical Areas: Entire Lower Laguna Madre	
Goal: Reduce damage and recovery time during and after natural disaster	
Potential Funding Sources: GLO CMP, CIAP, RESTORE Act, EPA GOMP, TPWD, USFW, NOAA, FEMA, local and national non-profit foundations	
Implementation Strategies	
Participation	Recommended Strategies
Local Utility Companies	Work with local utility companies to implement proactive water conservation strategies

Municipalities	Work with municipalities to establish routine monitoring of drainage infrastructure and implement proactive water conservation strategies
Drainage Districts	Work with drainage districts to establish routine monitoring of drainage canals and ditches and construct regional detention facilities.
Stormwater Taskforce	Develop monitoring plan and stormwater surface water elevation connected to early warning systems
Local Universities	Develop watershed models and decision-making tools for municipalities that help to forecast surface waters elevation.

Table 3.5 Lower Laguna Madre Estuary Program planned action items for restoring and revitalizing the regional Gulf economy.

Critical issue. Restoring And Revitalizing The Regional Gulf Economy	
Coalesce and quality assure ecotourism and coastal economic data and information from various sources	Develop proposals and resources to establish cyberinfrastructure and data management tools and warehousing for LM quality assured ecotourism and economic data and information
Acquire more quality assured coastal economic data and information for the LM to improve cost-benefit analysis evaluations and decision making for regional stakeholders	Develop sources of support for additional economic and ecosystem services data acquisition to help decision makers plan for appropriate mitigation and ecosystem protection planning for projects such as the planned second access causeway to SPI, the planned LNG terminals, and SpaceX launch site
Critical Areas: Entire Lower Laguna Madre	
Goal: Reduce damage and recovery time during and after natural disaster	
Potential Funding Sources: GLO CMP, RESTORE Act, EPA GOMP, TPWD, , NOAA, FEMA, USEDA, local and national non-profit foundations	
Implementation Strategies	
Participation	Recommended Strategies
Municipalities	Improved emergency planning
Stormwater Taskforce	Coalesce efforts on emergency planning and resiliency
Local Universities	Develop improved resiliency planning and technologies for integration with the LMEP

References

Alvarado, S.A. 1996. Hard substrate. Pp. 111-50 in J.W. Tunnell Jr., Q.R. Dokken, E.H. Smtih and K. Withers (eds.), Current Status and Historical Trends of the Estuarine Living Resources within the Corpus Christi Bay National Estuary Program Study Area. Corpus Christi Bay National Estuary Program CCBNEP-06A, Corpus Christi: Texas Natural Resources Conservation Commission.

Arroyo Colorado Watershed Protection Plan (2017), approved by TCEQ and U.S. EPA and published at the ACWPP website (http://arroyocolorado.org/media/671263/arroyo-colorado-wppfinaloptimized.pdf).

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R. 2011. The value of estuarine and coastal ecosystem services. *Ecological Monographs* 81(2): 169-193.

Bighash, P. and Murgulet, D. (2015), Application of factor analysis and electrical resistivity to understand groundwater contributions to coastal embayments in semi-arid and hypersaline coastal settings. Sci Total Environ 532:688-701 doi:10.1016/j.scitotenv.2015.06.077.

Breuer, J.P. 1962. An ecological survey of the lower Laguna Madre of Texas, 1953-59. Publications of the Institute of Marine Science, University of Texas 8: 153-83.

Cameron County (2015), Hazard Mitigation Plan, http://www.co.cameron.tx.us/document_center/Approved_Cameron_County_HMAP_Ready_for_Web_Page.pdf

Carpelan, L.H. 1967. Invertebrates in relation to hypersaline habitats. Contrib. Mar. Sci. 12:219-229.

Church JA, White NJ (2006), A 20th century acceleration in global sea level rise. Geophys Res Lett 33:1–4.

Cobb, R.A. 1987. Mitigation Evaluation Study for the South Texas Coast, 1975-1986. Corpus Christi State University Center for Coastal Studies Technical Report, USFWS Cooperative Agreement 14-16-002-86-919. Corpus Christi. 88 pp.

Cornelius, S.F. 1977. Food and resource utilization by wintering redheads on Lower Laguna Madre. Journal of Wildlife Management 41: 374-85.

Costanza, R., D'Arge, R., De Groots, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R.G., Sutton, P. 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 253-260.

DeYoe, H.R. and J.L. Kowalski. 2013. Reassessment of Seagrass Distribution and Biomass in the Lower Laguna Madre, Texas. Final Report. Prepared for the Texas General Land Office Coastal Management Program. 120 p.

Diener, R.A. 1975. Cooperative Gulf of Mexico Estuarine Inventory and Study – Texas : Area Description . NOAA Technical Report NMFS CIRC-393. Natl. Marine Fisheries Lab, Galveston, TX. 97 p.

Dunton, K., Pulich, W., Mutchler, T. 2011. A Seagrass monitoring program for Texas Coastal Waters: Multiscale integration of landscape features with plant and water quality indicators. Coastal Bend Bays and Estuary Program. Final report, Contract No. 0627, 39 pp.

Etemad-Shahidi, A., Rohani, M.S., Parsa, J. (2015), Effects of Sea Level Rise on the Salinity of Bahmanshir Estuary, Int. J. Environ. Sci. Technol.12:3329–3340.

Federal Emergency Management Agency, Chapter 8 Floodplain Natural Resources and Functions, https://training.fema.gov/hiedu/docs/fmc/chapter%208%20-%20floodplain%20natural%20resources%20and%20functions.pdfCarpelan, L.H. 1967. Invertebrates in relation to hypersaline habitats. Contrib. Mar. Sci. 12:219-229.

Hildebrand, H. 1981. A historical review of the status of sea turtle populations in the western Gulf of Mexico. Pp. 447-53. In K.A. Bjorndal (ed.), Biology and Conservation of Sea Turtles: Proceedings of the World Conference of Sea Turtle Conservation. Washington, D.C. Smithsonian Institution Press and World Wildlife Fund.

Hogarth, P.J. 2007. The Biology of Mangroves and Seagrasses. New York: Oxford University Press. 273 p.

Jones and Taneyr-Abur (2001), “Impacts of recreational and commercial fishing and coastal resources-based tourism on regional and state economies”, Texas Water Resources Institute TR-184.

King, T.L., R. Ward and E.G. Zimmerman. 1994. Population structure of eastern oysters (*Crassostrea virginica*) inhabiting the Laguna Madre, Texas and adjacent bay systems. Canadian Journal of Fisheries and Aquatic Science 51: 215-22.

Koch, E.W., Barbier, E.B. Silliman, B.R., Reed, D.J., Perillo, G. ME., Hacker, S.D., Granek, E.F., Primavera, J.H., Muthiga, N., Polasky, S., Halpern, B.J., Kennedy, C.J., Kapel, C.V., Wolanski, 2009 Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. *Front Ecol Environ* 7(1): 29-37.

Larson, Jane E. (2002). "Informality, Illegality, and Inequality". *Yale Law & Policy Review* New Haven, CT, US 06520: Yale University. **20** (1): 137–182.

Metz, T.L. and A.M. Landry, 2013. An assessment of Green Turtle (*Chelonia mydas*) stocks along the Texas Coast, with emphasis on the Lower Laguna Madre. Chelonian Conservation and Biology 12(2): 293-302.

National Oceanic and Atmospheric Administration – Harmful Algal Blooms. 2017. https://oceanservice.noaa.gov/hazards/hab/.

National Oceanic and Atmospheric Administration - National Estuarine Eutrophication Assessment (NOAA-NEEA) NOAA-National Estuarine Eutrophication Assessment Update. 2007. http://ccma.nos.noaa.gov/publications/eutroupdate/front_materials.pdf

National Seashore, Texas: U.S. Geological Survey Open-File Report 2007-1261, 34 p.
NOAA National Centers for Environmental Information – NCEI (2018), Billion-Dollar weather and climate disasters, https://www.ncdc.noaa.gov/billions/.

Onuf, C.P. (1994), Seagrasses, dredging and light in Laguna Madre, Texas, U.S.A.: Estuarine, Coastal and Shelf Science, v. 39, p. 75–91.

Onuf, C.P. (2006), Seagrass Status and Trends in the Northern Gulf of Mexico: 1940–2002, https://pubs.usgs.gov/sir/2006/5287/pdf/LagunaMadre.pdf

Onuf, C.P., and Ingold, J.J. (2007), A GIS analysis of seagrass resources and condition within Padre Island, Texas: U.S. Geological Survey Open-File Report 2007-1261, 34 p.

Ph. Chardonnet, B. des Clers, J. Fischer R. Gerhold, F. Jori and F. Lamarque (2002), The value of wildlife, Rev. sci. tech. Off. int. Epiz., 21 (1), 15-51.

Onuf, C.P. 2007. Seagrass Status and Trends for the Texas Laguna Madre. In:L. Handley, D. Altsman, and R. DeMay, eds. 2007. Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002. U.S. Geological Survey Scientific Investigations Report 2006-5287 and U.S. Environmental Protection Agency 855-R-04-003, Washington, D.C., USA. pp 29-40.

Pulich, W. Jr. and S. Rabalais. 1986. Primary production potential of blue-green algal mats on southern Texas tidal flats. The Southwestern Naturalist 31(1):39-47.

Quammen, M.L. and C.P. Onuf. 1993. Laguna Madre: Seagrass changes continue decades after salinity reduction. Estuaries 16:302-310.

Rio Grande, Rio Grande Estuary, and Lower Laguna Madre Basin and Bay Expert Science Team for the Lower Rio Grande Basin. 2012. Environmental Flows Recommendations Report. Final Submission to the Environmental Flows Advisory Group, Rio Grande, Rio Grande Estuary, and Lower Laguna Madre Basin and Bay Stakeholders Committee, and Texas Commission on Environmental Quality.

Schoenbaechler, C., C.G. Guthrie, and Q. Lu. (2012), Coastal Hydrology for the Trinity-San Jacinto Estuary. Texas Water Development Board, Austin, Texas.

Sheridan, P., C. Henderson, and G. McMahan (2003), Fauna of natural seagrass and transplanted Halodule wrightii (Shoalgrass) beds in Galveston Bay, Texas. Restoration Ecology 11:139–154.

Shaver, D.J. 1990. Sea Turtles in South Texas Inshore Waters. Padre Island National Seashore Report to U.S. Fish and Wildlife Service Contract no. 14-16-0002-89-919. Albuquerque. N.M.

South Texas Nature Marketing Coop. 2011. An Initial Examination of the Economic Impact of Nature Tourism on the Rio Grande Valley. 18 p. https://www.fws.gov/uploadedfiles/naturereport-mcallencvb-2011_508.pdf

Texas Department of Public Safety (2014), Emergency Management Planners' Guide, https://www.dps.texas.gov/dem/Preparedness/plansUnit.htm

Texas Department of Transportation (2016), Texas Rail Plan Update, Chapter 2: Texas' Existing Rail System, https://ftp.dot.state.tx.us/pub/txdot-info/rail/2016-rail-plan/chapter-2.pdf

Texas General Land Office (2017), Coastal Erosion Planning & Response Act, http://www.glo.texas.gov/coast/coastal-management/forms/files/cepra-report-2017.pdf

Texas General Land Office, Dune Protection and Improvement Manual for the Texas Gulf Coast Fifth Edition, http://www.glo.texas.gov/coast/coastal-management/forms/files/dune-protection-manual-gpb.pdf

Texas Parks & Wildlife (2003), Endangered and Threatened Animals of Texas https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_w7000_0013.pdf

Texas Transportation Institute (2008), Hurricane Evacuation Traffic Operations https://static.tti.tamu.edu/tti.tamu.edu/documents/0-4962-1.pdf

Texas Water Development Board (1998), Laguna Madre Estuary economic impact of recreational activities and commercial fishing, accessed on December 2017, https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/97483188b.pdf

Texas Water Development Board (2012), TxBLEND Model Calibration and Validation for the Trinity-San Jacinto Estuary, http://www.twdb.texas.gov/surfacewater/bays/major_estuaries/trinity_san_jacinto/doc/TWDB_TxBLEND_GalvestonBay_20120322.pdf?d=103309.99999993946

Texas Water Development Board, Desalination, http://www.twdb.texas.gov/innovativewater/desal/index.asp

Texas Water Development Board, Estuary Circulation & Salinity Models, http://www.twdb.texas.gov/surfacewater/bays/models/index.asp

Texas Water Development Board, Water Conservation Plans, http://www.twdb.texas.gov/conservation/municipal/plans/index.asp

Texas Department of Water Resources (TDWR). 1983. Laguna Madre Estuary: A study of the influence of freshwater inflows. TDWR Report LP-182. Austin, Texas. 270 pp.

Texas Water Development Board (1998), Laguna Madre Estuary economic impact of recreational activities and commercial fishing, accessed on December 2017, https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/97483188b.pdf

The Attorney General Office of Texas, Border Colonias Geography Map Online https://coloniadata.oag.state.tx.us/

TNRCC. 1994. State of Texas Water Quality Inventory: 305b Report. Austin, Tx.

TNRCC. 1994. Regional Assessment of Water Quality in the Rio Grande Basin including the Pecos River, the Devils River, the Arroyo Colorado and the Lower Laguna Madre. AS-34 Texas Clean Rivers Program.

Tolan, J. and Fisher, M. 2009. Biological response to changes in climate patterns: population increases of gray snapper (*Lutjanus griseus*) in Texas bays and estuaries. Fish. Bull. 107:36-44.2008.

Tunnell, J. W., Jr. and S. A. Alvarado. 1996. Checklist of species within Corpus Christi Bay National Estuary Program study area: references, habitats, distribution, and abundance. Texas Natural Resource Conservation Commission, Corpus Christi Bay National Estuary Program No. CCBNEP-06D. Austin, Texas, USA. 298 pp.

Tunnell Jr., J.W., Judd, F.W., Barlett, R.C. 2001. The Laguna Madre of Texas and Tamaulipas. Gulf Coast Studies, Texas A&M University-Corpus Christi John W. Tunnell, General Editor. Texas A&M University Press, College Station, Texas, 372 pp.

Tunnell, J. W. Jr. and F.W. Judd, eds. 2002. The Laguna Madre of Texas and Tamaulipas. Texas A&M Univ. Press, College Station, Texas. 372 pp.

TXDOT (2017), available at https://ftp.dot.state.tx.us/pub/txdot-info/rail/2016-rail-plan/chapter-2.pdf.

U.S. Army Corps of Engineers, Resaca Boulevard Resaca Ecosystem Restoration, Cameron County, Brownsville, Texas, https://www.swg.usace.army.mil/Portals/26/docs/Planning/Resaca%20Boulevard%20Cap%20206/Resaca%20Boulevard%20Resaca%20Ecosystem%20Restoration%20Sec%20206.pdf?ver=2017-01-10-162135-483

USFWS. Reddish Egret (*Egretta rufuscens*) Conservation Action Plan. 2014. http://www.reddishegret.org/REEG_plan_final_single.pdf

U.S. Department of the Interior, Bureau of Ocean Energy Management Office (2013), Offshore Wind Energy Development Site Assessment and Characterization: Evaluation of the Current Status and European Experience, https://www.boem.gov/ESPIS/5/5305.pdf

U.S. Fish & Wildlife Service, National Wildlife Refuge System, Lower Rio Grande Valley, https://www.fws.gov/refuge/Lower_Rio_Grande_Valley/visit/wildlife_watching_areas.html

U.S. Fish & Wildlife Service, National Wildlife Refuge System, Steadily Connecting the Dots Along the Rio Grande, https://www.fws.gov/refuges/refugeupdate/MayJun_2014%20HTML/steadily_connecting.html

U.S. Fish and Wildlife Service (2014), Draft Environmental Assessment Bayside Wildlife Drive Project, https://www.fws.gov/uploadedFiles/Public%20Review%20Draft%20EA%20Sept%202014%20(1).pdf

U.S. Fish and Wild Service. 2017. Next steps for a health Gulf of Mexico Watershed: Laguna Madre and Lower Rio Grande Valley Landscape at a Glance. Last Updated: April 21st , 2017. https://www.fws.gov/southeast/gulf-restoration/next-steps/focal-area/laguna-madre-and-lower-rio-grande-valley/

U.S. Geological Survey (1998), https://pubs.usgs.gov/fs/fs-167-98/pdf/FS-167-98.pdf

U.S. Geological Survey (2006), https://pubs.usgs.gov/sir/2006/5287/pdf/StatewideSummaryforTexas.pdf

U.S. Geological Survey, Water Science School: How urbanization affects the hydrologic system, https://water.usgs.gov/edu/urbaneffects.html

Ward, G.H. and N.E. Armstrong. 1997. Current Status and Historical Trends of Ambient Water, Sediment, Fish and Shellfish Tissue Quality in the Corpus Christi Bay National Estuary Program Study Area. Corpus Christi Bay National Estuary Program CCBNEP 13, Corpus Christi: Texas Natural Resources Conservation Commission. 270 pp.

Withers, K. 1994. The relationship of microbenthic prey availability to shorebird use of blue-green algal flats in the Upper Laguna Madre. Ph.D. diss. Texas A&M University, College Station. 117 pp.

White, W.A., T.R. Calnan, R.A. Morton, R.S. Kimble, T.G. Littleton, J.H. McGowen, H.S. Nance and K.E. Schmedes. 1983. Submerged Lands of Texas, Corpus Christi Area: Sediments, geochemistry, benthic macroinvertebrates and associated wetlands. Austin: Bureau of Economic Geology, University of Texas. 137 pp.

White, W.A., Calnan, T.R., Morton, R.A., Kimble, R.S., Littleton, T.G., McGowen, J.H., Nance, H.S., and Schmedes, K.E. 1986. Submerged Lands of Texas, Brownsville—Harlingen Area: Sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. Bureau of Economic Geology Report. University of Texas at Austin, Austin, TX. 138 pp.

Whitledge, T.E. 1993. The nutrient and hydrographic conditions prevailing in Laguna Madre, Texas before and during a brown tide bloom. *In* Smayda, T.J. and Shimizu, Y. (eds.) Toxic Phytoplankton Blooms in the Sea. Proceedings 5th International Conference on Toxic Marine Phytoplankton. Elsevier Science Publishers, Amsterdam.

Whitledge, T.E. and Stockwell, D.A. 1995. Effects of nutrient distributions on phytoplankton in the Lower Laguna Madre, with particular reference to the brown tide. Univ. Texas at Austin Marine Science Institute, Technical Report No. TR/95-004.

Appendix A - Resolution of Cameron County to establish Laguna Madre Estuary Program

RESOLUTION NO. 2015R03031

BE IT RESOLVED THAT ON THE 9th DAY OF APRIL, 2015, THE CAMERON COUNTY COMMISSIONERS' COURT CONVENED IN REGULAR SESSION, AND UPON THE REQUEST OF THE CAMERON COUNTY COMMISSIONERS, THE FOLLOWING ITEM WAS PLACED ON THE AGENDA OF THE SAID COURT FOR SUCH MEETING, PURSUANT TO GOVERNMENT CODE SECTION 551.041 et. Seq., VERNON'S TEXAS CIVIL STATUTES (THE TEXAS OPEN MEETING ACT) TO BE CONSIDERED:

A RESOLUTION TO CREATE
"THE LAGUNA MADRE ESTUARY PROGRAM"
TO BE LOCATED IN THE CAMERON COUNTY
ENGINEERING DEPARTMENT

WHEREAS, Cameron County located within the State of Texas, strives to protect our County's human and natural resources, promote opportunities to provide funding mechanisms to the County and its communities, and to seek economic development programs;

WHEREAS, the Laguna Madre, the tidal section of the Arroyo Colorado, and the Port of Brownsville Ship Channel located within Cameron County are designated as impaired bodies of water and are named on the Clean Water Act 303(d) list;

WHEREAS, Cameron County and numerous Lower Rio Grande Valley local governments and other stakeholders are actively undertaking and/or pursuing projects that mitigate, minimize and/or reduce adverse impacts on the Laguna Madre and Arroyo Colorado watersheds;

WHEREAS, the Clean Water Act, state and federal non-point source pollution programs, and coastal management programs provide several funding opportunities to address impaired bodies of water;

WHEREAS, the Resources, Ecosystems, Sustainability, Tourist opportunity and Revived Economies (RESTORE) Act enacted in 2011 by the federal government to oversee the distribution of billions of funds attributed to the anticipated civil and criminal penalties resulting from litigation between local, state, and federal entities and British Petroleum and its partners associated with the Deep Horizon oil spill in the Gulf of Mexico

WHEREAS, Cameron County is located in a region targeted to receive RESTORE funding;

WHEREAS, the Lower Laguna Madre is identified as a high priority region by the Texas Commission on Environmental Equality (TCEQ) and the United States Environmental Protection Agency (USEPA);

WHEREAS, the Lower Laguna Madre is designated as a major estuary by the State of Texas;

WHEREAS, the Lower Rio Grande Valley is currently not part of the National Estuary Program;

WHEREAS, the USEPA has designated 28 National Estuaries in the United States that were collectively funded by the USEPA in 2015 with $17M;

WHEREAS, Cameron County desires to develop a work group in partnership with Texas A&M University Kingsville (TAMU-K) to develop an estuary program;

WHEREAS, an Estuary program will position the County to become eligible for funding associated and limited to Estuary programs (Clean Water Act Chapter 320 funding, etc.);

WHEREAS, TAMU-K, part of the Texas A&M System, will work with Cameron County officials to identify work group members, will use its faculty, staff and students to support Cameron County, and will utilize its national network to facilitate this project;

NOW, THERFORE, BE IT RESOLVED BY THE COMMISSIONERS COURT OF THE COUNTY OF CAMERON, TEXAS, THAT

1) Cameron County will create the "Laguna Madre Estuary Program".
2) Cameron County will assign the County Engineer to this project;
3) Cameron County will partner with TAMU-K in planning, developing and creating a National Estuary designation.

Passed and Approved on this 9th day of April, 2015

COMMISSIONERS' COURT OF CAMERON COUNTY, TEXAS

____
PETE SEPULVEDA, JR.
COUNTY JUDGE

____
SOFIA C. BENAVIDES
COMMISSIONER PRECINCT 1

____
DAVID A. GARZA
COMMISSIONER PRECINCT 3

____
ALEX DOMINGUEZ
COMMISSIONER PRECINCT 2

____
DAN A. SANCHEZ
COMMISSIONER PRECINCT 4

ATTEST: ____________________________________
SYLVIA GARZA-PEREZ, COUNTY CLERK

Appendix B - Key Stakeholders and Federal/State Agencies

LMEP Workshop Series original notice/bulletin.

THE UNIVERSITY OF TEXAS RIO GRANDE VALLEY
TEXAS A&M UNIVERSITY – KINGSVILLE
THE LOWER RIO GRANDE VALLEY STORMWATER TASK FORCE
CAMERON COUNTY COASTAL TASK FORCE

SAVE THE DATES
LOWER LAGUNA MADRE ESTUARY PROGRAM WORKSHOP SERIES

- Workshops conducted to promote feedback, to identify stakeholders and to provide an update on the estuary initiative –

January 12, 2017 **Speers Mem. Library** **801 E. 12th Street** **Mission, TX** **10 am – 12 noon**	**January 20, 2017** **San Benito Library** **101 W. Rose St.** **San Benito, Texas** **10 am – 12 noon**	**January 27, 2017** **Raymondville EDC** **700 FM 3168** **Raymondville, TX** **10 am -12 noon**	**February 6, 2017** **Brownsville Library** **2600 Central Blvd** **Brownsville, TX** **10 am – 12 noon**	**February 17, 2017** **To Be** **Announced** **Port Mansfield, TX** **10 am – 12 noon**	**February 24, 2017** **World Birding Center** **714 S. Raul Longoria** **Edinburg, TX** **10 am – 12 noon**

March 10, 2017 **Starr County Courthouse Annex** **100 N. FM 3167 Suite #211** **Rio Grande City TX** **10 am – 12 noon**	**March 31, 2017** **SPI Community Center** **4501 Padre Blvd.** **4501 Padre Blvd.** **10 am – 12 noon**	**April 5, 2017** **Texas A&M University -Kingsville** **Lucio Hall Dining Room** **1015 N. Retama St.** **Kingsville, TX** **11 am – 1 pm**

PLEASE RSVP IF YOU ARE ATTENDING. SPACE IS LIMITED SO PLEASE RESERVE YOUR SEAT.
AGENDA WILL BE SENT TO YOU UPON RECEIPT OF RSVP.

For RSVP please email: Javier.Guerrero@utrgv.edu or Deanna.Gomez@utrgv.edu
For more information please email: Javier.Guerrero@utrgv.edu or Augusto.SanchezGonzalez@utrgv.edu or Kim.Jones@tamuk.edu

.

Table B-1. Listing of actual completed planning workshops, forums, technical assistance workshops and academia worskhops for the establishment of a Laguna Madre Estuary Program (2016-2017)

Event no.	Event Date	Workshop focus/location	Participants	Workshop/Meeting Type
1	11/16/2016	Planning Team meeting /San Benito	UTRGV, TAMUK, Cameron, EPA	Project Team Planning
2	11/17/2016	General Stakeholder planning/San Benito	Miltiple Agencies	Stakeholder Planning
3	12/8/2016	Planning Team meeting	UTRGV, TAMUK, Cameron, Bronwsville	Project Team Planning
4	1/4/2017	Academia Workshop	UTRGV faculty and graduate students	Academia Workshop
5	1/12/2017	Workshop Mission	Regional Stakeholders	Technical Assistance Workshop
6	1/20/2017	Workshop San Benito	Regional Stakeholders	Planning Forum
7	1/27/2017	Workshop Raymondville	Regional Stakeholders	Planning Forum
8	2/6/2017	Workshop Brownsville	Regional Stakeholders	Planning Forum
9	2/24/2017	Workshop Edinburg	Regional Stakeholders	Planning Forum
10	3/10/2017	Workshop Starr County	Regional Stakeholders	Stakeholder Planning
11	3/31/2017	Workshop SPI Community Center	Regional Stakeholders	Stakeholder Planning
12	4/5/2017	Workshop Kingsvville	Regional Stakeholders/Academia	Academia Workshop
13	5/2/2017	LM Initiative Team Meeting May 2nd	USFWS, Ducks Unlimited, UTRGV/Academia	Technical Assistance Workshop
14	5/10/2017	Thrust Leaders Meeting-Planning	UTRGV, TAMUK, Cameron	Project Team Planning
15	5/26/2017	LLMEP Strategic Planning SPI	Multiple Agencies	Planning Forum
16	10/20/2017	Meeting with SPI shoreline managers	UTRGV, TAMUK, City of SPI	Technical Assistance Workshop

This section also includes a list of key LMEP stakeholders, interested entities and partners including international agencies/organizations as well as local, state, and federal governments.

B-2. Local and International Stakeholders

- Texas Bee Keepers Association
- Ecotourism departments
- Chambers of commerce
- Duke Energy
- LNG industries
- Sierra Club
- International Boundary and Water Commission (IBWC)
- BECC/North America Development Corporation (NDC)
- Valley Proud Environmental Council
- Ports Isabel, Harlingen, Brownsville
- Schools and ISD's
- Gorgas Science Foundation
- Sea Turtle Incorporated, South Padre Island, TX
- Gladys Porter Zoo
- Micro-tidal flats
- PINS
- Paragion fund
- Texas Agrilife Exp. Station
- Cameron County Regional Mobility Authority (CCRMA)
- Birding groups
- UTRGV Tourism Dept.
- North American Butterfly Assoc.
- Coastal Conservation Assoc.
- Texas Shrimp Association
- Fishing guides
- Lower Laguna Madre Foundation
- Irrigation Districts
- Regional Mobility Authorities (RMA)
- Coastal Conservation Organizations
- Planners Organizations
- Economic Development Corporations
- "Non-green" departments (fire dept, planning, code enforcement, sanitation)
- Ducks Unlimited
- Kennedy Foundation
- "Huellas" Organization

International Stakeholders

- Pronatura
- Semarnat
- Conagua, Note: LLM in Mexico is a protected area)
- Mexus Gulfo
- Instituto Mexicano de Technología del Agua
- Binational Sea Turtle Group
- US Border patrol
- US Coast guard
- Binet

B-3. Key State and Federal Agencies

- U.S. Chamber of Commerce
- U.S. Environmental Protection Agency (EPA)
- Texas Commission on Environmental Quality (TCEQ)
- BECC/North America Development Corporation (NDC)
- National Science Foundation (NSF)
- U.S. Dept. of Agriculture (USDA)
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Bureau of Reclamation (BOR)
- U.S. Fish and Wildlife (USFW)
- Texas Sea Grant Program
- Texas Railroad Commission
- Texas General Land Office (TGLO)
- Texas Parks and Wildlife Department
- Texas Nature Conservancy (TNC)
- Texas Water Development Board
- Texas Department of Health
- Texas Coastal Management Plan
- Texas Shrimp Association
- Texas Southwest Council